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Model Architecture

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Introduction

In the field of architecture, designers need to have notions about culture, society, fine arts, philosophy, history of architecture, politics, materials, technology, technique. But they also need to have awareness of the means they use to *make* architecture.

Process and communication are at the core of daily design activity, and models are powerful instruments both to do and express projects. This relatively new tool has increased its importance during the last and the current century, taking unexpected directions. On one side, it has followed artistic currents crossing the border between art and architecture. On the other, it has been the testing ground for new formal and technological experimentations.

Sometimes sculptures, other times industrial products, they do not stop to fascinate designers and public. Several publications and exhibitions have been dedicated to models, confirming their undeniable relevance in architecture.

Some recent manufacturing technologies renovate and increase again models' aesthetics, production processes, and uses.

My purpose is to critically analyse the last development of Computer Numerical Control machining through a study on the evolution of employments and appearances. I go deeply into the design approach of four offices – OMA, Herzog & de Meuron, Gehry Partners, Greg Lynn FORM – that make large use of models, assuming different attitudes. In this way it is possible to see which implications the model has had during the centuries until its latest multitude of expressions. In addition, it is interesting to notice how makers, methods and results are reciprocally influenced and correlated in the space where buildings are born.

All model's outcomes and applications do not stop to develop. This means that architectural *creativity* cannot stop to use models.

Model history

In the fifteenth century, when models started to be used in the course of architects' work, the intention was to build objects the most realistic as possible. Architects and craftsmen were employed to make models closely associated to their projects. This tendency has been continued for long time. Instead, during the twentieth century, the rise of abstraction in the fine arts strengthened the model's tie to the imagination. Abstraction allows the model to engage directly in the imaginative process, enabling the architect to isolate theoretical ideas, as well as un-formulated fragments of vision and imagery, from other aspects of the intended reality.

Models have always had the capacity to reveal elements of conceptual design that are not easily distinguishable in the built architecture, due to their complexity and external influences. Many sources note that Sir Christopher Wren's model of St. Paul Cathedral represents his ideal vision for that ultimate architectural expression of the Anglican faith.¹ But it is only in the twentieth century that architects have abandoned realism, aspiring to portray their conceptual ideas alone. This position is evident in the progressive afterthought of model's design, techniques, materials, aesthetic.

At the beginning of the century, architects feel the need to represent the abstract level of ideas, balancing their position between abstraction and realism. This question regards also twentieth century fine arts debates, reflecting a longstanding connection between art and architecture. Kasimir Malevich's explorations on spatial and volumetric forms constitute a manifestation of that phenomenon. By applying the methods of suprematist painting to the development of volumes, Malevich creates a series of models first in cardboard (1920-21) and then in plaster (1922-23). These objects are created from the sequential proliferation – both horizontal and vertical – of cubes and parallelepipeds. Although they materially originate a possible trajectory of pure forms, their existence as prototypes always refer to an “immaterial” presence. His Architektons are pure concept, devoid of purpose.²

1 Wilton-Ely J., “The Architectural Model: 1. The English Baroque”, in *Apollo* 88:80, October 1968, p. 254

2 Celant G., “Il progetto é un oggetto”, in (*Maquette*), *Rassegna*, December 1987, pp. 77-78

In the 1970s, with Postmodern Architecture affirmation, the attention to the plan and the model as a work of art became widespread and generalized. The distinction between creative products started to disappear.³ In the models by Paolo Soleri, Maurizio Sacripanti, Bernhard Leitner, and many others, materials are not the conventional ones used for traditional model-making. Mediums are chosen not for their realism but for their effects. While the pressure for making highly realistic “bonsai architecture”⁴ for clients, models that express concepts and thoughts are more personal and significant. During the latest decades of the XX century, working models have been considered the best objects that embody and reveal project’s imagination and intimacy. They are now purposely shown in publications and exhibitions. Three-dimensional tools are used to explain concept, project evolution, articulation of the interior spaces, materials, shapes, design investigations. The new attention on working models can also be linked to the Conceptual Art movement. Conceptualists do not focus on the final “artistic object” to be displayed, but on the documentation of the process.⁵

Models become free expressions made by architects; they do not exclusively belong to the sphere of realism.

The detachment from realism, towards abstraction, has been so exaggerated that, in some cases, models lend themselves to the representation of imaginary. They are the natural territory for visionary proposals, consciously unbuildable. Like the Living pod by Archigram, models seem more as point of reflection, making the fantasy more real. Models become then instruments of provocations and experimentations. Architects who, especially at the beginning of their career, have new proposals, find in models the perfect means to submit their ideas to public and clients. When possibilities for building are slight, some professionals work on models to give fulfilment to their desires. Kiesler’s Endless House, Branzi’s Agronica, Hadid’s and Rashid’s early design, Gramazio & Kohler’s explorations in robotics are examples of those two, sometimes convergent, tendencies.

3 Ibid. p. 86

4 Jaques Herzog interviewed by Theodora Vischer, in *Architectures of Herzog & de Meuron. Portraits by Thomas Ruff*, Exh. Cat. Herzog & de Meuron, New York: Peter Blum, 1995, p. 29

5 Lucie-Smith E., *Late Modern: The Visual Art since 1945*, New York: Praeger, 1976, p. 261

Looking at model's history, it is possible to state that those particular objects keep being influenced by fine arts. There is nothing new in saying that architecture has connections with painting and sculpture. But those specific objects have often found themselves on the limit between architecture and art, making that line blurry and undefined. This influence regards not only the aesthetic and expressive aspect of models, but also the typology that is shown as project's representation and symbol. If during the fifteenth century the main effort was put building products in accordance with project's appearance, during the last century, the concept has been the generating force. Architects needed powerful and exemplifying means for communicating their ideas. As photography and video-making have opened a debate about which purpose of painting has become, the increasing ability of model-making in mimic the reality has made architects question the aim of models. From that point on, abstraction and innovation have seemed to be the keys of model's "success". This process has kept going on until exhibiting study models. They, very interesting for experts, maybe less for the public, have started being a kind of flagships for many offices.

Another consideration about models' evolution, it is their correlation to innovation. If they are the ground for testing and showing new proposals, maybe it is licit to think that moments of their proliferation correspond to innovations in the history of architecture. Brunelleschi, Borromini, Wren, Gaudì, Le Corbusier, Mies Van der Rohe are masters who have made large use of models in their work, each of them introducing something new in the architectural practice. Many architects at the beginning of their careers, researchers, students have seen in models a way and a tool to express their investigations. This tendency, at a bigger scale, is linked to new forms of architecture. After all, result derives from process and language.

Renaissance

Starting considering architects as independent intellectual figures was an important step in models' use during the design process. There are models' samples dated before the XV century but they can be considered as "objects representing buildings". In most of the cases they were created after the building had been realized. This happened just for embodying project's image than for pre-visualizing it. Their proper aim was representing architecture constructions.

During the Renaissance period, making models had become a regular practice. Architects were asked to insert originality in their work in contrast to Medieval ones who belonged to a sort of conservatism based on repetition of traditional elements. Models came to be the main tool in which transposing ideas and hypothesis to be communicated to clients. They were used also in the construction phase for perfectly visualizing details or parts of the building.

Even if many models of that time are still intact, they represent only few examples of the big production of the Renaissance.¹ Some remarkable examples are the models made for the Basilica of Santa Maria del Fiore which were used both for structural tests and as representation of the project. According to one of Filippo Brunelleschi's biographer, Antonio Manetti, he started building models of the cupola at the end of XIV century. For the Tuscan architect decorations are not necessary for defining buildings' models, therefore they become sort of three-dimensional sketches useful to show the important parts with clarity and simplicity. They should concentrate on architectural criteria then on manufacturing abilities.² In the 1419 he impressed the competition's jury realizing a big model made by bricks and wood without any scaffoldings. In this way he gained and made static tests bringing forward structural experiments of the XVIII century.

Brunelleschi commissioned models also for several construction sites among which there are Church of Santo Spirito, Santa Maria degli Angeli, Pazzi Chapel, Saint Lawrence's Basilica.

1 Magnago Lampugnani V., Millon H. (edited by), *Rinascimento da Brunelleschi a Michelangelo. La rappresentazione dell'architettura*, Milan: Bompiani, 1994, p. 19

2 Sardo N., *La figurazione plastica dell'architettura. Modelli e rappresentazione*, Rome: Edizioni KAPPA, 2004, p. 35

Brunelleschi, like many other Florentine architects – Ghiberti, Michelozzo, Giuliano da Maiano - received an education as craftsman. This is the reason why they knew how to deal with architectural forms, terminology, proportions and they had the ability of drawing and making models.³ Referring to Leon Battista Alberti this training is fundamental for the development of models' use. Furthermore they are necessary to control complicated systems and to illustrate projects independently from construction problems. He underlines that those objects have practical uses, such as relations with the context, walls' constitution, cladding solidity, building costs. Moreover according to Alberti, models are the only way to examine, test and improve ideas and drawings. They are part of the design process.⁴

In opposition to Alberti's point of view, Brunelleschi and Michelangelo consider models as the last representation of the idea for the public and as a construction guide for workers. Antonio Averlino, known as "Filarete", thinks at models as objects clients should receive for project approval. He also establishes a direct correlation between drawings and models.

Another competition for which several models have been built is the St. Peter's Basilica in Rome. Today only one by Antonio da Sangallo and two by Michelangelo Buonarroti are still intact. For Sangallo it took seven years to complete the full illustration of the Basilica representing also interior spaces through sections and removable elements. It is the greatest example of Italian Renaissance models.⁵ It was big [scale 1:30], expensive and detailed. For these characteristics it keeps being well known by everybody interested in architectural models. Even though today only the interior is painted, in origin also the external surface had been coloured. Another remarkable feature is the presence of visual expedencies in order to improve viewer's sight certainly higher than real visitor of the church.

Michelangelo reproduced several parts of the project at different scales and with different materials – wood and clay-. He started using models rather than perspective drawings for better studying ambiances by different points of view. The cupola's one

3 Goldthwaite R., *La costruzione della Firenze rinascimentale. Una storia economica e sociale*, Bologna: Il Mulino, 1984, p. 494

4 Alberti L. B., *De re aedificatoria* (1482), Portoghesi P. (edited by), Milan: Il Polifilo, 1989, pp. 860-862

5 Sardo N., *La figurazione plastica dell'architettura. Modelli e rappresentazioni*, Rome: Edizioni KAPPA, 2004, p. 34

had been the main representation of Michelangelo's idea and after his death it became a reference for workers and craftsmen. It was built at 1:15 scale representing half of the whole cupola underling the section.⁶

Michelangelo made also two wooden models for the study of Saint Lawrence's Church façade after several examples in clay. The smaller one was lost, but the bigger one was, another time, the reference during the building phase. This Michelangelo's habit is underlined also from the absence of graphic drawings and sketches.⁷

Renaissance's models were used also to represent changes during the construction phase. For instance, the wooden model for Santa Maria della Consolazione's Church is composed by several parts made in different moments. Models became the main guide for building sites.

It is important to notice that architectural models have changed between XV and XVI centuries. In opposition to Brunelleschi and Alberti many later objects have put in evidence decorative and chromatic elements. The interest moved from the prefiguration of the idea to the visualization of effects. They were conceived as three-dimensional illustration for clients and they anticipated virtuosity of baroque period.

6 Schiavo A., "Il modello della cupola di San Pietro nel suo quarto centenario", in *Studi Romani*, n. 5, September-October 1961, pp. 519-532

7 Ackerman J. S., *L'architettura di Michelangelo*, Einaudi, Turin 1968

XVII-XVIII centuries

Looking for being the closest as possible to the real reference, was the aim of Baroque's models. Architects' interest regarded chromatic, volumetric, compositional, material and decorative features. Each element had to be declined into the smaller scale of models. They were made especially as projects' representations but, at the same time, they had become fundamental design tools. Drawings were no more capable of representing forms' complexity and spaces' articulation.

Borromini and Bernini did large use of model: the first architect for directly transposing into three-dimensionality his ideas during designing phases, the second one to illustrate projects at the last step of that process. Unfortunately none of their models lasted till today but we know their existence from many sources. Notary Olimpo Ricci wrote about many Borromini's models in the inventory made at his death.⁸ Most of them were made of clay and they were representing his most important projects. They are also index of Borromini's necessity of working with material that directly transposes his ideas.

On the other hand, Bernini realized very detailed wooden models to illustrate projects after drawings were finished. Those different behaviours reflected their personal working methods: Borromini was constantly present in construction sites, instead Bernini delegated others for building supervision.⁹

A great product of that time is the large-scale model made for the St. Paul Cathedral in London by Christopher Wren. Wren realized the model for project approval at a scale around 1:25 (one inch to one foot) of both internal and external spaces.¹⁰ After one year and a half of meticulous work, all details had been precisely realized together with material and colour specifications. Wren assigned other models to sculptors and decorators of those parts that necessitated of particular attention for the structural and decorative development.

In France models were made from small to 1:1 scale. In Rome they had a didactic scope in Saint Luca's Academy and they

8 Portoghesi P., *Borromini nella cultura europea*, Rome: Laterza, 1982, pp. 441-452

9 Contardi B., Curcio G. (edited by), *In urbe architectus: modelli, disegni, misure. La professione dell'architetto*, Roma 1680-1750, Rome: Argos, 1991, p. 10

10 Wilton-Ely J., "The Architectural Model: English baroque", in *Apollo*, n. 80, October 1968, pp. 250-259

were required for applying to public competitions.

In Filippo Juvarra's work designing tests were constantly unrolled by models.¹¹ More and more relevance was given to the creative phase thanks to approaches that envisage models' decomposition and interior visualisation. Those objects were supports for Juvarra's compositional choices and difficult nodes resolution. They helped him with static and decorative control. Through restorations many graphical signs were brought to evidence as testimony of architect's work on them.

A similar approach can be observed in Luigi Vanvitelli's work. Vanvitelli commissioned Royal Palace of Caserta's models to the German ebonise Antonio Rosz. They were necessary for taking design decisions and introducing projects to the royal family. Vanvitelli was conscious of communicational potential of his wooden objects. For this reason he used them for convincing clients of his ideas. At the same time he recognized that serious architecture is more visible by models than by drawings.¹² They had become guides for the construction process and put on the site. Later they had been fundamental to the design development comprehension.

Other practice that became more and more usual during the sixteenth and seventeenth centuries, were site models. Two main factors contributed to this phenomenon: the production of military and strategic models - which in many cases encompassed entire towns and their environments - and an increased interest in garden planning. However the advantages of this new model type were not fully appreciated until well into the twentieth century, when issues of context and urban planning came to the fore.¹³

11 Sardo N., *La figurazione plastica dell'architettura. Modelli e rappresentazione*, Rome: Edizioni KAPPA, 2004, p. 49

12 Strazzullo F., *Le lettere di Luigi Vanvitelli della biblioteca palatine di Caserta*, Galatina: Congedo, 1976

13 Moon K., *Modeling Messages. The architect and the model*, New York: The Monacelli Press, 2005, p.35

XIX century

During the XIX century a systematic use of graphic representation and technical necessities of construction had reduced model benefits. A decline of models' use was due to the change of esthetical expressions that became devoted to past standards. Design practice followed pictorial process and the tendency towards two-dimensional façades made models useful only for volumetric and spatial considerations.

There were also remarkable examples in the engineering field for both the representation of new construction techniques and the study of static problems. Notable are the models English engineers used to decide forms and dimensions of metal bridges. Literature was produced on this habit. For instance, Robert Stephenson and William Fairbairn gave fundamental contribution to bridges' design conceiving Conway and Britannia tubular bridges.¹⁴ Many experimentations were done for investigate potentials and strength of metal elements, something new in the construction field.¹⁵

John Soane realised complicated models which can be opened to show interior spaces' complexity.¹⁶ Soane's importance to three-dimensional objects is evident since he collected cork reproductions of Greek and Roman great examples. Those products had been inspiring for his work.

In Italy, architects such as Alessandro Antonelli and Giovanni B. F. Basile commissioned respectively models for the San Gaudenzio's Church's cupola in Novara and the Teatro Massimo in Palermo. Antonelli built up a model for analysing the structural system (1844) without decorative details, and a second one that described the whole cupola.¹⁷ Basile referred to his model as an archetype of the project.¹⁸ This reveals his methodological approach to design in which models play a fundamental role. This model made of wood was decomposable along longitudinal and

14 Fairbairn, *An account on the Constructions of the Britannia and Conway Tubular Bridges*, London 1849

15 Guillerme J., "Il modello nella regola del discorso scientifico", in (*Maquette*) *Rassegna*, n. 32/4, December 1987, pp. 29-35

16 Richardson M., Steven M. A. (edited by), *John Soane architetto. 1753-1837*, Milan: Skira, 2000

17 Gavinelli C., *Storie di modelli espositivi e critici. Modelli storico-critici di rappresentazione oggettuale di visualizzazione interpretativa*, Florence: Alinea, 1993, pp. 179-180

18 Pirrone G., *Il Teatro Massimo di G.B. Filippo Basile a Palermo*, Rome: Officina, 1984, p. 59

transversal axes revealing the internal structure.

At the end of the century Antoni Gaudí had been one of the figures capable of anticipate modern themes. Particular models, made by cables and fabric, are just some examples of his huge repertoire. For Gaudí these spatial representations were the principal tools for plastic control. Famous are his realisations for the Güell's Chapel and the Sagrada Familia.¹⁹

19 Giraldo-Miracle D., *Gaudí. La ricerca della forma*, Milan: Jaca Book, 2003

XX century

In contrast to the previous one, the XX century's approach re-discovers the plastic representation of architecture thanks to the protagonists of the architectural scene of this period. Different positions are registered but, in general, models acquire new expressive values becoming the main modality for promoting new ideas. The loss of conservative aesthetics typical of XIX century makes models the perfect ground for experimentations.

By the strong link between art and architecture, historical avant-gardes see in models the representation of their expression urgency, they acquire sculptural values not necessarily linked to architectural construction. Through models it is declared the will to investigate new forms. The rediscover of axonometric drawings as principal way of representation goes together with models use. This process is not characterized by its capacity of better simulate three-dimensional reality but, instead, for its attitude to a spatiality completely different from the perspective one.²⁰

It is necessary to wait a pair of decades to have some great examples. At the beginning of the century, using models as design tools does not appear to have been common practice. The art historian Hans Karlinger asserts that model practice is not so well known by architects of the 1920s, very few of them use models. This situation is seen as an heritage of the nineteenth century, during which, architecture was characterized by ornaments and two-dimensionality.²¹

Compared with the early days of Modernism, the development of models envisaged a professionalization of makers and more potential for simulation in photographs and films. Material use and techniques are indicative of a new way of thinking at models. A direct relation to reality is no more required. On the other hand, they achieve an autonomous value.

Twentieth century's models are not only about buildings' representations, they illustrate larger scale projects, such as the *Ville contemporaine* (1922) and the *Plan Voisin* (1925) in Paris by Le Corbusier.

20 Sardo, Nicola, *La figurazione plastica dell'architettura. Modelli e rappresentazione*, Rome: Edizioni KAPPA, 2004, p.57

21 Karlinger, Hans, *Architekturmodelle*, in "Die Plastik. Illustrierte Zeitschrift für die gesamte Bildhauerei und Bildnerei und ihre Beziehungen zu Architektur und Kunstgewerbe, von Alexander Heilmeyer, n.10, 1921, pp.53-56

A mix between art and architecture is explicit in neo-Plasticism. In this current abstraction and antinaturalism found their equivalence in models. Theo van Doesburg uses materials in an experimental way and his products do not have anything related to buildings' tectonic. Looking forward objectivity pushes architects to give more attention to spatiality and functionality, which are drawn through axonometric method. In this way a simultaneous view of all parts of a building is possible without vanishing points. The plane tends to disappear allowing a synoptically view, in which necessary masses and structures stay visible as they are. Consequently also sketches, from foundations to roofs will be elaborated in axonometry.

Also in the soviet context painting, architecture and sculpture are fused together in a mutual formal repertory. If in models by Ivan Leonidov and El Lisitskij the connection with reality has a naturalistic feature, in Kazimir Malevič's objects it is evident hid way of experimenting and his tendency towards sculptural autonomy.

In Germany, expressionism and modelling have a complex interrelation. On one side models are capable of perfectly describing plasticity of forms. On the other they become insufficient for representing fantastic spatial suggestions.

At the beginning of the century, in Italy Futurism plays a fundamental role. Besides graphic expressions by Antonio Sant'Elia and Mario Chiattoni there are models of some pavilions by Fortunato Depero.²²

Rationalism reiterates avant-garde's anti-naturalism with rigour and incivility. The preference towards axonometric graphical representation comes together with a particular colour use. Models propose this essentiality, avoiding simulation of metrical reality. Shells want to show clean volumes without distractions. Bauhaus's models reveal this principle. According to Walter Gropius, the unity among forms of art founds the best expressive mean in models, in continuity with soviet avant-garde.

Ludwing Mies van der Rohe's passage from his first expressionist experiences to minimalism is evident in his models. One of his best examples is Friedrichstrasse skyscraper in Berlin (1922). This object is a symbol of a new way of making architecture. It is indeed capable of illustrating the transparency given

22 Van Doesburg, Theo, "Het Bouwbedrijf", in *De Stijl*, n.15, 1919

by a huge glassy building façade. If in his European production architectural shape is put in evidence; in the following American objects realism is the important result to be achieved. This is the reason why each element of the composition is extremely precise.

The important character of Le Corbusier has a specific consideration about models. All his masterpieces are strictly linked to work-in-progress and final models. Like his drawings, they have a great communicational power. He made models both at an urban and building scale. Many of them have a strong identity losing, at the same time, a naturalistic tendency. A remarkable fact is that Le Corbusier starts showing interest not only in final representations but also in the genetic project process representation.²³ To understand Le Corbusier's dedications to models it is necessary to consider his education as craftsman. This aspect puts in continuity his work to Renaissance architects.²⁴ Giuseppe Terragni is one of the most important protagonists of Italian environment. Since his first works it is evident the relevance he gives to models representation. Eloquent essentiality is the main feature of his realisations. International culture influenced models such as the ones for the Novocum and the Gas Officine. During the following years Terragni's models become more detailed and precise in order to communicate all projects elements.

Once again, as in the XV century, competitions are occasions for architects to make several and particular models. In Rome the main ones are for Littorio Palace, Duca d'Aosta Bridge, E42 buildings.²⁵ Notable participants are Terragni, Adalberto Libera, Luigi Moretti, Mario Ridolfi, Luigi Figini, Gino Pollini, BBPR Group. Due to site competition sizes, models have more volumetric than expressive scopes.

Organic architecture does a particular use of models. Architects have some difficulties to clarify models features. They are aware of the risk to create bad-taste objects because of the quality and quantity of information represented.

Thanks to his architectural style, Frank Lloyd Wright creates very detailed models comprehensive of natural contexts where

23 Rossi, Loris Aldo, *I modelli originali e le riproduzioni de-costruibili*, in Izzo, A., Gubitosi, C. (edited by), *C.E. Janneret-Le Corbusier*, Rome: Officina, 1979, p.101

24 Maldonado, T., *Questioni di similarità*, in "Rassegna", December 1987, p.58

25 Rossi, P. O., *Roma. Guida all'architettura moderna 1909-1984*, Rome-Bari: Laterza, 1984

projects are integrated. Also for Wright urban models have an important role. Remarkable is his plastic representation of Broadacre City exposed in New York in 1935.

Alvar Aalto produces especially urban-scale models addressed to competitions. Among his production it is necessary to mention the Essen Opera House model. For its representation he made prepare a big section model of the main hall.

After the First World War different and complex architectural positions dissert on modern architecture development. Louis I. Kahn is one of the main figures of this period. He is able to impose his charisma and ideas. Future architects will get lot of influence from him. His models are significant for volumetric values.

During the second post-war period urban-scale projects interest architectural experimentations and models are fundamental for their illustrations. Frei Otto, Arata Isozaki, Archigram and Paolo Soleri are just some firms that take part at this phenomenon. The fantastic side of their proposals is balanced by extreme realism and precision. For others, such as Constant, the model itself is the ground for making research through the study of materials and shapes.²⁶

In Italy Maurizio Sacripanti, Luigi Pellegrin and Superstudio Group are interesting profiles to analyse for their experimentations and researches through models. Sacripanti investigates new shapes and spaces making unconventional objects made by original materials and techniques.²⁷ In continuity with historical avant-gardes, Superstudio produced abstract and essential models, presenting an a-naturalistic and self-referential kind of architecture.²⁸

Post-modern architecture assumes different positions about models. On one side refined and precise objects are made with handcrafted ability. On the other side an exasperation of formal interpretations has been registered.

Analysing Aldo Rossi production it is possible to understand how model use follows linguistic changes. During the '70s his projects underlines formal concision and archetypical figuration. Later on models show the enrichment of Rossi's formal vocabulary through a specific colours use.

26 Cereri, F., *Constant. New Babylon. Una città nomade*, Turin: Testo & Immagine, 2001

27 Neri, M. L., *Maurizio Sacripanti maestro di architettura*, Rome: Gangemi, 1998

28 Lang, P., Menking, W., *Superstudio. Life without object*, Milan: Skira, 2003

Next to post-modern tendency, high-tech current develops some avant-garde's aspects. High-tech models manifest their precision and refinement through the study and realization of articulated construction details. They are so well done and innovative that become points of reference for later architecture. Some Renzo Piano's works are representative of this phenomenon.

Richard Meier's and Tadao Ando's models are characterized by a-materiality and refinement. The american architect shows a direct continuity with twentieth century's rationalism. Tadao Ando, son of a long wood manufacturing tradition, demonstrates great ability in working with this material.

catalogue



filippo brunelleschi
lantern of Basilica of Saint Mary of the Flower
1418



filippo brunelleschi
Basilica of Saint Mary of the Flower
1418



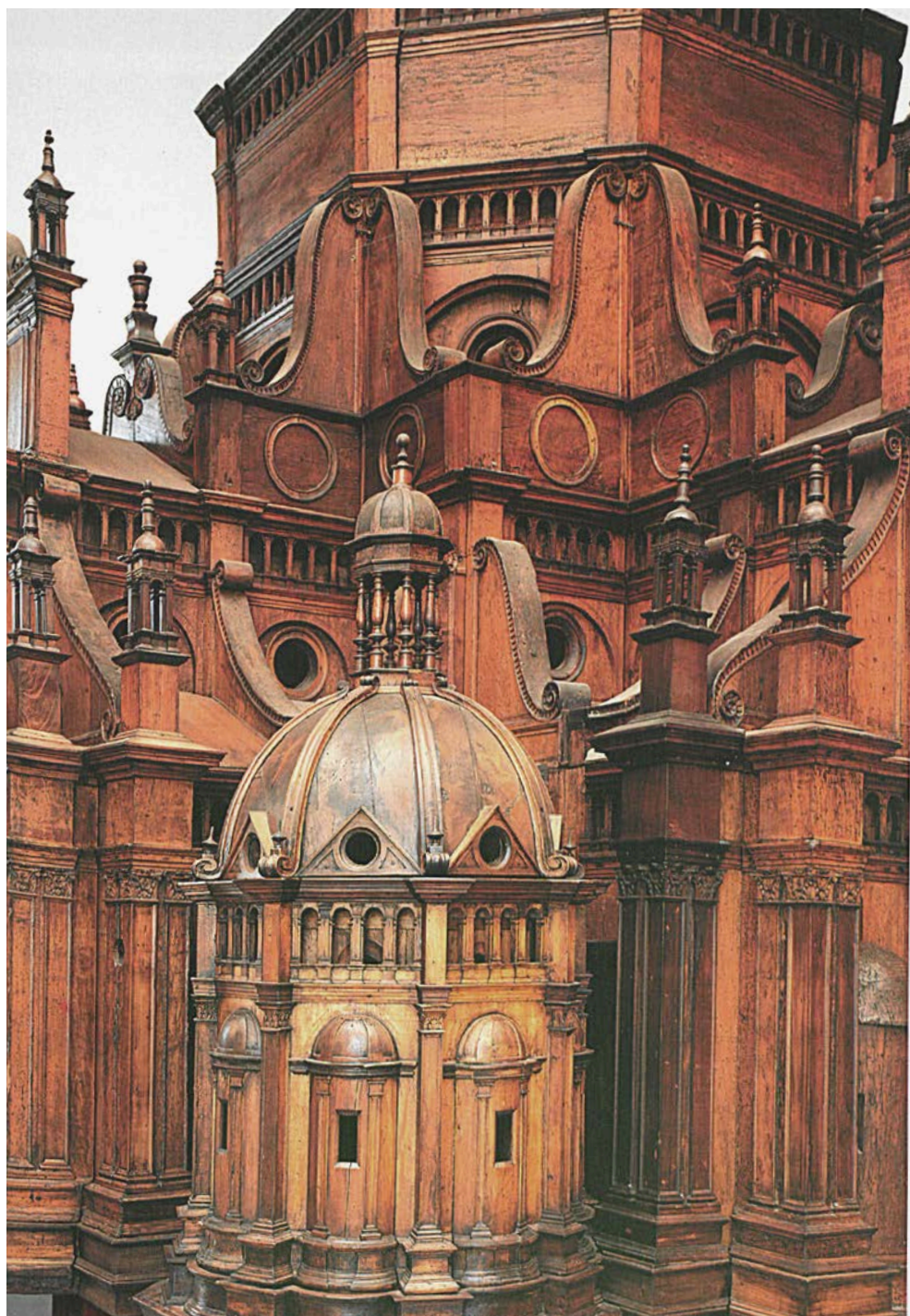
giuliano da sangallo
palazzo strozzi
1489



giuliano da sangallo
palazzo strozzi
1489



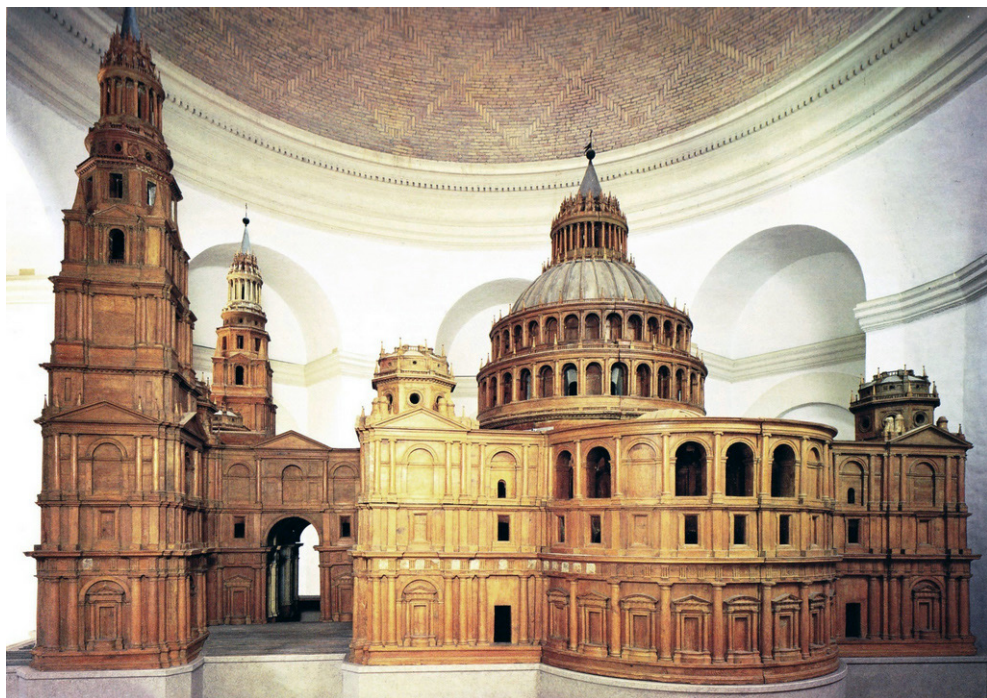
cristoforo rocchi, giovan pietro fugazza
pavia cathedral
1495



cristoforo rocchi, giovan Pietro fugazza
pavia cathedral
1495



giuliano da sangallo
st. peter's basilica
1505



giuliano da sangallo
st. peter's basilica
1505



santa maria della consolazione, todi
1508



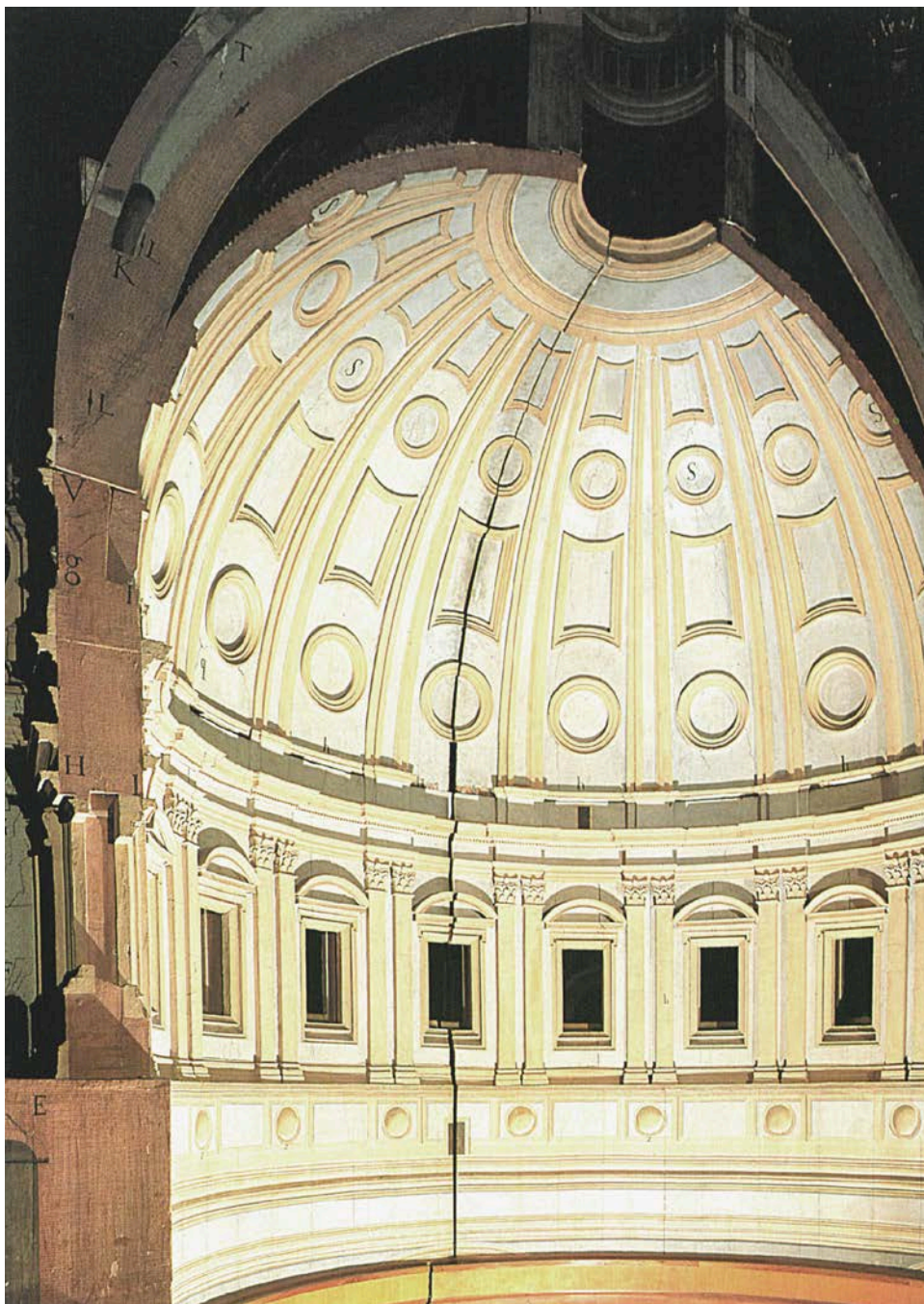
michelangelo buonarroti
façade of basilica of san lorenzo
1518



prospero sogari, il clemente
reggio emilia cathedral
1544



michelangelo buonarroti
st. peter's basilica
1557-58



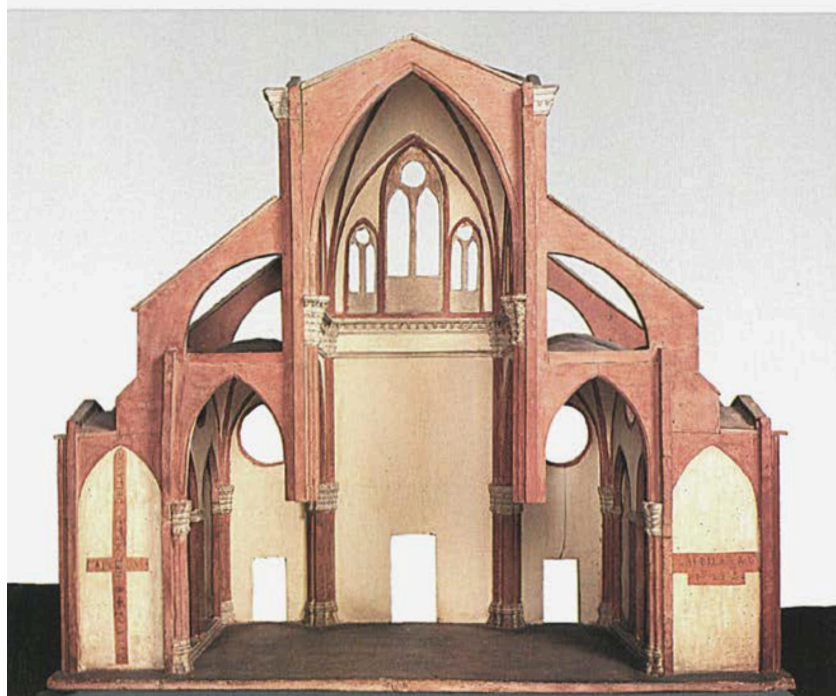
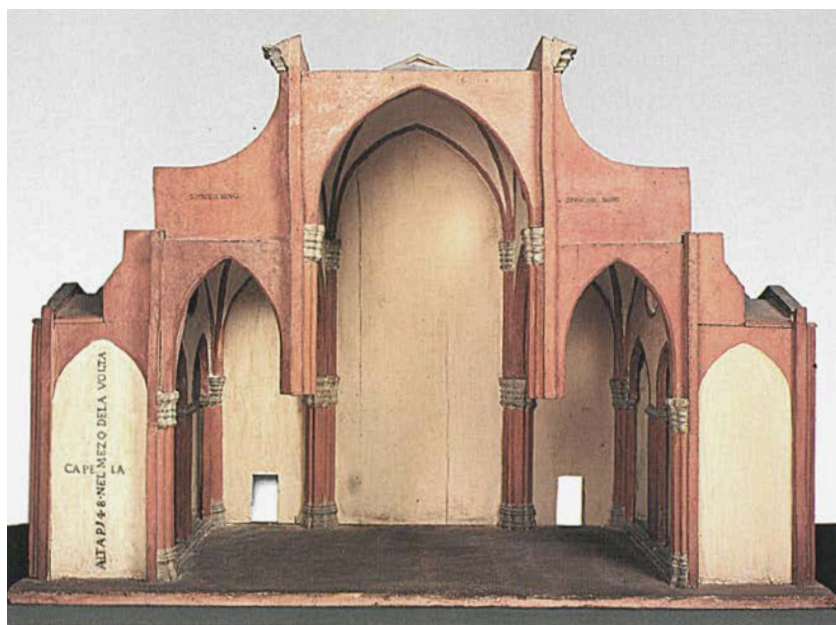
michelangelo buonarroti
st. peter's basilica
1557-58



alessandro pieroni
façade of Basilica of Saint Mary of the Flower
1587



bernardo buontalenti
façade of Basilica of Saint Mary of the Flower
1587



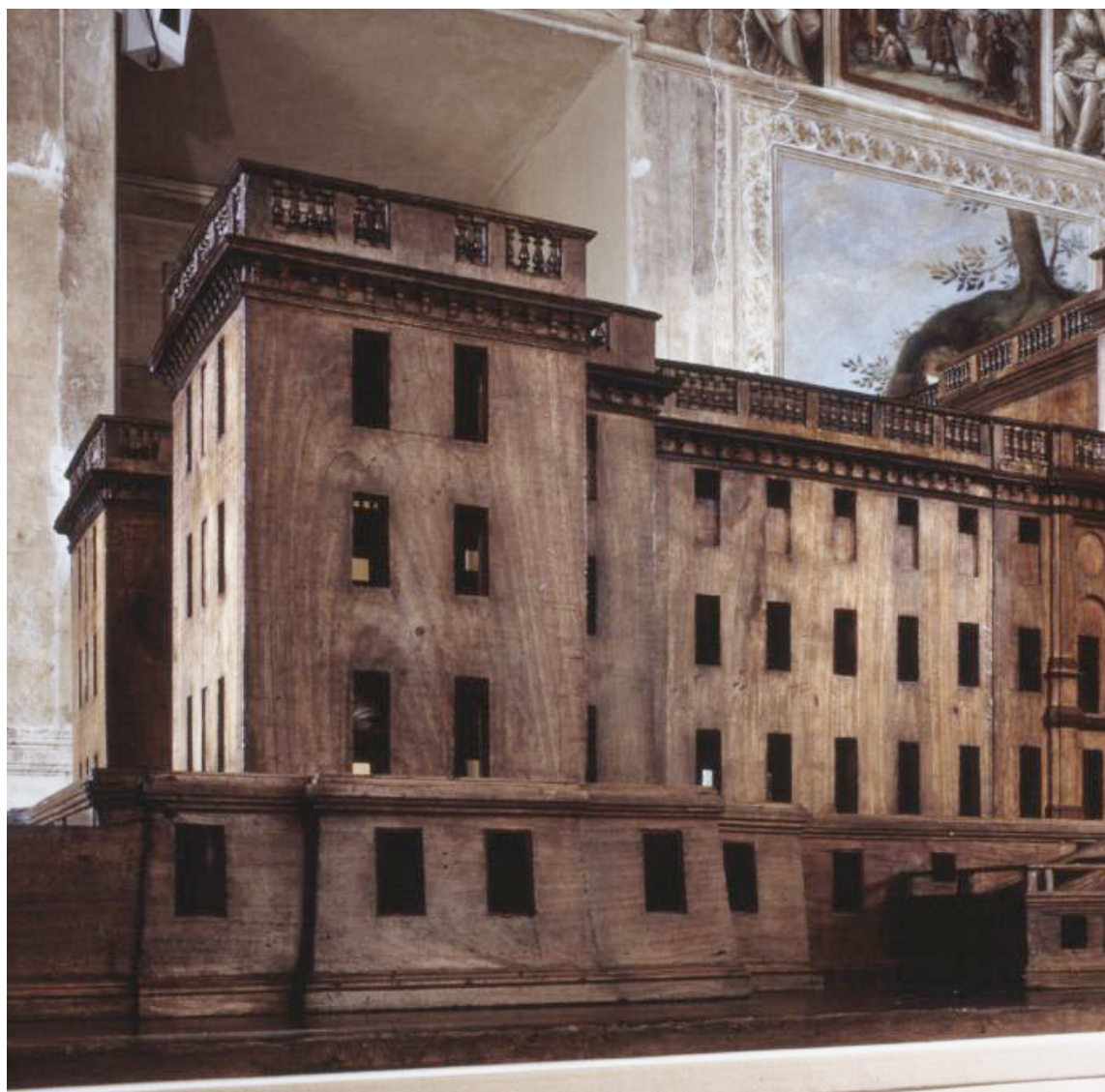
floriano ambrosini
san petronio
1592



arduino arriguzzi
san petronio
1592



christopher wren
st. paul's cathedral
1673

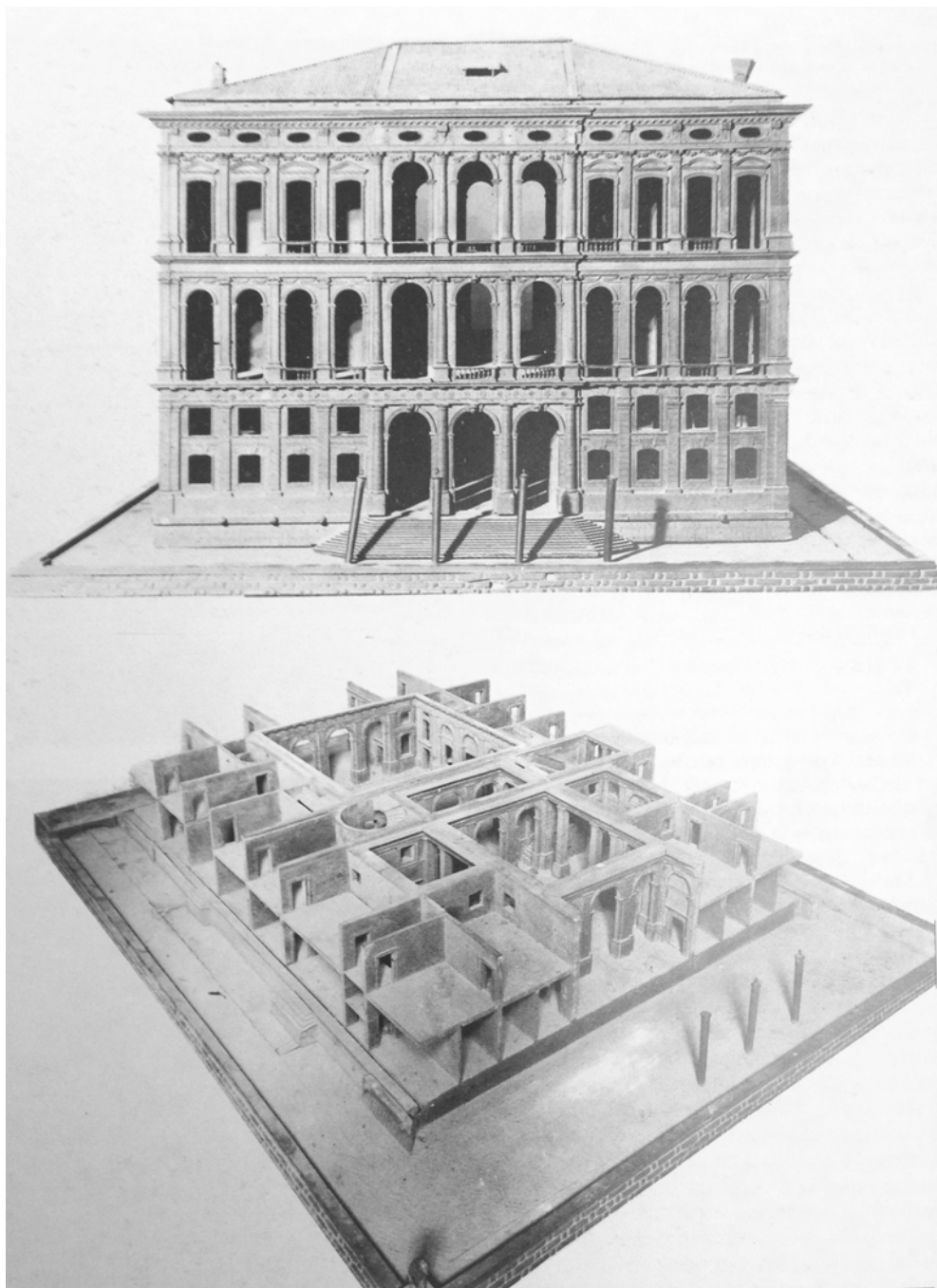


filippo juvarra
castello di rivoli
1718





nicola salvi
trevi fountain
1735



lorenzo boschetti
ca' venier dei leoni
1749



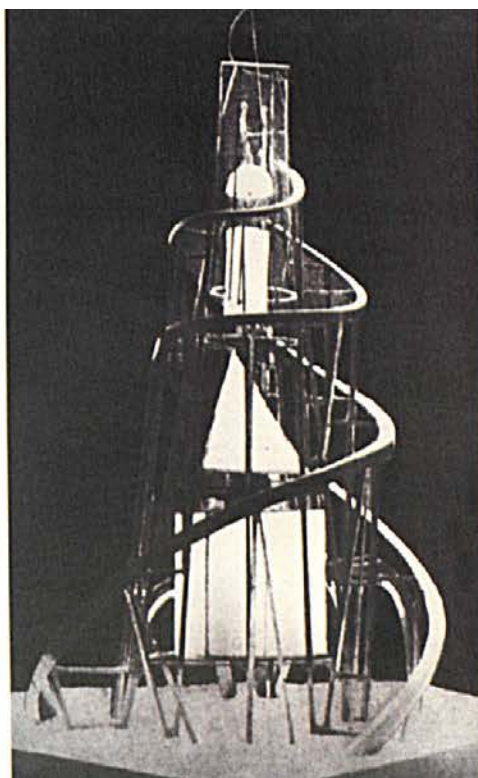
luigi vanvitelli
royal palace of caserta
1752



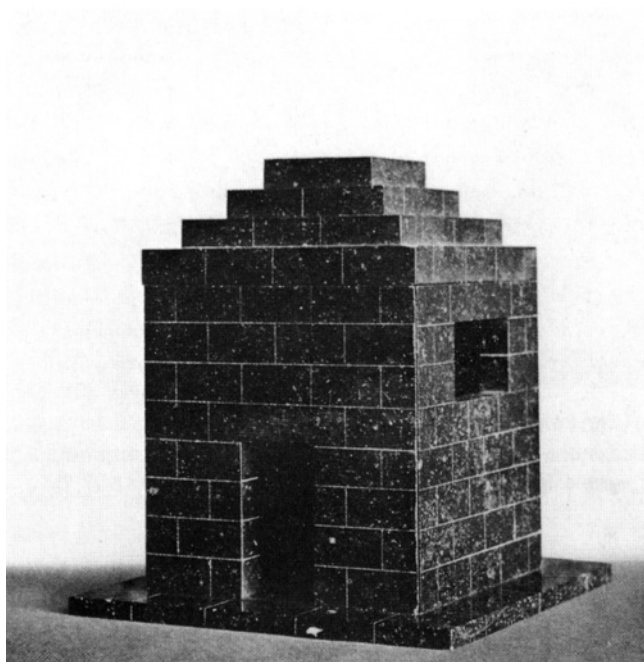
fernandino bonsignore
gran madre, torino
1818



antoni gaudí
structural model
1882



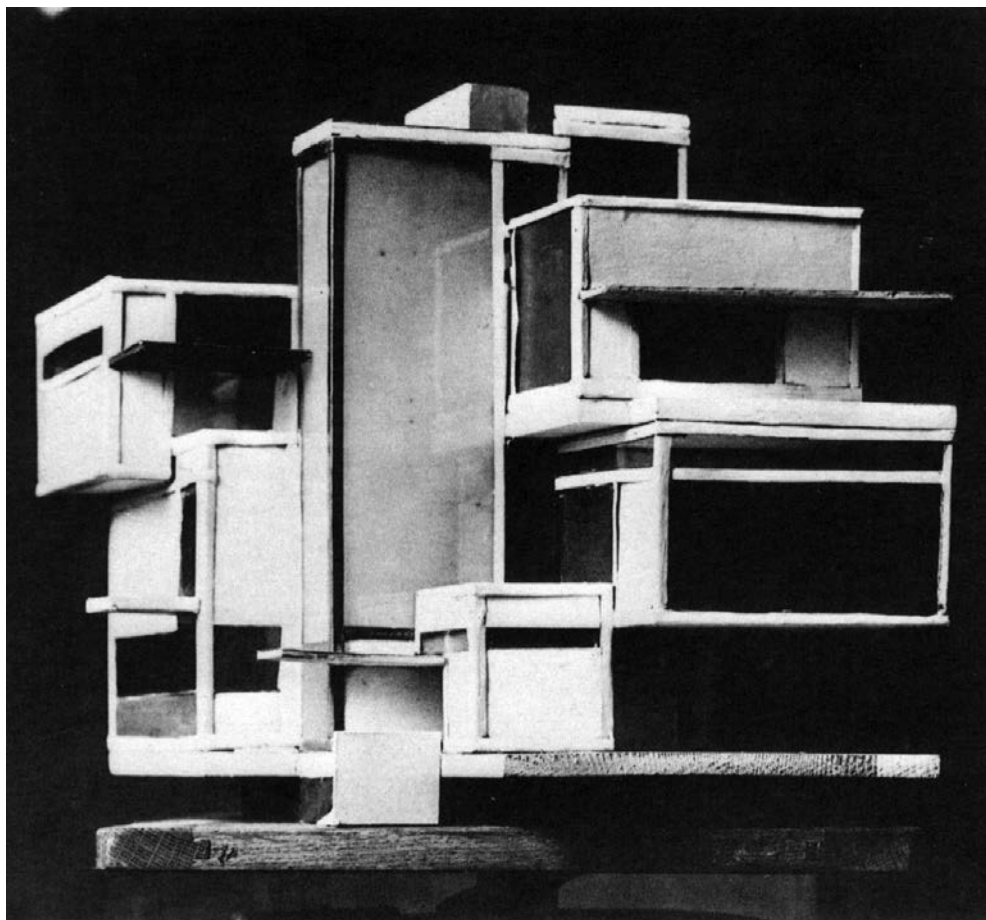
vladimir tatlin
monument to the third international
1920



adolf loos
mausoleum max dvorak
1921



ludwig mies van der rohe
skyscraper
1922



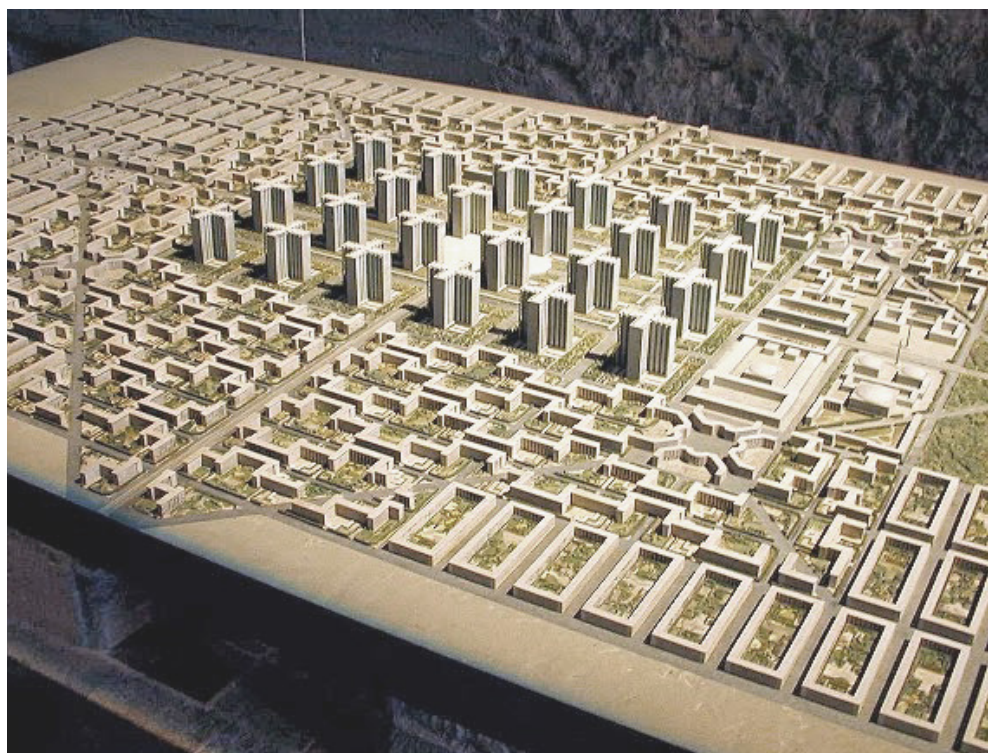
theo van doesburg
house for an artist
1923



kazimir malevich
arkitekton gota
1923



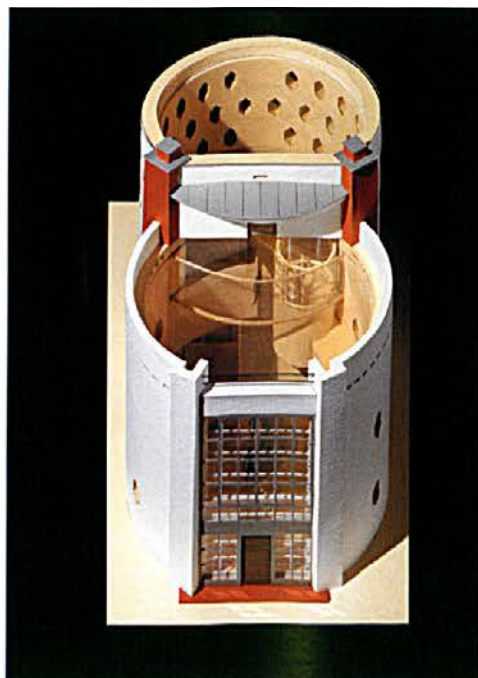
fortunato depero
progetto di chiosco pubblicitario
1924



le corbusier
radial city
1924



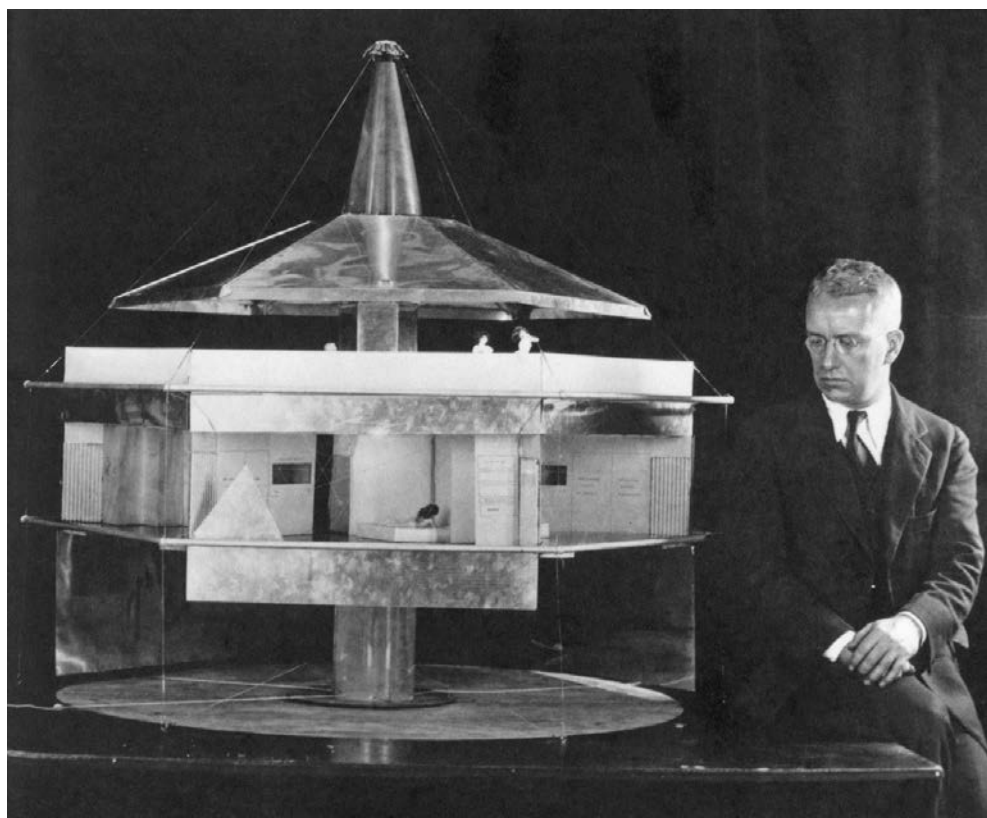
gerrit rietveld
schröder house
1924



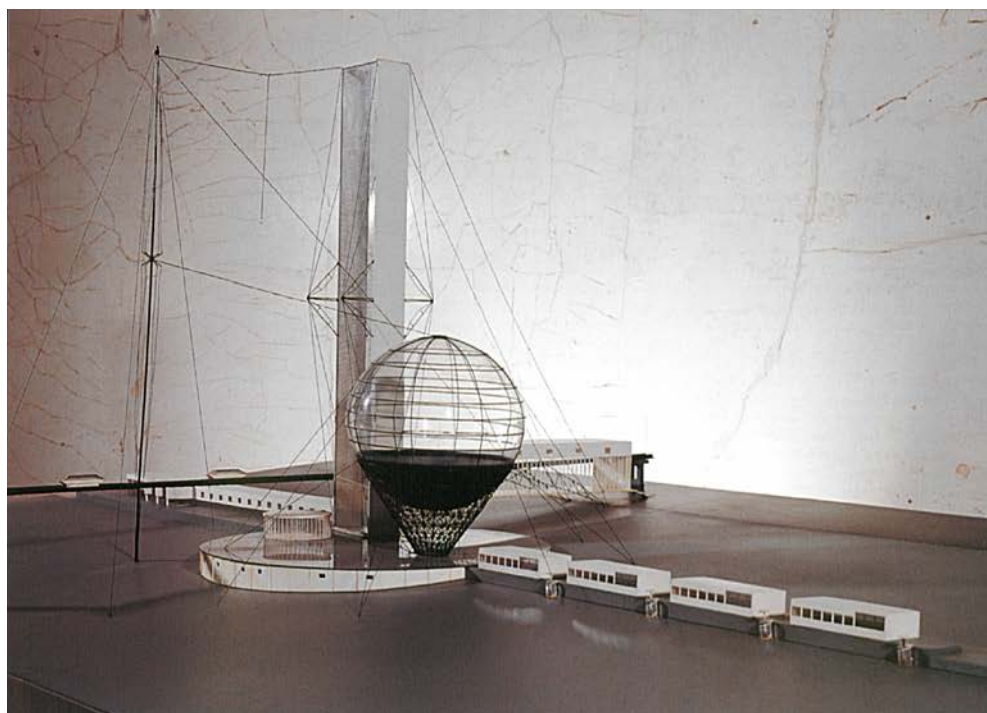
konstantin mel'nikov
mel'nikov house-studio
1927

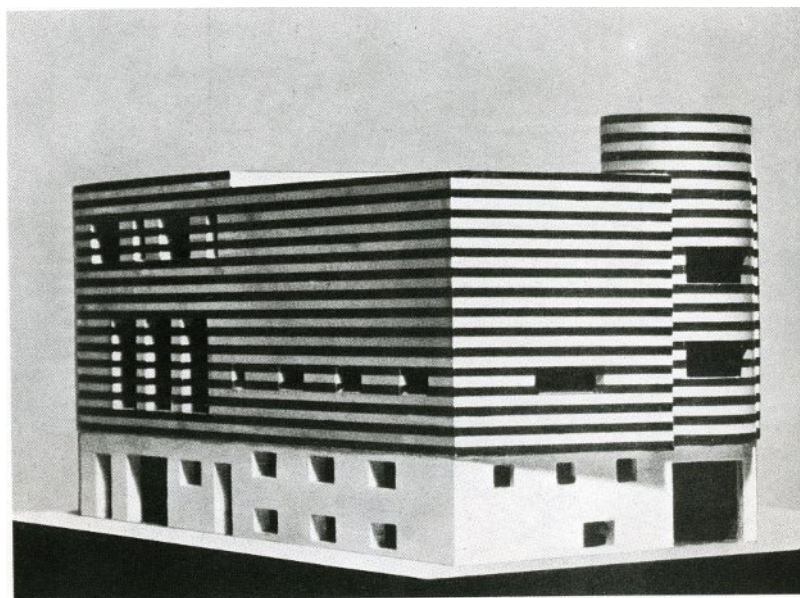


fortunato depero
progetto pubblicitario Bestetti Tumminelli Treves
1927

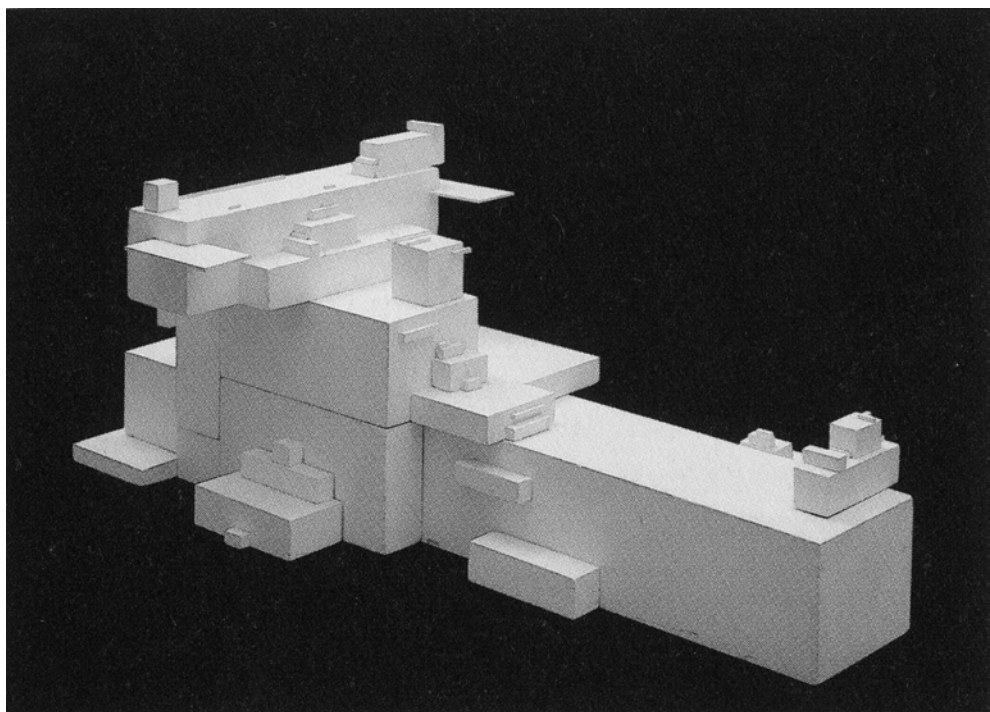


buckminster fuller
richard dymaxion house
1927

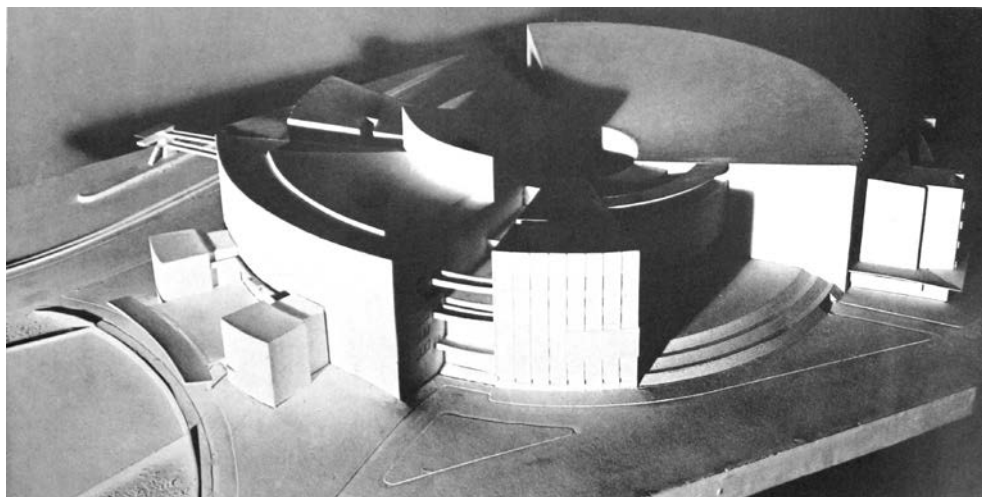




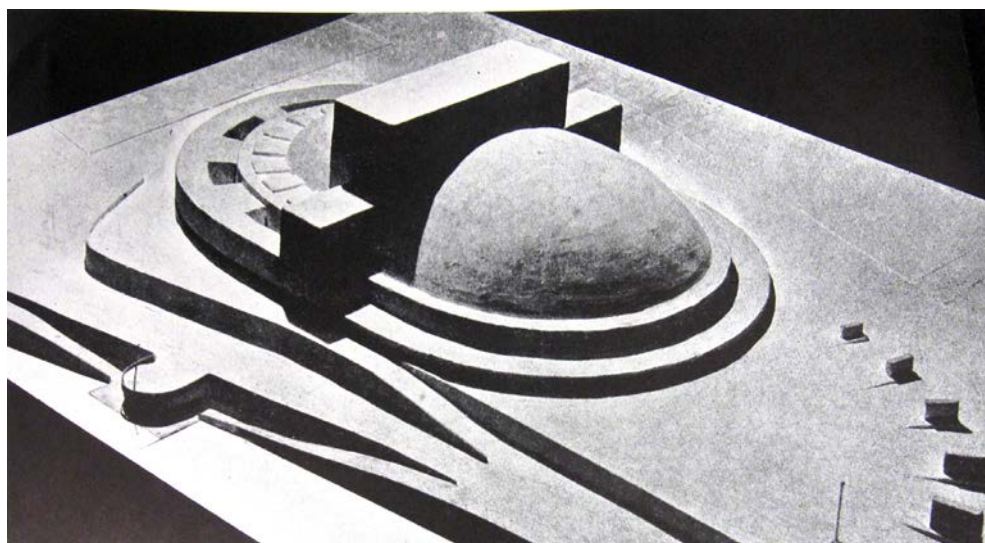
adolf loos
casa baker
1928



kazimir malevich
arkitekton
1929



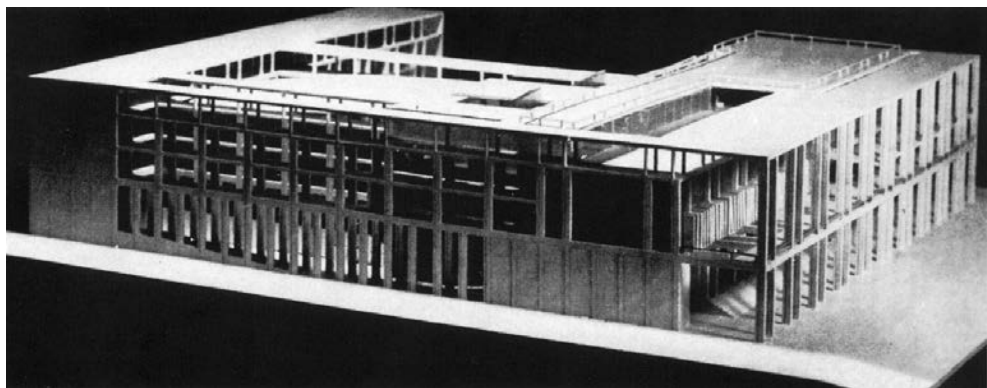
walter gropius,
soviet palace
1931



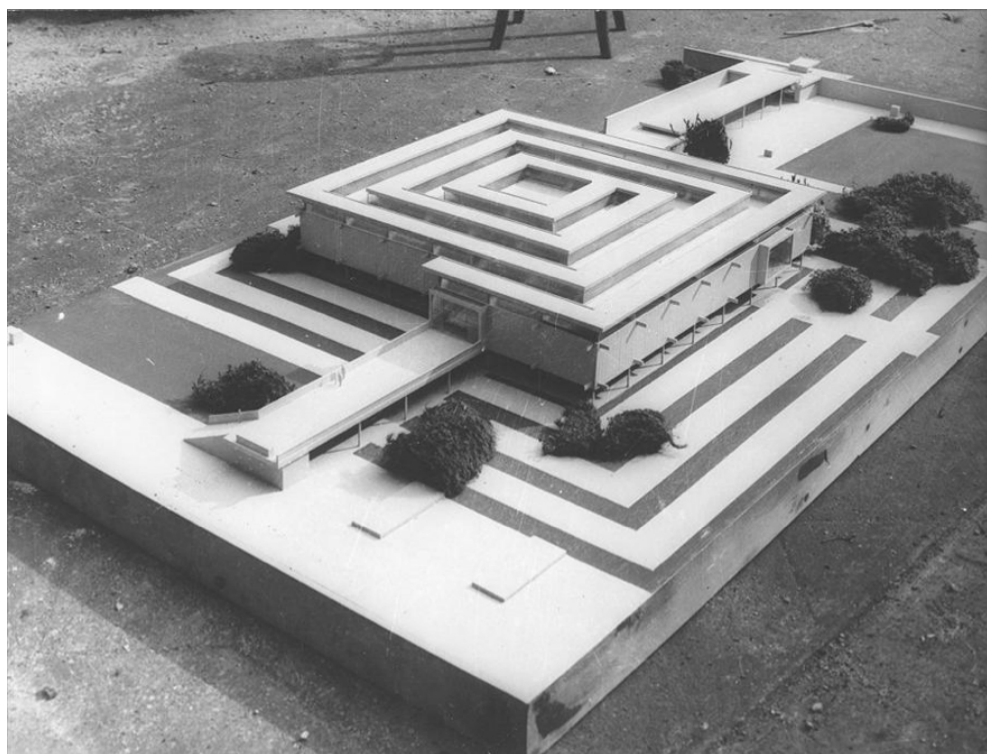
erich mendelson
Palace of the Soviets competition
1931



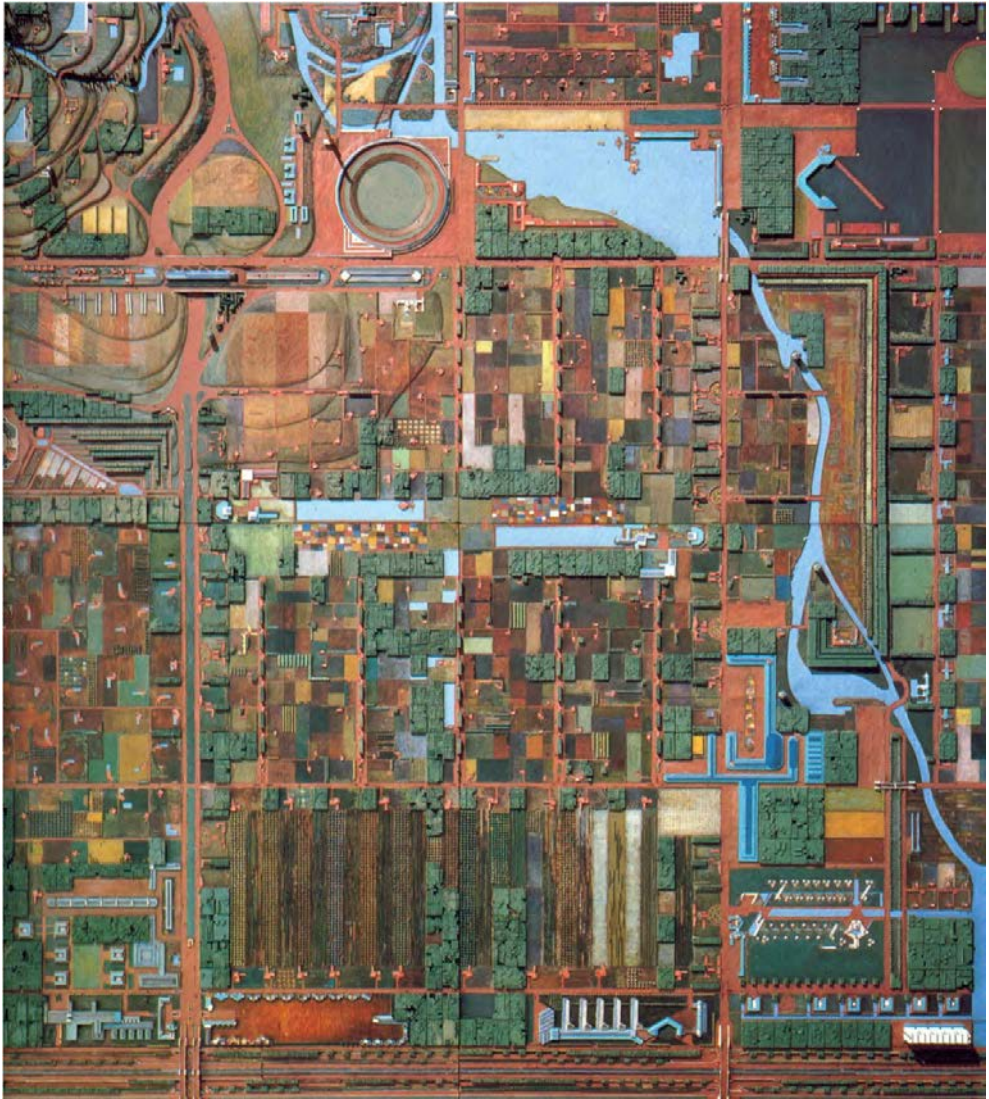
luciano baldessari
E42 palace of the italian civilization
1937



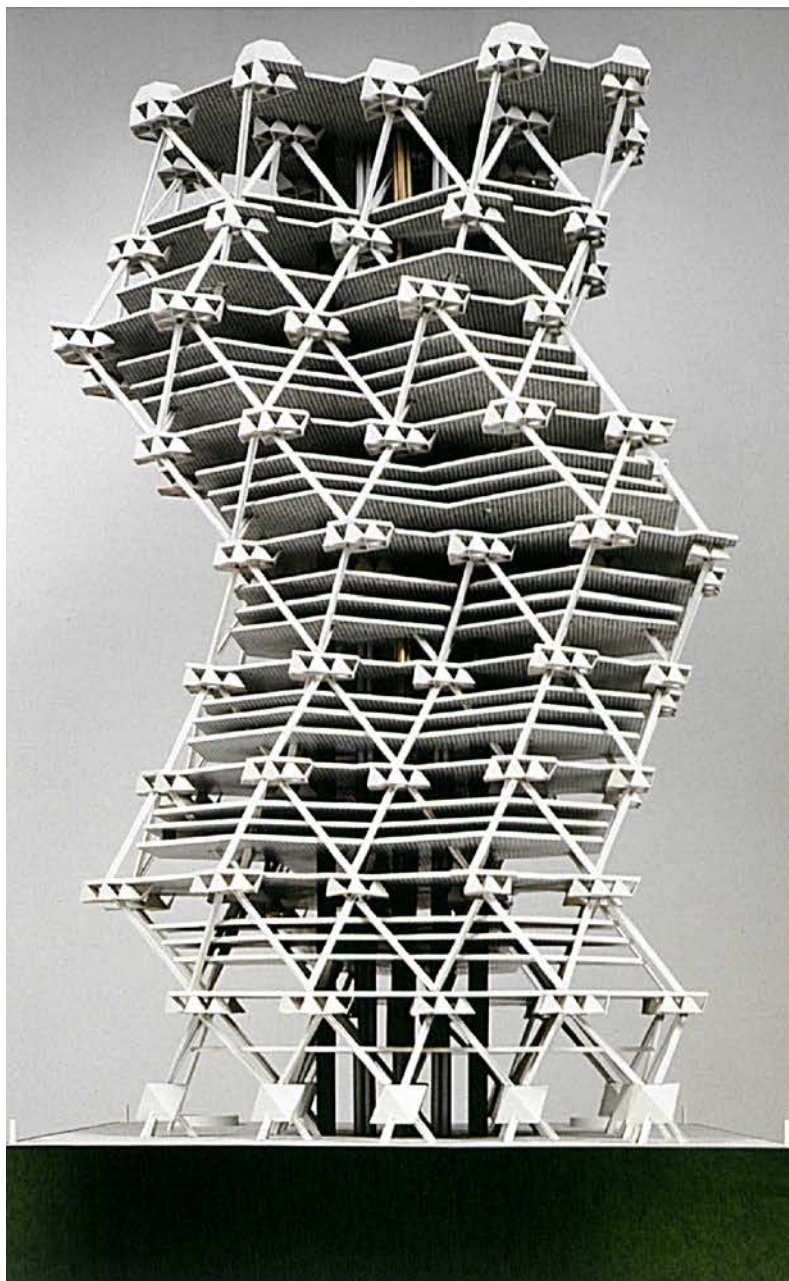
langeri, terragni
palazzo dei congressi
1937



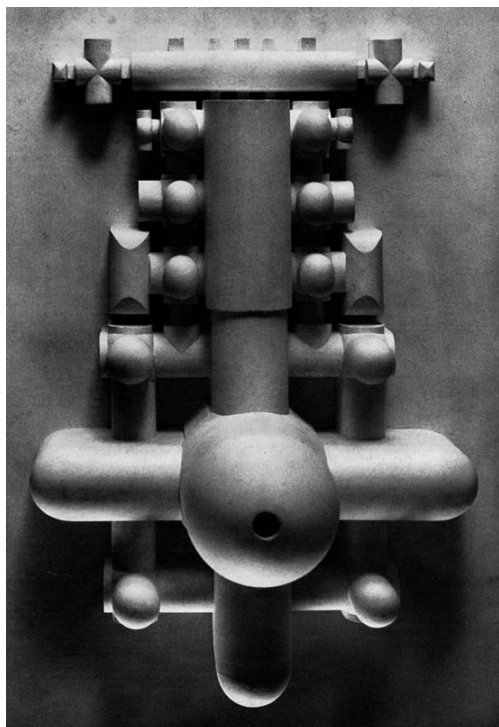
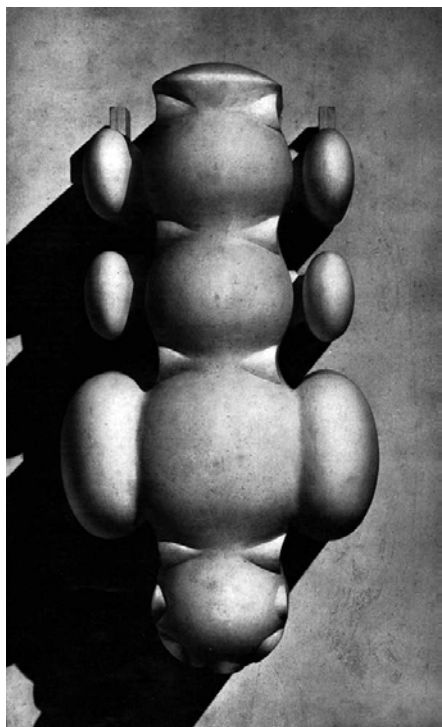
le corbusier
Musée à croissance illimitée
1939



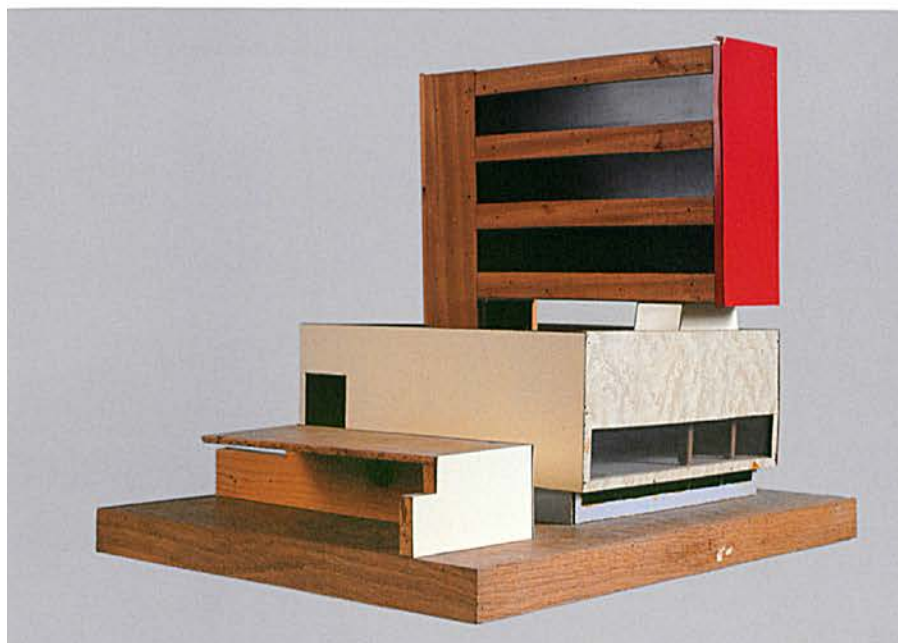
frank l wright
broadacre city
1934



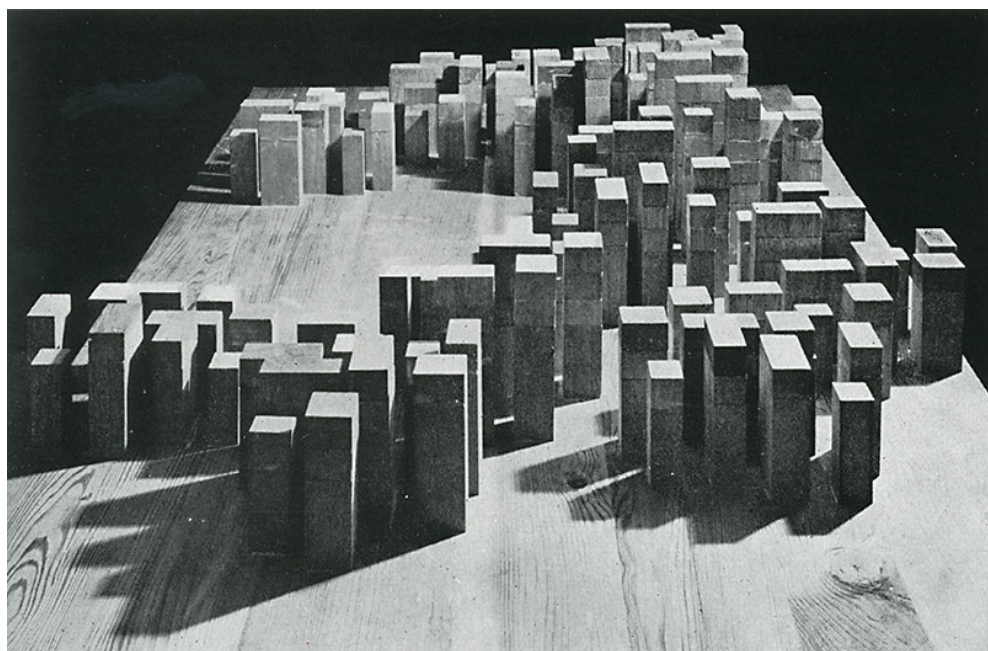
louis kahn
office tower center philadelphia
1952-57



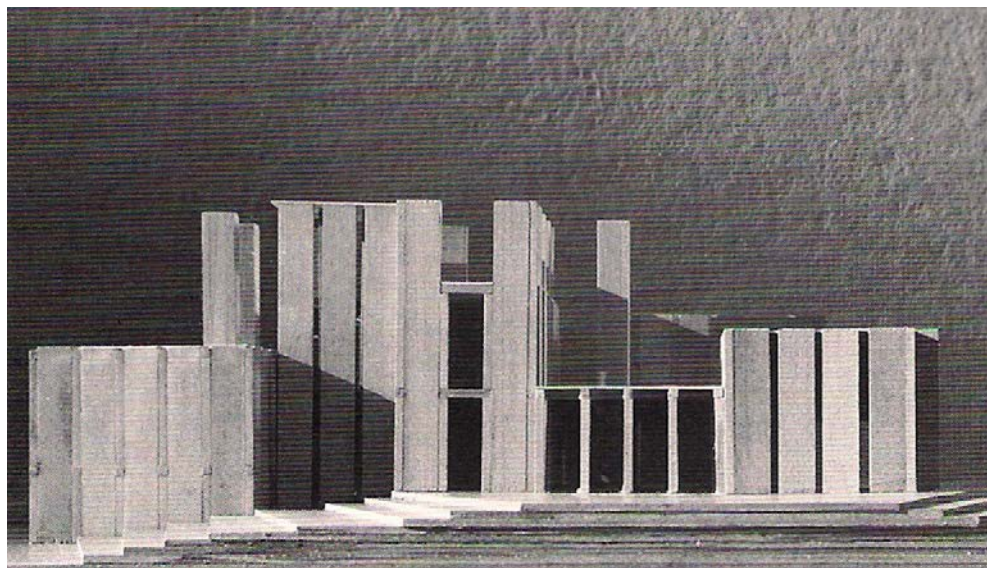
luigi moretti
model of inner space
1950s



ivo pannaggi
project for the house of the people, porto di sant'elpido
1956



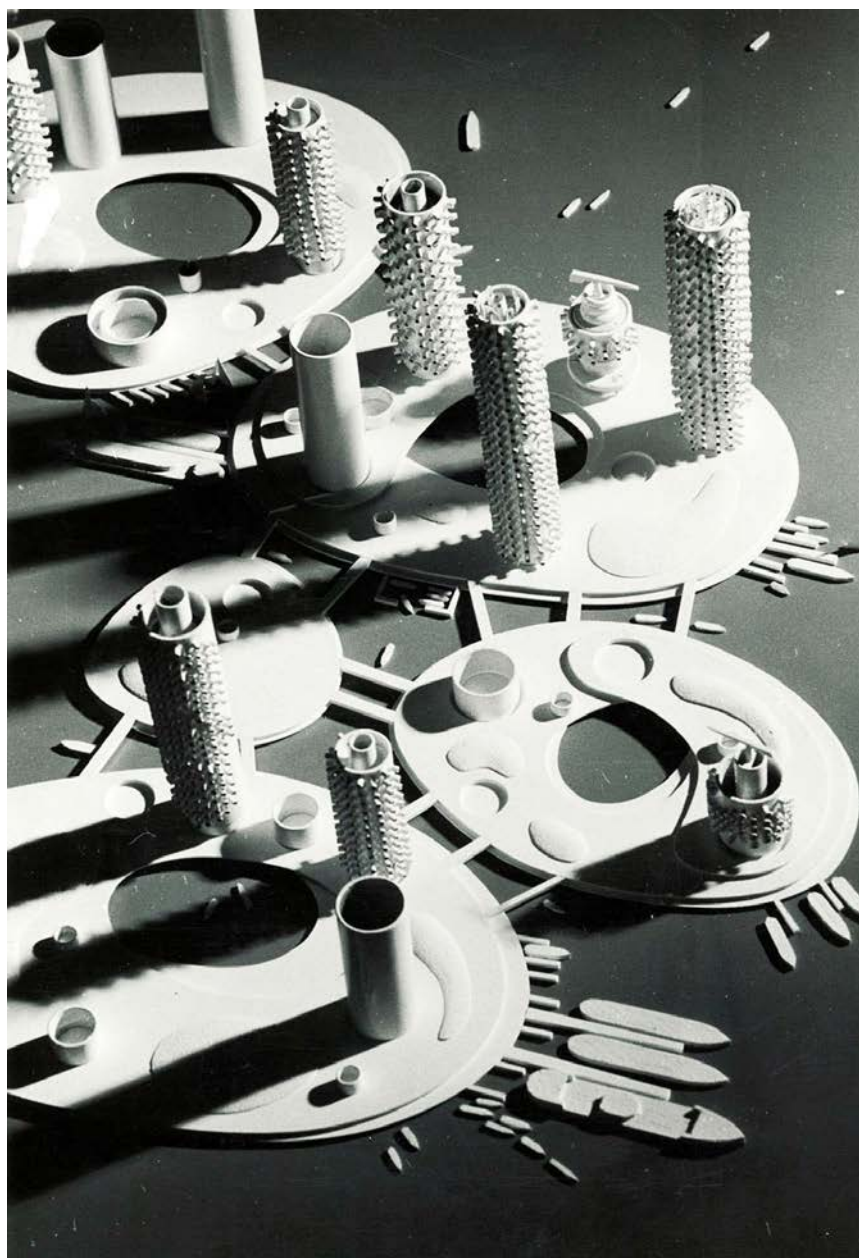
mathias ungers
neue stadt
1957



louis kahn
morris house
1955-58



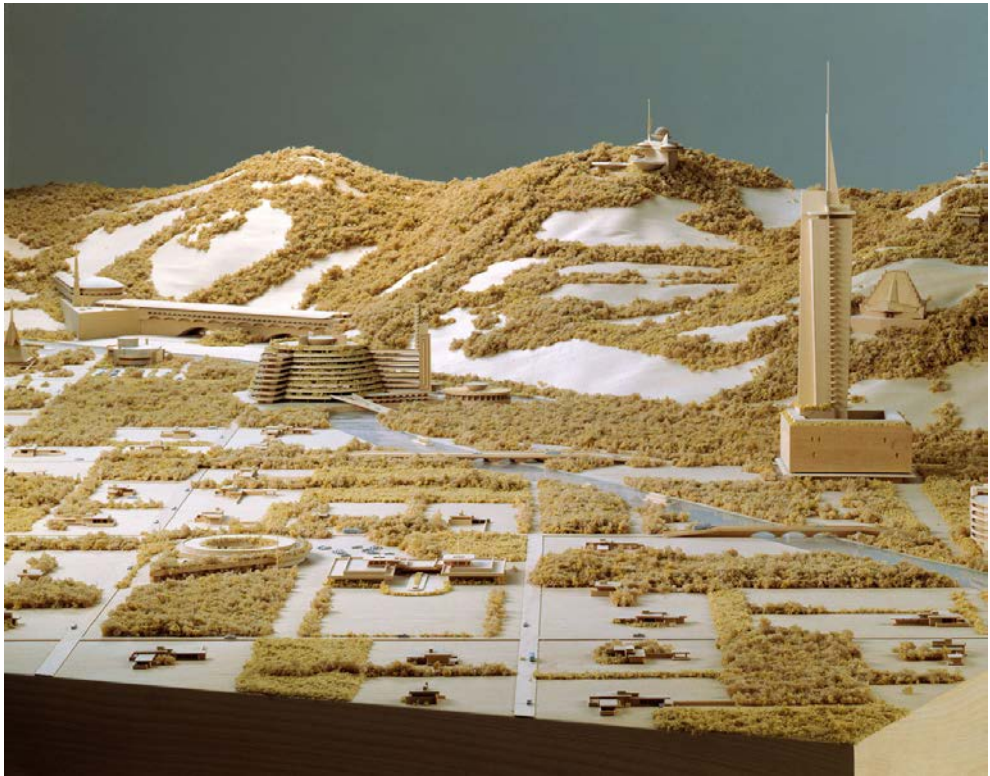
fredrick kiesler
endless house
1959



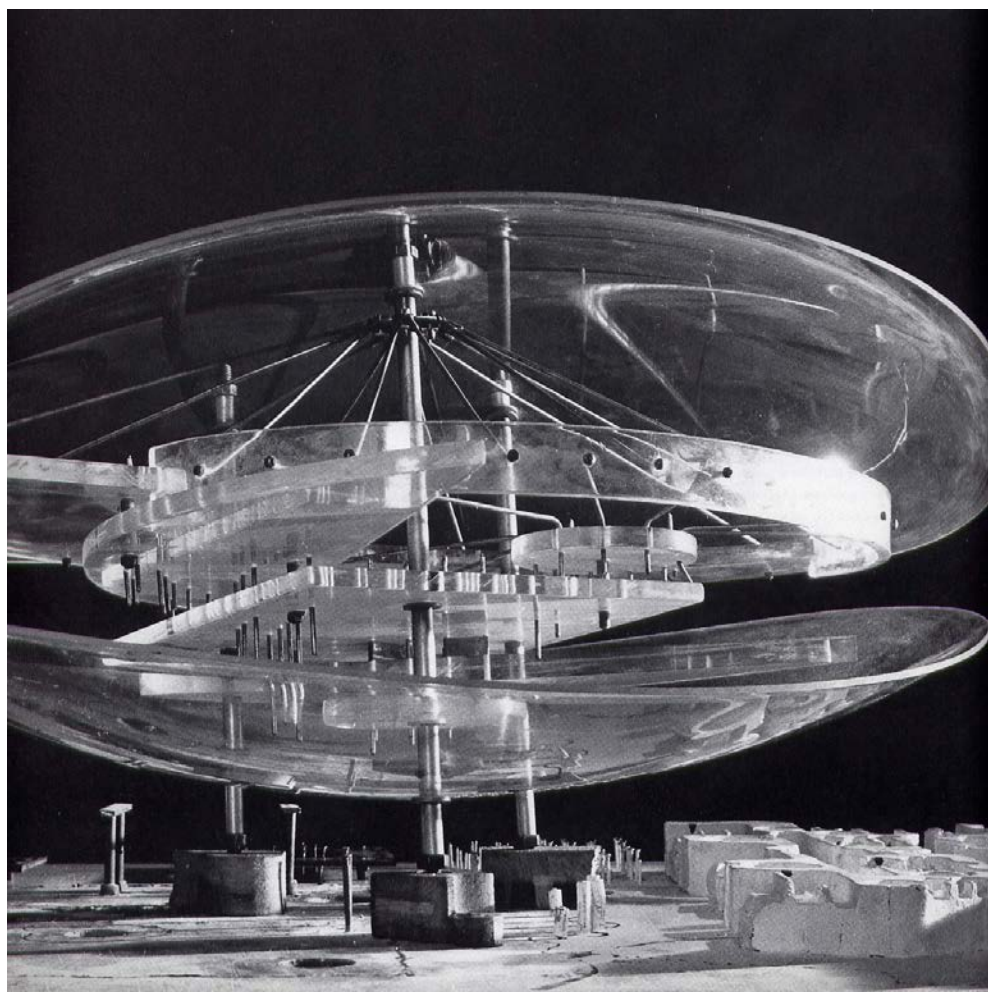
kikutake, kurokawa
marine city
1958



tange kenzo
tokyo bay
1960



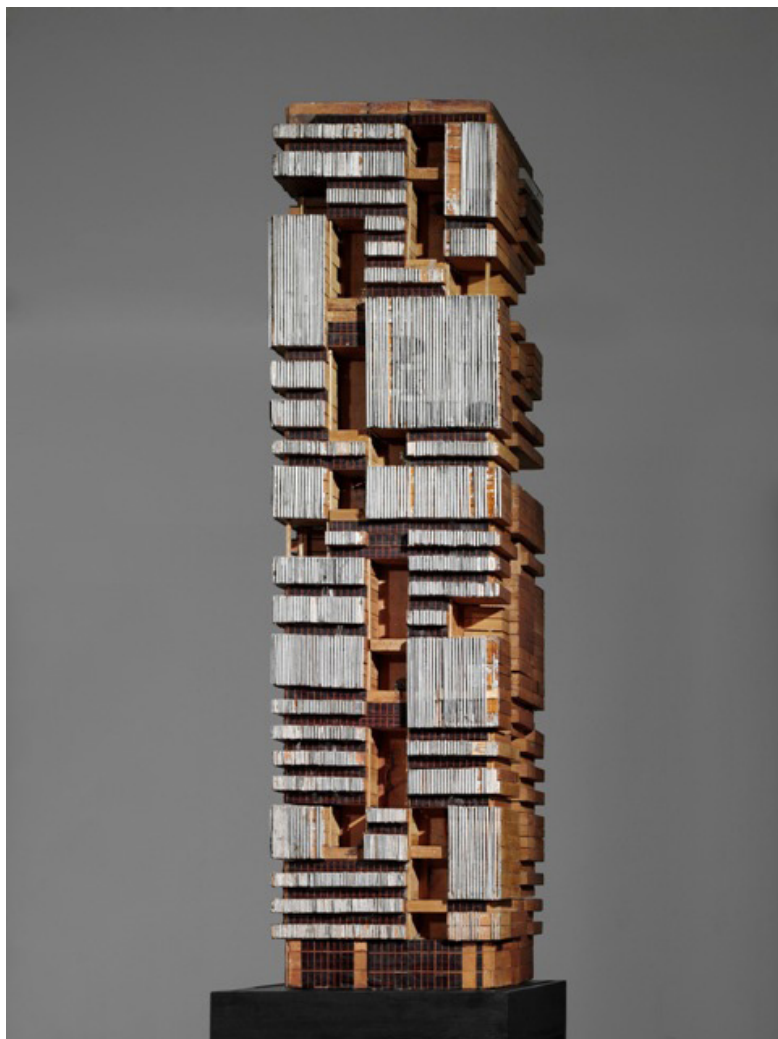
frank l wright
living city
1959



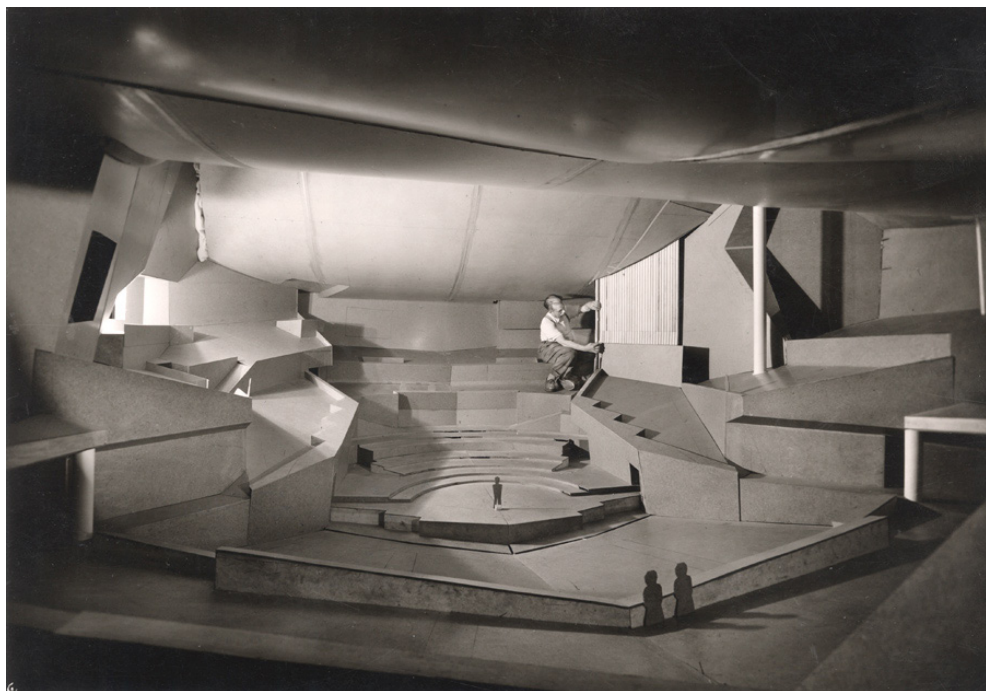
constant
spatiovore
1959



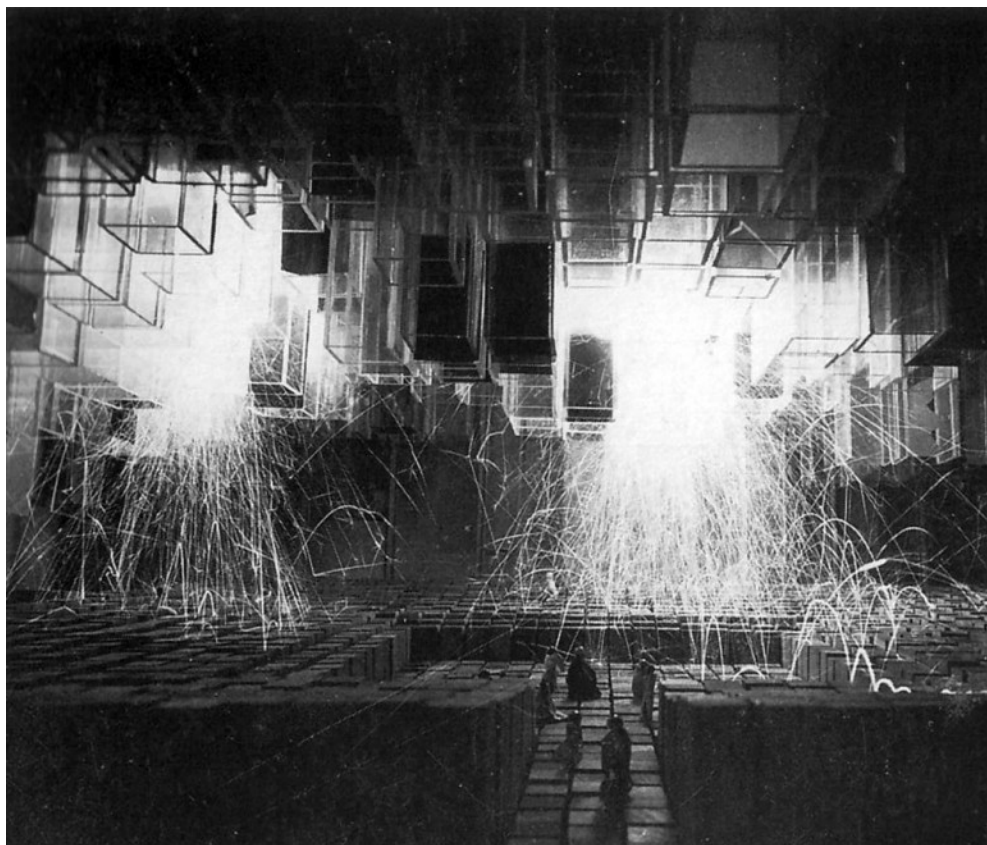
alvar aalto
opera house essen
1959



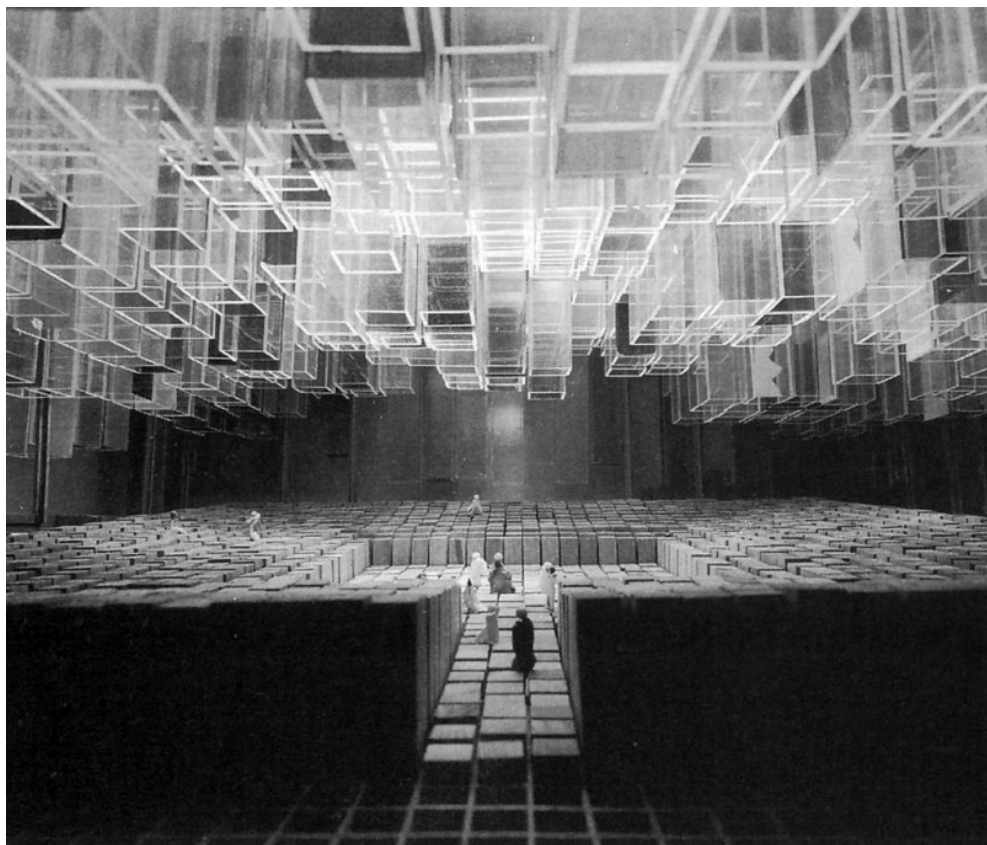
maurizio sacripanti
peugeot skyscraper
1961



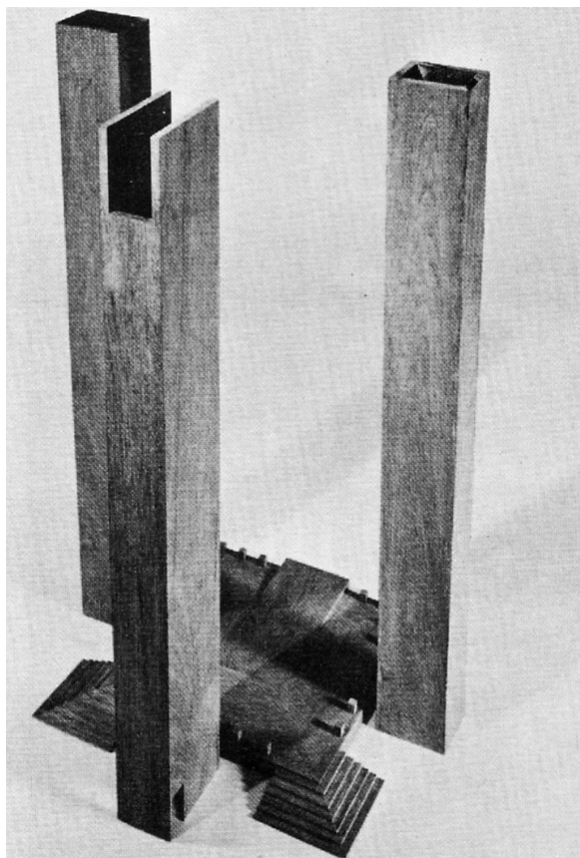
hans scharoun
berlin philharmonic concert hall
1963



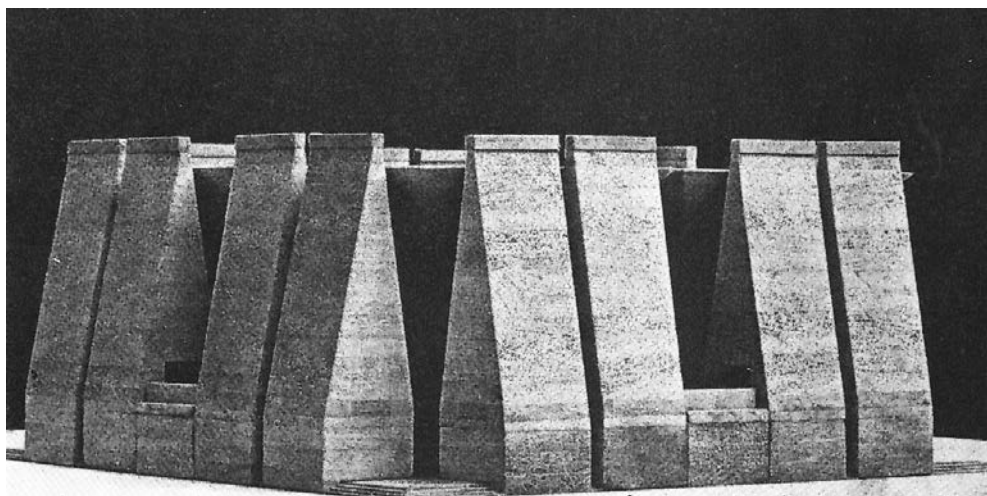
maurizio sacripanti
teatro, cagliari
1965



maurizio sacripanti
teatro, cagliari
1965



louis kahn
david goddard laboratories
1965



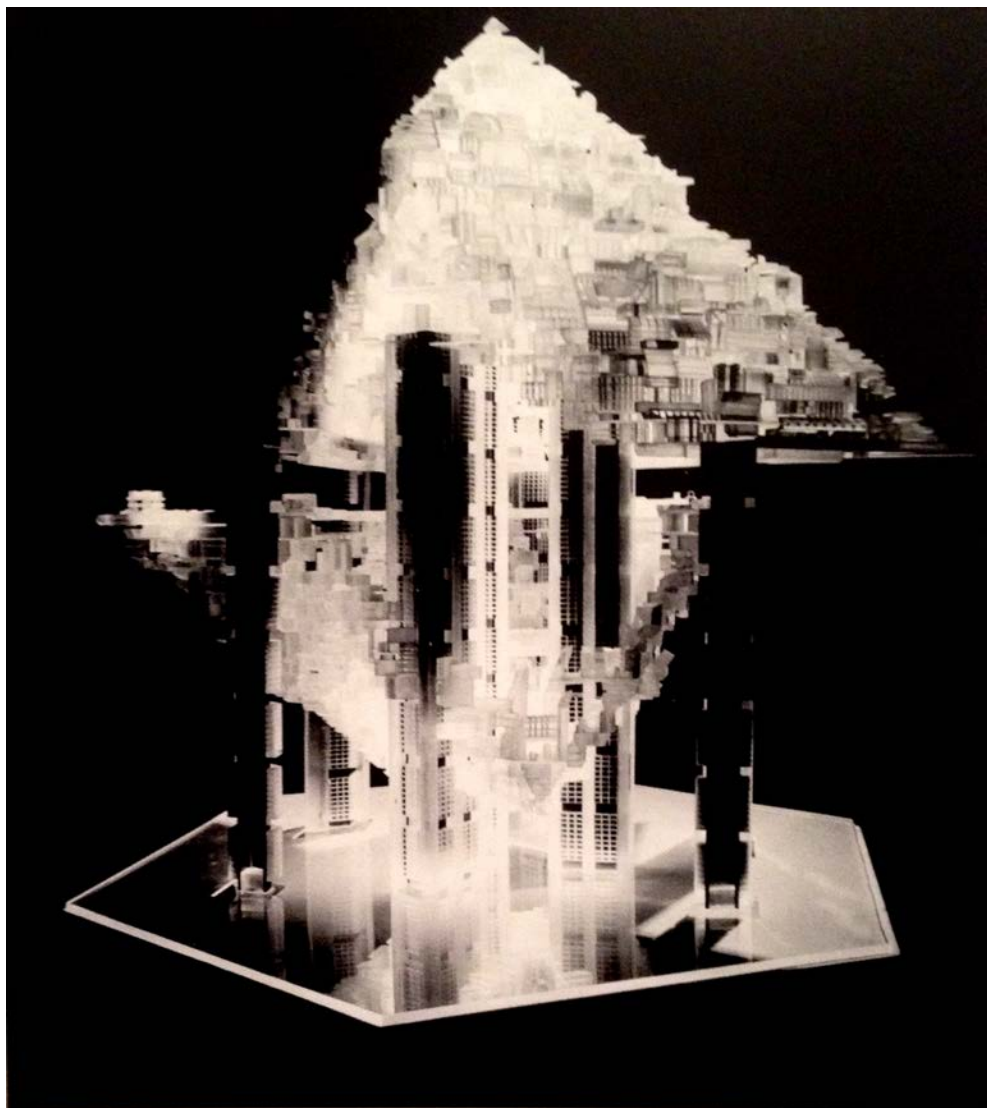
louis kahn
hurva synagogue
1965



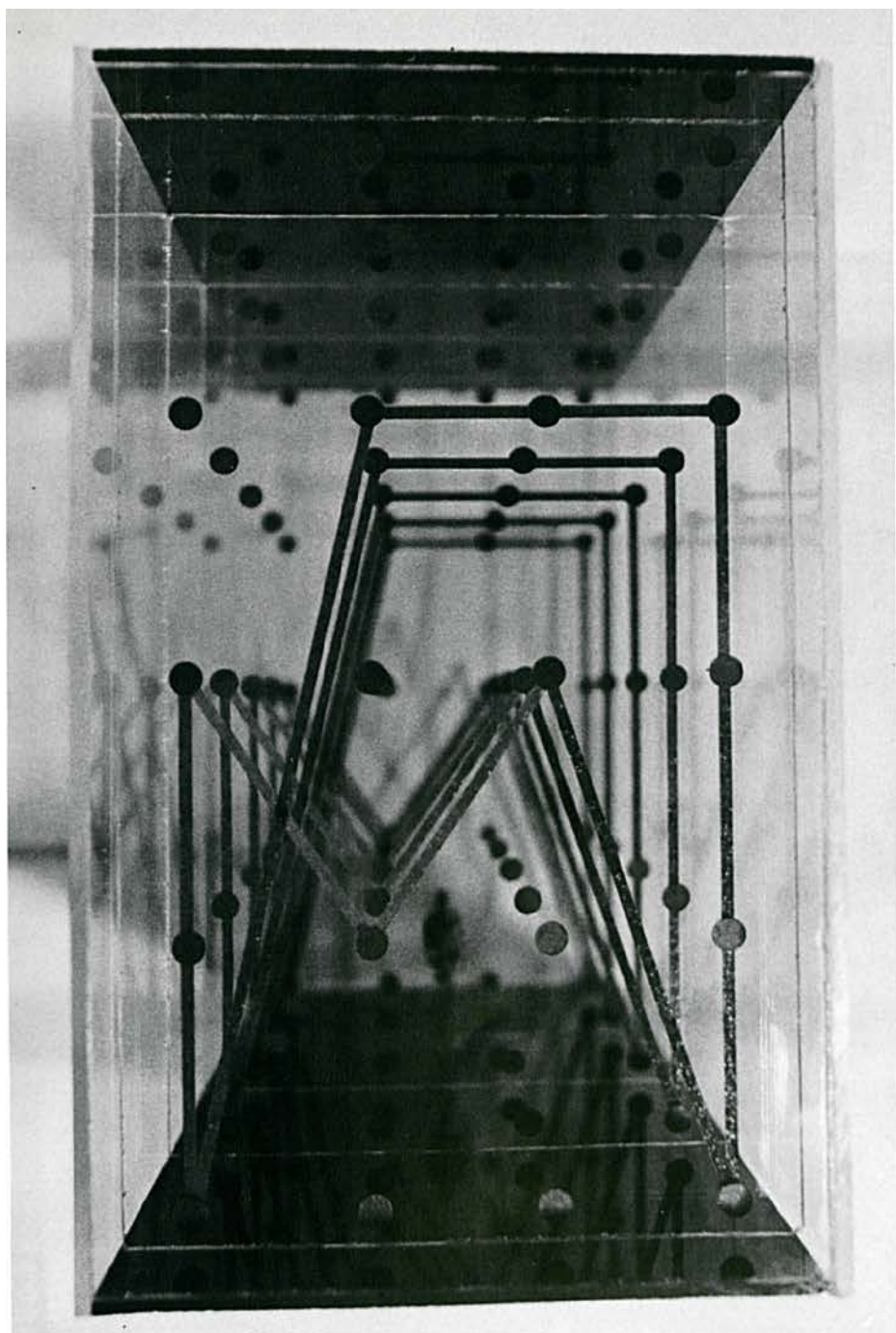
archigram
living pod
1966



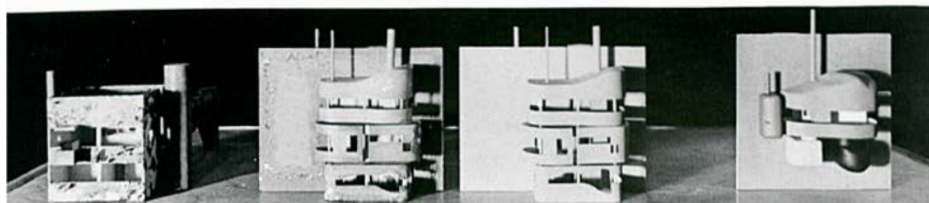
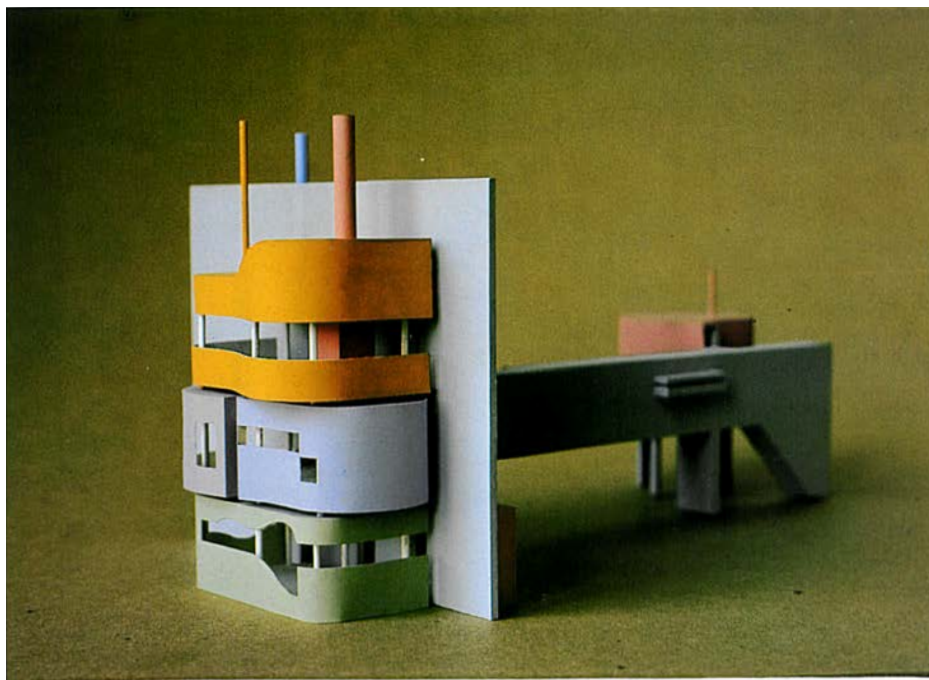
maurizio sacripanti
italian pavillion, osaka expo 70
1968-69



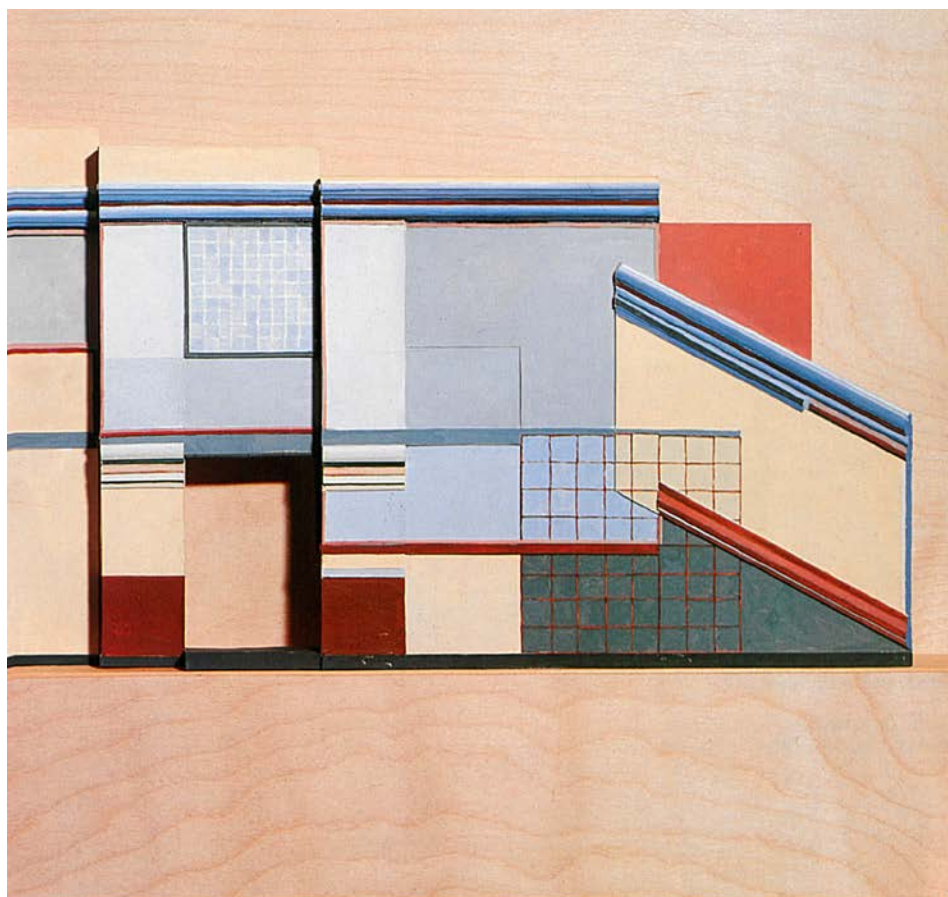
paolo soleri
arcology
1970



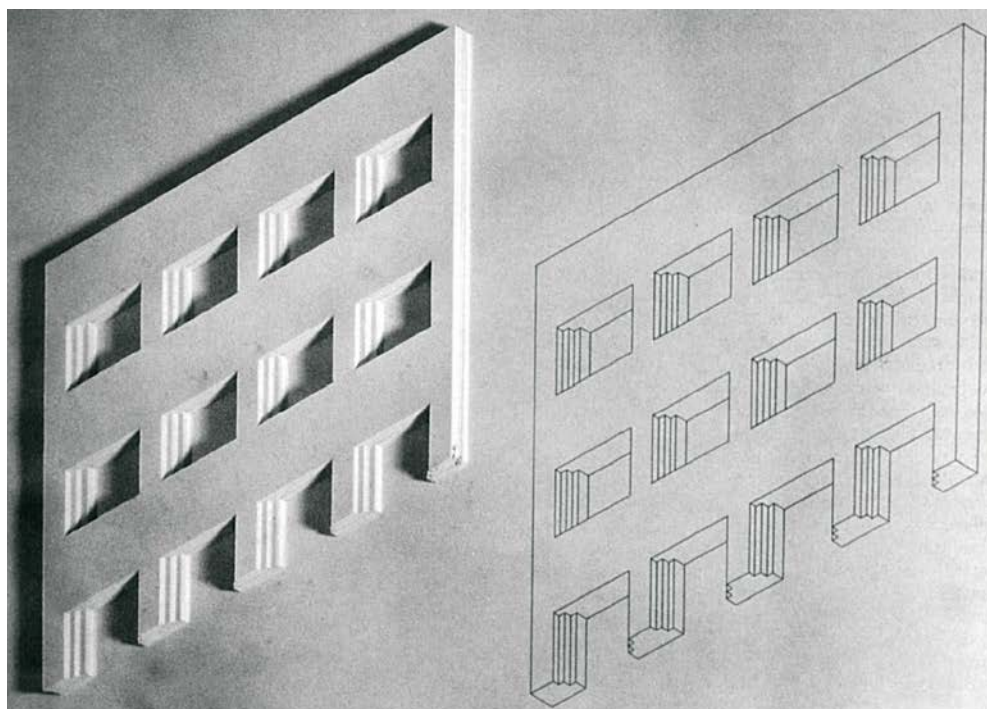
bernhard leitner
four spatial transformation of a grid
1972



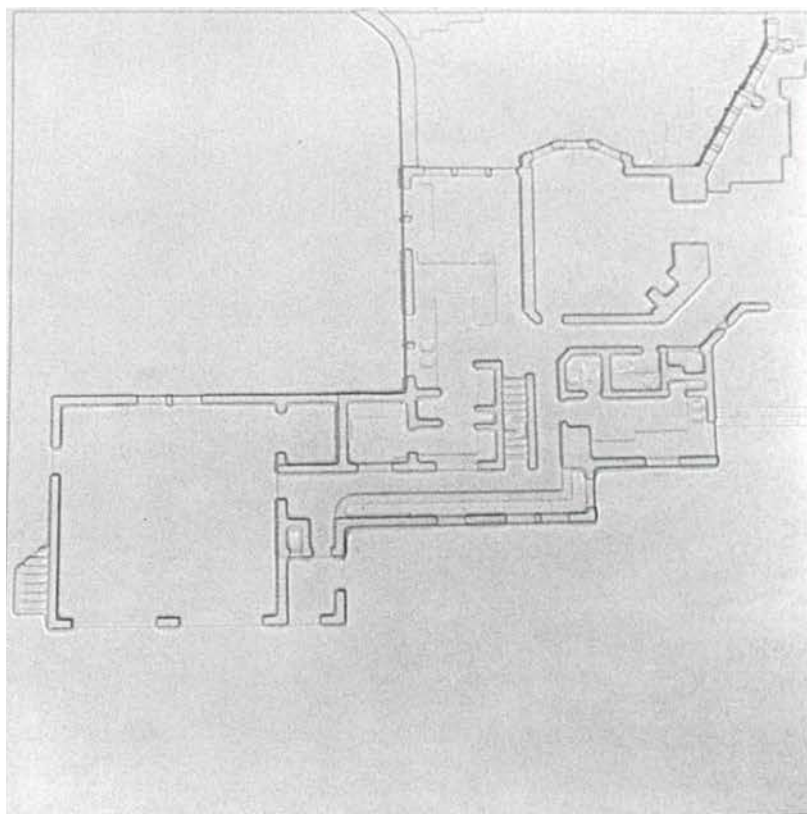
john hejduk
bye house
1973



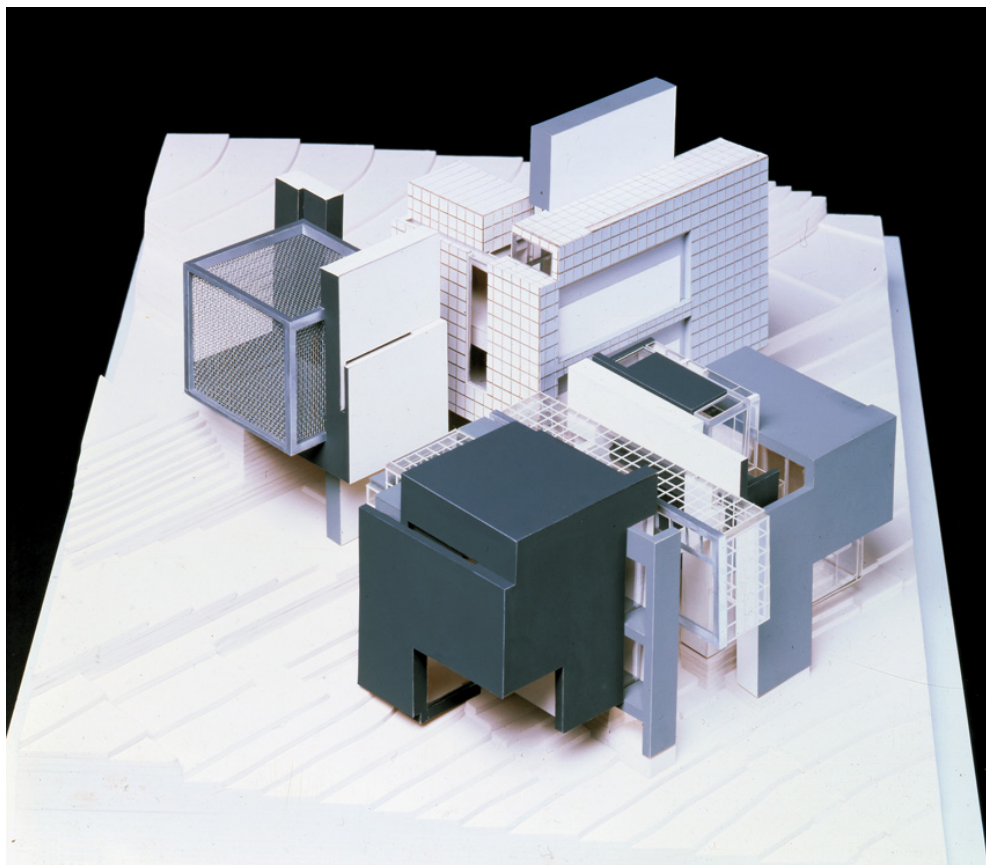
michael graves
crooks house
1976



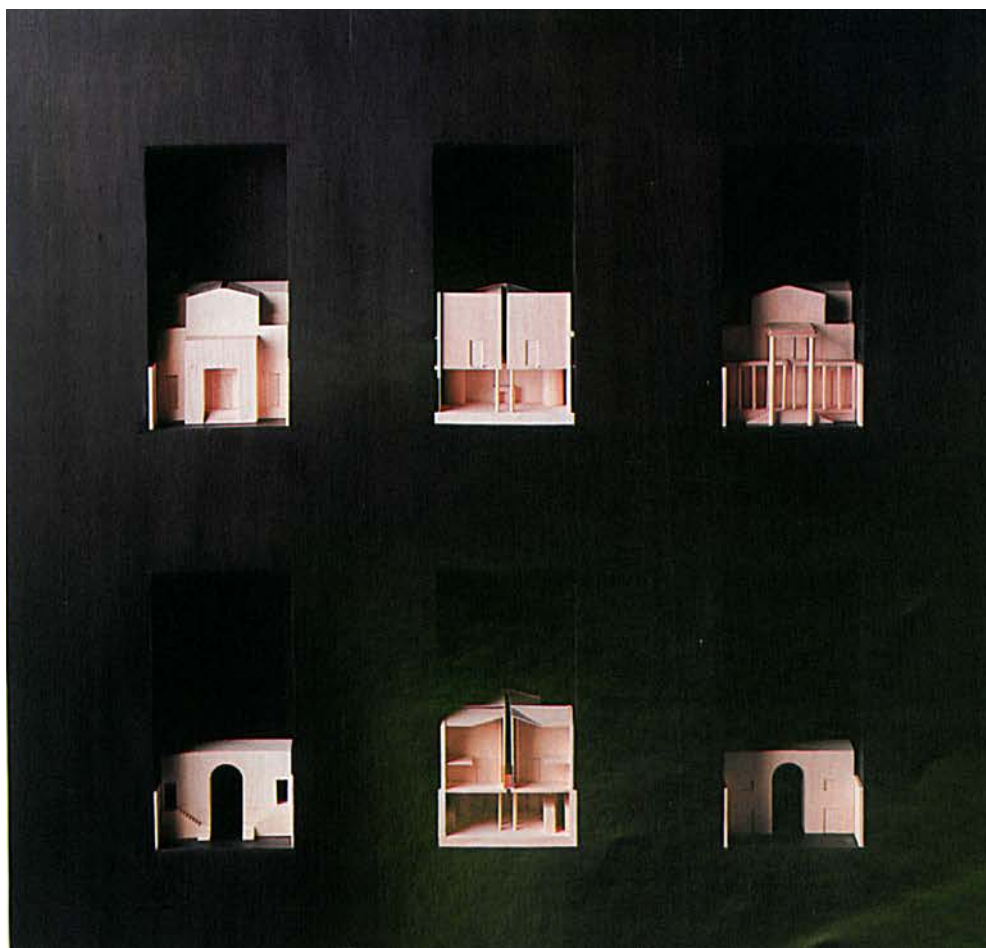
rafael moneo
study of the wall of a house



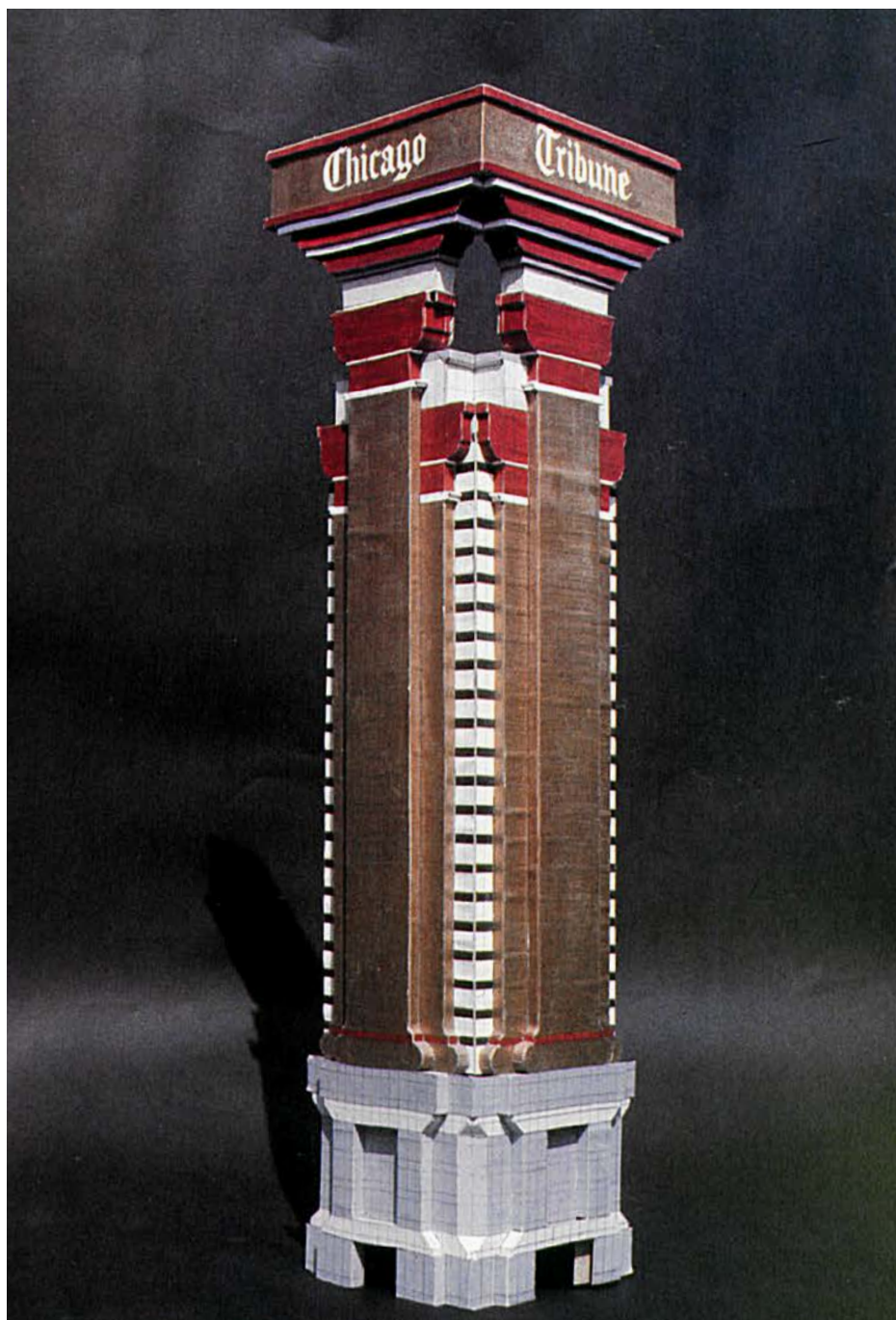
moore, oliver
house, new york



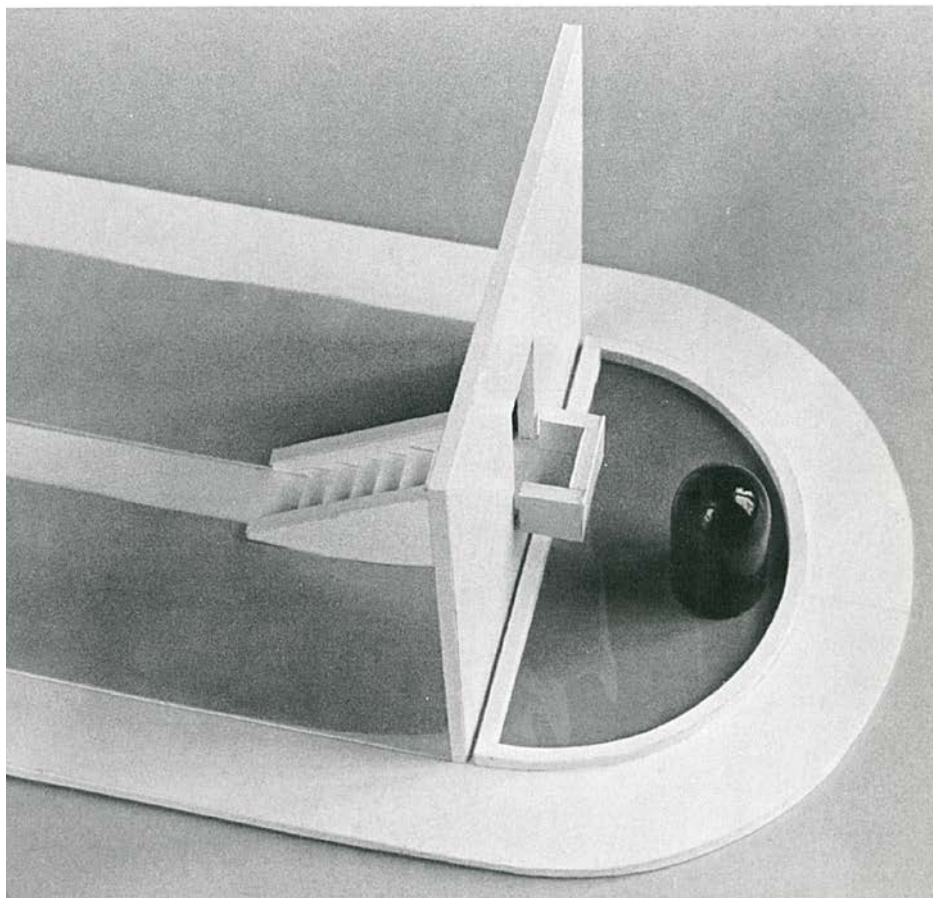
peter eisenman
house x
1978



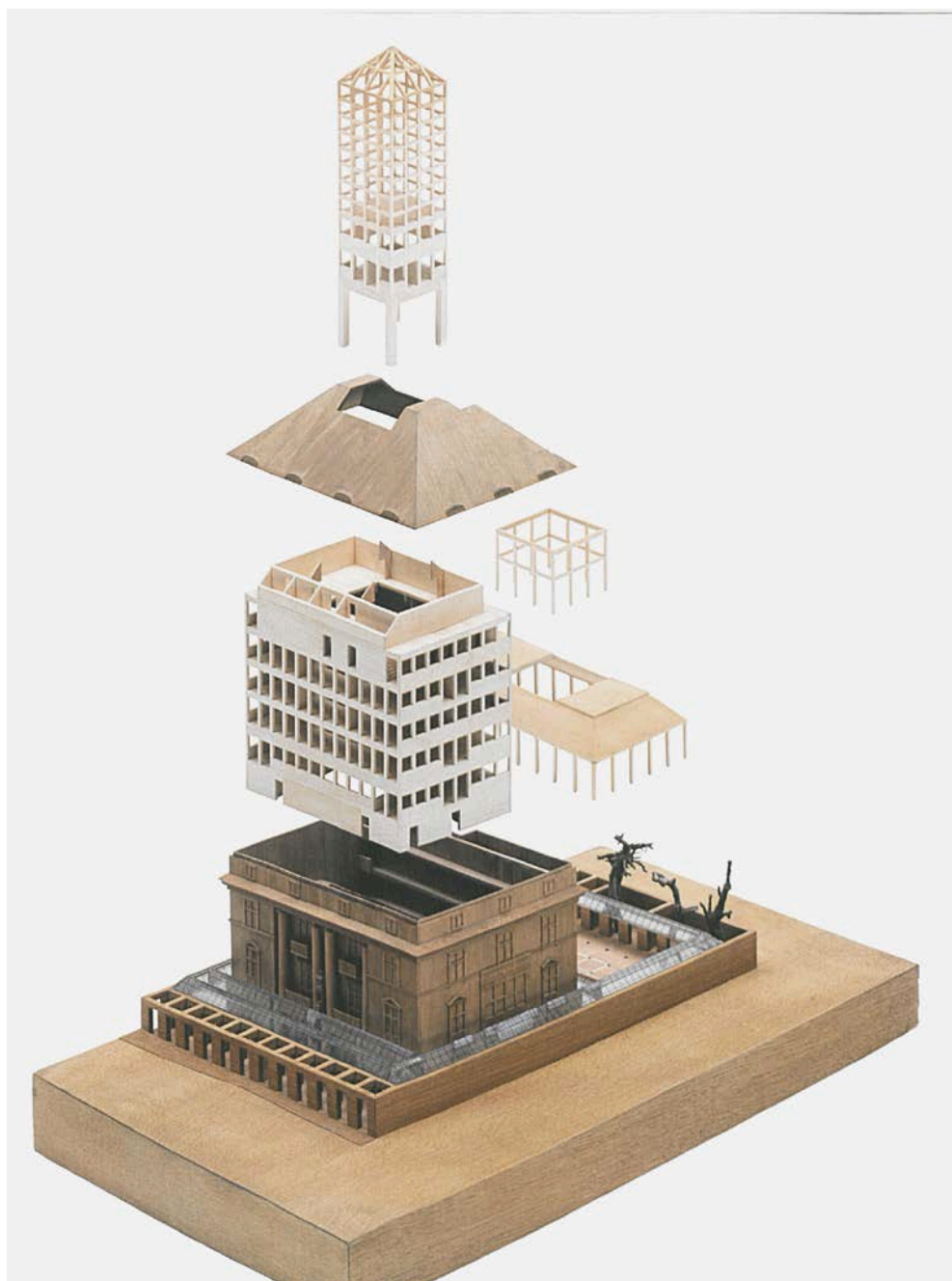
agrest, gandelsonas
house for a couple of psychoanalysts
1980



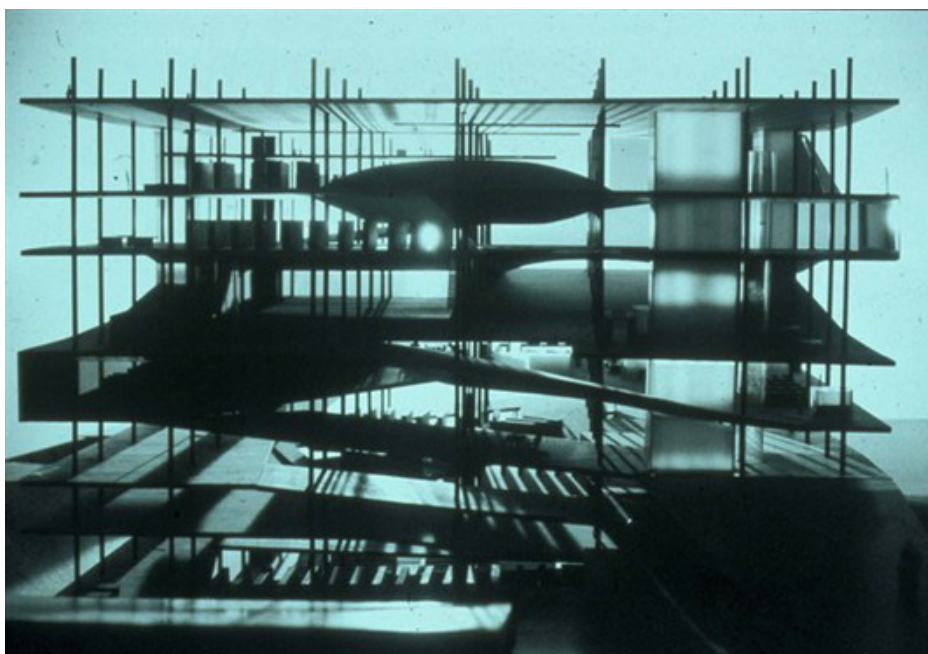
robert stern
new chicago tribune tower
1980



stuart wrede
romeo and juliette foundation
1980



oswald mathias ungers
deutsches architekturmuseum frankfurt
1979-84



OMA
jussieu library
1992

scale

The choice of scale is a very important decision. According to Scot Walls, of practice NBBJ, it is the first thing a modelmaker should fix. He says that there is a wrong scale, a right scale and a balance.¹ Typically, the model is reduced in scale according to size of the building. But separated decisions on scale should be made for every model constructed. Each scale reveals different details and aspects of the project. Moreover, they have different impact to the viewer.

As Edwin S. Parker pointed out in *Architectural Forum* already in 1919, is that “If the scale is large, one-half inch, for instance, the details are easy to cut and handle, though their size and increased number greatly increase the cost. If the scale is small, say one-eighth inch, most of the details can be left out. But in between is dangerous ground, for the details must be shown and are yet so small that they are difficult to work with, taking much time to make and assemble.”² Referring to the project’s typology, it does not work the relation the bigger the building is the bigger the model should be. Even for skyscrapers large scales are not always the best.

The “right” scale is also affected by the materials chosen and the techniques available. Ross Wimer asserts: “We have cut some models from the laser or we’ve had the pieces made out of house, etched out of metal; you can get an exquisite sort of jewel-like quality that is often much more convincing. It depends a little bit on where you’re presenting it, and who you’re presenting it as well.”³

Sometimes the choice of scale is influenced by factors beyond the circumstances of the project. In the 60s there had been a growing inevitable tendency to work to smaller scales due to the general rise in costs and the greater complexity and size of schemes required.⁴ Early in the twentieth century models had been small in scale, becoming gradually larger in the 40s and 50s, after which time they began shrinking once again.

For what concerns the study model, it usually gets larger as the design progresses from initial concept to resolution of finer details. Anyway models are made throughout the design process in every

1 Walls S., videotaped discussion on models, NBBJ, Seattle, May 5, 2000

2 Parker E. S., “The Model for Architectural Representation”, *Architectural Forum* 30 (April 1919), p. 121

3 Wimer R., interview with Karen Moon, May 19, 2000 in Moon K., *Modeling Messages*, New York: The Monacelli Press, 2005

4 Pfaendler R., “Architectural models”, *Architectural review*, 140 (July 1966)

convincible size. The smallest models can be held in the hand, while the largest may be the same size as the building. Yet a large model can be of a single component while a much smaller model may study the entire urban area surrounding a single structure. If at the beginning of the twentieth century full-scale models appeared as revivals of a more holistic tradition; from the second half of the century on large-scale models had been reduced in number and used with differing intentions. During those years there is more concern with formal arrangement and massing, as well as the effects on these of light, and with a return to the earlier practice of testing structural elements of the design. Eero Saarinen constructed a portion of the façade of John Deere Building (1959), largely of wood, to assess the articulation of design. He fabricated also a plywood replica of the access stairway to the St. Louis Gateway Arch (1958-59) to see if the lightening of each successive step would pose a problem for walking. Foster and Partners performed a similar exercise for the step ramp of the Daewoo Electronics Headquarters (1997-2000). Eric Owen Moss created a full-size mock-up to test the irregularity shaped roof section in his Umbrella project in Culver City. Another example is the simplified model I. M. Pei made for the extension to the Louvre.

A distinction could be drawn between full-size models, which simulate the shape, and mock-ups, made of the construction material. The second ones are useful for more functional considerations. At Gehry Partners mock-ups are built in order to test component fabrication and overall construction methods and materials.

While large-scale models continue to be made, smaller size ones are the greatest in numbers. Usually they are made since the outset of a project for representing ideas and for giving form to new ones. These first studies are made of “ready-to-use” materials like foam, clay, plasticine, paper, cardboard, and they are used for developing formal ideas, investigating concepts and exploring mass possibilities. The smaller scale is chosen because it facilitates rapid fabrication and a broad estimation of the project. Another use of small-scale models is the study of the surroundings of the project’s site.

As the size is reduced, models cannot be so detailed. Door handles, texture of materials, windows’ frames, railing details are just some parts that are not represented. Rather than trivializing the result object, this process often reveals a fascinating distillation

of architect's own priorities. The building is suddenly recognizable, despite the lack of details. Even at really small scales, such as 1:1000, the project is evident and it can still represent the main idea.

Then, to study interior spaces some stratagems have been developed to make comprehensible and visible the inside of a building. The most conventional strategy is to remove vertical partitions or the roof for showing the insides. In some cases, with models of single interior spaces, nothing is left of the exterior. Already in the Renaissance period and in the eighteenth century models of this kind have been built, as the one for Royal Palace of Caserta's staircase. Viewed from outside the model appeared as a wooden box but inside an accurate reproduction of the stairway hall has been sculpted. This Baroque tradition kept going on through centuries. At the mid-twentieth century, Eero Saarinen produced many models solely for the study of interiors.⁵

While some "old tricks" for accessing the interior have been kept current through centuries, some modern approaches have taken different directions. Transparent materials like acrylic have made it possible to explore interior spaces without removing perimetral parts and, at the same time, preserving building's external form. Wire-frame models made by Zaha Hadid and Peter Eisenman indicate the outer form and the interior arrangements. By the way those representations are really far from the miniaturization of the project. They access to a different level of realism.

The model's contracted scale is not able to transmit the buildings' size. Again, various methods have been adopted to counter this problem. Many accessories, like people, trees, cars, have been inserted to indicate proportions. But if on one side they aid the viewer's imagination, on the other they cannot themselves dispel awareness of true size.

One simple solution has been to encourage viewing from the correct eye level, which gives an impression of the building as it would appear to a real-life spectator.

Since the 1920s attention was turned to the possibilities offered by optical devices. According to Professor A. Boring "If a complete model is observed with the eye at the correct level, particularly if viewed through a small hole in a card, the simulation of the complete building in natural size is convincing".⁶ The next step has

5 Millon H. A., *The Triumph of the Baroque: Architecture in Europe, 1600-1750*, New York: Rizzoli, 1999

6 Boring W. A., *Use of models in the Study of Architecture*, *Architecture: The Professional Architectural Monthly*, vol. 45, June 1922

been taking in account all the possibilities photography supplied to architects. “Charles Garnier used photos of a model composed of interchangeable parts to study his design for the Paris Opera in 1861, and five years later Owen Jones superimposed a photograph of a model of his competition design for the National Gallery over photographs of the site”.⁷

Photographs, which place the model in a convincing setting, have become useful for addressing the problems of scale after the 1920s. Early efforts were impeded by technical inadequacies: photographic lenses and equipment were insufficiently developed to cope with the combine difficulties of close-up work, inaccessible viewpoints and the considerable depth of field presented by model’s diminutive proportions.

After World War II, the application of model photography expanded. The first firms to develop this practice have been the ones which did much use of models. Eero Saarinen’s office has been created many interior and exterior images with models.⁸

The following evolution of this technique is the photomontage. Model shots, cut and pasted in photos of the site context have been used to insert the merge the project and its surroundings and to give a vision of what the project would be once realized. During decades, this trick has been largely used among architects who were able to update photomontages with contemporary technologies and means of image postproduction. By the way there will always be a trade-off between the real landscape photo and the three-dimensional object.

In addition to a correct light exposition, the realism of the final image is heavily dependent on the accuracy of the model’s scale. The slightest error of proportions can be devastating to an otherwise persuasive scenario.

Another technique to explore models is to use them as sets for videos. In the late 1970s, Herzog & de Meuron began to use video as a way to envision their work in the setting it would occupy. In this way, the video frame not only compressed the space of the building-to-be within the surface of the monitor, it also made the model newly animated.⁹

7 Physick J., Darby M., *Marble Halls: Drawings and Models for the Victorian Secular Buildings*, catalog exhibition in Victoria and Albert Museum, 1973

8 Packard R. T., Korab B., *Encyclopedia of American Architecture*, New York: McGraw-Hill, 1995

9 Ursprung P., *Herzog & de Meuron. Natural History*, Montreal: Canadian Centre for Architecture and Lars Müller Publishers, 2002, p. 36



buckminster fuller
geodesic structures

le corbusier in his office
1946



superstudio
1960s



mies van der rohe
lake shore drive apartments
1956

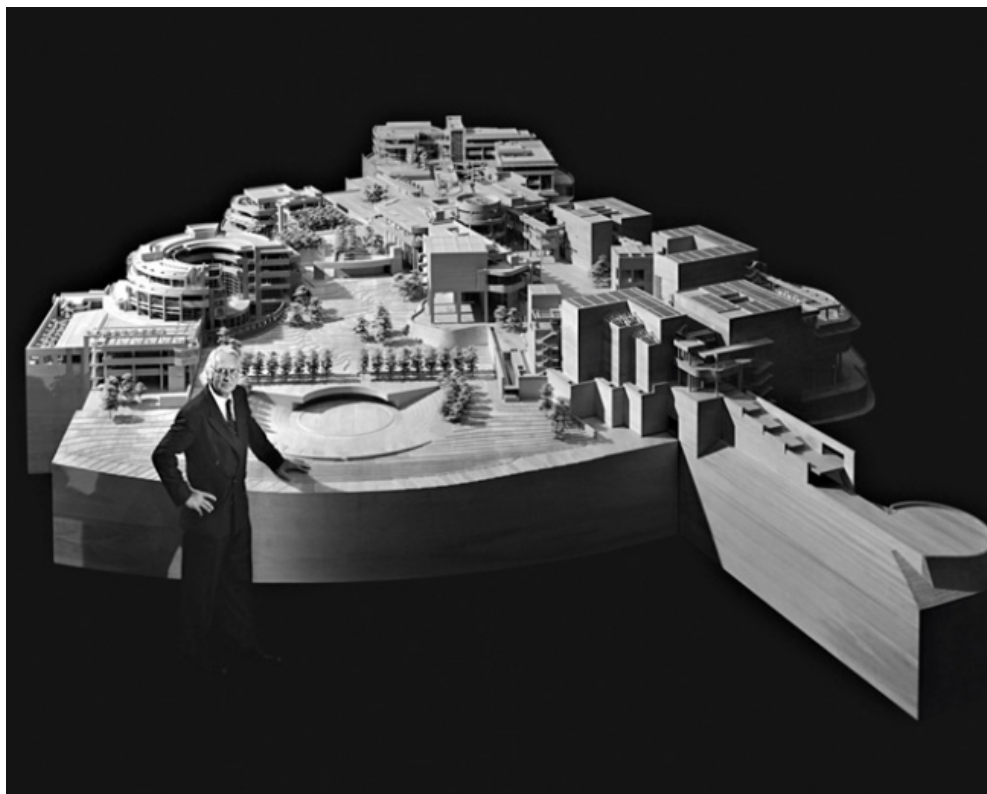


mies van der rohe
skyscraper bahnhof friedrichstrasse
1922



eero saarinen
stairway case to the
st.louis gateway arch
1958-59

minoru yamasaki
world trade center
1969



richard meier
getty center
1994

methods

methods

Analysing the design process of OMA, Herzog & de Meuron, Gehry Partners, and Greg Lynn FORM, differences and similarities in attitude and practice are evident. Their concepts come from different sources, world of art, nature, industry, society, previous work. Sometimes ideas occur observing reality, other times sketching or making models. Inspiration can be found anywhere according to the sensibility of the architect. This “anywhere” is important because it involves not only big theories, but also humbler points of departure.

The following descriptions highlight that in those firms, designing is not a lone genius process, but the set of a specific studio practice. Their buildings are born in the studio world.

In that ambient day-by-day minute operations take place. In Rotterdam people shape foam, scale it, refine its texture, classify and reuse old models, struggle to repeat tentative. In Basel inspiration is given by the world of art, precise and detailed models are built up, original mock-ups are made, façade's concept is fundamental for the perception of buildings. Gehry's collaborators realise master-architect's inputs, fabricate big and small models by modifiable materials, scan three-dimensional “sculptures”. In the office lead by Greg Lynn computers are used for any single change, prototypes are produced by CNC machines, composite materials are researched. All four firm's production results from this series of interconnected actions.

Models are vehicles of discovery. They can be instrumental in realizing and fixing those evanescent, conceptual ideas that dart about in the architect's head during the early stages of project development. They contribute to the evolution of emerging design, simulating ideas as the material is formed, become basis for change and test throughout the design process. Useful for investigate shape, material, structure, technology, the working model is representative of those office practice. Observing that a model is made by versatile blue foam or by 3D printed ABS plastic, reveals which kind of approach to design and architecture their users have.

In all the study cases, instruments are chosen by designers

because they feel comfortable with them. They trust their tools and they do not know how they could operate without them. Albena Yaneva's words about OMA are revealing.

"I soon understood why this experiment [one month without models] couldn't take place at the OMA in spite of the fact that Ole and Rem were strongly committed to revolutionizing the office methods. The architects at OMA think by making and rescaling models, by packing models in boxes and moving them to the ground floor, by staging models for presentations, by circulating them within the networks of design. OMA architects cannot substitute making with pure thinking."¹

It is interesting to notice that the "cutting-foam method" does not involve just a single individual. It is used by dozens of people in the studio. It is a process of doing projects embraced by a cooperative group. It means that it is a method that can be taught and learned. It does not regard personal intuition, talent and predisposition, these qualities cannot be changed by a process.

If it seems that to make in OMA architects could not work differently, also Frank Gehry states that he could not make the same kind of buildings without his team and his hand-use tools. The same reasoning can be applied to the other two offices.

Analysing those four architect's practices, it is possible to see their attitude towards the field. Their daily actions of doing and, especially, re-doing things, establish a strong connection to their buildings. They are not about a linear and immediate process, but about numerous convictions and hesitations, proposals and adjustments, reuses and experimentations.

This humble side about architectural practice reveals a lot about its results. Being aware of design experiences does not explain which big theories architects follow, but, for sure, it permits to reveal more about their buildings than exterior observation. Afterwards it is possible to *understand* their architecture.

¹ Yaneva A., *Made by the Office for Metropolitan Architecture. An Ethnography of Design*, Rotterdam: 010 Publishers, 2009, p. 47

blue world

Inside OMA firm, work has a precise rhythm and tempo. The design process is a collaborative activity that does not have defined and predetermined phases. It is composed by minute material operations of design through which models and plans take unpredictable directions, architects move according to different trajectories of space and time, concepts are questioned whatever the stage of design may be.¹ It is a “bottom up, labour-intensive, research-lead way of questioning everything. His products are assemblies, where Koolhaas refuses to give any easy answers, and instead reveals a selection of evidence and demands from spectators to form their own interpretations.”² What Koolhaas demands to his collaborators is a critical way of approaching the project.

Models are crucial inside OMA studio, considered by the lead-architect what “thinking produces in its raw form.”³ Architects have the freedom to arrange materials, methods, working hours, but everything starts with models. They are the physical embodiments of concepts and constraints. As soon as designers approach a new project, they go to the models’ laboratory and begin cutting blue foam. They give form to dozens of hypotheses in an endless circulation between ideas and shapes. Even objects - quickly whittled from foam - are one of the primary mediums through which a design’s intelligence is tested.⁴

olga: ‘If you try desperately to find a smart idea, you go cutting foam.’

ay: ‘Are you telling me that you do not do a sketch or a drawing before making the model, and that you do not have a particular idea in mind before cutting the foam?’

olga: ‘You stop thinking, you just look at the piece of foam and

1 Yaneva A., *Made by the Office for Metropolitan Architecture. An Ethnography of Design*, 010 Publishers, Rotterdam 2009, pp. 13-14

2 Timmer S., *Rem Koolhaas – designing the design process*, February 2012, notura.com, November 12, 2014

3 Zalewski D., *Intelligent design. Can Rem Koolhaas kill the skyscraper?*, in *The New Yorker*, New York March 14, 2005

4 Ibid.

you try to make it beautiful, you cut. Some- times you slice something, and then another thing, and ou-u-u-p-p-p something is there. And you think: “Oh, that’s interesting”; it’s there. Of course we always have a sense of what Rem would like, but when you cut you no longer know what you like in advance.’ ”

This is an extract of an interview to OMA’s architect Olga Aleksakova by Albena Yaneva.⁵ It explains how foam models surprise as they disclose the germs of new ideas. There is a continuous contrast between what the architect expects to discover and what appears in front of him or her. Foam cutting is the medium for rapid thinking, allowing them to imagine the new shape in the moment of cutting instead of anticipating in advance.

Design at OMA begins with collective experimentations at the table of models and not with a single-authored sketch. What happens is a “heterogeneous and genuinely co-operative venture”. It is not a strict hierarchical office, but more a horizontal atelier structure where projects come out from a network and collaboration of many people. Koolhaas rarely takes part in the collective process of drawing and modelling. He rather inspects teams developments and questions concept and choices at any level of progression the design is. Nothing is made randomly. Everything has to have a reason to be.

Koolhaas tells his opinion and gives suggestions. These last can involve previous projects that are meticulously collected in the archives. All first test models, even if they are not chosen as the main ideas for the project, are put into boxes and catalogued. This is the core of OMA’s archive, an useful tool for designing. Models are made in the internal laboratory, then moved and re-moved between architects’ desks, exhibition tables, then again model lab, entrance, desks until the archive. Those are the trajectories trough space and time that models follow in OMA’s office. It is a continuous operation of recycling and reusing material from the past projects. It is a process of model coming into being.

What architects in OMA’s office need is a material easy and fast

5 Yaneva A., *Made by the Office for Metropolitan Architecture. An Ethnography of Design*, 010 Publishers, Rotterdam 2009, p. 57

to manipulate. They want to be able to cut fast and to modify models once they are assembled. These are the reasons why blue foam is their favourite material to work with. Chunks of foam are everywhere in the office. All the possible options are made of foam. F. H. Wagenaar, one OMA's collaborator, says that "you can do anything with Styrofoam - cut it with a knife, dissolve it with spray paint, glue it, warp it with a hot gun, burn holes in it with your cigarette, and transport it on a plane. The material is easy and quick to work with. No OMA without it. [...] In Rotterdam ideas are never judged before they are materialized. The intellectual level of our labour is extremely low. We generate models without censure. Rem accepts no assumptions. He only wants evidence and a lot of it. Most models look clumsy and rough. We cannot spend a day building an exquisite model in the wood shop if we have to make 10 more for the next meeting".⁶ All options are evaluated. Even if they are "stupid and standard", they can have something interesting that interrupts the routine of model-making. Afterwards they are analysed and the designers come to a final decision. The more it is realized, the better it is. What they look for is to have a panorama of possibilities among which they can choose the one that convinces them and take the best from each one. The overproduction is part of OMA's designing process. It allows to examine many proposals and to keep complexity into projects. Models are tools to control morphology and spaces' articulation. Good or bad models do not exist. There are rather some that illustrate ideas better than others. Appearances are not important. "Sometimes things that are grotesque or perhaps the more repugnant models may have some interesting qualities on closer inspection. It all depends on who is evaluating it and how he or she is able to explore the opportunities in the model, the resources".⁷

All these considerations bring to the assumption that models are taken seriously. This is the basis of novelty and innovation at OMA. Architects think by making and rescaling, packing models in boxes and moving them to the archive, staging models for presentations, circulating them with the network of design.

6 Koolhaas R., OMA, AMO, *Content. Triumph of realisation*, Taschen, 2004, p. 205

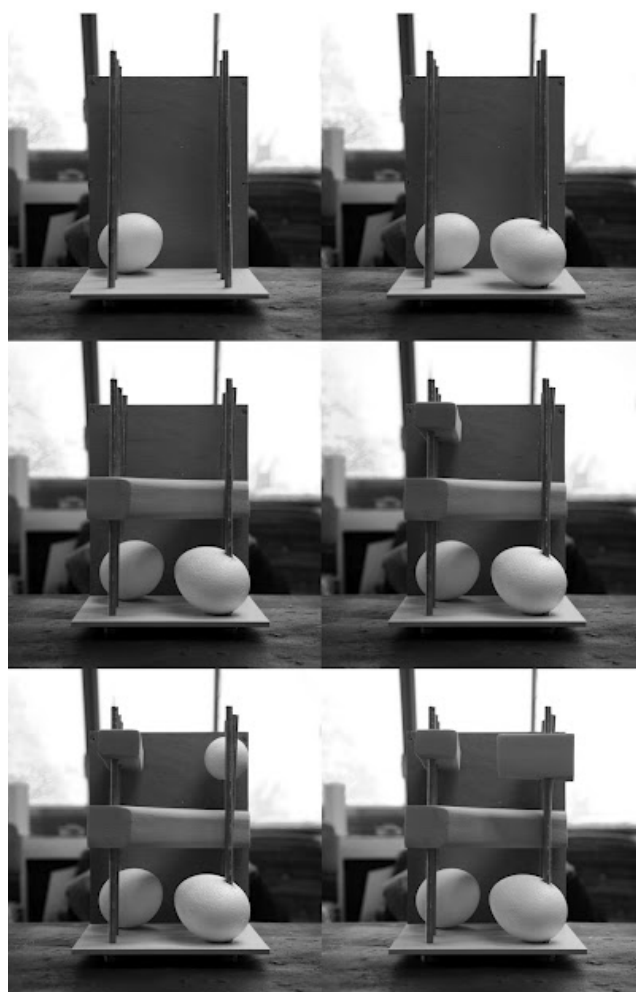
7 Kunlé A., interviewed by Yaneva A., in Yaneva A., *Made by the Office for Metropolitan Architecture. An Ethnography of Design*, 010 Publishers, Rotterdam 2009, p. 42

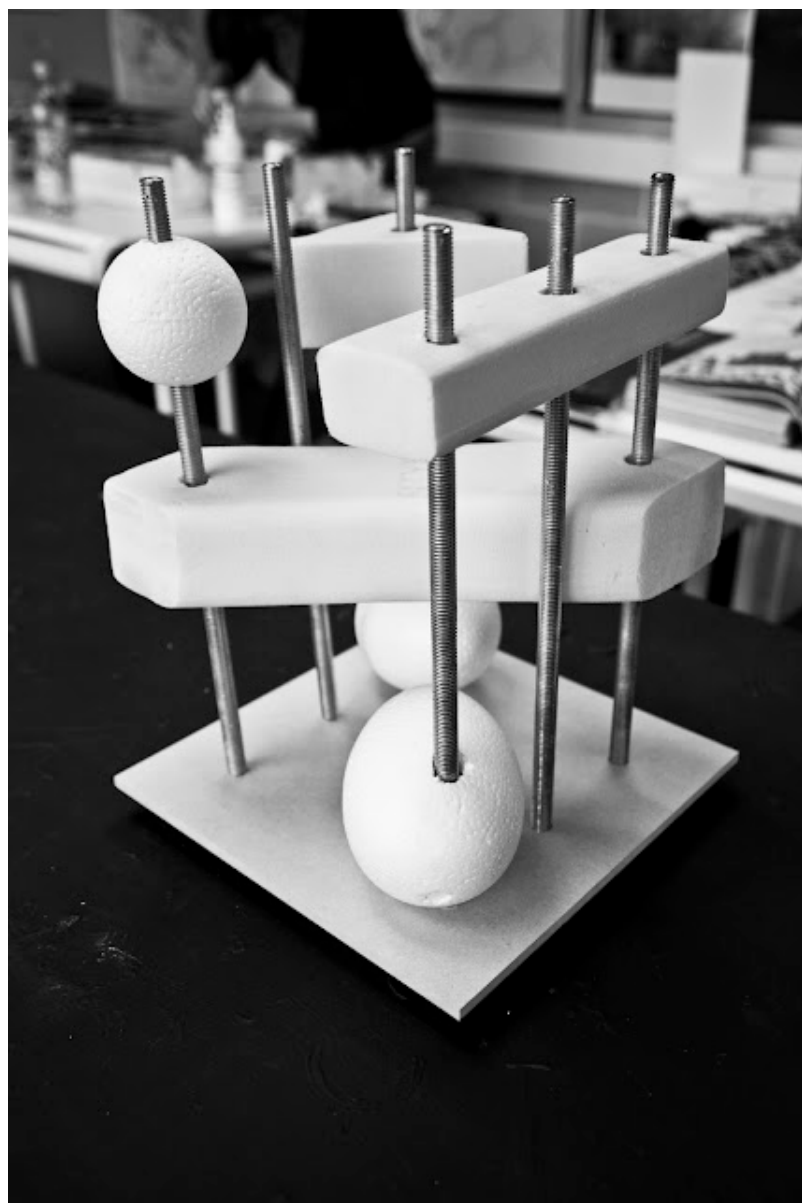
“OMA architects cannot substitute making with pure thinking”.⁸

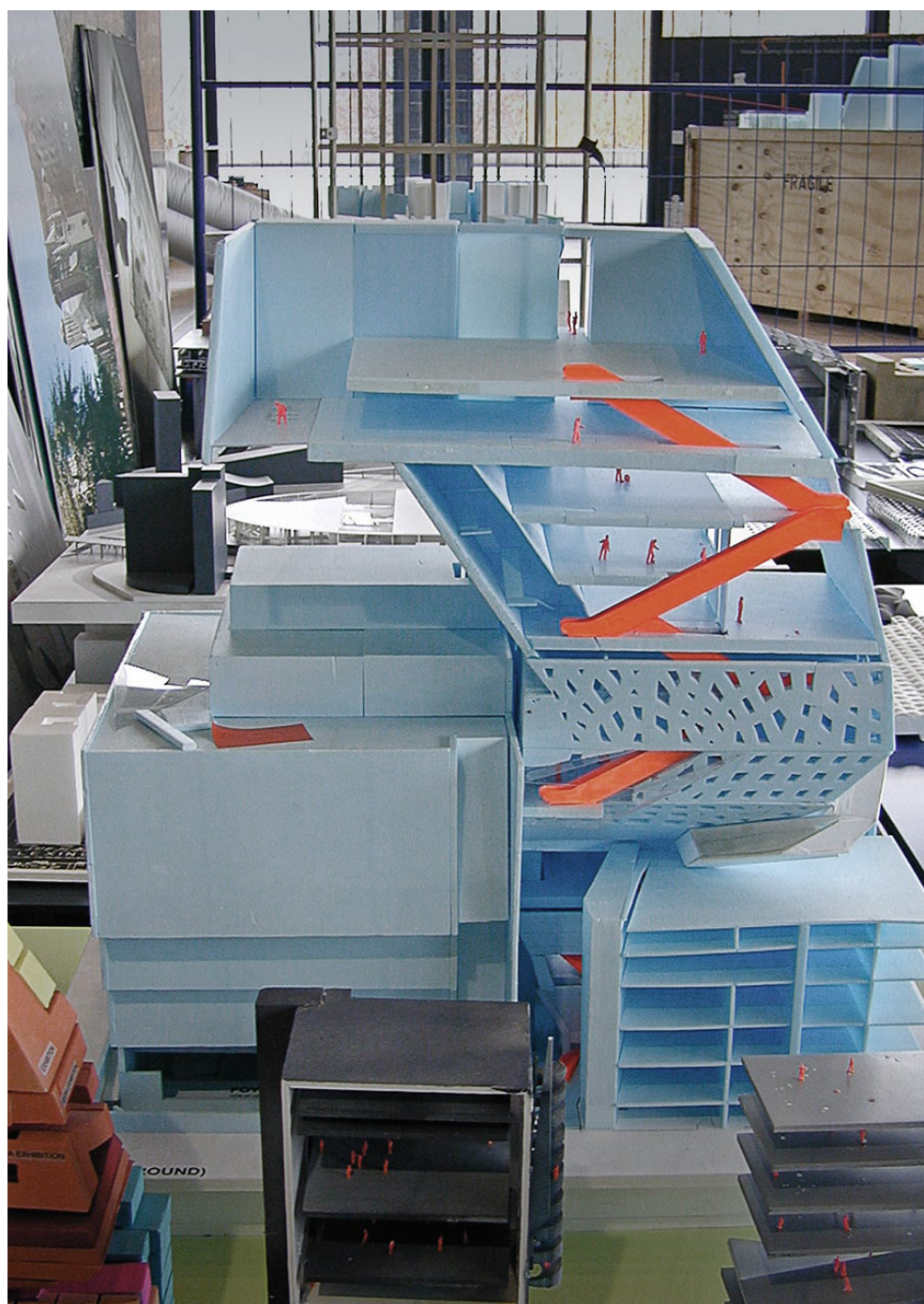
When the materiality has to be chosen, once again foam is used as basis for experimentations. Architects try to imitate material effect on model surface, painting it, or putting textures on it. Blue stands for the not-yet-finished materiality of the building-to-be. After the desired effect is obtained, they start testing the real material. They can go for a standard material or for a new effect. In the last case collaboration with manufactures begins in order to find out the best solution.

Models have fundamental relevance in the office where they can be found everywhere: on table of models, on the shelves of bookcases, in the presentational concept books, in the archival boxes, in offices presentations, in the office kitchen, in the archive drawers. They are working objects that can be used as reference, as concept representation, as embodies of new meaning and shape, as design investigation. In OMA office models accompany each stage of design process until project presentations in front of clients. It does not import which level of precision and detail they achieve. What matters is the idea they represent. They are, at the same time, traces and messages of the continuous process of redoing

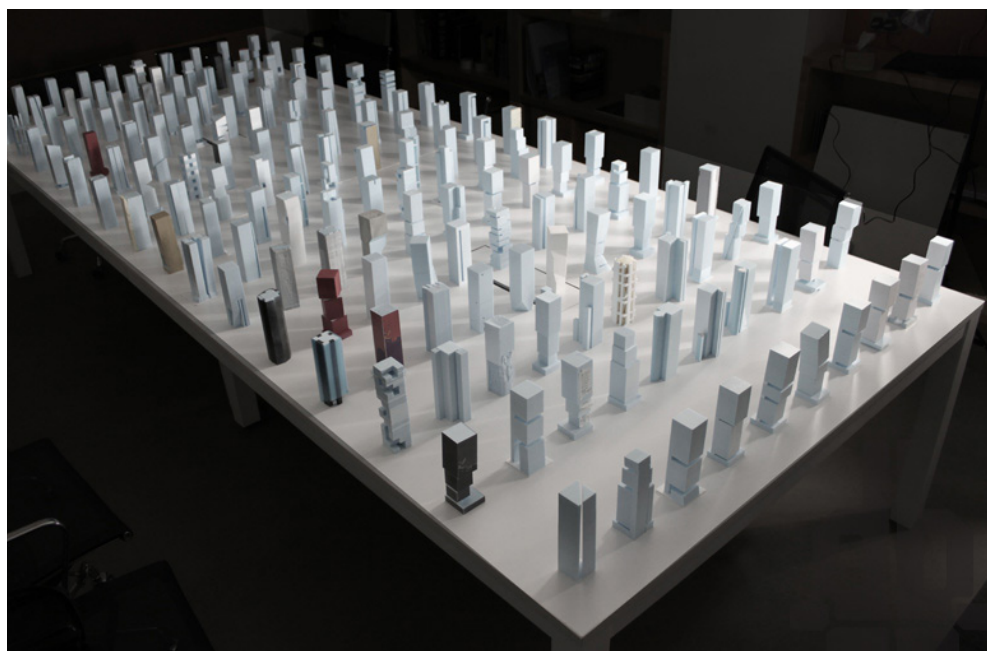
⁸ Yaneva A., *Made by the Office for Metropolitan Architecture. An Ethnography of Design*, Rotterdam: 010 Publishers, 2009, p. 47

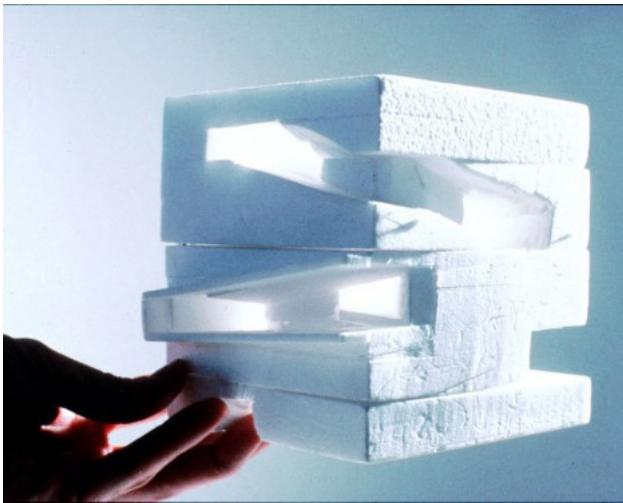
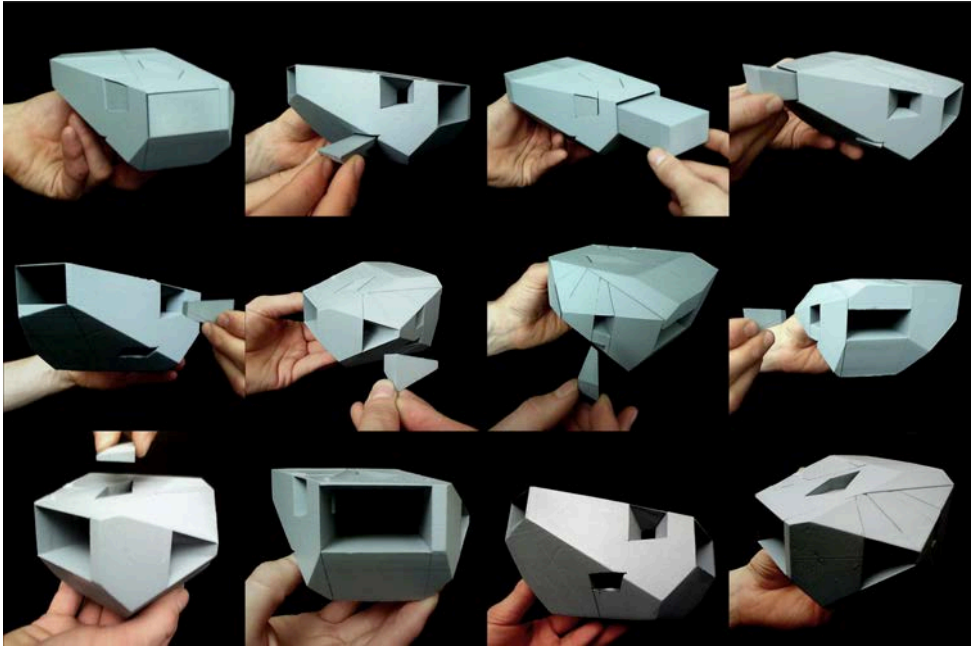


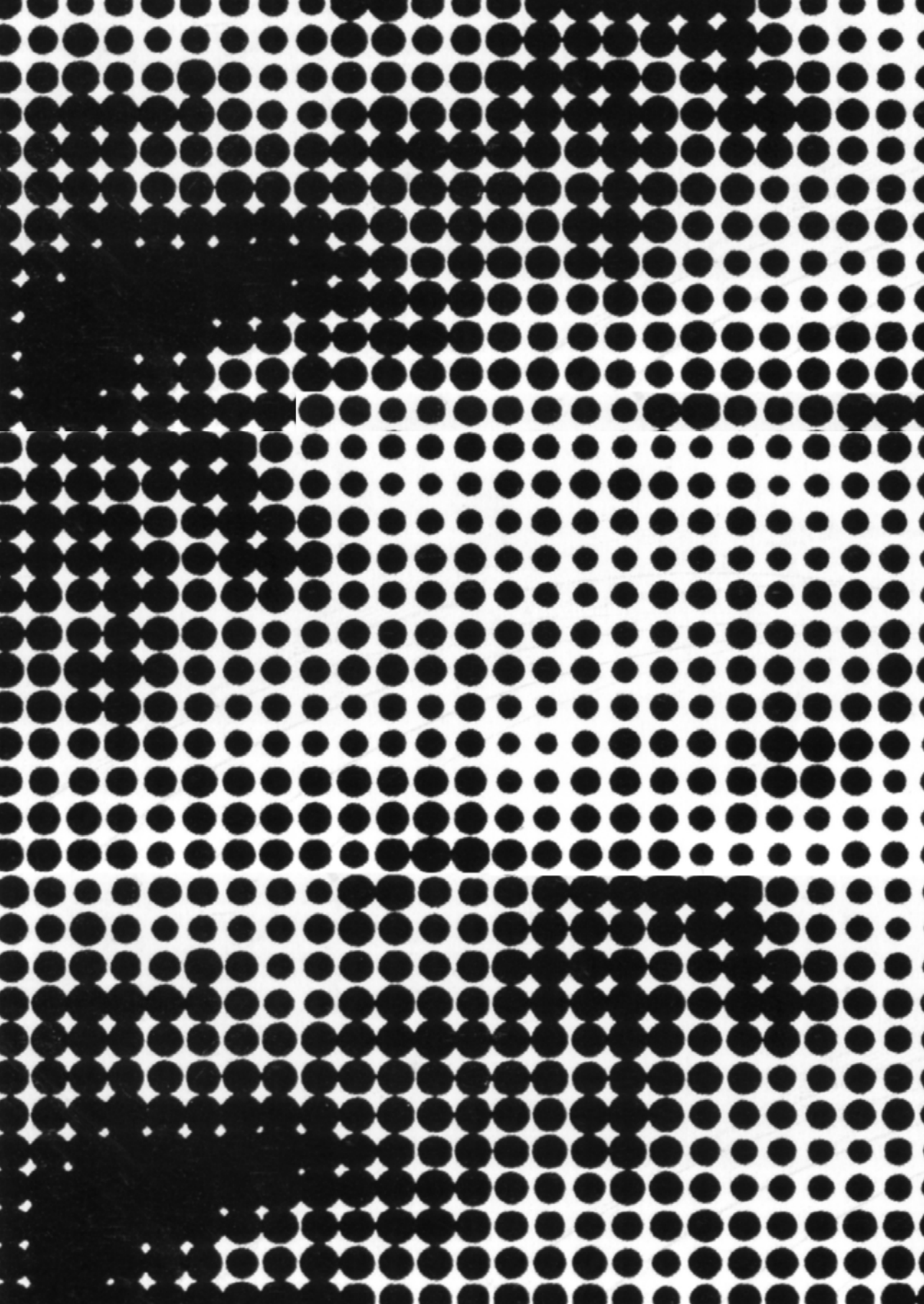












Herzog & de Meuron

perceptual objects

The particular interest that Herzog & de Meuron firm has towards a specific kind of model, reveals which its design approach is. “Models are an obvious means of representation not only in architecture but in other professions, in fact everywhere, in everyday life as well. Even children use them. They are still a useful and appropriate medium today, especially because they can cover such a wide spectrum. Working models are particularly interesting, that is, models that help to find solutions and therefore show the course of a project’s development. Good working models sometimes have an aura that is much more effective in communicating the architectural idea than a perfectly detailed replica of future structures”.¹ With those words Jaques Herzog expresses the significance he gives to models used during the design process.

Working models are tools useful to find new shapes and to study how buildings are perceived. The architecture they aim for has a lot to do with perception. From the beginning, they have been influenced by the world of art and, during their activity, they have counted many collaborations with famous artists such as Joseph Beuys, Rémy Zaugg, Ai Weiwei. They have been fascinated by Zaugg’s publication *Die list der unschuld*.² From this book they learned an important notion regarding Donald Judd masterpieces that would have become the aim to reach with their architecture. That one was a vision without prejudices and pretensions. Zaugg wrote that if Monet represents one appearance of reality in his paintings; on the other hand, an artist like Donald Judd creates a reality that generates a multitude of appearances. Therefore, the viewer is not limited by the choice of the artist.

This is to understand how their way of thinking about architecture has a lot to do with artistic fields and, consequently, how much perception of buildings through materials and shapes is fundamental for them.

The strong emphasis on process of perception that characterizes

1 Jaques Herzog interviewed by Theodora Vischer, in *Architectures of Herzog & de Meuron. Portraits by Thomas Ruff*, Exh. Cat. Herzog & de Meuron, New York: Peter Blum, 1995, p. 29

2 Zaugg R., *Die list der unschuld. Das Wahrnehmen einer Skulptur*, Eindhoven: Verlag des Stedelijk Van Abbemuseum, 1982

their work is related to the contemporary world. “It is an architecture produced today in an age of communication, not in an age of traditions and even less in the more recent modern age of utopias that inspired the work of Le Corbusier and Mies van der Rohe”.³ They investigate lettering and images as building materials. It is evident that, for achieving this new architectural expression, they need adequate tools to control and test it. Therefore, the model has been the chosen instrument to create new forms, new materials, new textures, new appearances. Since the first stages of project development, many models are made. Working teams build models with “extravagant shapes” made of different materials according to the idea they want to express. Jaques Herzog pretends instant perfection, no improvisation or approximation are accepted. Concepts come together with built-in details and reality checks. Models must have a tangible surface that can be touched and examine.⁴ Working models are not only made of fast-to-use materials, like cardboard and foam, but also more complicated materials, like concrete, resin, metal, plastic. These materials express, from the beginning, façade concept and they help to perceive the building-to-be. Materials are chosen to endow buildings with a particular character or “reality”; more than liberating materials from their bondage to conventional practice, materials are put to the test.

The great archive, where any kind of model is preserved, has been shown in the exhibition “Herzog & de Meuron. Archaeology of the Mind” at the Canadian Center for Architecture in Montreal in 2002-2003. This physical accumulation of the documents has been produced in order to initiate and accelerate mental processes or, on the contrary, to arrest and propel them in another direction. “They bear mute and lifeless witness to the considerable energy that we as a group, in varying combinations, have invested over the years in order to set such intellectual processes in motion. In some cases buildings have actually emerged as a result.”⁵ All those objects express their

3 Jaques Herzog interviewed by Theodora Vischer, in *Architectures of Herzog & de Meuron. Portraits by Thomas Ruff*, Exh. Cat. Herzog & de Meuron, New York: Peter Blum, 1995, p. 31

4 Koolhaas R., AMO, OMA, *Content. Triumph of realisation*, Taschen, 2004, p. 205

5 Ursprung P., *Herzog & de Meuron. Natural History*, Montreal: Canadian Centre for Architecture and Lars Müller Publishers, 2002, p. 36

interest in projects and buildings through modelling, creating an instrument for the perception of reality and the interaction with it. Herzog & de Meuron aspire to build an architecture that relies upon just such perceptual models, whose material qualities are less a manifestation of manual competence than of conceptual intelligence. Each object repeats an earlier conception and transforms it. Repetition is an important operation in Basel office.

Models allow also ideas to pass from hand to hand, from one member of the team to another. Archives are like wunderkammer where all the objects are preserved, waiting for inspire a new concept or to remain as the only physical trace of design process. "The reality of architecture is not built architecture. An architecture creates its own reality outside of the state of built or unbuilt and is comparable to the autonomous reality of a painting or a sculpture. The reality of which I speak is also not the real building, the tactile, the material. Certainly we love this tangibility, but only in a relationship within the whole of the (architectural) work."⁶

In Herzog & de Meuron firm there are no predetermined ways of representing architecture, of making models, of designing a building. Each project is its own world, has its own philosophy, its own identity. In some cases they invent a form that interacts with the context. In others, like the Cultural Complex Luz in Sao Paulo, the form of the building appears gradually as the distribution of its functions become clearer. The design method becomes form. In drawings and models each function has a different colour. Interactions and mixtures have been produced among functions. This is a process that little by little becomes architecture.⁷

Herzog & de Meuron models reflect their continuous expressive research. They are concrete materializations of projects' histories and indispensable objects for making architecture of perception.

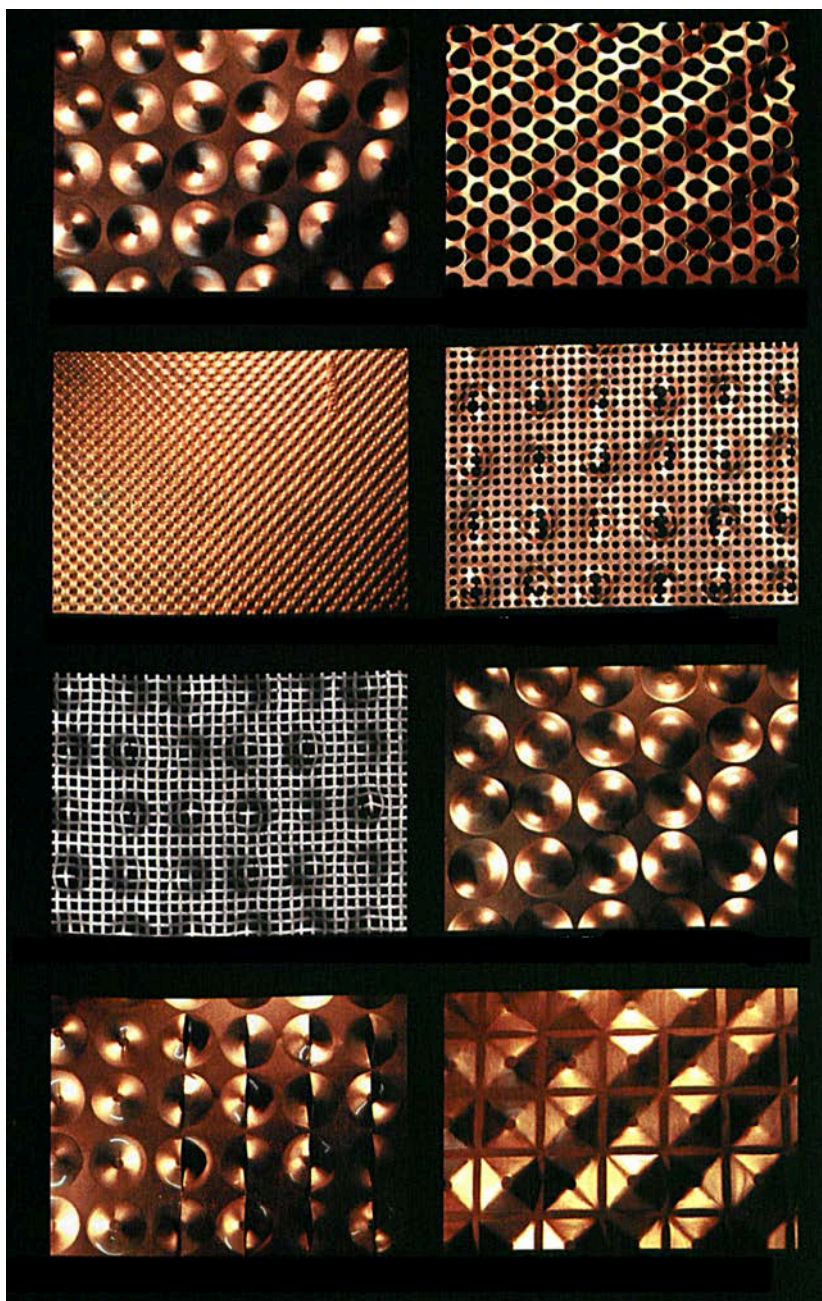
⁶ Lecture held by Jacques Herzog at the Harvard University in the Symposium Emerging European Architects, 18 October 1988

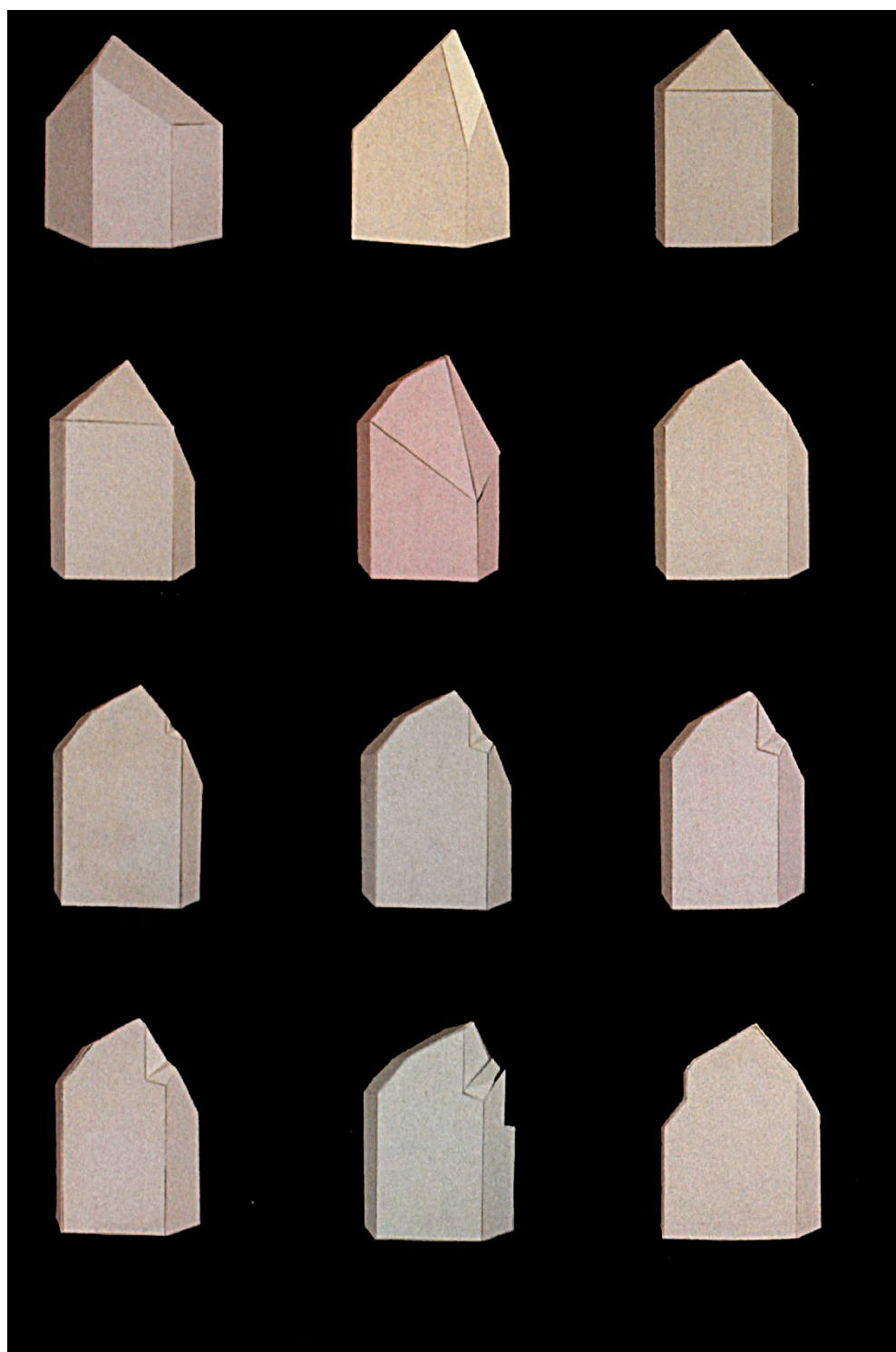
⁷ Herzog & de Meuron. 2005/2010, *El Croquis* 152 + 153, Madrid 2010, pp. 32-33

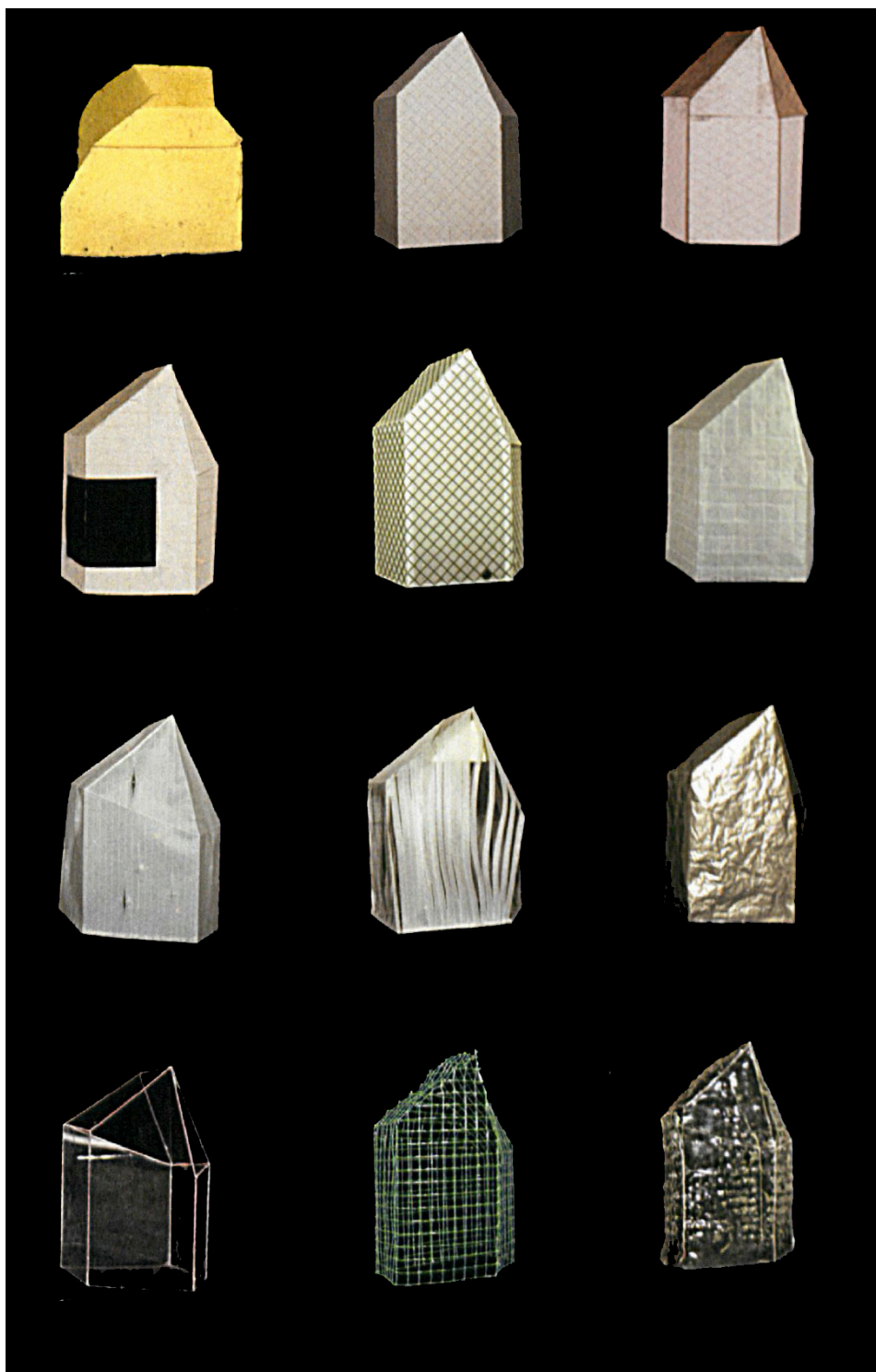














Gehry Partners

personal sculptures

Frank Gehry has an original relationship with architectural models. They are his personal hand-made creations that are “directly” transformed into buildings. If models are physical tools that can be constantly shaped and modified in order to find out the desired form, sketches are the first approach to design.

In Gehry Partners firm, concepts are launched by diagrammatic drawings made by the master architect. He draws a line guide that can find inspiration in different disciplines. For a long period of time Gehry has been inspired by the sinuosity of maritime animals, especially fishes. He justifies himself explaining that if architectural references should be taken from the past, there is no reason to stop at ancient Rome and Greece epoch. They should go back to the first life forms. He began drawing fishes and the results are projects like *The Whale* in Barcelona and the series of *Fish Lamps*. Other sorts of inspiration are works of art. Paintings reveal to Gehry a hidden composition of volumes, and those volumes correspond to buildings’ assemblies. For instance, *Christ Mocked* by Hieronymus Bosch inspired the floor plan for the *Jerusalem Museum of Tolerance*. The *Winton Guest House* had been inspired by a painting by Giorgio Morandi. What Gehry does is actually look at those pictures in an “architectural way”.

After this first step of immediate conceptual drafting, Gehry starts to operate directly on models for defining buildings’ morphology. He uses easy materials to modify and work with, like paper, cardboard, acrylic, wax. He works on two or three scales at once. This trick allows him to do not focus on a precise building proportion and it gives him the opportunity to think about the real building. He cuts, folds, glues, bends, assembles, curves pieces of material until he finds the configuration that responds to his desires. Shape conception and model manipulation are two moments that coincide in Gehry’s design process. When he works with models he does not have a pre-established form in mind. He follows an idea, represented in sketches, that generates building’s shape through models. He tries to put “feelings” in three dimensional objects. He seems to be a sculptor in front of material looking for a new form.

Even if working models are not craft masterpieces, they describe quite well shapes and materials. Textures and colours of paper refer to specific building materials. They are also chosen for their appearances and for how they look in the composition. This approach indicates that buildings' global shape and material are defined by the master architect of the office. The design comes mainly from his talent and his personal taste. His partners give suggestions but their main ability seems to be to understand what Gehry is referring to with his models and words.

Once the form is defined, an empirical and original phase starts. Software specialists accurately scan models with 3D scanners. They pass from physical objects to digital models, to plans and sections. This is a precise translation of analogic to digital. This process gives the possibility to "save" all details represented in models. As firm's partner Jim Glymph notes, technology has been brought into the office in a way that did not change Frank Gehry's method. Instead, technology has improved it through a perfect digital control of building-to-be shape. "This process's precision allows more freedom to designers to explore shapes".¹ Gehry does not have a digital formation. This is the reason why he needs to use design tools he is practical with. Afterwards he takes advantage of digital technologies to make projects realizable.

Further step is "making things working". Architects at Gehry's office work on digital models in order to draw functional plans and correct details. This is not an easy job. Gehry's shapes are so complicated that they require a big effort on a structural point of view. When the shape needs to be modified, another model is built to verify the new situation. This is a process of going back and forth between plans and models. It is a teamwork phase that allows architects to see opportunities that they have not noticed before. If the conception of a building is done almost exclusively by Frank Gehry, the daily work on physical and digital models and drawings is made by his collaborators.

Gehry started to use software from his project for Vitra Cam-

¹ Chan E., interviewed by Pollack S., in *Sketches of Frank Gehry*, Sydney Pollack, Sony Pictures Classics, 2006

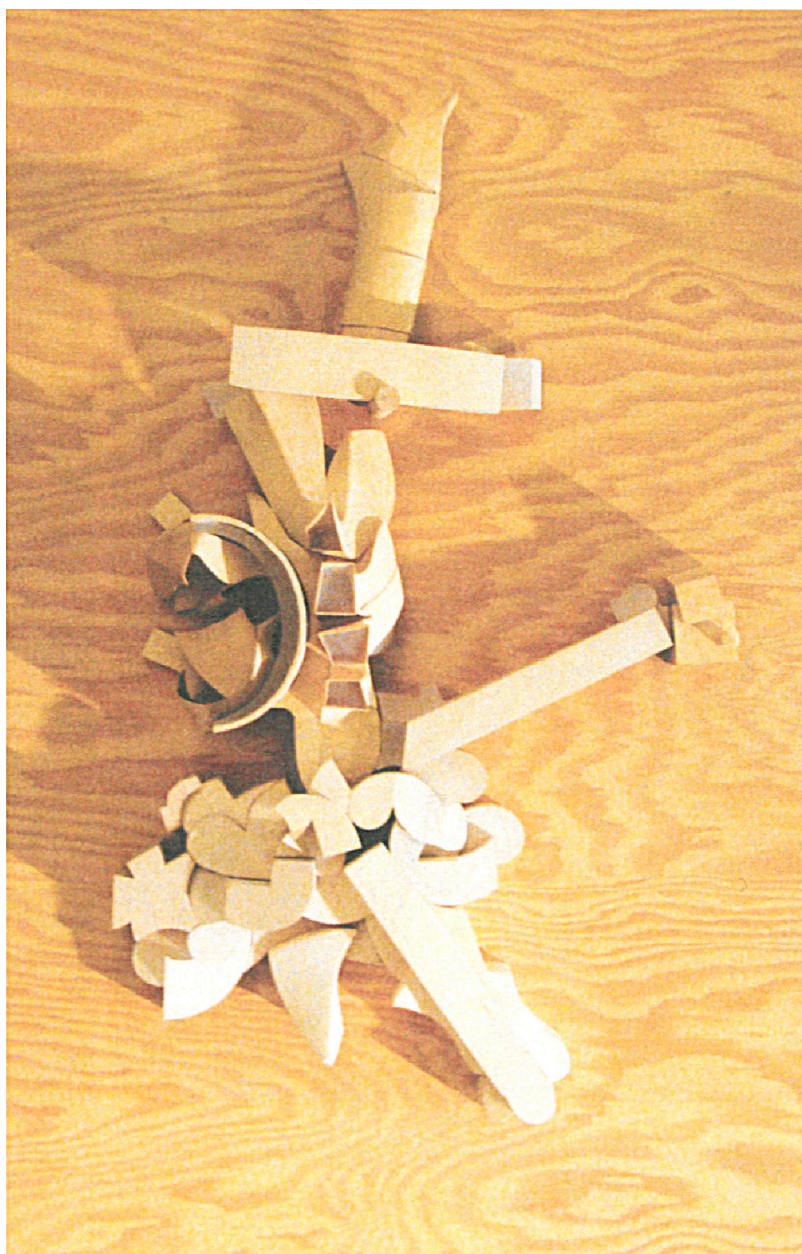
pus on. At that time he tried to communicate his idea to the constructor with descriptive geometry, but the result was not satisfying. It was not able to communicate Gehry's idea and the shape he conceived. So Jim Glymph started to look for a solution in the digital world and he got it.

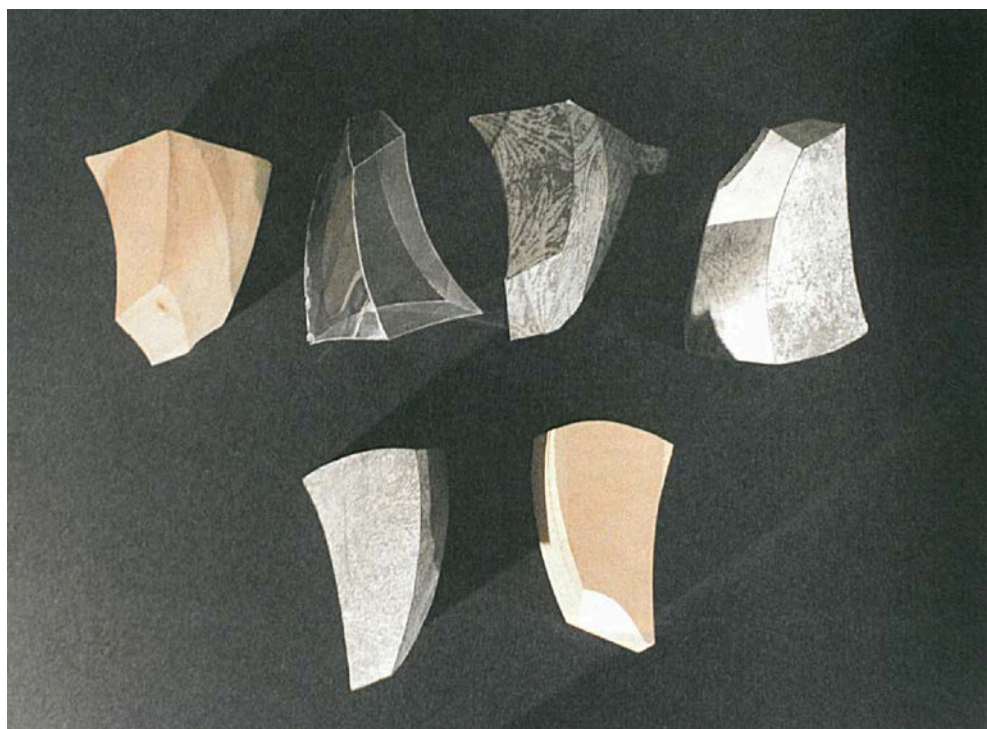
The same process was then applied to The Whale in Barcelona and to the Guggenheim Museum in Bilbao. Form became immediate to communicate and structures easier to calculate. The "digital" is for Gehry an instrument at the service of his architecture. He cannot conceive a building at the computer. It is impossible for him because he does not know "how to think with digital". His means will always be pencil and models.²

² Lynn G., *Archéologie du numérique. Peter Eisenman, Frank Gehry, Chuck Hoberman, Shoji Yoh*, Montreal: Centre Canadien d'Architecture and Sternberg Press, 2013, pp. 27-28

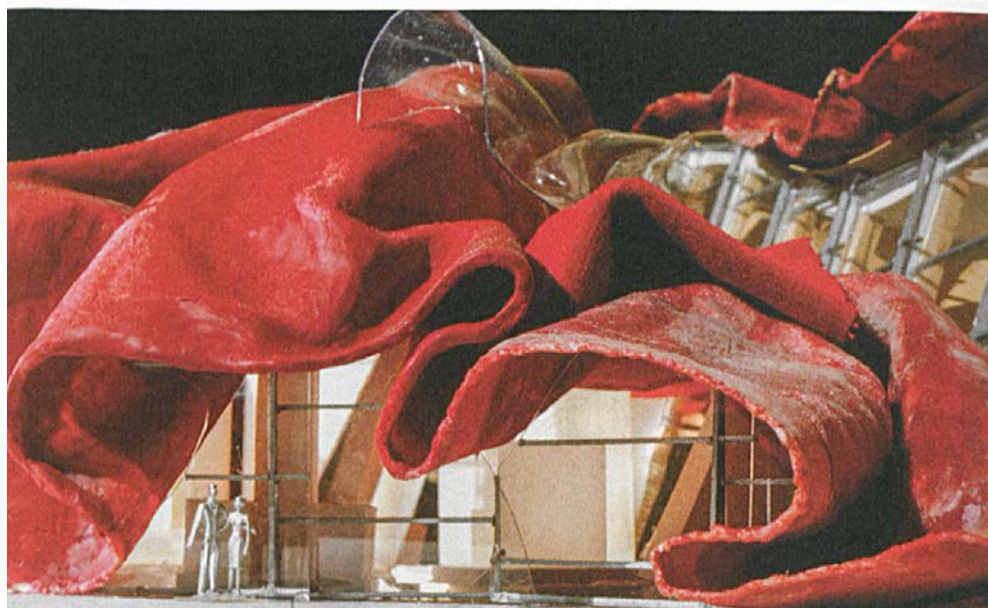
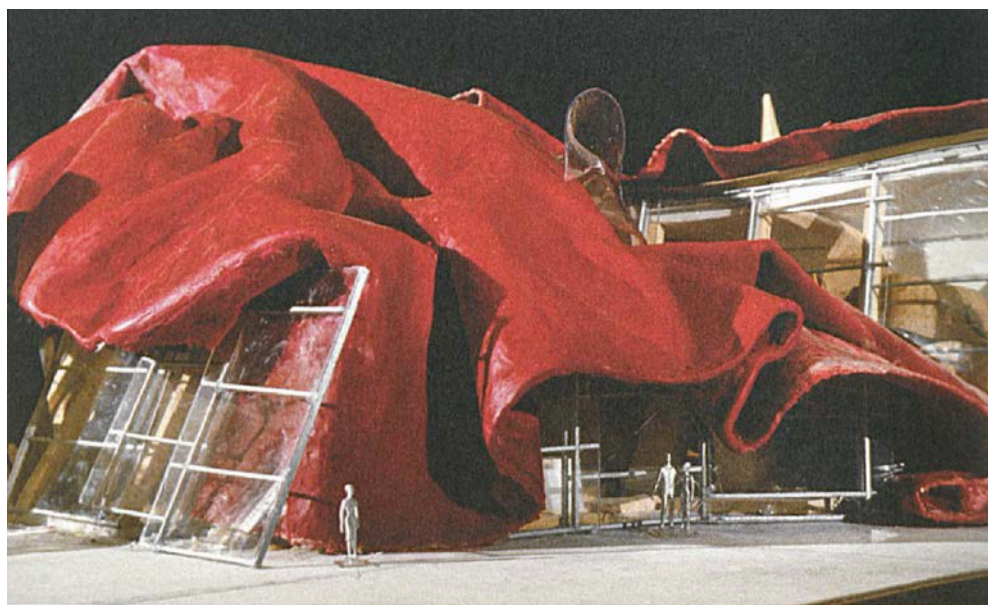


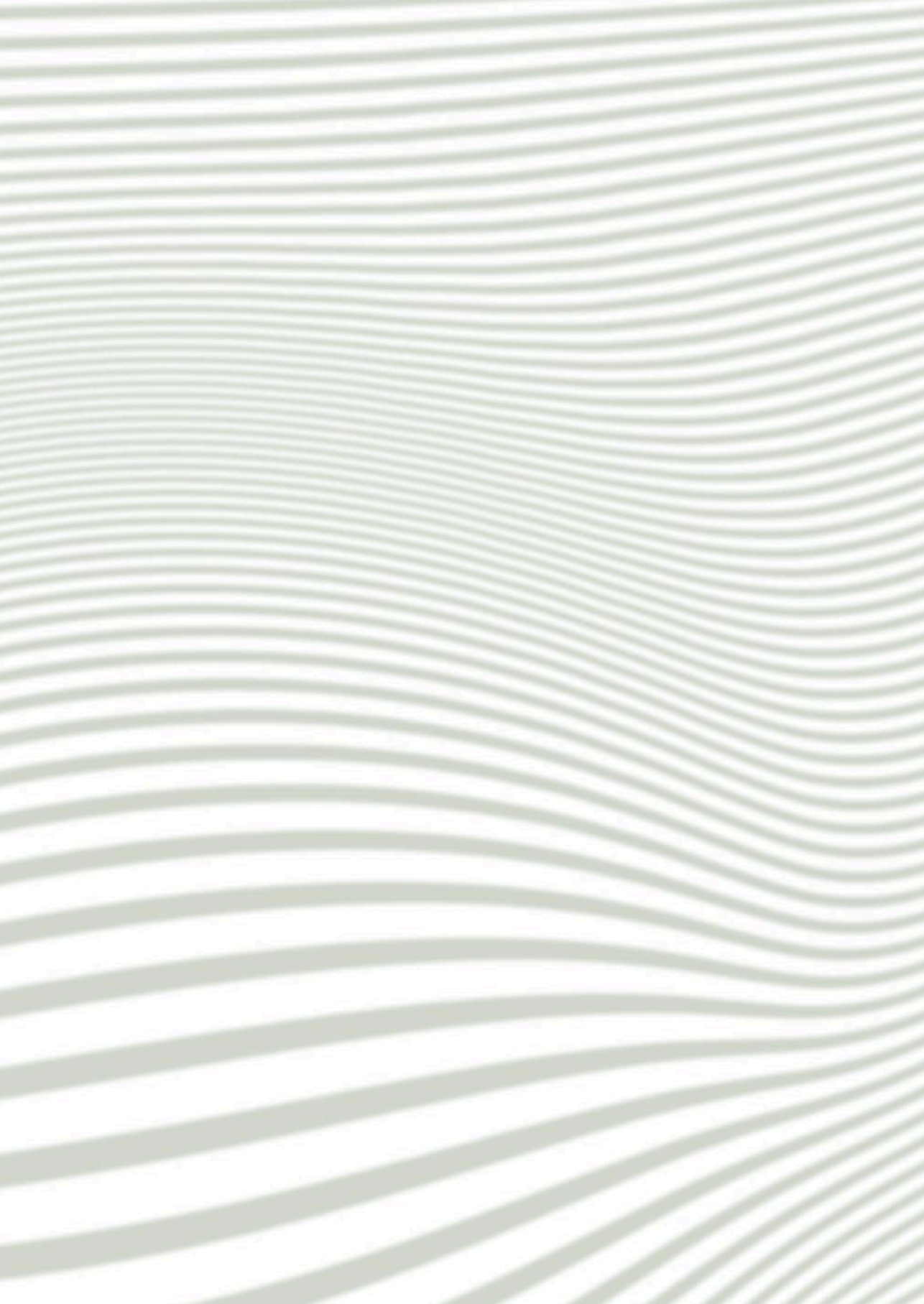












Greg Lynn FORM

digital essays

Greg Lynn does large use of models produced with CNC machining. In his office in Venice (California) models are arranged loosely on many places. Several find some space on shelving units and tables, others are gathered with their iterations on shelves. They come from various stages of design process.

Lynn does much of his modelling in-house, designing on his computer the three-dimensional digital form and sending the files to a CNC mill, a 3D printer or a laser cutter. Other prototypes and materials are sourced from the aerospace industry, sail making factories, places seemingly unrelated to architecture. His interest in typically technical production's fields becomes manifested in his creation. Not only as an architect, but also as a designer, Lynn creates pieces which combine technical efficiency of industrial materials and innovative shapes. 3DI Chair is a hanging chair moulded with a technique used in the sailing industry that makes it lightweight and resistant. Index Award Pavilions are eight transportable, carbon fibre reinforced, lightweight, outdoor pavilions for the display of award winning products and prototypes. A tea set for Alessi is metal, but because the liquid is held in an internal pocket separate from the shell to prevent burning one's hands, it requires no handles.

Innovative shapes and materials are two important aspects of Lynn's work. He sums up that he is invested in "how curves and surfaces and the formal language of undulating surfaces can work in a lot of scales. Stylistically, I don't feel like I have strong preferences. But, always surfaces. Always curves and surfaces in some way."¹ According to Lynn, functions are used by his colleagues to justify choices. Functions shouldn't put any limits or constrictions to the work of a designer.

If surfaces, in opposition to grids, are the core of Lynn's architectural thought, computers and CNC machining are the means respectively to calculate and to realize them. Shapes' conception at Greg Lynn's office is made through digital technologies. The ability of the architect is to imbue software with "some creative

1 Hammon K., "Instudio Greg Lynn", in *A+D Architecture and Design Museum*, August 16, 2011

and intellectual force that engages the history or architectural problems and ambitions”.² They use animation software and computer programs that imply evolution of a form and its shaping forces. “The project is to solve the problem between the one and the many – how to make a generic thing and 50,000 variations of a generic thing”.³ For example, Embryological House is a project through which Lynn re-thinks the notion of the manufactured house, moving from the idea of a form based on modules to a form based on potentially unlimited iterations derived from a basic form. With a number of set parameters, he was able to generate limitless variations of the same house.

Once he creates this multitude of possibilities through animation software, he tests their shapes through physical models. It is evident that, for a “digital mind” as Lynn’s one, the use of CNC manufacturing is a natural passage during his design process, but not the unique reason for its employment. With this prototyping step, Lynn tests design’s compatibility with available manufacturing technology. Through laser-cut and additive and subtractive manufacturing he has also the possibility to see and control details in a more accurate and precise way. In a digital dimension where the unit is no more the module but the infinitesimal component, tolerances of less than a millimetre make the difference. At Greg Lynn FORM practice series of dozen of models at small scale are produced to verify concepts and production process.

The use of CNC manufacturing is also influenced by one of Lynn’s fascination: naval industry.

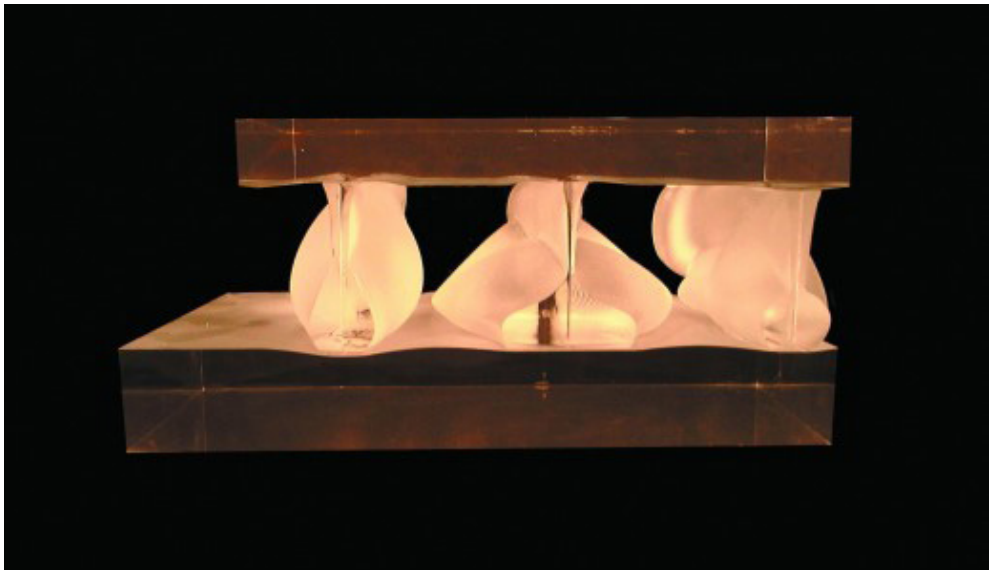
In naval architecture software and computer numerically controlled model building are tools integrated to design process. They are used to find forms that can be shaped by the collaboration between envelope and the context that surrounds it. Another choice that these machines allow him to make, it is the material one. Lynn has been inspired by the logic of composites, outperforming materials obtained from the intelligent combination of distinct materials. These materials have been used in naval, automobile’s and aircraft’s industry for years. Before, also

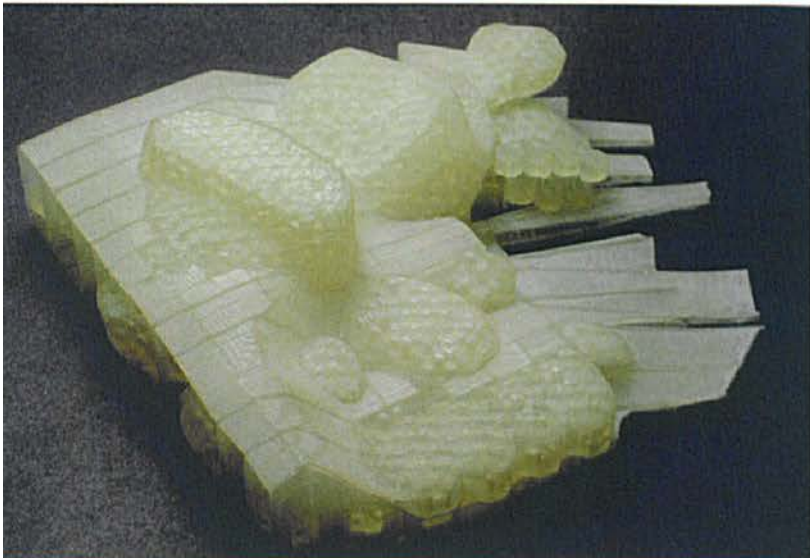
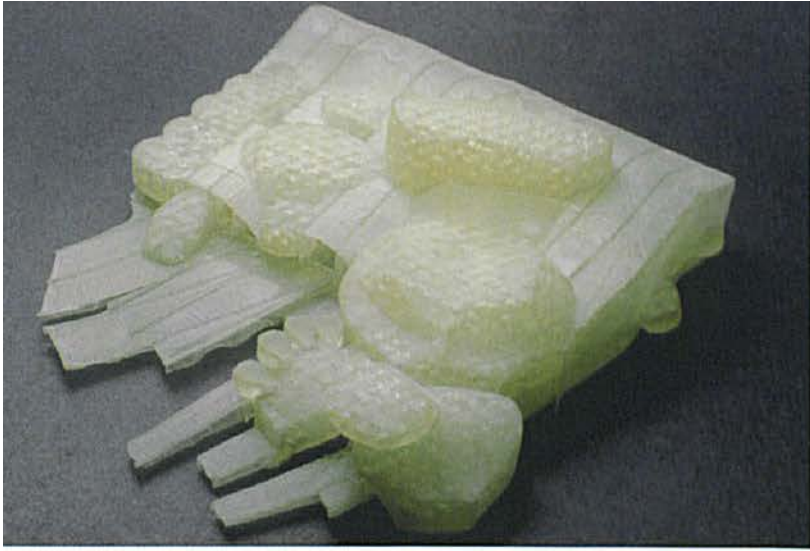
2 Lynn G., “Introduction”, in *Folding in architecture (revised edition)*, Great Britain: Wiley Academy, 2004, p. 11

3 Lynn G., interviewed by Chan C., “Greg Lynn: Curve Your Enthusiasm”, in 032c, #15, Summer 2008

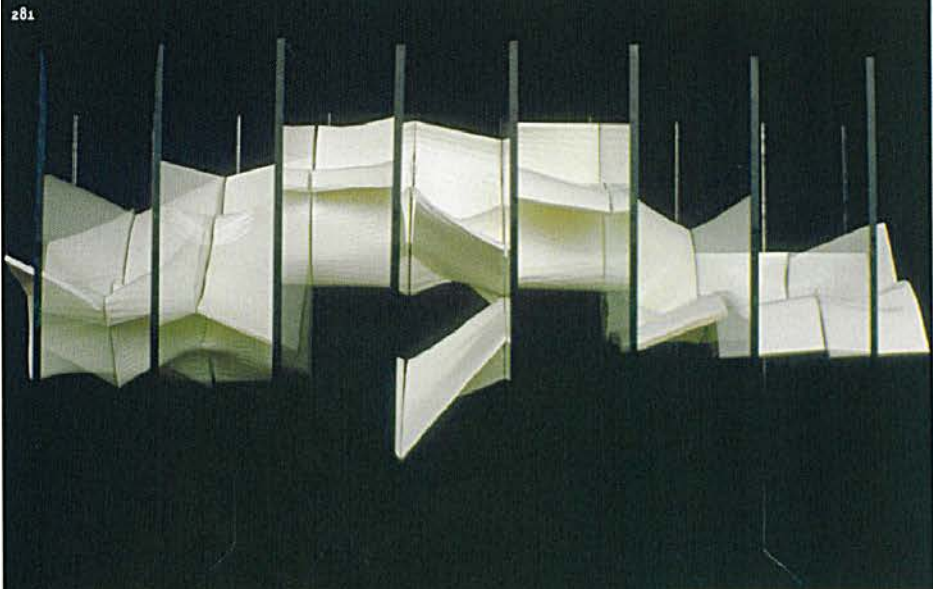
in those fields, there was assemblage instead of fusion. Lynn is interested in applying this passage to architecture and he uses the same tools to reach his objective. He believes that “with changes in media come changes in concept, changes in construction, and changes in form”⁴

4 Lynn G., Foster Gage M., *Composites, Surfaces, and Software: High Performance Architecture*, New Haven: Yale School of Architecture 2010, pp. 20-21

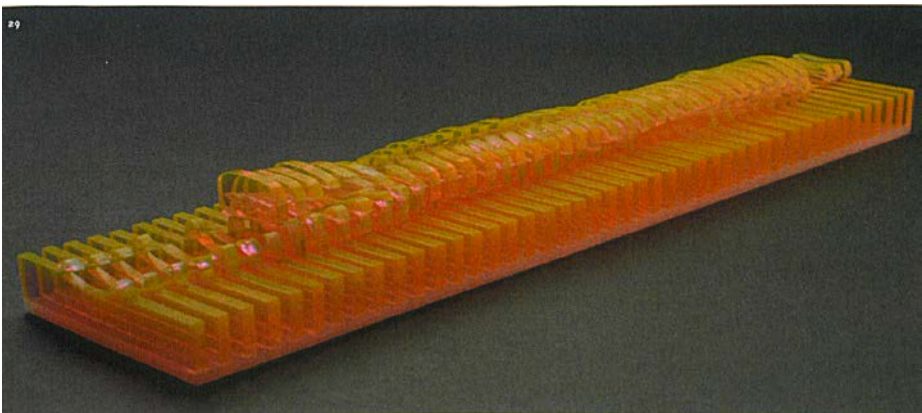


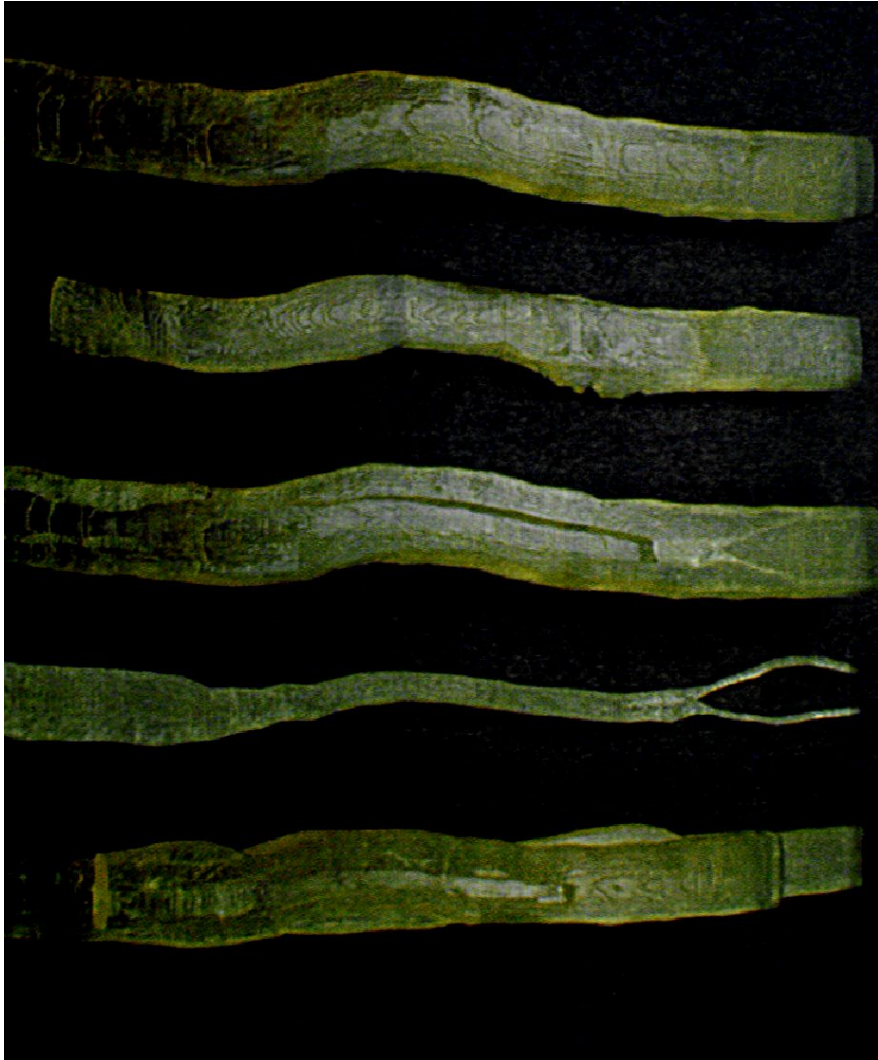


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digital production

Laser cutter

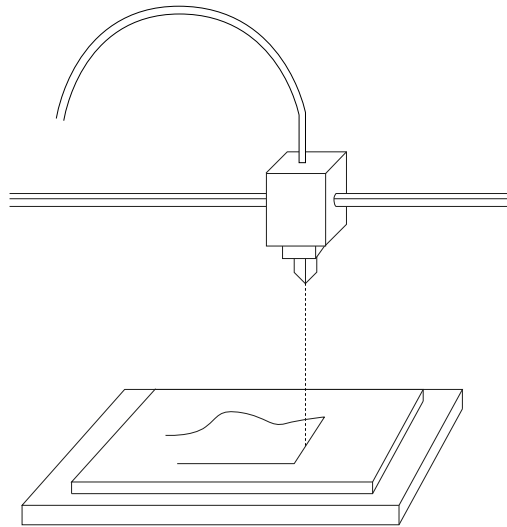
precision: -

materials: cardboards, plexiglass, MDF, plywood, cotton

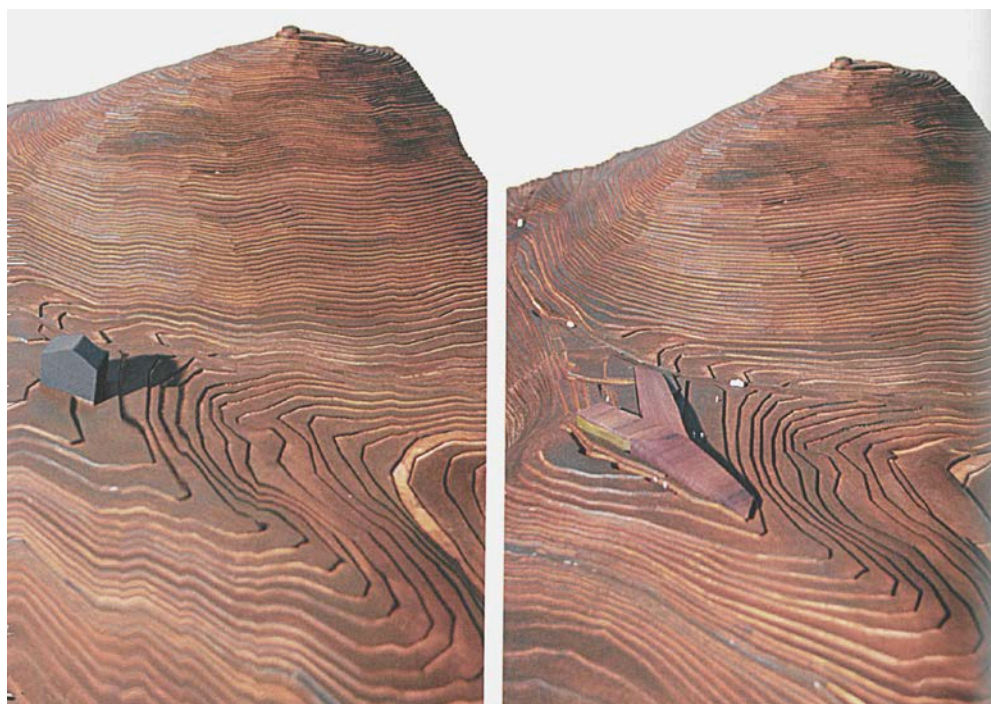
dimensions: -

colour: same colour for the whole object

aesthetic: -

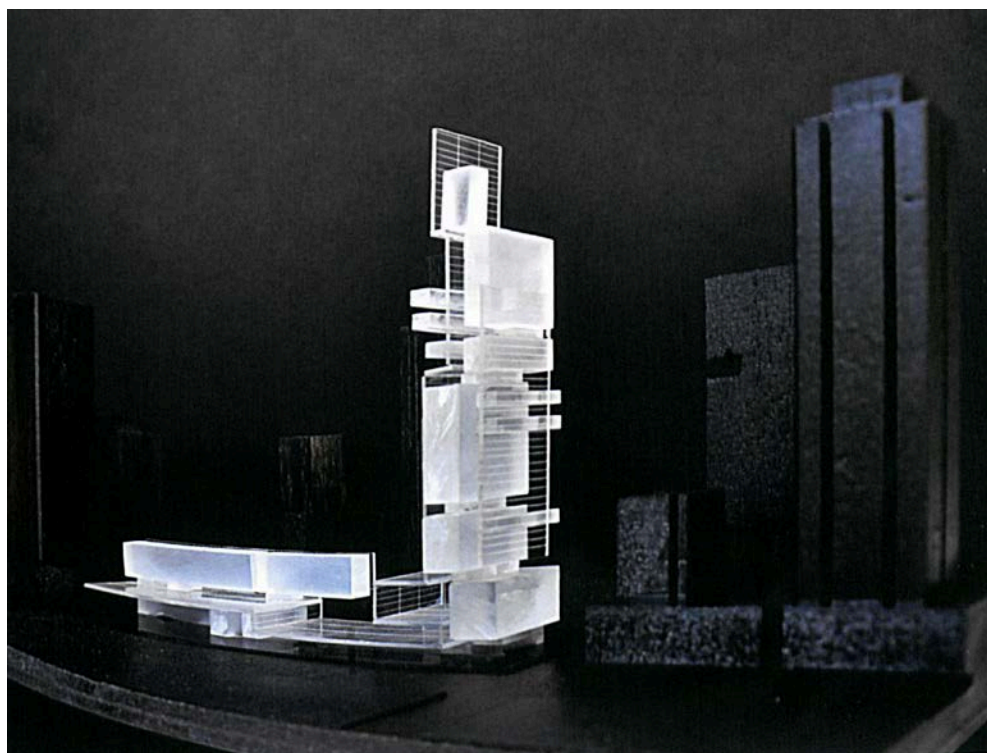


Laser cut machining permits the mechanization of the simplest and immediate manual action. It allows to cut or engrave panels made of cardboard, plexiglass, or wood, along a precise path. The CAD file requested is to be specifically prepared. Lines need to have zero thickness and should not be superposed. Each line colour corresponds to a specific command (cutting or engraving) and to a precise order the machine will operate with. Before launching the cut, it is necessary to calibrate speed and power. In order to reach the best result these parameters have to adapt to every material is to be used. Otherwise some defects will appear on the final piece: plexiglass borders could be melted and no-defined, some geometries could not be cut. When the machine has finished, the pieces are ready to be used. This technique usually does not produce final objects on its own, but it cuts pieces that will be assembled on a second time. The 2D pieces will be glued together to create the final model. Sometimes, due to the complexity of the final model, it is necessary to draw its 3D digital volume that will be the base each piece will be extracted from. This trick makes the operator sure to cut elements with the correct shape considering also materials' thickness. Another factor to be considered are the typical "burnt borders" the laser produces. In fact, even if the main colour of the piece is dictated by the base material, the perimeter will appear darker because of the laser's temperature. The same effect is obtained for engravings. This characteristic is be used to give a specific effect to the final object.



2tr architettura
research centre monte labbro
2007







grupo aranea
revitalization of the vinalope river

Subtractive manufacturing

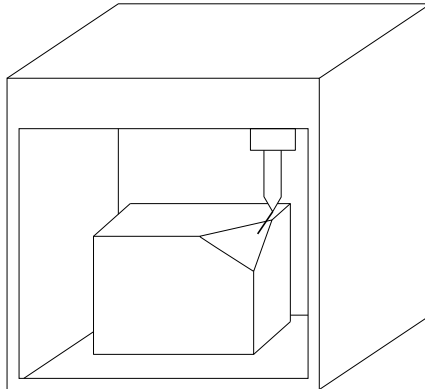
precision: -

materials: plastic, metal, wood, wax, foam, resin

dimensions: 1220x1220x75mm

colour: one colour for the whole object

aesthetic: smooth surface



Subtractive manufacturing machining with CNC control is the latest evolution of a long hands-on material work. It is the heir of the familiar lathe-turning, milling and cutting machines which remove material like metal, wood and composites from a block.

The file to be used is a 3D digital model that can be drawn with several programs. Then the software calculates movements the cutting tool will make.

There are three main types of machining:

- three axes: straight, no undercutting - the machine bed and model move in two axes (x and y), the cutting tool move in z-axis;
- four axes: similar to the previous one except or the object is rotated in one axis and the cutter moves in the x, y, z-axes; or the cutter tool is free to move itself along four axes. Rounded forms are possible with minor constraints;
- five axes: similar to the four axes except or the model is rotated in two axes and the router moves in the x, y, z axes; or the cutter goes along five axes. Fully rounded forms with complex profiling and undercuts are standard.

Some machines are provided of an aspirator that sucks in residual material.

Once the machine has finished to operate the model is ready to be used. Unless particular surface's effects are searched, no additional treatments are needed.

To save time, it is possible to set the machine in order to realize some precise parts, and others with lower definition. In this way parts that are at the margin will not require long time to be shaped.



Harris
void
2013



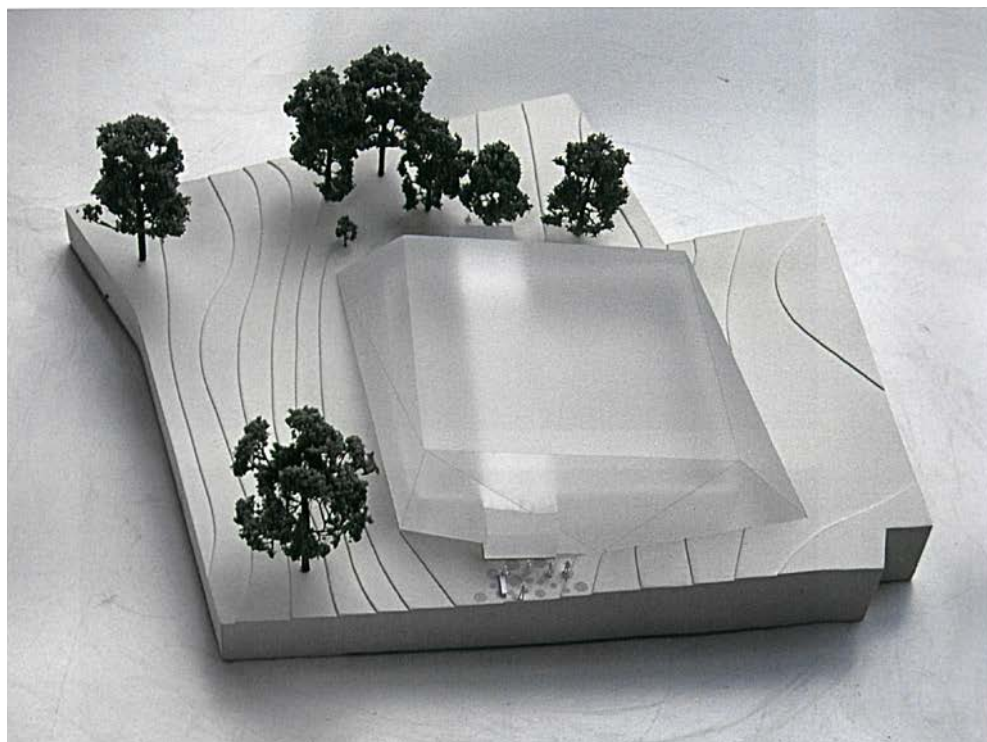
façade tests



karen m'loskey, keith vandersys
2011



Mark F. Garge
Disheveled geometries
2010



frama architects
depot museum cologne



samantha stein
gutter to gulf



gyeong
royal palace

FDM

fused deposition modelling

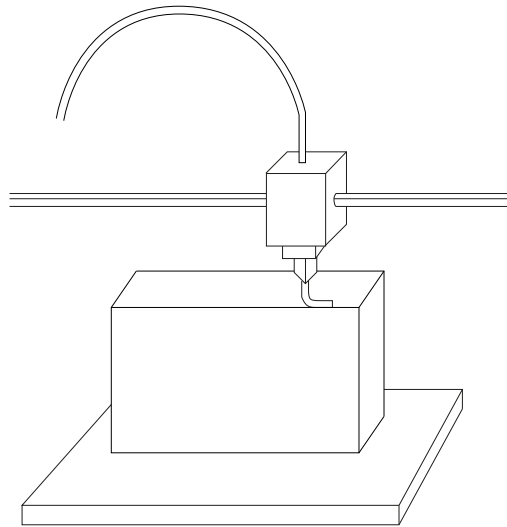
precision: 0,127mm

materials: ABS, PC, PPSF, nylon, laywood, PLA

dimensions: 914x610x914mm

colour: different colours allowed

aesthetic: striped surface



FDM (called also Fused Filament Fabrication, FFF) can easily be understood as drawing with a very precise hot glue gun. The machine extrudes and deposits molten thermoplastic in layers to build the part from the bottom up. The extruded plastic then hardens immediately as it bonds to the layer below it. The quality of prints using this technology depends largely on layer height; the thinner the cross sections, the less noticeable they are, and the smoother the printed objects are. FDM technology is common in desktop 3D printers and less expensive than professional ones.

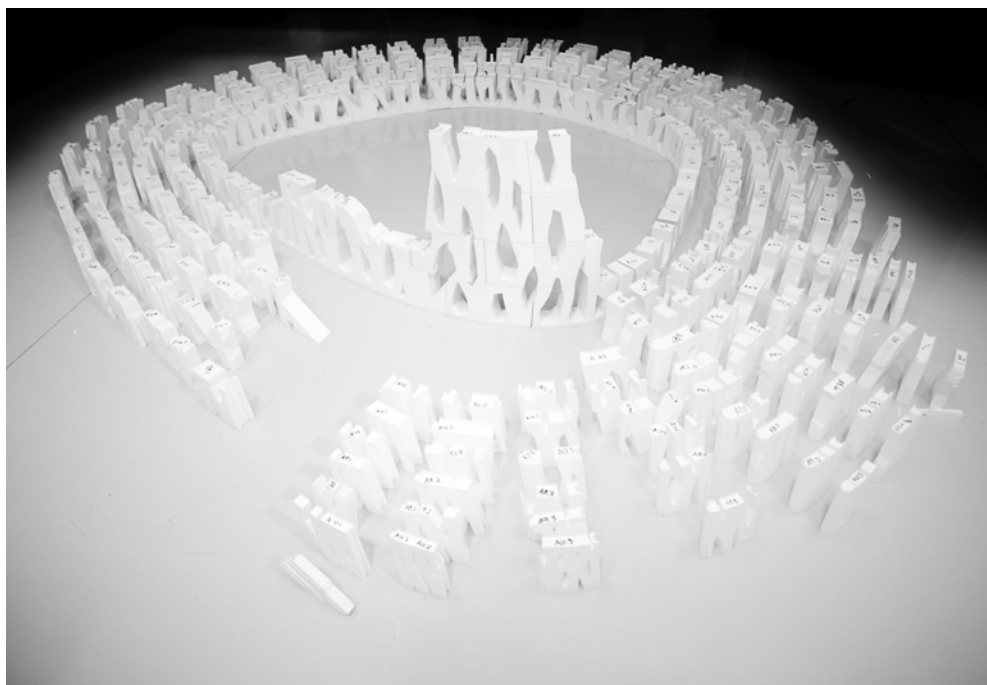
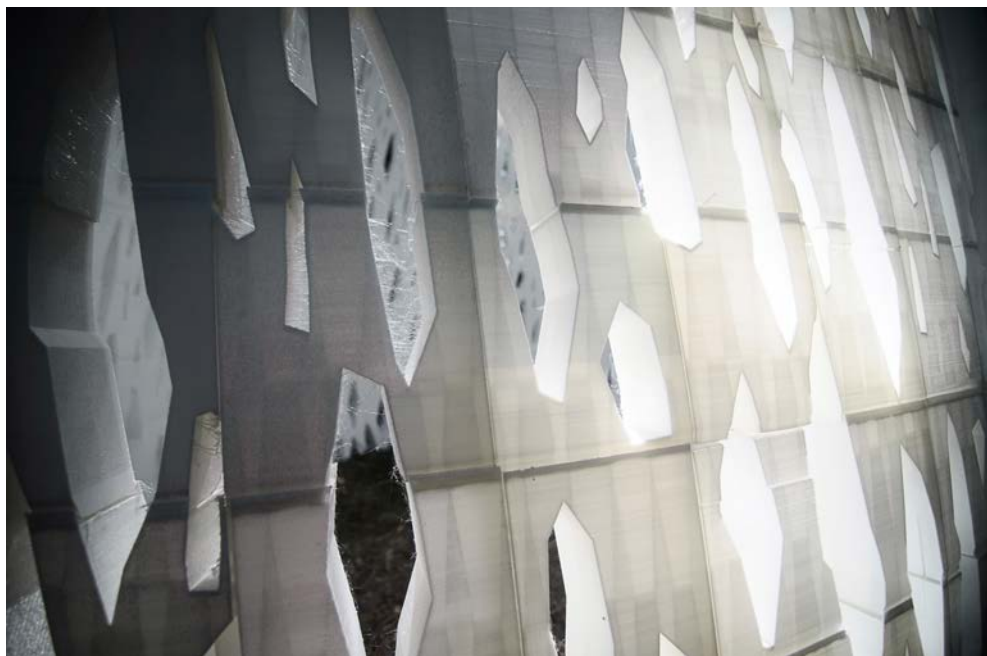
The process starts with several parameters' selection on *build-preparation* programs: fabrication material, colour, slice thickness, support style, orientation the part will be built in. Then the software sections the 3d CAD model into layers which correspond to paths the extrusion head will follow. Once the "print" button is pushed, heat is applied to soften plastics. The printer builds the object using two different materials, one to make the part and the other to support it -if necessary-. The extrusion head lays down ribbons of material layer by layer moving about X and Y axes (horizontal plane) while the platform lowers gradually along the Z axis. Layers instantly fuse to one another.

When the part is complete the support material can be removed through a water based detergent solution if it is a soluble support or by breaking it if it is not. To improve surface smoothness, post-processing steps are fundamental. Sanding is a common way to reduce or remove the visibly distinct layers of the model. Anyhow sanding is a time-cost process that can't even reach all the surfaces of complex shapes. Another possibility is acetone vapour bath. Vapour creates a cloud when heated and smooths object surface. This bath leaves the part with a glossy shine, similar to glazed ceramics.

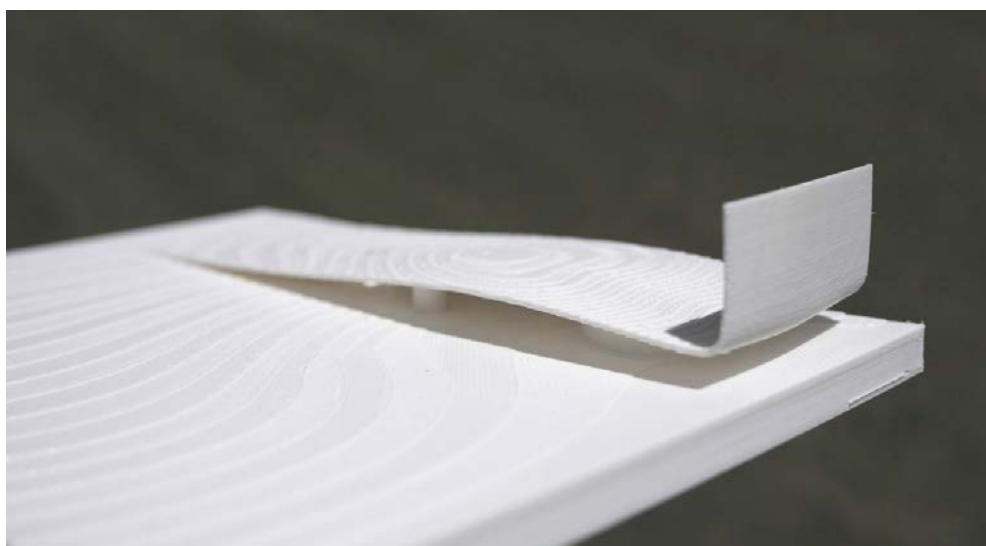
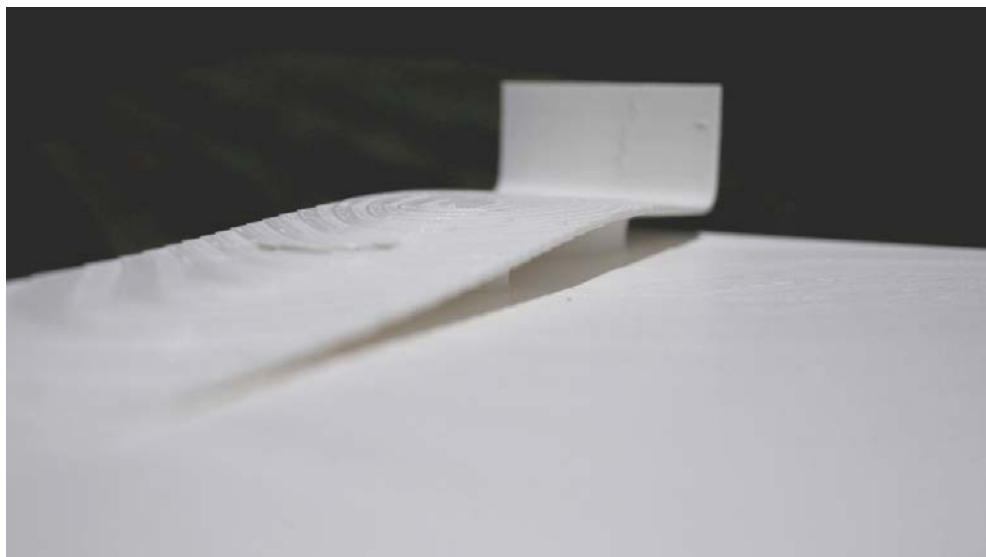
FDM is a very flexible printing process but it can have trouble printing sharp angles and overhangs. Choosing an efficient orientation for the model on the printing bed can make a big difference.

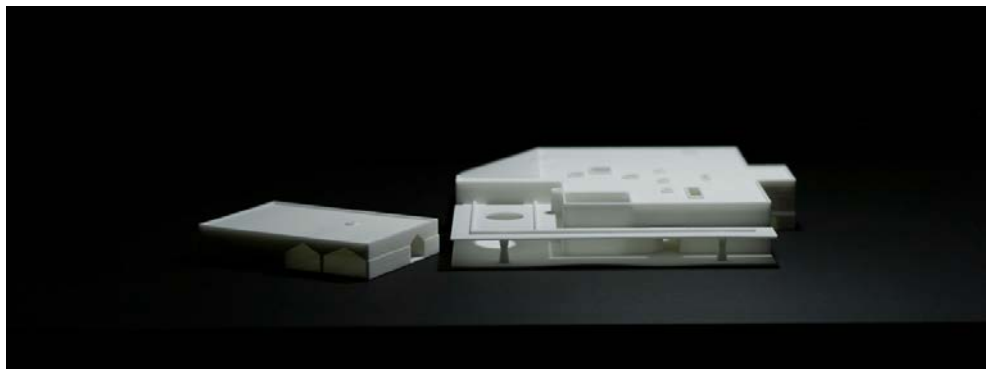
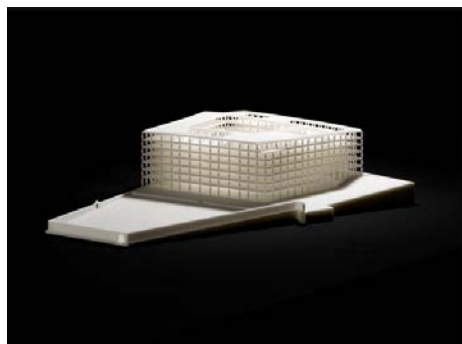


ENSAD students
2013

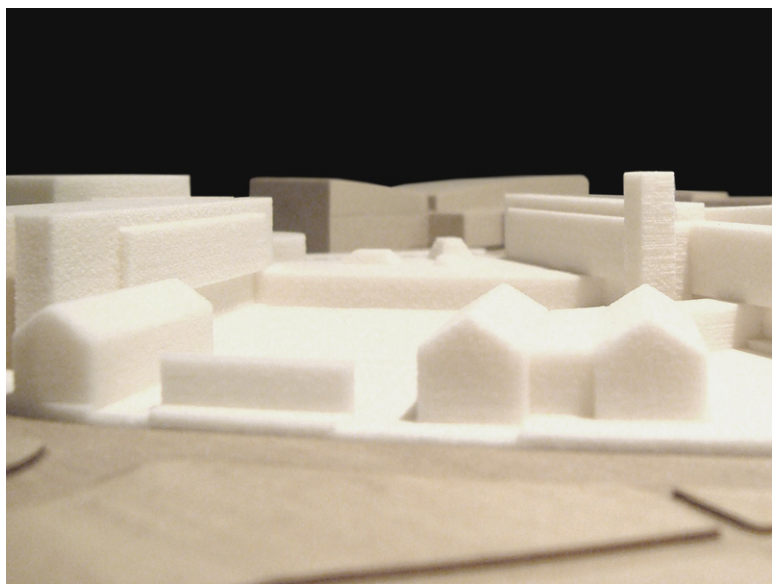
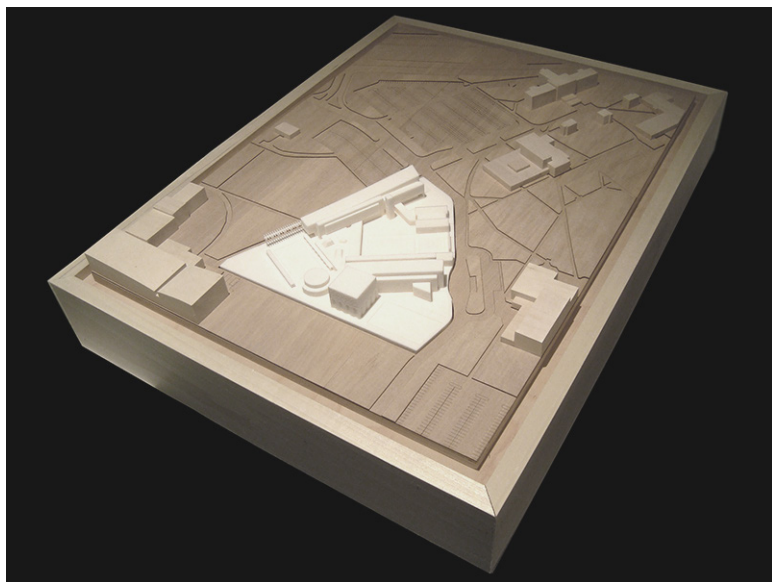


Smith|Allen
Echoviren
2013





pascal flammer



cannon design

PolyJet/MultiJet

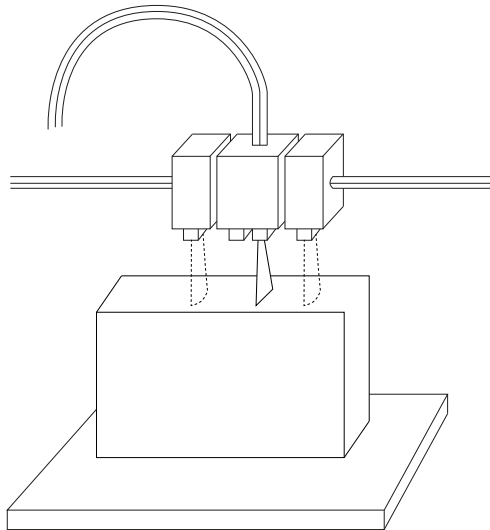
resolution: 0,016mm

materials: photopolymers, digital materials, PP, PEHD, PS, PMMA (Plexiglass), PC, ABS, EPDM

dimensions: 533x381x300mm

colours: large variety

aesthetic: smooth surface



This technology is similar to ink-jet 2d printing but instead of jetting drops of ink it jets liquid photopolymer onto a build tray.

There are two main technologies developed by several societies that are part of this group: Polyjet, Multijet. They have different specificities but the basic idea can be considered common for all of them. The process begins with the placement of material and supports calculation from a 3d CAD file. The software slices the volume in several sections.

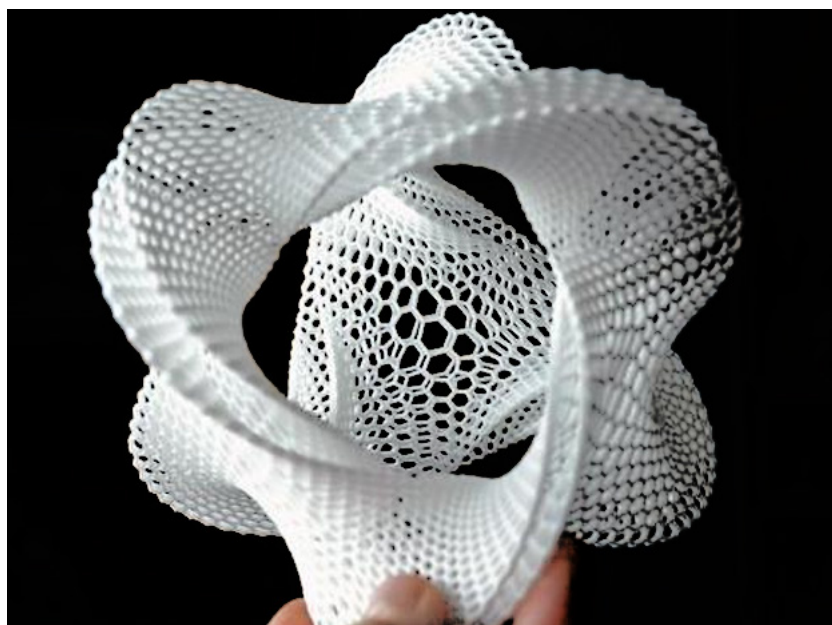
Afterwards material is deposited in different ways.

Polyjet printer sprays tiny liquid photopolymer droplets which are cured with UV light. The support material is also jetted to fill voids and other non-freestanding features. When the printing process is done the support material can be easily removed by hand or pressurized water jets. If there are residual supports they can be finally taken away soaking the piece in a chemical bath.

Multijet machines proceed in a similar way. They use photocurable plastic resin or casting wax. The main difference concerns the post-production treatment. This time parts have to go into ovens to melt wax supports. No manual labour is required. Any excess material can be removed by an oil bath and the final soap wash.

Those material jetting 3D printers are relatively large machines; often allowing for multiple objects to be printed in each run, resulting in a high productivity output, or capacity for large prints. The capacity to print using mixed materials eliminates the need to design and print each separate part in their respective materials and then assemble after printing, reducing production time.

One big advantage that polyjet and multijet 3d printers allow is the smooth surface of the object.



Stratasys
Sample
2012



Neri Oxman
Monocoque 2
2007



Neri Oxman
Monocoque 1
2007



Tishman Speyer
San Francisco
2014

SLA
stereolithography

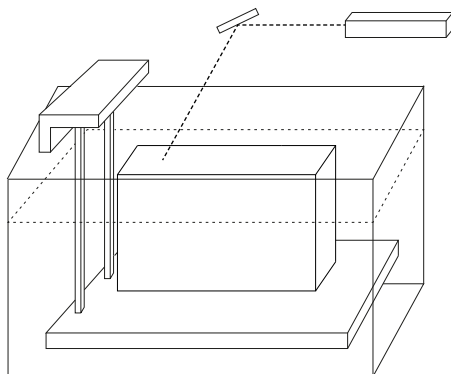
resolution: 0,1mm

materials: PP, ABS, PC

dimensions: 508x381x229mm

colour: same colour for the whole object

aesthetic: smooth surface

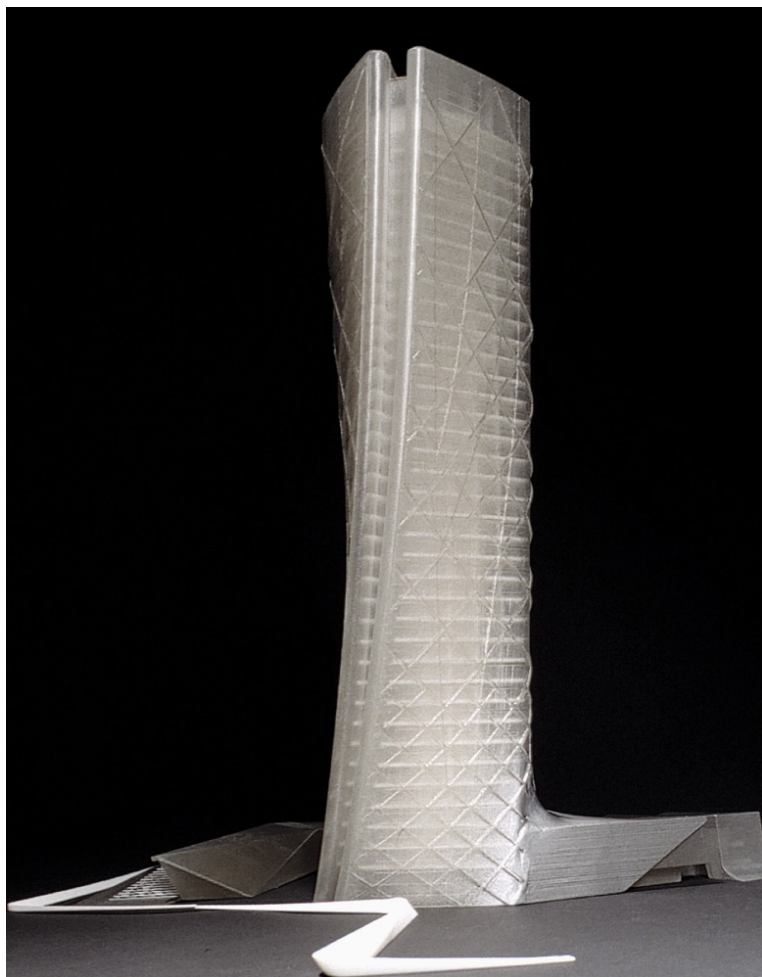


Stereolithography works converting liquid materials and composites into solid cross-sections using an ultraviolet laser.

Firstly the software slices the model into several sections. Then the object is built in a vat of resin through the solidification of the material made by a laser beam. Once the layer is completed the bed lowers, the part is coated with liquid resin and a new layer is built on top of the previous one. Because of this, for all instances with sharp angles or overhangs, there must always be vertical supports connecting them to the platform. Supports are thicker in their columns and base than where they connect to the object in order to withstand the tensions and stresses of mechanical movement. However, the points of contact between the support and the model can be minimized, resulting in an ability to have strong support columns while maintaining easy removal and post processing later, as well as minimizing surface blemishing.

When the volume is complete SLA parts need post-processing treatments. The object has to be immersed in a chemical bath in order to remove wet resin remains. It is put in a UV oven to be definitely cured. Finally support structures are taken off by vapour honed or bead or sand blasted. The unused resin stays in the vat for future projects.

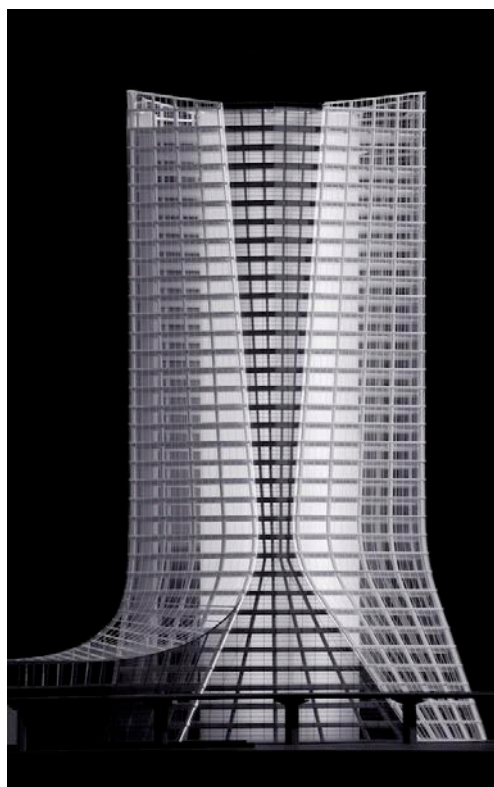
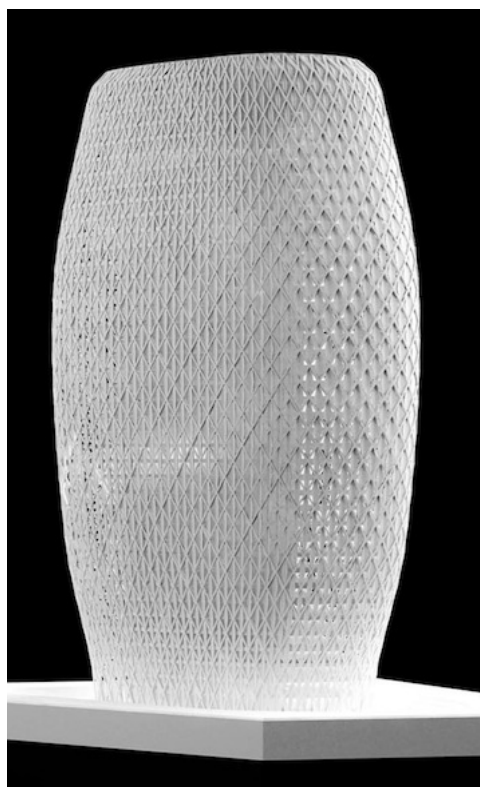
Prints using photopolymer can become brittle with increased exposure to light over time. Moreover with this process, only one material can be used at a time because the object is built out of a vat containing a singular photopolymer solution. This technology allows high precision fabrication level with tolerances of less than 0,05mm. This is a fraction of a sheet of computer paper, it is even lower than other additive manufacturing techniques tolerances, but still visible.



Zaha Hadid
City life
2009



Smart geometry
PAD work



Zaha Hadid
towers



makoto sei watanabe
subway station iidabashi
2000

SLS/Inkjet Powder Printing

SLS

resolution: 0,08mm

materials: PP, ABS, rubber-like polymer

dimensions: 550x550X750mm

colour: different colours

aesthetic: smooth surface

Inkjet Powder Printing

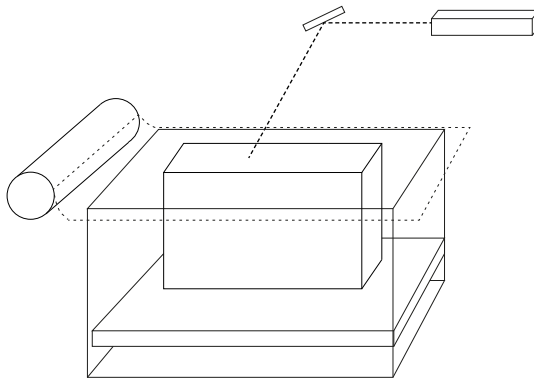
resolution: 0,05mm

materials: PP, ABS, rubber-like polymer

dimensions: 1800x1000x700mm

colour: different colours

aesthetic: smooth surface



SLS (Selective Laser Sintering) and Inkjet Powder Printing technologies allow making objects from small grains of materials. The software “cuts” the 3d digital model into cross sections which correspond to paths the laser will trace.

SLS machine applies powder layer by layer on a movable bed. Each time the laser traces the profile of 3d design’s cross sections. When one layer is built the bed lowers and the process is repeated. SLS-created pieces do not require supports because they lie in powder’s beds. So there is no worry about damaging while removing support material and it is possible to produce complete and complex objects at once.

On the other side Inkjet Powder Printing machine sprays binder solutions on powder layers. In this way colours can be applied very easily by an inkjet printhead that prints colours directly onto the cross section after binder’s deposition. Inkjet Powder Printing objects have less mechanical resistance than SLS ones because of the materials used and the lower level of adherence between particulates.

In both cases once the part is complete the loose powder surrounds and supports the object in the build chamber. Then just the powder removal is needed to be ready. The excess material is usually removed by pressurized air. The leftover material can be reused.



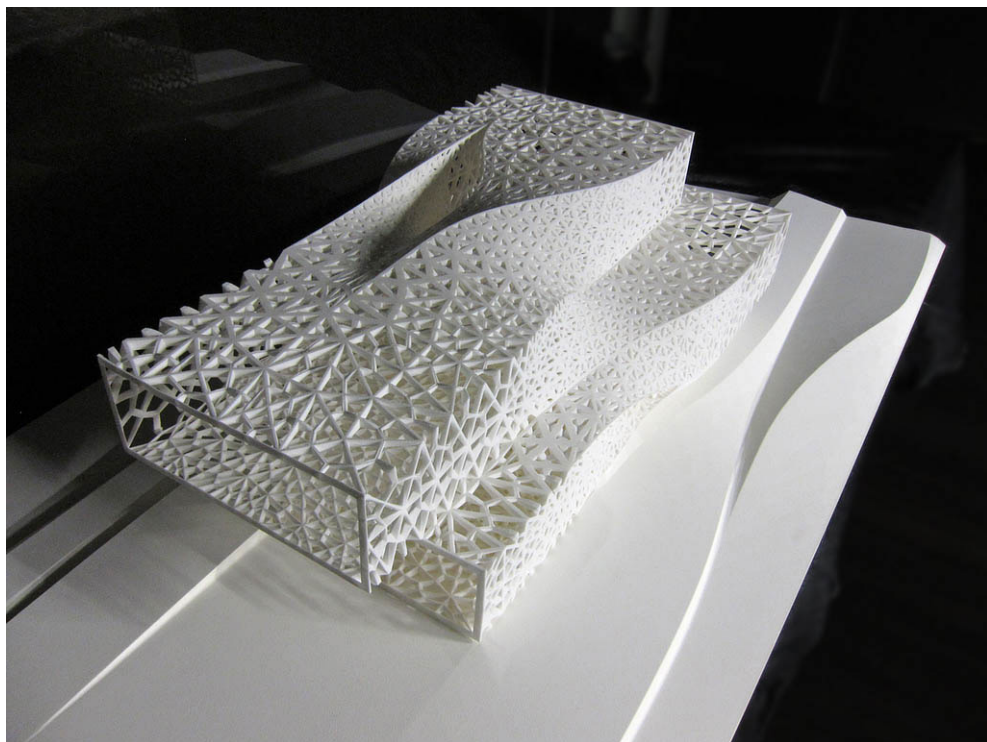
Morphosis
Perot Museum
2012



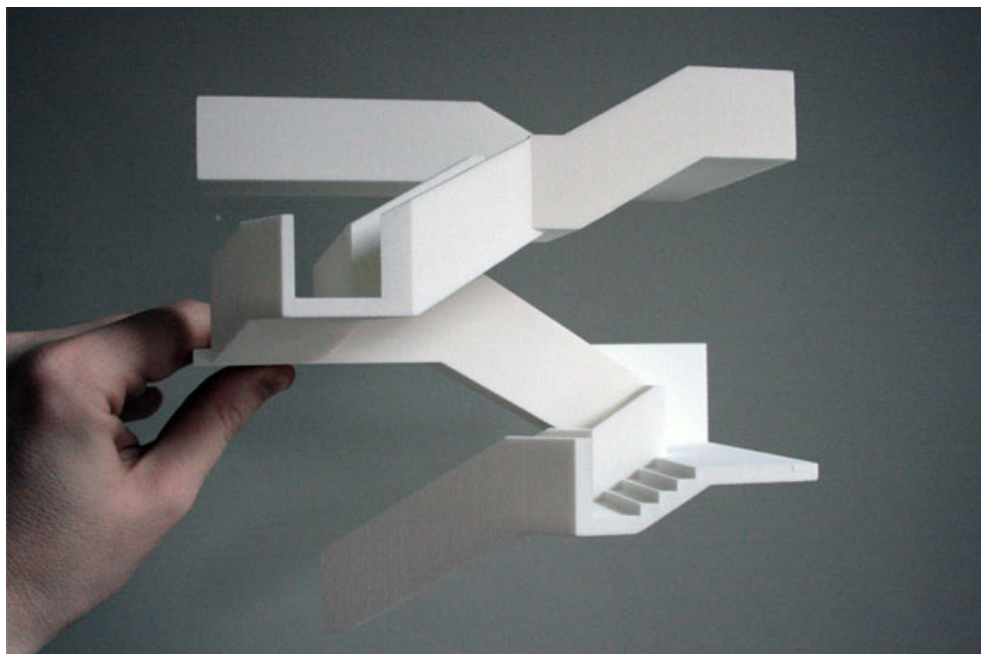
UNstudio
mercedes museum
2006



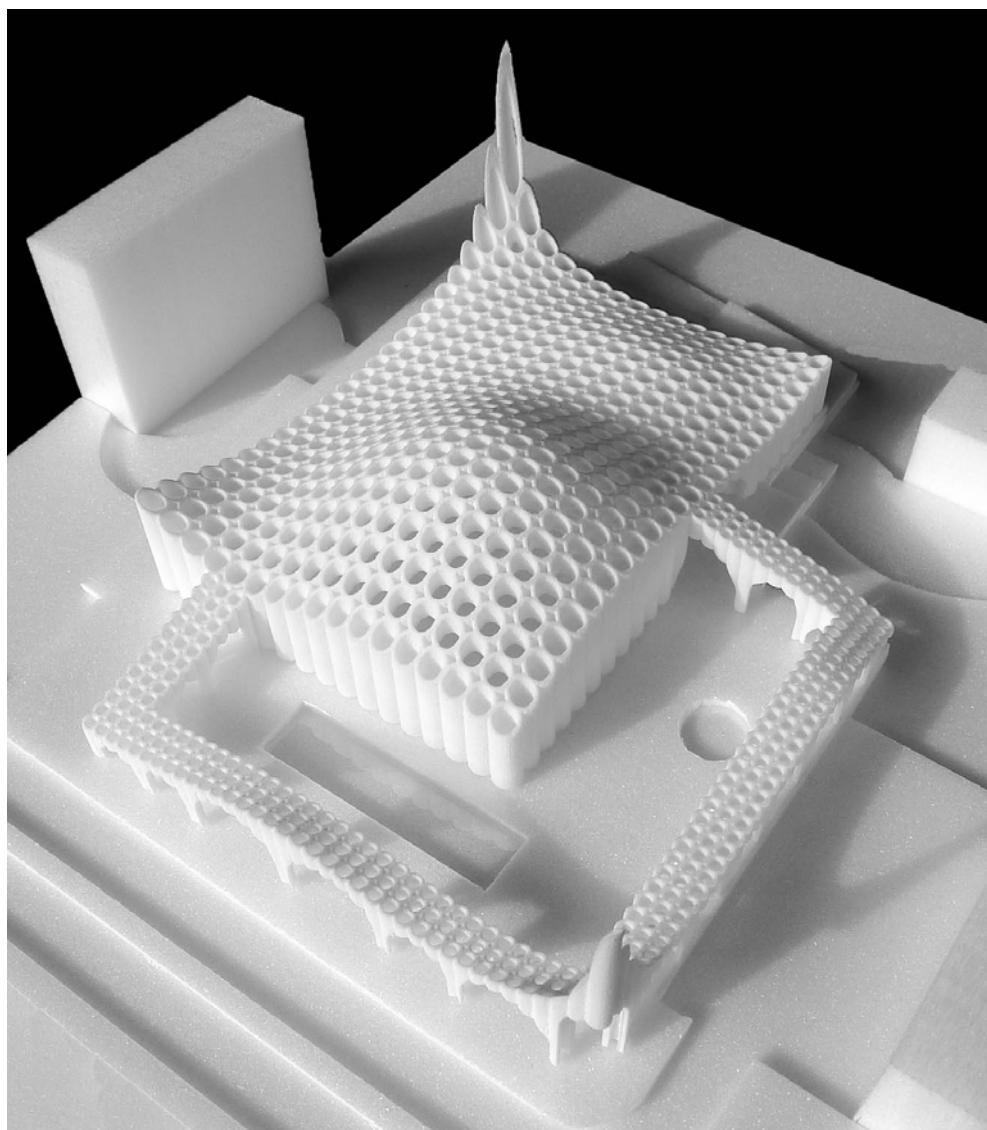
one architekci
logica tower
2014



iwamoto scott architecture
jellyfish house
2012



stairs model



Prishtina Central Mosque
Taller 301, L+CC
2012

Comparison

Computer Numerical Control manufacturing has changed the notion of production. If before it was impossible to think about the realization of a model without operating directly on the material; now-a-days there is the possibility to materialize something analogical simply “pressing a button”. This connection between digital and physical has never been so direct. By the way the common thought that “anything can be immediately and directly produced” should change in relation to machines’ and processes’ limitations.

All rapid prototyping technologies analysed above allow designers to care less about the fabrication scale. CAD 2D or 3D files can be easily rescaled in order to produce the same model at different scales. Another great advantage these technologies permit is the precision level they can achieve. They build up objects with a great accuracy in short period of time in comparison to hand-made models. Machines are able to transpose every single line and shape in concrete reality. In fact they can produce organic forms without any problem, opening the possibility to study and develop new aesthetics. Curves and waves have always been difficult to fulfil. Now CNC machines are able to reproduce the same model for an infinite number of times. Reproducibility is in fact another point in favour of this process. No matter how many objects are needed, they will be always made with the same level of detail. Prototyping has become easier and faster. The little manual labour required avoids also mistakes and lack of precision. Machines can be in function twenty-four hours per day, reducing work force costs. The file can be launched in the evening and the model can be ready in the morning.

Since the creative phase has been finished or has been paused once the additive or subtractive manufacturing processes start, the designers’ savoir faire resides in the previous conceptual phases visualised in the 3D digital model. This is why transportation problems have been solved with those technologies. Files can be sent everywhere a device is located reducing, once again, costs. Another positive aspect of CNC methods is the simplicity composite models can be made. To produce the model of a

section or a plan of the project, it is sufficient to cut the digital model on the modelling software and suddenly the file is ready to be printed. In this way interior spaces can be easily represented completed with all details, from floor's cladding to furniture.

Additive manufacturing is also an efficient alternative to traditional model-making because it uses the exact amount of material needed for the printing. No residual material is left. If there is it means it was necessary for building supports. Technologies like FDM, SLA, Polyjet and Multijet require supports to sustain overhangs or particular shapes. On the other hand, SLS and Inkjet Powder Printing do not demand support material for building up a model. The powder that surrounds the piece is compact enough to sustain any kind of shape. Then post-production phase is way simplified and there is not the risk the object will be damaged from supports' removal. SLS products can also reach higher mechanical resistance in comparison to the other technics. It allows any kind of colour since colour is directly mixed with grains. Instead, FDM and SLA models have the same tint of the material they are made of. FDM is the cheapest technology available in the market but also the one that does not allow a high level of freedom on a morphological point of view. SLA allows more flexibility but it requires post-production treatments. If a smooth surface is needed, Polyjet and Multijet should be used. They can also print several pieces at the same time.

Besides these positive and characteristic aspects of CNC technology, there are some limitations. First of all it is not an immediate process. Long modeling time is required before being able to send the file to the machine. Designers cannot operate directly on the material. Modifications are impossible to be applied once the object is done. That is why this technology is not so recommended during the conception phase. It fabricates models so precise and defined that it is impossible to reach such detailed form at the very first stages of the project. Therefore, CNC machines are usually employed to test several ideas or to make presentation models. Considering that it is a relative new technology, there are not so many architects who know how to use it. This is a limitation for many offices that have also to deal with its price. It represents an investment that only firms

sure to use it, can tackle. All these factors encourage the birth of numerous fab-lab where people can rent machines and use them saving money.

The specificities of each machine do not answer to the question “which is the best technology?”. The answer to that question depends on what exactly needs are. Both additive manufacturing and subtractive manufacturing methods have their own advantages which make them appropriate for different circumstances. By examining which goals have to be reached and which aesthetical effect has to be reproduced, the designer will be able to choose the appropriate method for production. The biggest difference between additive manufacturing and subtractive manufacturing methods is the complexity of the parts they are able to create in a limited timeframe. For parts with complex geometries or intricate designs, additive manufacturing methods can produce superior results than subtractive ones. The reason is because in additive technics, objects grow layer by layer. Each one corresponds to a very precise path and just the profiles are printed. The object is almost empty inside. In contrast, subtractive methods must remove materials from a larger source. Because of the limits of cutting and routing technology they cannot create hollow parts in a single piece, and they are limited in the amount of detail they can create on a single machine. It has to be considered which points the mechanical cutter can reach. Parts are more solid than additive manufacturing products and last longer than fragile additive manufacturing products. That is the reason why, in general, grounds and terrain basements are built up with subtractive technologies; instead, smaller and more detailed buildings are made with additive methods. Another discriminating factor is the material the model will be made of. Additive manufacturing works almost exclusively with plastic. If wood, foam or different materials are to be used, 3D milling machines are the only choice.

If architects are aware of all potentialities and limits of every technology, they will be able to use the tool which suits their need. When designers know how to use these machines, they will also be capable of combining them to reach the desired result. Every time a different evaluation has to be done, even

though one machine or one combination of machines will often result the best choice for a specific design method and aesthetic.

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