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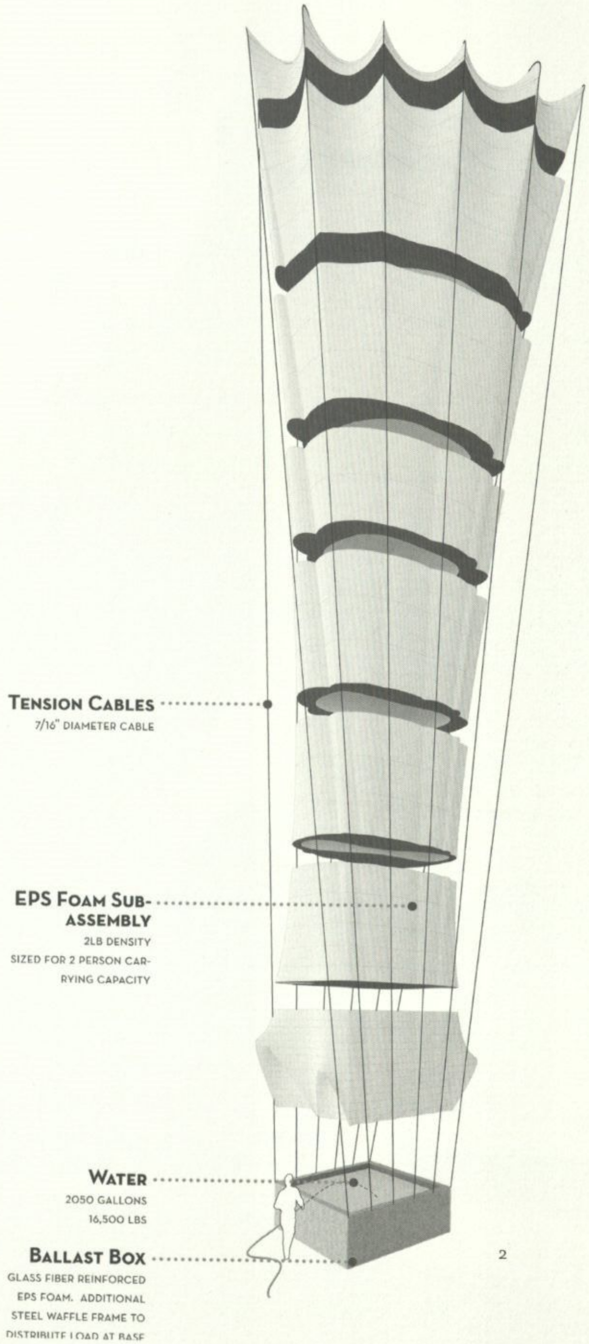
processes, such as milling and abrasive water jet cutting are being extended to leverage additional degrees of freedom. More experimental processes such as large scale additive fabrication, using rapidly curing two-part foam, have been developed to build large complex-curvature self-supporting formwork components without the material waste associated with purely milled forms.

While many, if not all, of these processes have existed in industry for many years, the productive impact of their specific set of possibilities and resistances on architecture remains an exciting and contested territory. What is significant is not the value of a particular machine, in this case an industrial robot, or of any specific fabrication technique. Rather it is the move away from static object-centric models, with neutral or deterministic relationships to material, towards operative models where a given project's physics – its way of materially entering and occupying the world – is *intrinsic* to the design process. The latent argument behind the fabrication research conducted at the University of Michigan is that the phrase 'file-to-factory' must not be a reductive celebration of expediency but instead a perpetual challenge to increase the number and quality of feedback connections between design, matter and making.



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PERISCOPE FOAM TOWER
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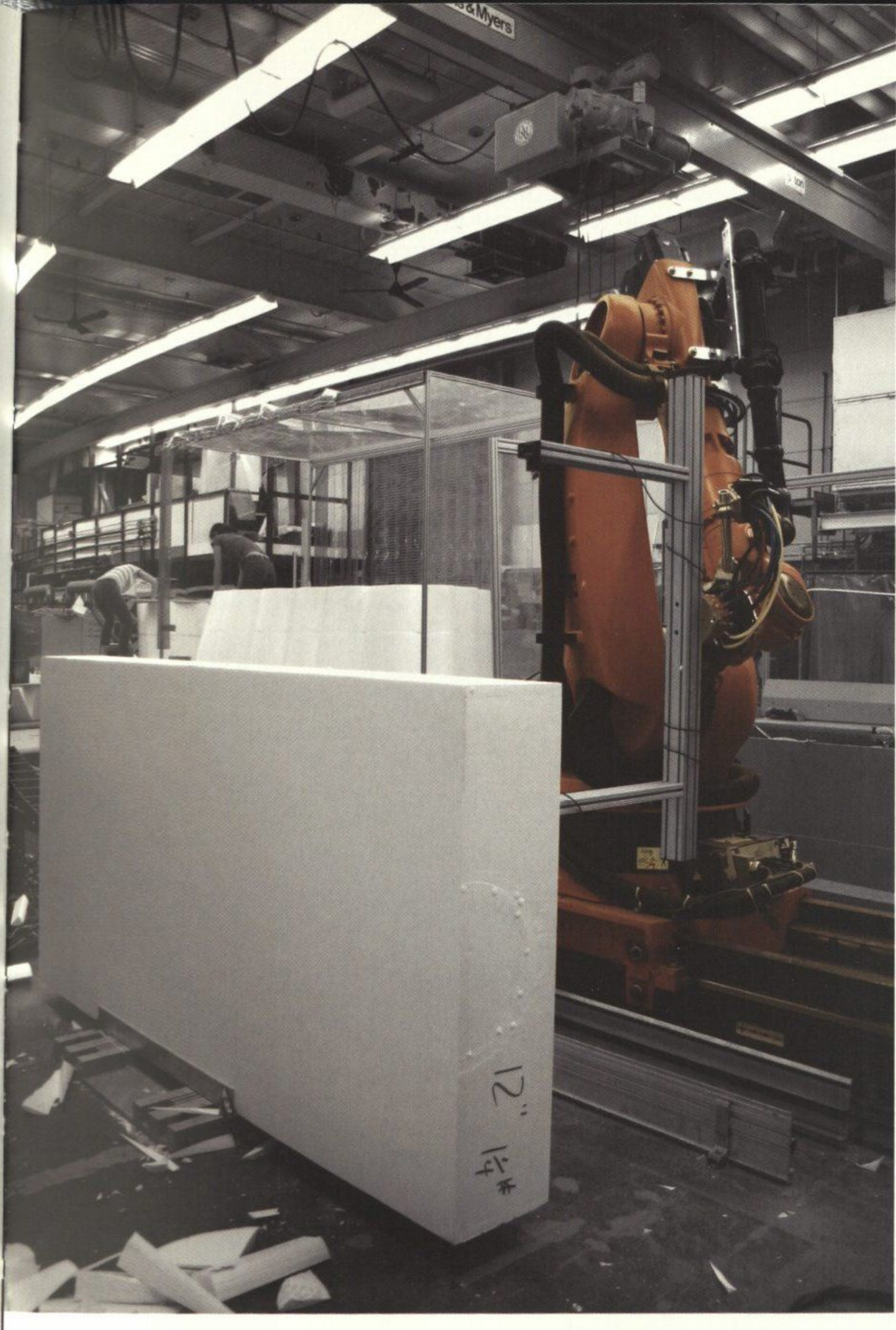
Periscope is the winning entry in the 10Up! National Architecture Competition: an experiment derived from Matter Design's ongoing preoccupation with volume. The 10Up! competition brief was an exercise in constraint. It called for entries that could be constructed by a two-person team, working with a $5,000 budget. The team would be given a month to design an installation for a 10-ft-sq. plot, which could be installed in less than 24 hours. Mounted in only six hours, Periscope is not only a beacon for the Modern Atlanta Event, but is also a product of contemporary digital fabrication culture in that the means and methods of fabrication were developed in parallel to the design, namely custom robotic fabrication tools. The regulations did not stipulate a height restriction and most entries assumed the 10-cubic-ft volume. Periscope, at 50 ft tall, was more ambitious.

From a distance, the observer confronts the sheer magnitude of the figure. The tower appears as tensile fabric stretched vertically by impossibly thin compression rods. This initial confusion is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1: Assembly of Periscope: Foam Tower.

2: Assembly diagram.

3: Custom Robotic hot-wire cutter.

productive: it pulls the observer in for closer inspection to reveal Periscope's logic of rough stereotomic construction. Two portholes at ground level invite the spectator to peer up the 'skirt' and through the body of the tower. This isolated view crops a view of the sky and reveals a new internal figure that is not coincident with the exterior surface. Rather, it is a figure created by the intersection of two conical views, a result of a solid boolean, not surface, offset. Persicope resists an initial reading of its form as a surface membrane. Where the eye once read tensile fabric there is now solid compressive foam. The compressive rods are actually tensile cables.

This rhetorical inversion is both a commentary on the contemporary practice of surface operation (as opposed to volume) as well as a vehicle to pull spectators in –ultimately to the Modern Atlanta Event. The tower was fabricated using a custom-built, seven-axis robot-controlled hot-wire cutter at the University of Michigan's Taubman College of Architecture and Urban Planning. Over 500 custom foam units are carved from stock blocks of EPS (expanded polystyrene) foam. These blocks are then stacked in a running bond and assembled into 3-ft-tall sub-assemblies. At the top and bottom of each of these sub-assemblies is a plywood profile performing as both shipping protection and, more importantly, as a jig to ensure the manual aggregation of units would not drift away from its intended geometry. The stacking of units is a manual process. Attempting to align irregular units results in subtle variations between each course. While these misalignments emphasise the stacked logic, further precision could be achieved with a jig at each coarse, indexing rods or locking geometry connections. In addition to these manual misalignments, a small error tolerance is needed with such a long hot-wire cutter as the slack of the length can cause drifting. More robust fixturing methods for the foam would also reduce these errors.

Each sub-assembly was designed to be light enough for two people to easily carry. When stacked three high, each would fit snugly inside a semi-trailer. Fourteen sub-assemblies stack to construct the 50-ft-tall figure held down with tension cables to the ballast base. This ballast weighs approximately 16,500 lb in order to resist the overturning forces of the design wind.[2] The interior and exterior surface of the volume kiss at a minimum of 4 in. in the centre of the tower, but are free to expand and depart from each other to serve their individual purposes resolved with a poché of foam. This technique, as well as the material properties, questions the notion that contemporary architecture must perform in the realm of paper-thin surface.

In recent years, the digitally fabricated installation boom has empowered architects. By directly engaging the making process the architect is able to regain control over fabrication methods that were once the sole province of the construction industry. Unfortunately, industrialised construction materials have been compressed into economically friendly paper-thin sheet materials. Composite woods are covered in luxurious veneers, walls are reduced to 6 in. of depth, stone construction is typically wafer-thin cladding on a CMU wall. This economy-driven industry has good intentions, providing better building materials at an efficient price. These well-intentioned innovations have also had a parallel effect on architecture, causing the collapse of depth via materials and methods, as well as encouraging the tendency towards understanding the interior and exterior as isomorphic. Left with a catalogue of sheet materials, contemporary digital fabrication methods have produced a plethora of folded/notched/bent/perforated-pattern/surface-deep projects. Matter Design has previously engaged the topic of volume in such projects as A Change of State,[3] the Drawn Dress[4] and AtmoSPHERE.[5] All these projects address volumetric occupation, but with thin material. In order to engage a broader reading of volume, one must advocate for a solid material with girth, while also competing with the fiscally efficient sheet materials.

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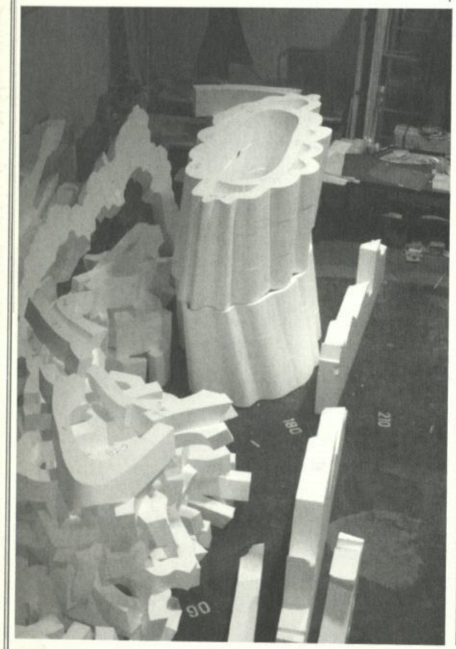

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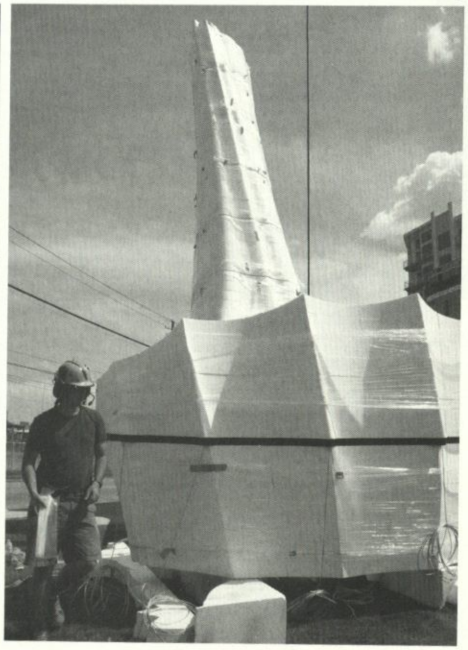


A number of volumetric materials have the potential to fulfill this research agenda: AAC (Autoclaved Aerated Concrete), Reconstituted Stone and EPS foam.[6] Matter Design selected EPS foam as a volumetric and inexpensive case study material for the Periscope tower. After all, it is 98 per cent air by volume, making it around one dollar per cubic foot. Perhaps this is why foam is typically relegated to fill material. The Federal Highway Administration currently uses large blocks as earth-fill (EPS is inert when buried) under highways. By this example, it is literally cheaper than dirt. EPS also contains no CFCs and is 100 per cent recyclable. Manufacturers return to pick up scraps from the fabrication process to toss back into their next batch free of cost. Transportation by land can be an issue, since volume matters over weight. Whether one is shipping stones or balloons, the cost per volume is the same – making a truck full of foam inherently inefficient. This very restriction is why EPS foam manufacturers are widely and regularly dispersed, making local sourcing accessible. Of course this only helps as long as the fabrication facilities[7] are also equipped for the methods of making. The material properties of EPS foam, in conjunction with advanced fabrication methods, provide a solid platform to revert back to stereotomic[8] construction logic.

Most contemporary digital fabrication techniques are developed and informed by sheet materials. CNC (computer numerically controlled) milling a custom profile is no longer an innovative proposal. Milling a solid figure out of a block at the scale of a tower is cost- (and time-)prohibitive, and casting produces volumetric but regular components. In order to appropriately address the issue of volumetric fabrication, one is required to research the methods practised when working with volume was common practice. We at Matter Design translated the developed surface[9] technique into a digitised process as a way of embracing the somewhat lost practice of stereotomy. The developed surface (while ironically re-appropriated to the more widely known 'developable surface' that holds its roots in surface-thin materials) was a method for customising stone carving through the minimal means of a sweeping line that can be flattened or from a 3D geometry into a 2D drawing, otherwise known as a trait.[10] By extracting this principle, it is possible to conceive of this hypothetical line as a physical and CNC device – a custom robot controlled 4-ft-long hot-wire. This converging of past techniques with contemporary materials and methods informed reciprocity between drawing and making.

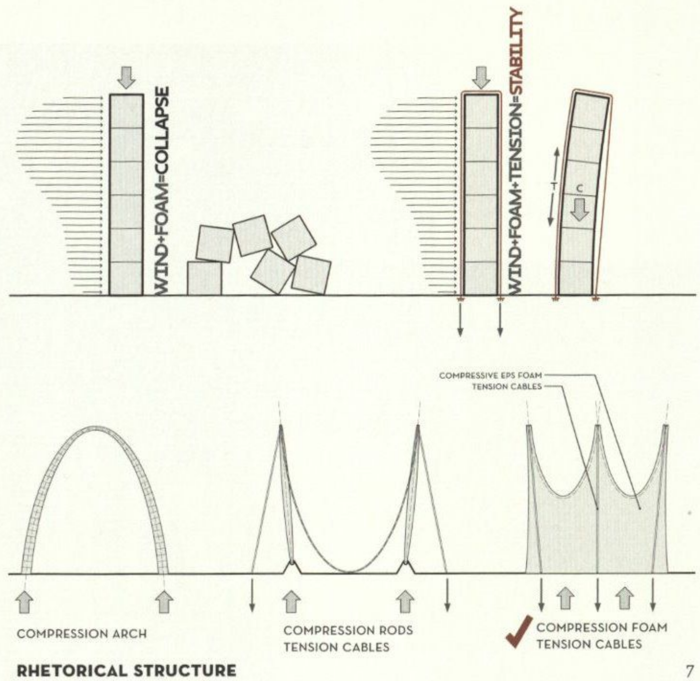
Stereotomic construction is inherently a compression-based system as its material is stone – a very heavy

4: Pre-assembly process.

5: The bottom half of the tower is built from the bottom up, while the top half is built from the top down. The top half is then lifted by the crane on to the bottom half and strapped down with the cables at the base.

6: A crane is required to aggregate higher than the first three sub-assemblies. A person is still required to rappel with the unit in order to assemble.

7: Explanatory diagram of tension cable and foam compression structure.



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material. Foam, on the other hand, is without significant self-weight. Ironically the impetus to engage the process of stereotomy conflicts with the prompt for a temporary installation. In designing this tower, tension is required, but the research agenda is not limited to lightweight materials. Today a majority of compression-structure research is occupied by thin-shell research utilising form-finding techniques. When considering advanced techniques of custom carving solid blocks of material to variable depth dimensions, one can envision compression-only structures that are not dedicated to structurally determined forms. By varying the sectional depth with volumetric materials, a method of 'depth-finding' as opposed to 'form-finding' could emerge. Further applications of these methods with materials of self-weight will position contemporary architecture with the knowledge to undermine the well-intentioned construction industry and re-empower the discourse with the old and now new tool – volume.