# Scaling Up: Model Fitness

Model fitness engages a design process that inspires innovation. This paper explores how digital modeling, material studies and rapid prototyping can be connected to produce surface models that explore architectural volume. Surpassing a singular interest in surface, a common limitation of digital work, the projects produce novel volumetric relationships through the build-up of geometric order. The research includes work from design practice and a pedagogical context—foundational design studios and advanced seminars—that address the Design-Build issue of scaling up the architectural model in anticipation of full scale construction. The large physical model prioritizes modeling fitness and relies on a cultivated relationship between digital and analog fabrication. The work is exploratory and draws connections between contemporary volumetric ambitions and fabrication capabilities as a design development tool and a pedagogic model.

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Scaling up exposes literal and figurative problem areas that offer opportunities for targeted toning and editing. This is architectural calisthenics. The workflow moves between digitally calibrated tactics and intuitive revisions resulting in visually rich volumetric environments that can be accessed by the designer. The process interrogates multiple geometries to create intricate relationships between interior and exterior, expanding the contemporary capacity of architectural poché.

## DIGITAL FITNESS

The volumetric surface expands the emphasis on topological surfaces that has developed over the last two decades. It offers a move beyond the continuity of the single, folded, animated surface to reintroduce thickness, structure and threshold. This is increasingly important as limp surfaces are bearing the pressure of advertising (think media surface) and performance driven demands (think solar panels). In contrast, the volumetric surface can anticipate this need for complex relationships between spatial experience and embedded technologies while elevating the status of volumetric exploration.

As architecture negotiates more complex systems, what we expect from models is changing. The large volumetric surface model can be operated on from within, have parts added and removed and sponsor multiple iterations between the analog and digital. It strikes a balance between the precious qualities associated with 3D printing and the heft of a full-scale mock-up. In many cases, especially within a teaching context, surfaces are developable, computationally calculated, precisely cut and

manually assembled. Negotiating between three-dimensional and two-dimensional anticipates the planar quality of most building materials, promotes construction innovation, and addresses issues of tectonics and composites. Digital fabrication is altering the way surfaces are constructed. The relationship of fit neighbors is shifting from a "notion of standards as a dimensional agreement that streamlined manufacturing following the industrial revolution to that of the agreement of parts."[1] As models scale up, connections, seams and detail considerations are paramount. Testing the fitness of the architectural model sharpens the specificity of the design intent. They are no longer content to passively represent a single idea; they are active, and challenge issues of orientation and gravity by asking can it stand up? Can it hang? And can it tumble? A robust and fit model can.

**TARGETED WORKOUT**

A subset of the ubiquitous architectural model, the volumetric model is often an extracted element. Volumetric models—like their cousins, object oriented prototypes and construction mock-ups—target parts over the whole, with the added roles of generating and studying spatial qualities. These models transcend a comprehensive viewing, instead engaging the viewer to peer inside. Historically, due to their massive scale and experiential leaning, the investment in large models was reserved to persuade, evaluate and represent a "long shot" spatial idea. Take for example Christopher Wren's infamous "Great Model Design" of 1673. The model, large enough to stand in, was used to persuade a reluctant England to construct a centralized plan for St. Paul's Cathedral over the ultimately executed processional plan. In 1933 Sir Edwin Lutyens built a colossal model of his unbuilt proposal for the Liverpool Cathedral. Both models are now on permanent display in the Trophy Room of the Cathedral and the Museum of Liverpool, respectively.

Today large models are primarily built to be exhibited for an inquisitive public or as a site for testing performance, such as acoustical, structural or fire suppression-related systems. This is the case with Herzog de Meuron's series of large models of the Elbe Philharmonic project in Hamburg, Germany. A model near the construction site offers visitors the ability to pop their head into the hall, while a suspended sectional model at the Venice Biennale in 2012 revealed the poché. José Oubrerie developed a sectional volumetric model of the Church in Firminy after the project's completion, exhibiting the geometric virtuosity of the project. And Frank Gehry's team used volumetric models to evaluate the relationship between surface geometry and acoustics in the Disney Concert Hall. The volumetric surface models role is an excellent tool in a contemporary practice that seeks geometric complexity. It was integral to the development of Preston Scott Cohen's "LightFall". A twisting eighty-seven foot atrium comprised of hyperbolic parabolas that connect adjacent galleries, an example of 'dexterous architecture'.[2] UNStudio engages the volumetric model frequently in their practice, most notably in the development of the spatially complex trefoil geometry of the Mercedes Benz Museum in Stuttgart.[3] A 1:24 scale study model was developed by designers that could get inside. Richard Knight, Eero Saarinen's house photographer, captured an image of Saarinen's legs dangling as he was deep inside a model for TWA.[4] A project notorious for its attention to surface geometry. The volumetric model continues to develop alongside architecture's other spatial tools; perspective, digital walk-throughs (or the more adventurous fly-through) and the emerging virtual reality headsets such as the Oculus Rift. They are simulating to various degrees the immersive experience of being there. The research seeks new modes to digitally develop and capture contemporary volume not through the tradition of mass, but rather by the accumulation and layering of designed surfaces.

## DOG SIZE MODELS

Beyond its role in practice, model fitness is an explicit pedagogic intention to develop and hone design skills and articulate ambitions in direct relation to the tradition of architecture. Today in academia there is a tendency towards vagueness, guised as mysterious and masquerading as promise. Design instruction through the large-scale model similar to the Design-Build project aims to contest this notion. The research approach seeks a connection between calibrated computation and general form finding, which blurs and challenges the contemporary dialogue of design research, technique and application. The series of design investigations isolates, interrogates and exaggerates the potential of these aspects as a means to wrestle convention and challenge typologies. The selected projects construct dog-sized models as the primary mode of representation to address contemporary issues related to volume and construction technology.

The current trend to develop large-scale volumetric models is a reaction to object oriented output, including 3D printed artifacts and the proliferation of single-surface projects. Going large extends beyond the limits of a single sheet or bed-size and promotes volumetric confrontation earlier in the design process. The digital model is unfolded, smashed, unrolled, and laid out with the assistance of software such as Pepakura[5] and Grasshopper. Designing to adapt to digital machining capabilities is relatively new, however Axel Killian points out that "there are always shapes for which a particular fabrication process works well and other shapes that need to be redesigned in order to be fabricated efficiently. As in conventional craft and manual production processes, there are 'easy' and 'hard' procedures in CNC." The difference is "the potential for the creative reinvention of details originating in conventional craft in a CNC process."[6] The projects address traditional architectural problems of aperture, sequence and thresholds, while seeking reinvention of details, acknowledging digital assembly as integral to the design process. Dog-size models engage two critical aspects within the discipline of architecture: tectonic, how do we construct it; and stereotomic, how do we experience it. Prioritizing model fitness promotes design decisions that link concept, constructability and representation.

## EXCESSIVE VOLUME

The large volumetric model was principally engaged in an advanced seminar entitled "Excessive Volume." This can be defined as a contemporary interest in the orchestration of depth and calibration of spatial intervals. It surpasses an internal discourse of generative computing in favor of a broader focus on the tectonic, optical and atmospheric effects generated by volumetric modeling. Historically, the relationship between volumetric interiors and the exterior massing has ranged from periods of literal offsets in geometry to fantastic sectional differences that surprise and delight. Through the calibration of thickness and depth the architect curates to what extent the technical necessities of a building correlate with the aesthetic experience. Recent design techniques and technology have resulted in "thinner" architecture comprised of many layered surfaces.

The review of precedents—including a range of typologies highly dependent on volumetric organization, from the intimate to the civic and cultural scale—oriented the discussion towards the dynamics of channeling multiple crowds, the sequencing of volumes, choreographed junctures and orchestrating a spectacle. Using digital modeling tools to emphasize volumetric precision, student's analyzed canonical and contemporary monumental interiors, such as Alberti's Basilica of Sant' Andrea and Neutelings Riedijk: Netherlands Institute of Sound and Vision. (Fig. 1, 2)They exaggerated and transformed the inherent volumetric qualities to develop innovative techniques for utilizing surface distortions (poché). Through the experimentation

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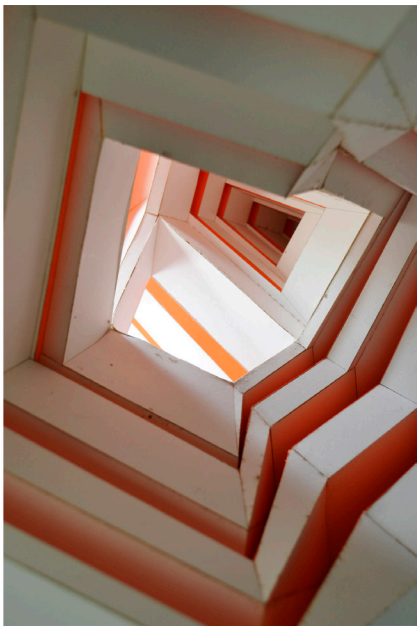

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across multiple mediums the fabrication of large physical models was used to imagine and represent with precision and dexterity the depth and detail of the three-dimensional form.

**A ROOM**

A foundational project was designed into the curriculum to examine two critical aspects within the discipline of architecture: the creation of borders (edges, transitions, threshold, corners) and the creation of space (enclosure, volume, interiority). The semester is organized to isolate, interrogate and exaggerate the potential of these aspects. The final project, a room, is a four week group project culminating in hanging models with an exhibition-style review. The model, in contrast to the

Figure 1: *Excessive Volume Seminar*: Spring 2012
Paul Adair, Sam Ludwig

Figure 2: *Excessive Volume Seminar*: Autumn 2012
Jeffery Anderson, John Yurchyk

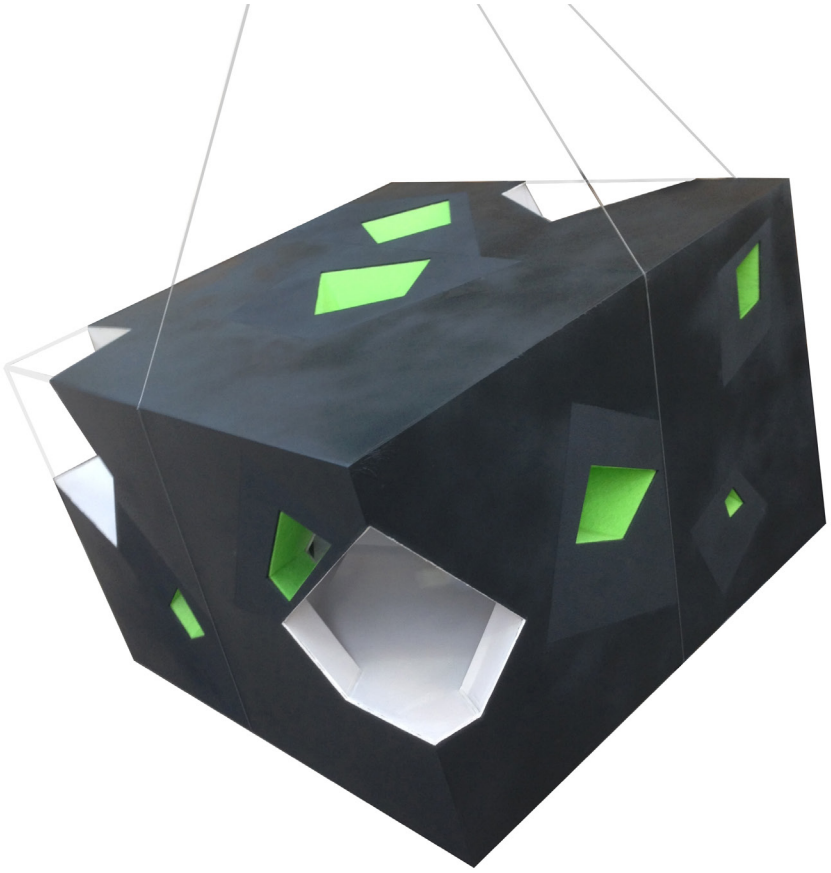

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Figure 3: Second Year Studio: Spring 2014 Hayes, Corbitt, Autry, Hirzel,Leavitt

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pavilion as room or the installation as room, is a room on exhibit—think contemporary Thorne Miniature Rooms[7]. The project, a room for a collector, focuses on the creation of volume, programmed poché and structure. The design negotiates a spatial relationship between an open viewing zone and semi-enclosed display zone. The scale of the model is 1:12. The exterior and interior develop incongruences as they negotiate the need to contain, structurally hang and present themselves as both spatial room and object. Similar to the contemporary Schaulager (looking/storage), which invented a new typology; this project is neither a museum nor a traditional warehouse, but rather a chamber for viewing a collection that tactically negotiates poché.

The project considers multiple viewing tactics and walkable surfaces. The space and its collection may overflow, pile or appear to burst at the seams, or it may be a refined, installation-style room. In the tradition of a Grand Hall, Rococo Salon, Victorian Parlor or Etruscan Room the projects utilize geometry, the relationship of surfaces and the illusion of abundant space to design a room that can act as a liaison between the user and the objects. As in any robust archive, apertures are deliberate and consideration of lighting, views and display are paramount. The projects exploit traditional architectural elements. In one project, the punched window-displays act as a zipper as they link the perimeter graphic shell and the interior surface of the room. The window frame is designed to hold the collection, negotiating the volumetric poché between the inner and outer surface to impact the galleries spatial qualities and the role of an archive(Fig. 3). Throughout the project a series of digital fabrication techniques are explored early and often to produce an output with substantial construction thickness that is integral to the design.

**BEYOND VOLUME**

The design project *Beyond Volume*[8] , developed in my practice, seeks the boundaries of and exploits the tension between contained volume and infinite space. The research takes a closer look at the traditional enfilade, a series of aligned volumes, and excessively multiplies the rich thresholds affiliated with this architectural device. The contemporary enfilade connects and releases volumes from view, tactically employing scale, medium and choreographed patterns to create an assembled

Figure 4: *Beyond Volume (*Photo: Philip Arnold)

interior figure. The large-scale model is comprised of three major components: volumetric shells, the oculi and the enclosure. The curvaceous shield-like shells intersect and nest within a tufted perimeter. (Fig. 4) They take advantage of their convex and concave geometry to both enclose and allow the volume to slip in and out of view as they recombine to create a multitude of spatial relationships with loose transitions. Oculi puncture the perimeter to connect and permit light to enter and frame views into the deeply layered interior. On the outside the oculi act as feet that allow the object to tumble into multiple positions.

A principle volumetric ambition is the intricate relation of surface geometry, patterns, seams, edges, openings and their developing relationship with contemporary fabrication possibilities. The shell is a composite construction, weaving layered developable surfaces cut from flat sheets to generate doubly-curved surfaces. The result is a thin structural and translucent shell that translates digital geometry into physical form. Computational techniques were critical throughout the design phase in order to maintain a tight, accurate fit of the layered surfaces while maintaining the expansive spatial qualities of the interior volumetric relationships.

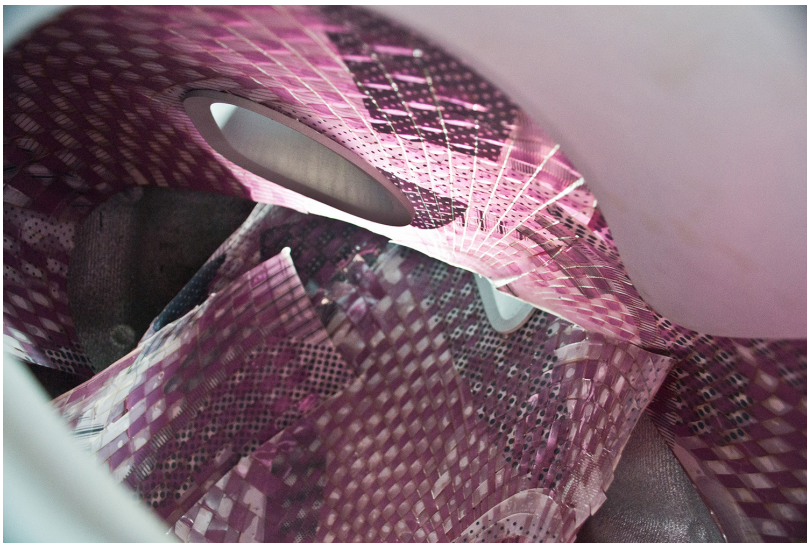
The desired scale of the shells—each approximately 18" x 20"—and the interest to have both physical continuity and visual interruption led to a panelized approach. Similar to how a butcher splits, cuts and selects in order to minimize waste while preparing "prime cuts," the surfaces were segmented into shields and strategically selected to maintain critical part to part relationships. The surface geometry was analyzed and modified to balance the desired curvature of the final volume and to reduce the severity of doubly-curved surfaces. By breaking down each volumetric shell into 4-6 shields, each shield could develop a customized weaving pattern based on the algorithm that translated its surface geometry. A double-sided matte plastic film was precisely cut, woven and registered to its mold. The boundary edges were selectively extended at various lengths to create a zippering connection between adjacent shields, blurring and highlighting seams. Epoxy resin was applied to the woven plastic film to obtain the optimal balance between structural stiffness and flexibility and effectively bind the plastic shields into a cohesive whole.

The project shifts between multiple scales: the literal material scale, the domestic scale of upholstered furniture and decisive scaleless-ness. The intricate pattern printed on the film is intentionally graphic and contributes to the scale-less quality of the interior, moving between two and three dimensions to supplement the desired visual effects. (Fig. 5) Tectonics of the seam at multiple scales highlight and diminish part to whole relationships in both thick and thin architecture. Modernism employed layers of patterned seams across flat surfaces to imply thickness and depth. Examples include Gordon Bunshaft's Rare Book Library, Lever House and Pepsi Headquarters. Contemporary architects, such as Florencia Pita and her use of pattern in her recent projects Land of Gables competition, continue to apply pattern to increasingly complex surfaces to blur and highlight seams. Pattern is used to cunningly intensify the geometric logic.

Oculi puncture the perimeter to connect outside to inside, permitting light to enter and frame views of the deeply layered interior. On the outside the oculi act as feet that allow the object to tumble into multiple positions, highlighting various interior views. The geometry of the oculi are developed as an appendage. They reference the architecturally specific aperture of the oculi, typically a circular opening at the apex of a dome, such as in the Pantheon. The form also borrows geometric properties of a kicking tee that is used to cradle, orient and accommodate complex form. A third reference is the fashion accessory known as the "dickey" or "false shirt." The

**ENDNOTES**

1. Helmut Pottman et al., *Architectural Geometry* (Bentley Institute Press 2007), 594.
2. Preston Scott Cohen, "Dexterous Architecture", Harvard Design Magazine No.29, 2008. Pp 65-69.
3. Andreas K. Vetter, *UN Studio Mercedes-Benz Museum Design Evolution* (Stuttgart: Wechsel Raum, 2006), 47.
4. Richard Knight, *Saarinen's Quest: A Memoir* (San Francisco: Stout Publishers, 2008).
5. Pepakura Designer – Tama Software. A software that generates unfolded patterns from 3D data.
6. Axel Killin, "Fabrication of partially double-curved surfaces out of flat sheet material through a 3d puzzle approach" (paper presented ACADIA, Indianapolis, 2003).
7. Kathleen Aguilar and Michael Abramson, *Miniature Rooms: The Thorne Rooms at the Art Institute of Chicago* (Abbeville Press 1984)
8. *Beyond Volume*, a large model designed for the Possible Mediums Exhibition. Liberty Gallery, Ann Arbor, January 2014. By Author.



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dickey, unlike the tee, assimilates to an adjacent surface, usually a shirt or jacket, and makes a connection between the outside job of presentation and the internal job of sealing, overlapping and approximating connection. This interest in combining similar geometric surfaces inspired how the oculi function as an external aperture and transition to the internal geometric organization. Integrated brims accentuate the simultaneous desire to fit in and extend beyond.

**CONCLUSION**

These projects situate themselves within a set of contemporary works that engage structure, construction and technology without fetishizing them. D¬igital design and fabrication techniques are employed to develop the architectural relationship between surface and volume by discretely transitioning from one to the other. The emphasis on volumetric precision, relationships of solid to void and large-scale effects across multiple scales can aid in the fabrication of models that inform full-scale architectural proposals. In modernism the thin skin of pre-assembled tectonic components was applied to a building, emphasizing its freedom from the structure. Today we develop complex curvature with integrated structural properties that are capable of innovatively defining volume.

Figure 5: *Beyond Volume* - Interior (Photo: Herron)