WITH THE EXPANDING WAVE OF CONTEMPORARY ARCHITECTURE INSPIRED AND INFORMED BY BIOMORPHIC DESIGN AND BIOMIMETIC PROCESSES, THE RE-EVALUATION OF WORK OF FREDERICK KIESLER HAS BECOME IMMANENT. Throughout the mid 20th century he became increasingly interested in the relationship of natural form and structure to architectural space and organization. The Grotto for Meditation proposed in 1963 for New Harmony, Indiana commissioned by Mrs. Jane Blaffer-Owen was the culmination of his life’s work. Though the project was not realized, it embodies all of the influences of his time from surrealism to biology and cybernetic theory. Through our university and the Blaffer Foundation, we engaged in formal research and tectonic resolution of the project employing digital modeling and fabrication technologies at our College and in Houston where Mrs. Owen lives when she is not in New Harmony. We based this project on the full catalog of archival material made available to us with support from the Blaffer and Kiesler Foundations. Our exploration also was influenced by discussions with Mrs. Blaffer-Owen who is still very interested in realizing this profoundly interesting and enigmatic project. Our university has opened the door to the opportunity that our reinterpreted Grotto become a permanent fixture on the campus next to a wetland landscape that it is currently under construction. Our research into Kiesler has engaged his esoteric concepts of “co-realism” and “continuous tension” as well as his early use of recursive geometry and biomorphic form in design. From reverse engineering and digital fabrication via 3D scanning to generative structural articulation, we are experimenting with a structural/spatial system that closely aligns with Kiesler’s originally proposed tile patterning dilated into a minimal structure. Our prototypes and the final version will be fabricated by one of the largest commercially for-hire water jet cutter in country and assembled on the site.
1 Introduction
The Grotto for Meditation was Frederick Kiesler’s last major architectural project before his death in 1965. The project was commissioned by Jane Blaffer-Owen to be built in New Harmony, Indiana on the recommendation of Philip Johnson who was building the Roofless Church next to its proposed site.

A bronze model of the project made by Kiesler, one of two in existence, was displayed in our College’s Gallery for an exhibition dedicated to the town of New Harmony and the architectural patronage of Mrs. Owen (Figure 1). That model and a series of sketches and site plans are all that exists of the project that was aborted by the client in its early stages of formation. A prototype was attempted by the architect at full scale by a local builder without substantial success as to how it could be built. The final blow to the project was Philip Johnson’s critical suggestion that it in fact was an un-buildable proposition at the time.

The project as truly ahead of its time given the trajectory of architectural design and practice in the following years and especially in the contemporary context of biomorphic and biomimetic design strategies becoming so pervasive in academics and practice.

The model reveals the essential thematic elements of the design: a shell and a dolphin. The shell is cave-like with two entrances into its inner space. This part of the model was cast with undercuts and opening it reveals a surface with a central stone from which water would discretely emanate and flow under a reveal between the shell and the exterior. The dolphin form emerges from the landscape as an earthwork that is surrounded by water. These symbolic interrelationships between the two metaphoric elements of the design were to be connected by the physical fluid presence of water and interplay of light on surfaces.

If the project had been realized it would have certainly been revolutionary. Next to the Roofless Church by Philip Johnson the two projects would manifest two polar opposites of mid-century architecture held in a tenuous dialogue: the rationality of Johnson’s modernism next to Kiesler’s surrealist influenced biomorphic dream.

The project’s deeply spiritual underpinnings were an important point of departure for Kiesler who was channeling the intentions of Mrs. Owen to dedicate the project to the theologian Paul Tillich. The embrace of the shell and dolphin in the site plan were a manifestation of a symbolic mother in child holding each other. While Kiesler was Jewish, he engaged the Christian symbolism and made it his own.

An important precedent for the Grotto was the Endless House project by Kiesler that was to be built in the courtyard of the Museum of Modern Art but ultimately was also never realized. Kiesler’s spatial concept of “continuous tension” and his existential philosophic notion of co-realism were both experimented with in these projects.

The Grotto’s site relationship was more developed which is revelatory and problematic at the same time. How can something that is in continuous tension even touch the ground much less be determined by gravitation forces alone? The materiality of the physical manifestations of the Endless House and Grotto are consistently monolithic and opaque. Large scale models and prototypes of both projects were made by Kiesler’s own hands out of wire mesh and plaster or concrete. These wet processes suited his desire to actively engage the process of making the space while the defining surface was held in suspension by external lines of tension. It is perhaps this way of constructing the space that is actually the closest he was able to get to realize his esoteric concepts.

A grotto in the historic sense is a man-made aberration in the landscape that is meant to evoke a natural or primitive cave-like space that becomes overgrown with vegetation incorporating water and indirect lighting. The resulting experiential qualities on the interior are mysterious and otherworldly but highly manipulated in order to channel the intended emotional effects. The blurring between the natural and artificial is an essential component the grotto.

2 Historic Research and Documentation
We initiated our reinterpretation of Frederick Kiesler’s Grotto for Meditation as a studio project with a series of investigations into the history of the project and a cataloging of the
Figure 1. Kiesler's Bronze Model
Figure 2. Kiesler's Site Plan
Figure 3. Roofless Church
Figure 4. New Harmony Site Plan. Roofless Church on left, Grotto for Meditation on right
Figure 5. Endless House
Figure 6. Kiesler Inside Model
Figure 7. Interior of a Natural Grotto
Figure 8. 3D Scan Mesh Model
Figure 9. Reproduction of Original Model
Figure 10. Kiesler's Tile
Figure 11. Plan Diagram
Among these materials was an opportunity to 3D scan (Figure 8) the original bronze model into a digital point cloud that could then be used to digitally fabricate our own reproductions of the model built by Kiesler’s hands. We chose to 3D print the shell because of its undercutting and CNC mill the landscape (Figure 9). This model served as the point of departure for us rather than an end result. It allowed the students to begin to reverse engineer the project on the level of its surface topology and begin studying ways of extracting information to carry forward to other processes.

Another archival piece we were given to work with was a sample of the tile that Kiesler designed. It was produced in Japan and shipped to New Harmony for the project (Figure 10). The ceramic tile was composed of three recurring geometric figures that nested into a seemingly random pattern that could be repeated and joined at their edges to hide the interstitial seams. We found a recursion of this form scaled up in the site plan and footprint of the Grotto (Figure 11). This demonstrated to us that Kiesler was aware of power of recursive geometry to assemble elements at different scales within a singular organizational schema.

We also were given access to a series of drawings and sketches made by Kiesler and his various draftsmen that provided clues to his intentions but also contradicted each other to the point that we did not have a fixed image of what the project was ultimately to be. The most developed site plan was based on an accurate survey of the site in relation to the Roofless Church (Figure 12). This gave us fixed idea of the scale Grotto and it generated a model of the two projects in the New Harmony context as it might have been.

3 Sectional Development

The digital scan of the bronze model was able to be studied in typical serial sections (Figure 13) which revealed the changing relationship between two basic elements of the shell’s form: an arching roof and wall structure which held a vertically extruded inner facing curved wall. The merging of these two elements was where the brilliance of Kiesler is most evident. From the floor were a series of benches, a water sluice, a stone pedestal and walking surfaces. These direct extractions from the digital model were compared to the various drawings from the archive that addressed these issues. Kiesler was keenly in control of the section and orchestrating the atmosphere like a stage set but the drawings don’t reveal anything else about the proposed tectonic system (Figure 14).

4 Detail Development

Kiesler has an active designer of furniture, theatrical spaces and exhibitions. This work spanned his career from the earliest De Stijl affiliations to his late surrealist inspired work where he found is own unique design language (Figure 15). An extensive catalog of these images was created to allow us to see further into the intentions of the undeveloped Grotto design by seeking clues from his larger body of work. Several pieces revealed a system of furnishings that formed a network of components that related to the form body as well as to their own self-referential forms. These tables and chairs seemed to jump out of his drawings that are derivative of the surrealist language of biomorphic forms held in a suspended spatial framework. His design for theatrical spaces involved the manipulation of light by channeling it through specially designed apertures (Figure 16). The Grotto had a “rose window” at its end that in various drawings is a spiraled form with perforations where colored glass was to be placed.

5 Material Research

The aforementioned ceramic tile and a series of photographs from the prototype that was built in New Harmony of mesh-reinforced thin shell concrete are the only physical indications of the intended materiality. Kiesler was very interested in the tactility of his architecture as if he wanted to mold every facet of the space to be experienced by the inhabitant with his own hands. His furniture was more diverse in its materiality: wood, polymers, met-
als and glass were all part of his palate but it’s wasn’t his obsession. There’s a sense that his abstract spatial concepts were constantly at odds with any fixed material manifestation.

Our reinterpretation of the Grotto in our contemporary plethora of material and manufacturing possibilities started with a tactical catalog of possibilities available to us in our city. We are surrounded by a vast array of small and large scale manufacturers and fabricators very different from what would have been available in New Harmony in 1963. We felt that this gave us creative license to explore the possibility to re-imagine the Grotto within a different building culture with new tools and materials.

6 Digital Modeling

The ability of reverse engineer the original bronze model through digital simulation allowed us to understand its fundamental surface morphology and begin to propose a way to embody its essential spatial qualities in a new model that was scaled down and did not presuppose it materiality (Figure 19). Digital wireframe studies began to suggest that the surface of the grotto wasn’t necessarily monolithic or void of structural potential on the level of its components. We began to project and map geometries on to the surface and express the surface as a frame or with perforations (Figure 20). The debate over what sort of patterns resulted from this process and their application was addressed through physical models that tested their structural fitness and ability to be fabricated at larger scales. We became interested in the ability to merge Kiesler’s spatial continuity with surface articulation. The role of minimal surface and structural patterning became a way for us to begin to develop the Grotto as a series of interrelated components that were generated along its surface. The type of pattern deployed and density of its articulation were the subject of several iterations. Our focus began to fixate upon a multi-directional cellular Voronoi pattern that transitioned into an oriented linear gridshell pattern. This allowed the system to be controlled as a gradient between organized and randomized modular arrangements of structural cells that formed a structural surface.

7 Visit to New Harmony and back

Halfway through our work and after our analytical phase we made the journey to New Harmony, Indiana to visit this idiosyncratic town and tour the original site for Kiesler’s Grotto next to Philip Johnson’s Roofless Church. The history of New Harmony goes back to the early 19th century. The client for the Grotto, Jane Blaffer-Owen, has familial roots in the town that go back to its founders. Her continued interest in the project to the present day is evident in the fact that the site has been beautifully maintained and dedicated to the theologian Paul Tillich in spite of the Grotto’s incompletion (Figure 21). Because Tillich was actually buried there upon his death the site is now considered state property so it is questionable the Grotto could ever be realized in that spot.

Our conversations with Mrs. Owen on the Grotto and its meaning inspired us to imagine how it might develop further in a new context. Her ambitions for the project to be a place of rest and reflection are still alive and therefore the relevancy of the Grotto is strong enough to be continued with her endorsement.

A parallel relationship between the site for the Grotto and an existing Philip Johnson building exists at our College and the University has just initiated an ambitious series of projects that include a new “meditation” pond and future quadrangle adjacent to our building. Our suggestion that the reinterpreted Grotto be built in this location was enthusiastically received by the Campus Planning Committee as a place of rest and reflection for the students (Figure 22). Where the original Grotto had deeply spiritual underpinnings in New Harmony, the new Grotto is rooted in contemplation of the different disciplines that use the adjacent buildings in the institution that face the quad containing the Grotto. These include architecture, fabrication, engineering and sculpture.

The work shifted from research and documentation of Kiesler’s work to tectonic resolution of the Grotto in its new context. We formed a hierarchy of workgroups that were to collaboratively investigate and propose a response to this opportunity.
8 Site Integration

Kiesler had draftsmen draw site plans of the project based upon the bronze model. This was based on a survey of the site and care was taken to understand the orientation of the project relative to cardinal directions, the Roofless Church and the topography as it sloped to an adjacent pond (Figure 23). The bronze model shows a dolphin shaped earthwork that wraps around in the shell and was supposed to be surrounded by a shallow pool fed by discrete fountains inside the shell and at the head of the animal (Figure 24). The project was drawn in a series of sketches that exemplify Kiesler’s frenetic design process (Figure 25).

We believe it is important to reinterpret these elements in our version of the Grotto but to remove the overt figurative representation and use the essential elements of formed earth and moving water to create an enclave in the landscape that focuses on the shell and the water. Our berms are subtle references to Kiesler’s forms and adapt them to the profile of the pond design we are working with. A curvilinear bridge completes the oval form that is reminiscent of the original site plan. Water will be piped under the shell, expelled from a discrete source within and meander across an inclined surface toward the pond. Our earth berms wrap around to the entry were they pass each other and create the same scenario of gated entry from the Kiesler project. The ellipsoidal gate was the only component of the project that was developed and drawn accurately enough to be built as it was originally conceived. It is our goal to copy this one element exactly in direct homage to Kiesler and assert our desire to form continuity with the history of the project, New Harmony and our site as corresponding realities (Figure 26).

9 Formal Coordination

From all of the analytical work we distilled the Grotto to its essential elements: a shell encompassed by an embracing earthwork with water as a catalysis for connecting to the site. The diagram of the shell suggested a spiraling cross-sectional space that was asymmetrical from one side that anchored to the ground and floated above it on the other (Figure 27). The Grotto became reformatted as an open structure rather than a cave-like space as a reaction to its new site. For climactic reasons a trellis is a better response to a hot humid climate and the possibility to grow vines on the structure is a reference back to the Grotto in its historic context.

The alignment of the Grotto was determined with a primary site line that connects the point of entry to the site and an island in the pond. This line corresponds to the north-south axis which situates the entry to the shell to the north and facing a landscape with large trees. The southern end of the shell slopes down to focus the view on the water at the edge of the pond and the island’s tip where a stone is placed to dedicate the project to New Harmony similar to the stone that dedicated the original Grotto to Paul Tillich.

Kiesler sketched shells obsessively throughout the period of the designs conception. A small conch shell was found in New Harmony that is very similar to some of the sketches and the model he made of clay and later cast with bronze was based on these studies combined with the cave’s interiority. We also initiated our interpretation with a series of sketches that pursued the shell as more of a diaphanous membrane that an opaque mass. These explorations were conducted in parallel with digital modeling that sought to optimize the space within the shell as well as scale down the project to a more manageable size for us to work with.

The formal coordination group became master planners in that they distilled the work of the other teams into a digital model that became the basis for feedback between the site and the work of other teams.

10 Inner Space

The interior of Kielser’s Grotto was focused on connecting to the human scale. His walls folded out to allow for benches to emerge. The floor pushed up to provide other places where one could sit and embrace the water that flowed through small channels in the horizontal surface (Figure 28). The mood of the interior was mysterious and other worldly.
Light was either indirect, reflected/refracted with water or modulated by colored glass like a Gothic church.

The interior of our Grotto embraces the human scale as well but does not completely separate the visitor from the exterior site. We are still interested in modulating the light reflecting off the water on the pond to the south up into the frame of the shell. As vegetation fills in the structure over time the light will be further modulated through foliage and a microclimate will emerge with ample shading, channeled breezes and evaporative cooling from the water moving across the slab to the pond (Figure 29).

The “core” on the interior is to be a focal point within the Grotto similar to Kiesler’s pedestal in the interior of the original. A sculpture was proposed to be placed on it. Our interior element will be a place for seating or lying down within floating above the sluice below (Figure 30). Water emanates from the object and creates the subtle sound of falling water on to the surface that feeds the channels into the pond outside the Grotto. As the shell curves and lifts on its side an opportunity for seating on its surface is created by introducing infill into the cellular structure.

11 Shell Development

The tiles designed by Kiesler and made in Japan became a very interesting point of departure for how our shell developed. A surface with double curvature can be tiled if the pattern is able to undulate in two directions. Another more conventional grid tile was proposed for the horizontal surfaces that contained water. While we can only imagine the success or failure of this proposal, it does provide an interesting lesson in topological geometry as it relates to Cartesian space. Kiesler was aware of the tension between the two systems of reference as evident in a sketch he did for the Endless Theater project in which he represents a curvilinear surface bounded by a cubic frame. The non-Euclidean form is the privileged element in the drawing but its clear that he understood that to build such a thing a frame of points and lines had to exist with it simultaneously. This became a way into understanding Kiesler’s notion of “continuous tension” in a way that became operative in our own means (Figure 31).

Voronoi patterns have proliferated architectural education and experimental practice to the point of exhaustion. While we are aware of it becoming somewhat generic, we do see the application here to be an appropriate way to employ Kiesler’s tiling strategy on the global geometry of the shell via a series of points that are projected from a Cartesian grid onto the surface from above (Figure 32). Several iterations of the pattern where implemented as the shell’s overall form developed to optimize the structure with the surface.

12 Continuous Structure

Through the writings and work of Frederick Kiesler we sought to elucidate his esoteric concept of “continuous structure” in our reimagining of the Grotto for Meditation. Described by Ben Nicholson as a “suspension bridge in 4-dimensions”, continuous structure has become not only an abstraction but an operative strategy for the production of architecture in relation to virtual space and a physical site. The images of Kiesler working inside his models where a series of meshes were held in suspension while he filled them with plaster are an indication that his project was more about inhabiting a space in the process of becoming rather than seeking a static reality. This working methodology is not unlike the virtual work spaces that we inhabit in contemporary design that are parametric and generative in nature rather than fixed and preconditioned with known structural typologies.

Through an analysis of the archival work we have found clear indications that Kiesler
sought to understand and develop alternative structural systems that were non-hierarchical and non-Cartesian. Tessellations of framework, cellular patterns and fluid organizations of space abound in his sketches (Figure 33). Through these allusions about form and his various writings on structure, we feel compelled that the structure for the Grotto and the notion of continuous structure can be updated with contemporary tools while a critical link to Kiesler’s process and language are maintained.

Kiesler’s tiling was designed to allow seamless continuity from one module to the next. It is a recursion of 3 different sized tiles that carry forward a form that occurs at several other scales in the project, including the site plan. An analysis of the pattern and its implication at other scales met our interest in naturally occurring patterns and their mathematical counterpart in Voronoi patterns (Figure 34). The use of a computational script to generate cells on a surface has become the counterpoint to Kiesler’s tiling. The point cloud we use to produce the framework is projected onto the surface from above to allow for elongations in the cells along the vertical parts of the surface in anticipation of the gravitational forces that accumulate at these zones of the geometry. In the roof region of the surface the cells become organized and more regular in size like Kiesler’s tiles. As the form embraces the ground the cells elongate and become linear in relation to the flat Cartesian plane of the site.

The surface of the reimagined Grotto was initially based upon a reverse engineering process by which we took a 3D scan of the original bronze model made by Kiesler and began analyzing and extracting its geometry using digital modeling software. These studies revealed the essential form of Kiesler’s Grotto as two nested shell forms that held each other a complex manifold. We sought to distill these two entities into more discrete elements; a shell and an inner space (Figure 35). The shell became lighter and more of a tracery of independent components that enveloped the inner space of the Grotto. Within the inner space, a core element emerged that could be of a heavier materiality and embrace the ground with solidity that engages water within the space and site. This dialectic situation between different materialities and structural solutions will be brought closer in relation as the project develops further. The shell will become one with its supporting elements through continuous tension.

Finally the temporal aspects of continuous tension are engaged by the use of vegetation to create a link between the Grotto and nature. The time it takes for the plants to weave into the structure and enhance its sheltering function within will create a dialogue with the history of the Grotto typology from the past to Kiesler’s vision projected into the future. The use of digital fabrication technology and innovative structures will be augmented by a force greater than what we can predict. This natural force is the common inspiration we share with Frederick Kiesler.

13 Digital Fabrication and Prototyping

The conclusive step in the process was the creation of models and prototypes directly from the digital models. The original Kiesler model was reverse reproduced using 3D scanning, CNC routing and 3D printing technology. We created a series of scale models of the site and the new Grotto using the same techniques in order to create continuity within our representational methodology (Figure 36). As we scaled up the work and developed the patterning we transitioned from 3D Prototyping technologies to 2D CNC technologies (Figure 37). We have found this to be essential to employing digital fabrication at the building scale and the facilities available to us allowed us to get very close to the scale of the Grotto with a one-quarter size full model and a full-scale component of one cell (Figure 38). There were many other models that led to this result where we designed a system of connection that allowed for incremental inaccuracy in the alignment of parts so as not to create a catastrophe during assembly. Our largest model was built in one day with one week of component extraction by the team to create the digital tool paths for cutting. Our fabrication partner has the largest for-hire water jet CNC machine near our campus in the vast light-industrial sector of our city. First time welders and former digital modeling novices became experts.
over the course of the project. As we developed this model we devised new means of assembly that now allows us to build the full scale version with minimal scaffolding.

When it came time to consider materials for the new Grotto we had to consider at least 50 year life span with minimal maintenance. We choose stainless steel as a material that we could work with through digital fabrication by extracting profiles from the virtual models. The infill materials might range from long-life wood or polymers and vegetation planted in specially made gabions within the cellular formwork which will be left open as much as possible (Figure 39).

14 Conclusion
Frederick Kiesler was clearly interested in technology as a means to achieving his design ambitions. He was constantly engaged in building his “endless” spaces from within. A photo of him inside his mesh surface suspended by cables from above is not unlike the space one experiences while modeling in the virtual space of contemporary 3D modeling software. We speculate that he would have been very interested in using this technology but not as the final site of creation but as a tool to arrive at new realities of space and form.

The use of patterns as structural modules was also evident in several of his sketches that are strikingly similar to the Voronoi and grid-shell structure we have used. We can assume he was influenced by the work around him at the time but we must remember he was a contemporary of Buckminster Fuller, predecessor of the Metabolists of the 1960’s and certainly the so-called blobists of the late 20th century.

We certainly have sought to channel Kiesler in this project for the reinterpreted Grotto for Meditation but we also pay allegiance to our common client, Mrs. Owen who is the enduring spirit and energy behind the project. At some point we were no longer merely developing Kiesler’s project and it took on a life of its own while maintaining a critical dialogue with the original. It is from Mrs. Owen and her town of New Harmony that we draw living inspiration and find the conviction to realize the project in a new context.

15 References
Blaffer-Owen, Jane, client of project. Interview by authors. (February 2008) Houston, TX. Audio recording. University of Houston.
Kiesler, Lilian (July/August 1966) “Kiesler’s Grotto” Austria: Kiesler Foundation.