MODERNITY AND TECHNOLOGY

Fuller, Rudolph, and Eames: case studies of the experimental use of military technology and materials in the post-war house

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Architecture has long benefited from the application of technological advancements in other fields, such as industry and the military. Some of the most innovative developments have come through the inventiveness of architects in finding applications for materials made for non-architectural purposes. In the work of at least three post-World War I and II architects, the application of military technology played a significant role in their response to housing. The American architects Charles Eames, Buckminster Fuller, and Paul Rudolph all transferred material applications from the military to housing, or, more specifically, houses.[1] Their various experiences with ships, airplanes, and automobiles gave each of them first hand knowledge of military experimentation and cutting edge material technologies. Fuller with assemblies, Rudolph and Eames with plywood, each brought their newfound expertise to the work they did immediately following the war. This work performatively demonstrates the validity of theoretical propositions forwarded most aggressively by Le Corbusier in Towards a New Architecture and less vociferously in the teaching of Walter Gropius at Harvard University's Graduate School of Design.

In the period following World War II, the American and European housing markets went through a well-documented boom due to immigration, better health care, and the emergent middle-class. The architectural profession and discipline had already recognized this trend and begun not only to theorize about the possibilities latent within the need for housing but to execute their ideas as well. Indeed, many of the greatest works of the Modern Movement were not institutions or palaces, but relatively humble single-family homes. The rising need and desire for single-family homes in the US led to the development not only of planning strategies for suburbs, but also for faster, easier, and more technically advanced ways of building. It was no longer feasible for individuals to build their own homes but methods of mass-production had to be employed. Obviously, following the two wars, many former military industries turned their attention to providing materials for the construction of homes. Fuller, Rudolph, and Eames were some of the most innovative American architects in adapting military technology and industrial products to the house.

The houses they designed following their experiences in the military represent serious attempts to reconcile the much more dramatic advances in material technology available to the military at that time. These houses were also attempts to reconcile the Modern Movements fascination with industrialization, particularly the work of Le Corbusier. Le Corbusier's adage, "the house is a machine for living" combined with the industrial imagery in Towards a New Architecture inspired generations of young architects to find associations between new materials and the idea of the house. *Towards a New Architecture* was published in English in 1931; however, its polemic was well known on the continent more than a decade earlier, published in serial-format in *L'Esprit Nouveau* (1919-1920) and later culled into *Vers une Architecture* in 1923.

In the opening chapter Le Corbusier argues, "The Engineer's Aesthetic and Architecture are two things that march together and follow one from the other: the one being now at its full height, the other in an unhappy state of retrogression."[2] He continues with this theme throughout, calling for a closer relationship between architectural progress and engineering, posited primarily as a function

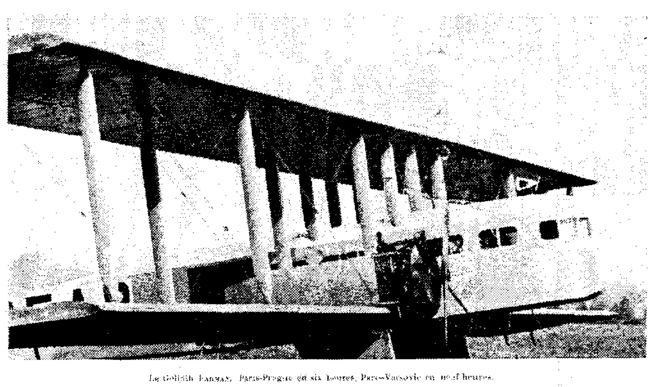

Fig. 1 From Towards a New Architecture.

of industry. Initially, he identifies the relation between "mass" and architecture, carefully supporting his textual argument with the imagery of feed mills and grain elevators from North America. He presents the reader with the simple and "pure" masses of these built industrial forms as rarified "beautiful forms," not unlike the Egyptian pyramids and the Roman Coliseum.

Later Le Corbusier focuses on how this new and industrial modern era will reshape the single dwelling. In the chapters on "Liners" and "Automobiles," the leisure class of transportation is the primary focus. It is in the chapter on "Airplanes," however, where he valorizes technological and material advances made possible by wartime investment.

The airplane is indubitably one of the products of the most intense selection in the range of modern industry.

The War was an insatiable 'client,' never satisfied, always demanding better. The orders were to succeed at all costs and death followed a mistake remorselessly. We may then affirm that the airplane mobilized invention, intelligence and daring: imagination and cold reason. It is the same spirit that built the Parthenon.

Let us look at things from the point of view of architecture, but in the state of mind of the inventor of airplanes.

The lesson of the airplane is not primarily in the forms it has created, and above all we must learn to see in an airplane not a bird or a dragon-fly, but a machine for flying; the lesson of the airplane lies in the logic which governed the enunciation of the problem and which led to its successful realization. When a problem is properly stated, in our epoch, it inevitably finds its solution.

The problem of the house has not yet been stated.[3]

In the last two sections "Mass-Production Houses," and "Architecture or Revolution," Le Corbusier demonstrates his point with his mass-produced housing in reinforced concrete.

The prime consequences of the industrial evolution in 'building' show themselves in this first stage; the replacing of natural materials by artificial ones, of heterogeneous and doubtful materials by homogeneous and artificial ones (tried and proved in the laboratory) and by products of fixed composition. Natural materials, which are infinitely variable in composition, must be replaced by fixed ones.

On the other hand the laws of Economics demand their rights: steel girders and, more recently, reinforced concrete, are pure manifestations of calculation, using the material of which they are composed in its entirety and absolutely exactly; whereas in the old-world timber beam there may be lurking some treacherous knot, and the very way in which it is squared up means a heavy loss in material.[4]

In these chapters, he calls for an increasingly synthetic palette of architectural materials, recognizing the possibilities within industrial production for more precise and sophisticated expression. Moreover, he offers ways for architects to critically think about these developments.

While Le Corbusier draws on technological advances in industry, particularly transportation, he remains unencumbered by the specific realities of the technology and any problems of transposing it to architectural production. The aesthetic value of industrial production interests Le Corbusier more than any specific substantive application. Nonetheless, his widely disseminated views on the relation of new technologies and architectural production influenced generations of architects practicing in the mid-20th-century and continue to inflect architectural practices today.[5]

Walter Gropius, while not as widely published and read as Le Corbusier, may in fact have had greater impact, particularly on the architects in this study, through his teaching at the GSD. Gropius speculated in New Architecture and The Bauhaus (1928) that the nature of enclosure would inevitably change based on the emergence of new building technologies, particularly glass. For Gropius, a singularly Modern desire for an architecture that allowed a more fluid visual relation between the interior and exterior propelled this change. This proved to be a prophetic observation as enclosure systems evolved throughout the last century. His investigations emphasized the connection between design and the production of physical artifacts, the connection between architecture and manufacturing. While he recognizes this connection, he clearly maintains the architect's position as guiding force in the relationship, leading rather than following. This contrasted the discourse forwarded by Le Corbusier, who focused more on the ways that architects could appropriate advances in engineering.

Core ideologies of the Modern Movement as expressed in the work of Walter Gropius and Le Corbusier, when connected to such technological developments, formed the basis for a critical stance towards innovation. Through their work, they helped create a critical discourse equal to the potential of new materials and assembly techniques. By combining engineering practice and architectural discourse, material investigations contributed to a sense of the "new" and, perhaps, the last legitimate avant-garde of form making in architectural production.

Of the three architects in this study, Buckminster Fuller was probably the least influenced by architectural theory although he was certainly aware of contemporary discourse. Fuller was in the Navy and Naval Academy from 1917-19. While he also received some formal education at Harvard, his time with the Navy was far more influential in his career. During that time, he worked with ships as well as airplanes. Two of his first inventions were a seaplane rescue mast and boom and a "jet-stilt" vertical take-off aircraft that he more fully articulated in the Dymaxion car of 1927. In his 1981 book, Critical Path, Fuller outlines his early career and involvement as early as 1917 in the problem of standardized, industrialized components for the housing industry.

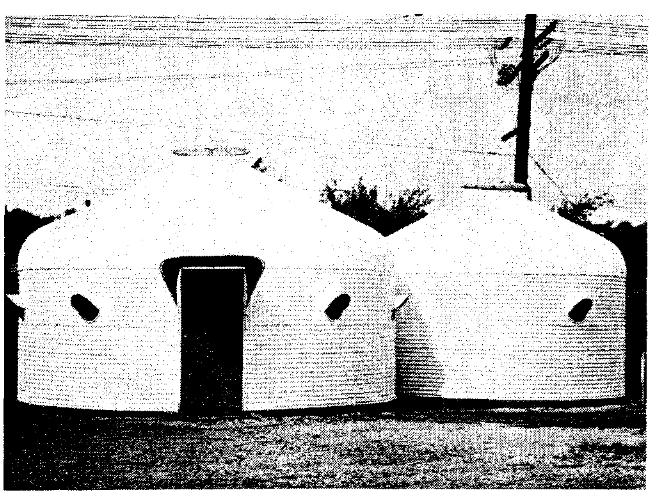

Fig. 2 Dymaxion Deployment Unit.

Although Fuller thought broadly from the outset about mass-production of housing, experimental prototypes such as the Dymaxion House model and the full-scale Dymaxion Bathroom unit primarily executed his ideas. The Dymaxion House model was the basis of the Dymaxion Deployment unit of 1940. The idea, developed and manufactured through the Butler Corporation, was to convert grain bins into housing units. The basic structural material was corrugated steel for the circular walls with a ribbed steel roof. Wallboards of plywood and fiberglass insulation lined the walls of the converted bins. The ease of construction and deployment were major factors in the design and dissemination of these units. By attaching multiple units together, Fuller created larger units for bigger families, including such novelties as a cylindrical bathroom unit. Although the army primarily used the units as temporary housing for GI's during the War, the Museum of Modern Art also mounted them as an exhibition/ installation in the museum garden.

Fuller's more fully developed version of the Dymaxion House became known as the "Dymaxion Dwelling Machine," or the "Wichita House" (1946). For this project, Fuller worked directly with the Beech Aircraft Company and made use of their aircraft manufacturing tools. Fuller re-examines the circular form in the Wichita House, not just for it's structural properties, but also for it's environmental qualities which he takes advantage of through the incorporation of an innovative ventilator on the peak of the roof. The structure makes use of aircraft materials, particularly stainless steel and aluminum. These projects are typical of the work he conducted throughout his career. He disseminated this work through lectures and publications, undoubtedly influencing his slightly younger colleagues such as Paul Rudolph and Charles Eames.

While Fuller became as widely known for his thoughts and theories as for his built work, Rudolph and Eames were far more prolific in built works than theories. Fuller's personal disposition and experiences led him towards more broad experimentation with entire systems and proposals for living. On the other hand, the early experimental work of Rudolph and Eames focused on a single material, plywood. In the case of Rudolph, one can see his work in plywood as a direct result of his military experience. In Eames case, his previous experimentation with plywood got him involved in the military. Moreover, the military facilitated his experimentation by providing him with the opportunity to work with plywood for the war effort.

The development of plywood dates as back in history as far as the Egyptian tombs. However, the technically advanced modern use of the material really began during World War I when the scarcity of metals necessitated the development of more readily available materials. Propelled by the War, military engineers sought a material with the characteristics of strength, consistent performance, and the ability to be molded while retaining these qualities. While furniture makers had long been familiar with the enhanced stability of cross-graining wood pieces, no good tool existed to mass produce the ply's needed to fabricated large quantities and sheets of the material. Following the invention of the rotary-cutter in 1890, the greatest impediment to plywood production was in developing a stable and reliable binding agent. Much of the research literature available from the time focuses on the specifications of binding agents for the thin slices of wood and even describes a kind of "plasticized" wood which is not just impregnated with plastic but actually breaks down the cells of the wood so that it acts in a plastic manner. An additional focus was different uses and associated manufacturing techniques for plywood.

While plywood was used in World War I aircrafts, World War II rapidly accelerated the research and development of plywood into what we are familiar with today. The American plywood industry quickly recognized the potential of their product for providing sheathing and diaphragm in the prevailing American stick-frame method of construction. Louis Meyer, writing for the United States Plywood Corporation in 1947 says:

"The economic dislocations of the 1930's and the exigencies of the Second World War have left the country with a staggering housing problem. This has, from time to time, developed into an acrimonious debate in which the word 'prefabrication' is batted around like a shuttlecock. Opponents of prefabrication scoff at its possibilities; proponents endorse it as the great panacea for the nation's housing ills. One of the few points of agreement between the contenders is that, when prefabrication is under consideration, the value of plywood is incontestable."[6]

Rudolph and Eames both utilized and advanced plywood as a material in their early houses designed and built following their experiences with the military.

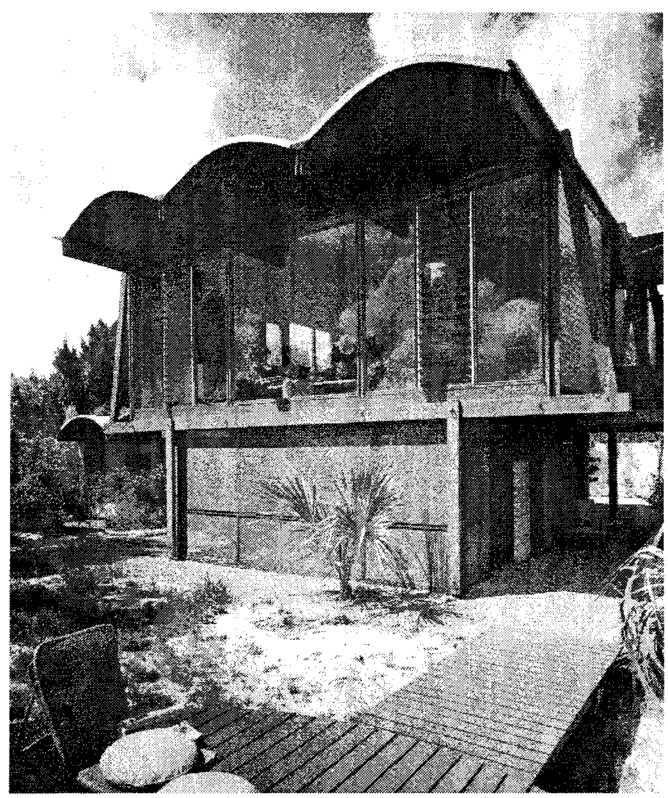

Fig. 3 Ingram Hook House.

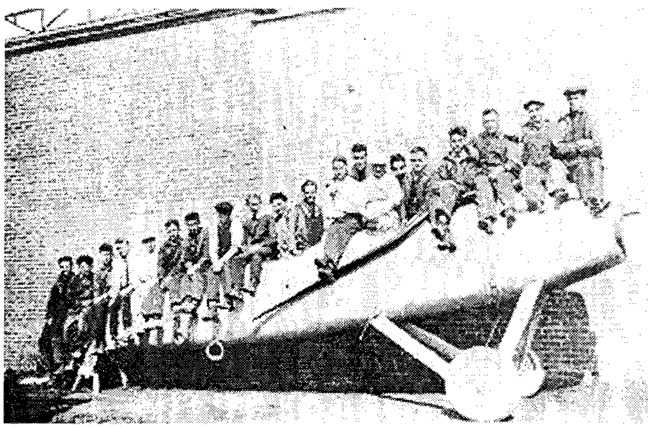

Fig. 4 Example of molded plywood hull.

Paul Rudolph had graduated from the Alabama Polytechnic Institute and was on the verge of entering Harvard's Graduate School of Design when he was drafted into the Navy. From 1943-46, he was the officer-in-charge at the Brooklyn Navy Yard. While at the Naval Yard he was in charge of ship construction and intimately aware of the latest technology. After his discharge, he completed his Master's degree at the GSD. Although he studied with Gropius at the GSD and, like the other students of his generation, learned from European modernism, he remained skeptical. While he sought authentic experimentation in building technology, what he found at the GSD was the image of technology made glamorous. Upon his graduation, he moved to Florida where he established a successful firm with Ralph Twitchell.

One of his first building projects after graduating was the Healy Guest House or Cocoon House in Siesta Key, Florida (1948-49). The term "cocoon" refers to the application of naval technology in the construction of the house. Sibyl Moholy-Nagy observes:

The earliest offspring of European theory and Navy know-how was a guest cottage, later called the 'Cocoon House', finished in 1950. Building board, glass fibre insulation, and a spray-on plastic, developed to keep battleships under wraps, formed a roof sandwich between a center ridge beam and external wall columns. A calculated sag was controlled by tension wires anchored in the reinforced concrete foundation. The 'structural honesty' and the angular plainness remained true to Harvard. [7]

The Cocoon House demonstrates Rudolph's facility for resolving his naval experience with architectural functions and form. Moholy-Nagy's comments notwithstanding, Rudolph was not entirely satisfied with the space created by the roof. Nevertheless, Rudolph continued to adapt military innovations to architectural projects. This ambition provoked Rudolph to be that much more experimental in another project, the Ingram Hook House, Siesta Key, Florida (1951-52).

Of this house, which represented his most profound use of new building technologies to that point, Rudolph observed:

The first use, as far as I know, of bent plywood to span architectural space. The engineering involved was accomplished by trial and error, utilizing a few small boys jumping on various thicknesses of bent plywood in my backyard. The structure could be kept light by utilizing temporary cross tension members to get it through the hurricane season. [8]

The strength of bent plywood was by this time well known for its use in the de Havilland Mosquito airplanes used by the British in World War II. Crafted completely of bent plywood with no armament; the Mosquito proved to be one of the most prolific and practical aircraft during the war. Rudolph used plywood arches again in his project for the Sanderling Beach Club, also in Siesta Key (1952-53). While Rudolph continued to work with materials in innovative ways throughout his career, military technology informed few of them as closely as these early projects.

Unlike Fuller and Rudolph, Charles and Ray Eames never enlisted in the military. Rather, the US Navy commissioned the Eames, through their company, the Plyformed Wood Corporation, in 1942 to design and build splints, stretchers, and a glider hull using plywood. This experience convinced Charles Eames that architectural production and military inventiveness were not mutually exclusive propositions. As Thomas Perry noted in his 1948 edition of Modern Plywoods, "Plywood splints...were widely used during the war years. These

Fig. 5 Eames House.

military developments under the imperative urge of war were accelerated far beyond the normal pace of such projects in peacetime...industry now must undertake a proper and considered evaluation of these new processes and research developments with reference to their permanent place in the woodworking industry of the future." [9]

Eames and John Entenza outlined their idea for an industrialized house using military technologies in an article in *Arts andArchitecture* in 1944. In their diagram, the primary components are "an understanding of family behavior," and "a vocabulary of materials and techniques." Under the latter heading the authors' propose, "a vocabulary of materials and techniques drawn from all our experience as a nation organized for war production and from all related scientific development." [10] Throughout his career, Charles Eames maintained an interest in military inventions and developments for material application.

Charles and Ray Eames adapted some of the techniques they developed for Navy splints in the line of furniture they designed in collaboration with the Evans Products Company. Among these was a rubber "shock absorber" connection between components, typically used in automobiles and aircraft but not in chairs. "Cycleweld" was another technique they adapted. In this process, fabricators join various parts with a synthetic resin and then briefly heat the object to cure the compound. The resultant joint is stronger than the wood. However, Eames also found ways to work innovative applications and techniques into his architectural practice. Although it is interesting to note that he did not make use of the more expressive, molded plywood he experimented with in these earlier, non-architectural works.

In the design and construction of their own house, the Eames' participated in the Case Study House program initiated by *Arts and Architecture* magazine. The program's goal was to reinvent the post-war house. One of the mandates within the program announcement charged architects with the freedom "to choose or reject, on a merit basis, the products of national manufacturers offering either old or new materials considered best..." [11] The Eames' used standard steel parts to create a basic structural frame and infill of plywood and stucco panels as well as glass. They built the house in collaboration with manufacturers searching for a wider market for their materials. In an un-attributed article about the house published in *Architectural Forum* (1950), one observer comments: "An avid reader of catalogues on marine and aviation equipment, he [Eames] is now sorry he stuck so close to the building industry, neglected several offerings from outside quarters." [12] Despite Eames expressed disappointment with his decision to work so closely with the building industry, the initiation of the house could only have come from his deep and long-standing interest in aviation and marine technology.

The architects described above responded to the challenges established decades earlier by Le Corbusier and Gropius in their built work and writings. Through their own experiments, all three investigated the application of different new materials and techniques to architectural projects. Their work remains a meaningful engagement of technology to the problem of human inhabitation, as stated by Charles Eames and John Entenza:

It is important that the best materials available be used in the best possible way in order to arrive at a 'good' solution of each problem, which in the over-all program will be general enough to be of practical assistance to the average American in search of a home in which he can afford to live.[13]

The application of wartime technological developments in materials lead these three architects to explore the question of architecture in ways that continue to inform our work today.

The work of these three architects demonstrates that despite the inherent destructiveness of war, potential exists for the advancement of human inhabitation through the positive application of technological advancements. As the complexity and sophistication of materials technology continues develop over time, the acceleration of research provided by military involvement should also continue to inform the ways and materials with which we build. These case studies illustrate that architecture can be critical and innovative, even if one may question the motivations and generative forces propelling certain advances.

Notes

1 While much of the influential thinking and writing of this time and these architects attempted to address the issue of "housing" for the masses, their most significant contributions to technological developments and materials are seen in the "houses" that they were actually able to build.

2 Le Corbusier, *Towards a New Architecture* (New York: Dover Publications:): 1.

3 Ibid, 109-110.

4 Ibid, 232.

5 Many European architects of this time were enamored of American industrialization including Richard Neutra and Erich Mendelsohn.

6 Louis H. Meyer, *Plywood: What It Is – What It Does* (New York: McGraw-Hill Book Company, Inc., 1947): 95.

7 Sibyl Moholy-Nagy, "Introduction," *The Architecture of Paul Rudolph.* (Praeger Publishers, 1970).

8 Paul Rudolph, *The Architecture of Paul Rudolph.* (Praeger Publishers, 1970).

9 Thomas Perry, *Modern Plywood* (New York: Pitman Publishing Corporation, 1948): 45.

10 The article pays a large tribute to the seminal ideas proposed by Buckminster Fuller in his early works. Charles Eames and John Entenza, "What Is a House?" Goldstein, Barbara, editor, *Arts and Architecture: The Entenza Years.* (Cambridge: MIT Press, 1990): 42.

11 Ibid, 54.

12 "Life in a Chinese Kite." *Architectural Forum* 93 (September 1950): 90-96.

13 Eames, 55.

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