Body Building:
Tangible Made Digital Made Tangible

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The two courses described here, *Fabricating Space* and *Thick Skinned*, taught at the University of California Berkeley in the fall semester 2002 and this fall 2003 respectively, explore relationships among the body, digital design and making. They combine investigations of perceptual and spatial effects with digital modeling processes and full scale CNC fabrication, focusing in particular on how new media practices forge alternative methods to represent and construct corporeal and sensorial experience.

Students using waterjet cutter.

Architecture continually informs, and is informed by its modes of representation, perhaps never more so than now where digital media is rapidly expanding what we conceive to be formally, spatially, and materially possible. The increase in the use of the computer has, on the one hand, led to the claim that the body is becoming evermore distant to architectural production. Clearly, the virtual is not physical. However, as architects engage computerized input and output technologies, opportunities arise for greater confluence and specificity between the embodied material world and architectural space. These seminars invite speculation on Frederick Kielser's vision for an architecture ripe with reference to a perceiving humanist subject, and explore methods to capture, represent, and construct this space. Pedagogically, the tangibility and availability of the body supplies a literal and direct means for students to connect digital data to physical space. It not only offers valuable and inescapable geometries that both push and draw upon CNC technology's ability to generate supple form, experientially, it also affords investigation and critique of something common and familiar.

The seminar programs question how daily experience is mediated by form, space, and environment. The installations are built full scale, and the immediacy of the work is made especially pronounced by the physical intimacy and small size of the projects. The two semesters employ inverted methods of design – one additive, making an object in a space; the other subtractive, making space in an object. This inversion developed both out of physical necessity, in the second semester the projects needed to be freestanding, as well as out of the desire to directly engage the body as spatial form-maker.

While pursuing such physical and phenomenological conditions, students explore the relationship of digital design to making. CAD/CAM practices suggest the potential to narrow the gap between representation and building, affording a hypothetically seamless connection between design and construction. As with any design process, however, there are invariably gaps in the arena between scales and modes of

production – for example, between rapid prototyping and full scale mockup, seamless form and sheet material, computer model and spatial, material or phenomenological effect. The final outcomes of the projects hinge on their ability to reconcile the developmental shifts in material and working method. Towards this end, the courses were in part constructed around exploring these gaps, and introducing students to new tools and technologies available in the area.

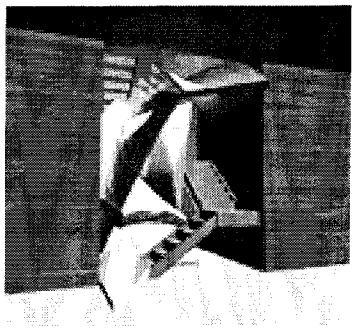
Student in motion capture suit.

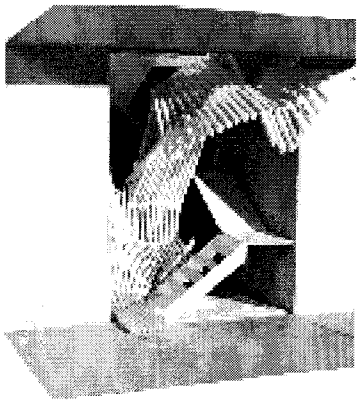
While the Department of Architecture does not presently have a CAD/CAM Laboratory, this absence led to fortuitous interactions with other departments and organizations on campus, such as the Department of Mechanical Engineering, and Lawrence Berkeley National Laboratory (LBNL).[1] Extensive research is currently being conducted using rapid prototyping equipment at the Integrated Manufacturing Lab (IML) in the ME Department. Similarly, the Design and Engineering Shop at LBNL builds state of the art parts and machinery, and has a vast array of computer numeric controlled instrumentation. One great advantage of working with these labs is having the opportunity to collaborate with experienced machinists. They are able to resolve issues students encountered using specific types of materials, and recommend appropriate cutting techniques. Both the IML and LBNL donated shop time and labor to the class. The time is extremely limited, however, especially at LBNL, requiring each group to test and retest their work prior to full scale waterjet cutting. This forethought, the precision afforded by translating information digitally, and the specificity with which the sites are initially documented, later facilitated rapid on-site installation.

Thick Skinned follows a similar course structure as this previous class. However, it pursues conceptual ideas developed in the first semester more aggressively and literally. Where *Fabricating Space* began with digitally modeling the site, this course begins with digitally modeling the body. The class employed new input technologies to more closely and directly map the human form. These include laser scanning and motion capture technologies that have the ability to track and represent highly specific physical data otherwise nearly impossible to collect. This data provides critical base information from which to draw upon in the designs.

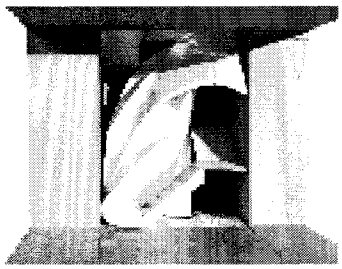
The design process is structured around a subtractive space making procedure. Students use the digital data to model 'body templates'. That is, digitally generated volumes formed by maps of the body that are used to carve (boolean) out of a specified volume. These negative spaces form physically or visually occupiable spaces. For this project, the volume is defined as a 3' deep x 5' wide x 8' high rectangle. The outer dimensions reflect the size of common sheet building materials, as well as allow sufficient space to create an inhabitable interior.

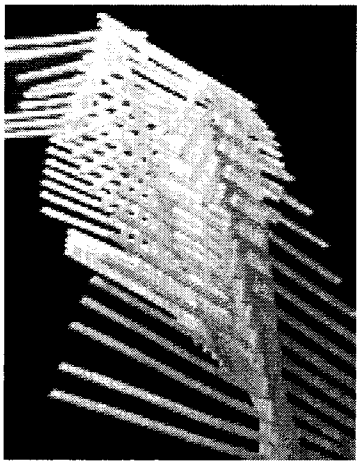
Lastly, it was an intention to have students work with relatively conventional building materials, not only to acknowledge restraints imposed by the more conservative and slower moving construction industry, but to also tackle issues of detail and assembly. The projects delve into relationships between contin-





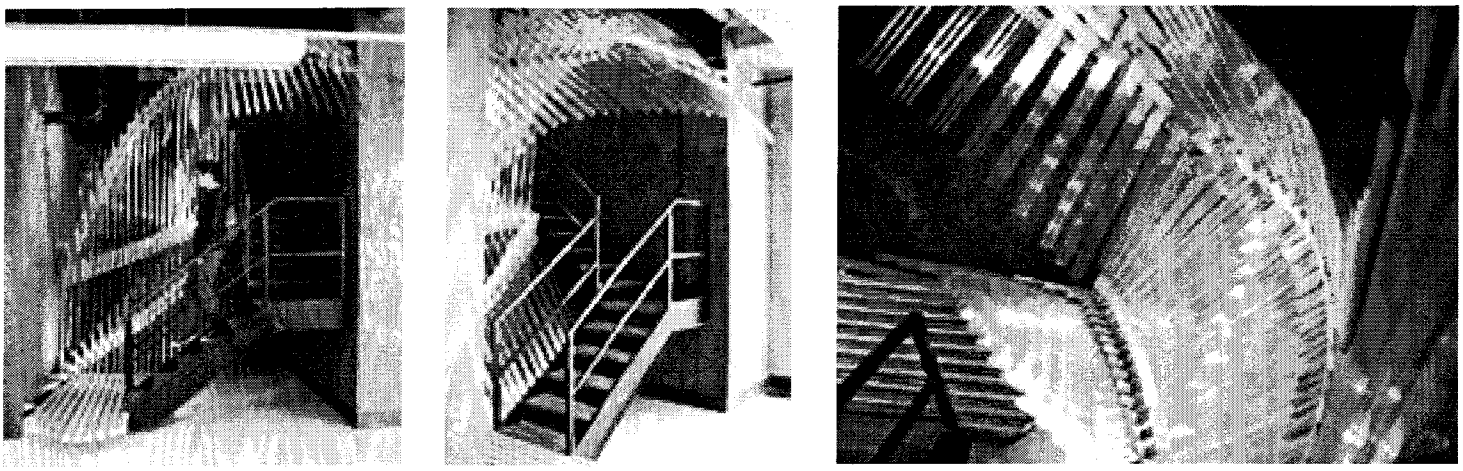
Physical models





3D Prints

Final computer model, waterjet cutting template, detail mock-ups.



Final Spiral Surface *installation.*

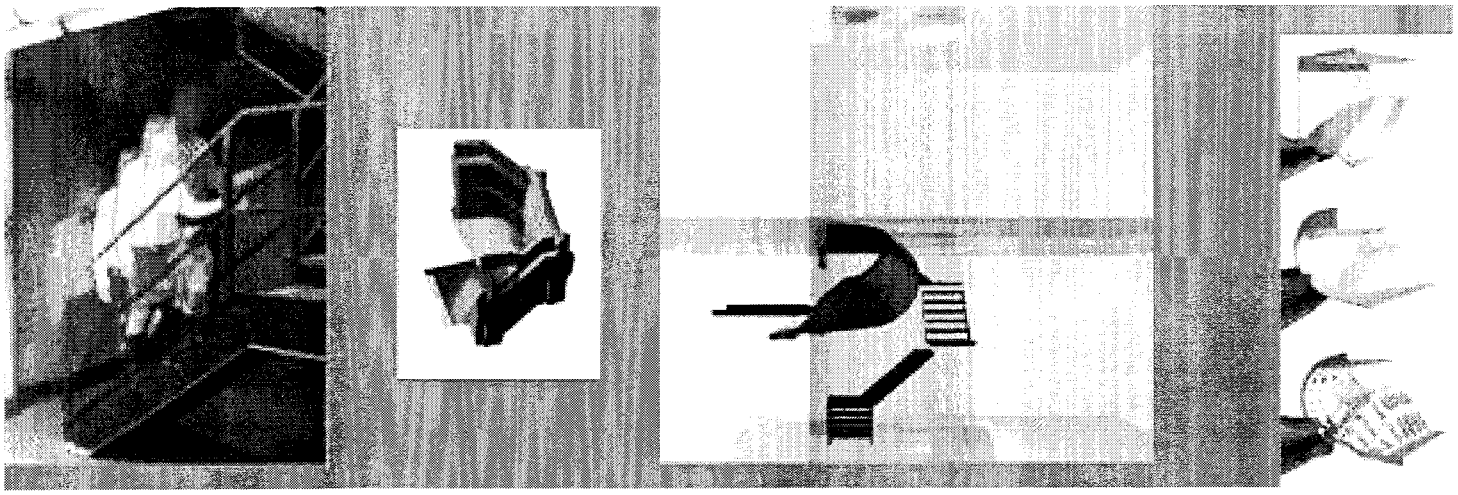
uous form and constructive articulation using pieces cut from standard two dimensional sheet stock.

Aggregation and accumulation are terms not commonly used in connection to construction industry, though the actual assembly of buildings relies almost exclusively on these techniques – asphalt shingles, board siding, hardwood flooring, vinyl tile, wood framing, essentially any mass produced item used in repetition to create a larger surface, are the most common means of making enclosure. Computer fabrication allows us to heighten and make visible the nature of this accretion through repetition and difference. Like the surreal obsession with accumulation, the intensity of material articulation that CAD/CAM presents has the capacity to relate back to the viewing subject on a visceral level. A latent theme underscoring the work is to tap into such a direct response, one aroused by the intricacy of manufacture and labor, while still employing an economy of means. The tension between smooth surface and assembly is partially revealed in the projects through the conflation or separation of structure and skin. Returning back to the body, students consider analogous relationships between body and building – for example, skin and surface, skeleton and structure. These investigations inform the constructive sensibility of the full scale design projects described below.

PROJECT BRIEFS:

Fabricating Space revolved around semester long project to design a threshold. Though simple in conception, the project foregrounds making a spatial intervention, one that distinctly addresses the specifics of site and the relationship to the body. Experientially, the idea of threshold involves constructing a dialogue between two contrasting conditions – above and below, light and dark, in and out.

Students work in teams of two and three to design, fabricate, and install their projects. They began by choosing, surveying and modeling their site. The site therefore became the first physical and digital artifact for the project, providing resistance to each subsequent design decision. They gained an intimate dimensional understanding of the site in relation to their bodies through this process. Following, work alternated back and forth



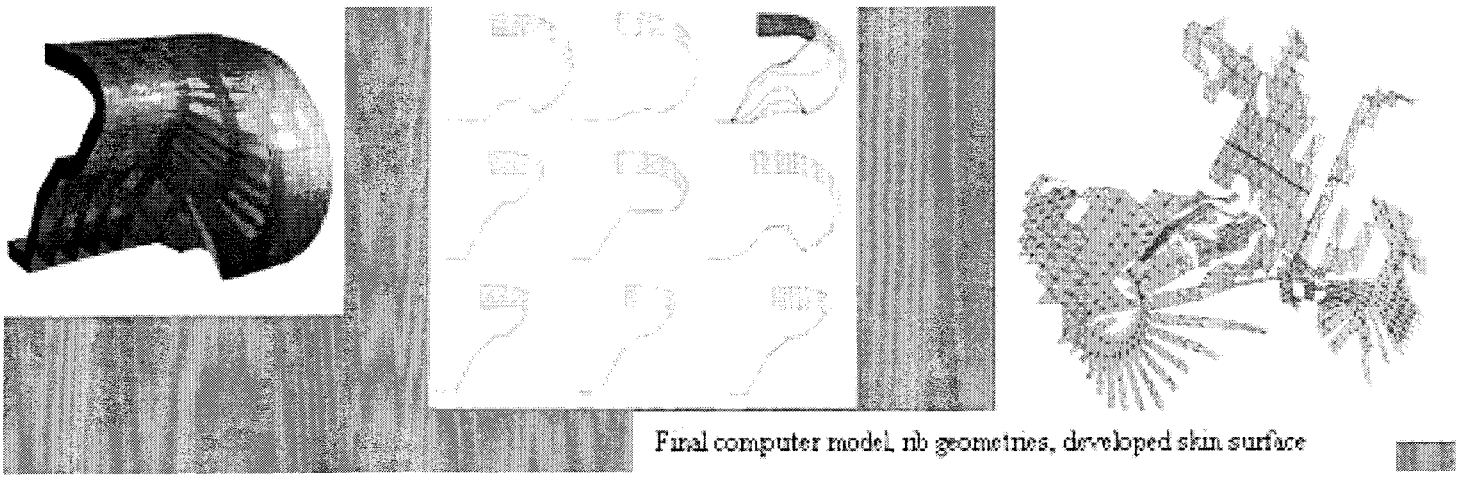
between physical and digital production. The designs begin conceptually, much like in any studio project. Both three dimensional prints and hand-made models are used to study successive iterations. Small, homogeneous models are made using rapid prototyping equipment to study overall form. Simultaneously, students conduct material investigations, and make full scale detail mock-ups to investigate constructability. This process later supports translating the digital information into full scale. The projects – *Spiral Surface*, *Ceiling Aura*, and *Lofted Mesh* – are described on the following pages.

The program asks the students to house the body within the volume in at least two ways. One physically: sitting / leaning / lounging / standing / etc. The other phenomenologically: through sight / movement / temperature / touch / etc. The students derive their initial volumetric templates based on ideas developed around these two aims. Overlaid on these first criteria, is also the requirement that the two voids intersect to form a third space, or 'double negative'. This constraint developed around the desire to heighten the perceptible presence and interconnectivity of the subtractive spaces. The double negative explores how two absences can make a positive.[2] In this case, absences formed by physical and experiential criteria. This design process is illustrated here through two projects from this semester – *Skinned Surface* and *Motion Map*.

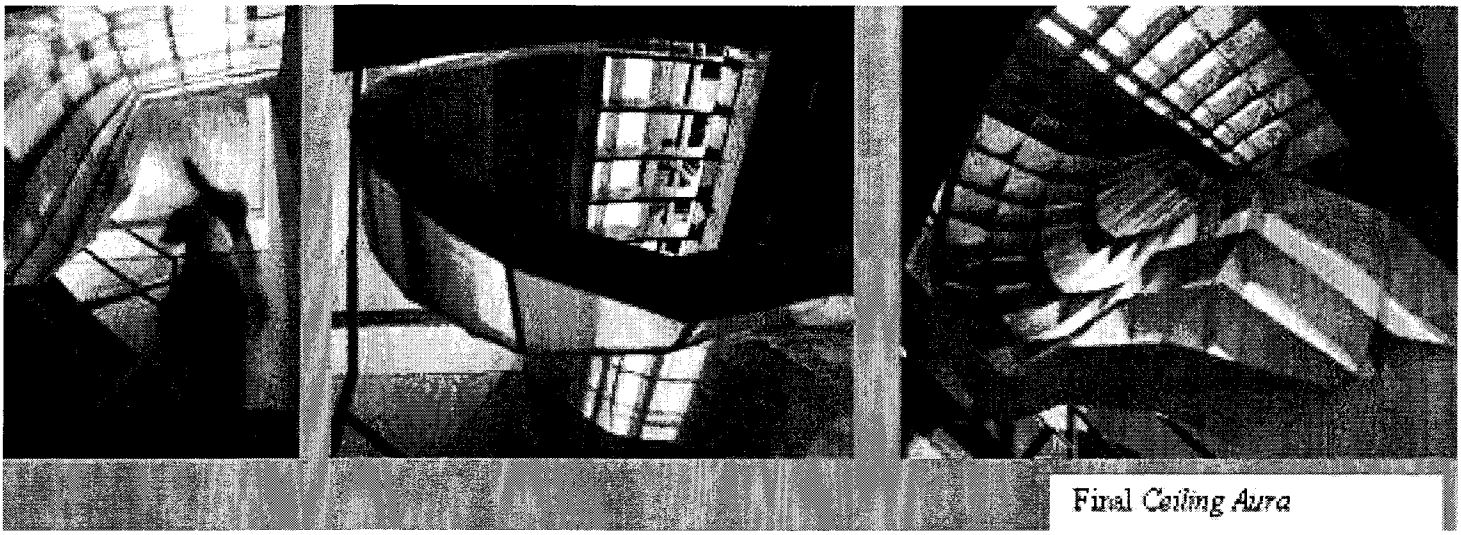
PROJECTS: *FABRICATING SPACE*

Spiral Surface develops threshold as an extended space that frames passage of the body as it descends the small staircase. Students saw this movement as a spiral progression reflecting the layout of the existing stair. The design is also inspired by two early conceptual images – Duchamp's *Nude Descending a Staircase*, and a photograph of the cross section of a spiral shell.

Early computer models describe the project as a group of intersecting, arced planes, forming a partial volume that wraps the occupiable space of the stair. One desired quality was to deny structural hierarchy, and elevate the role of surface as spacemaker. The sculptural arced pieces transformed into a series of interlocking members that systematically joined the planes together. A contemporary precedent shown in class,



Final computer model, rib geometries, developed skin surface.



Final Ceiling Aura.

SHoP's 'Dunescape' at PS1, served as a valuable precedent for the construction of this project. Students were, however, encouraged to rethink the constructive technique, and further develop the idea of aggregated parallel sticks. They decided to concentrate on the method of connection, which in turn transformed the overall form.

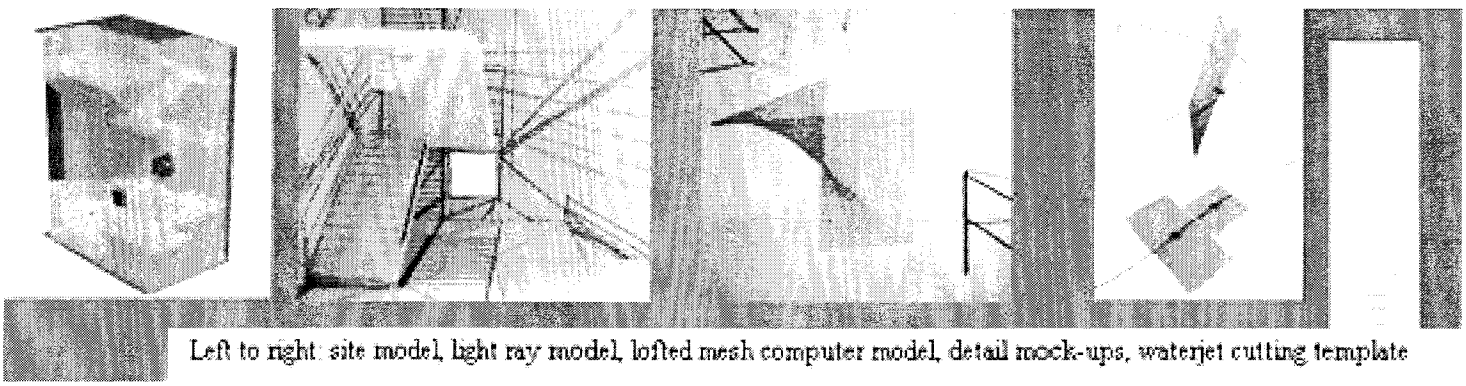
The intersections are designed to form fluid creases that highlight the continuity of line and surface. The joint is made from solid, laminated plywood while the rest of the project is cut from clear Lexan. This material distinction articulates the legibility of the crease both from above and from within the threshold space.

Ceiling Aura explores the notion of threshold as ceiling in the other small 'shortcut' stairwell of Wurster Hall. Like Spiral Surface, this project attempts to embody movement. In addition, it addresses the transmission of light from a skylight located above the second floor stair landing.

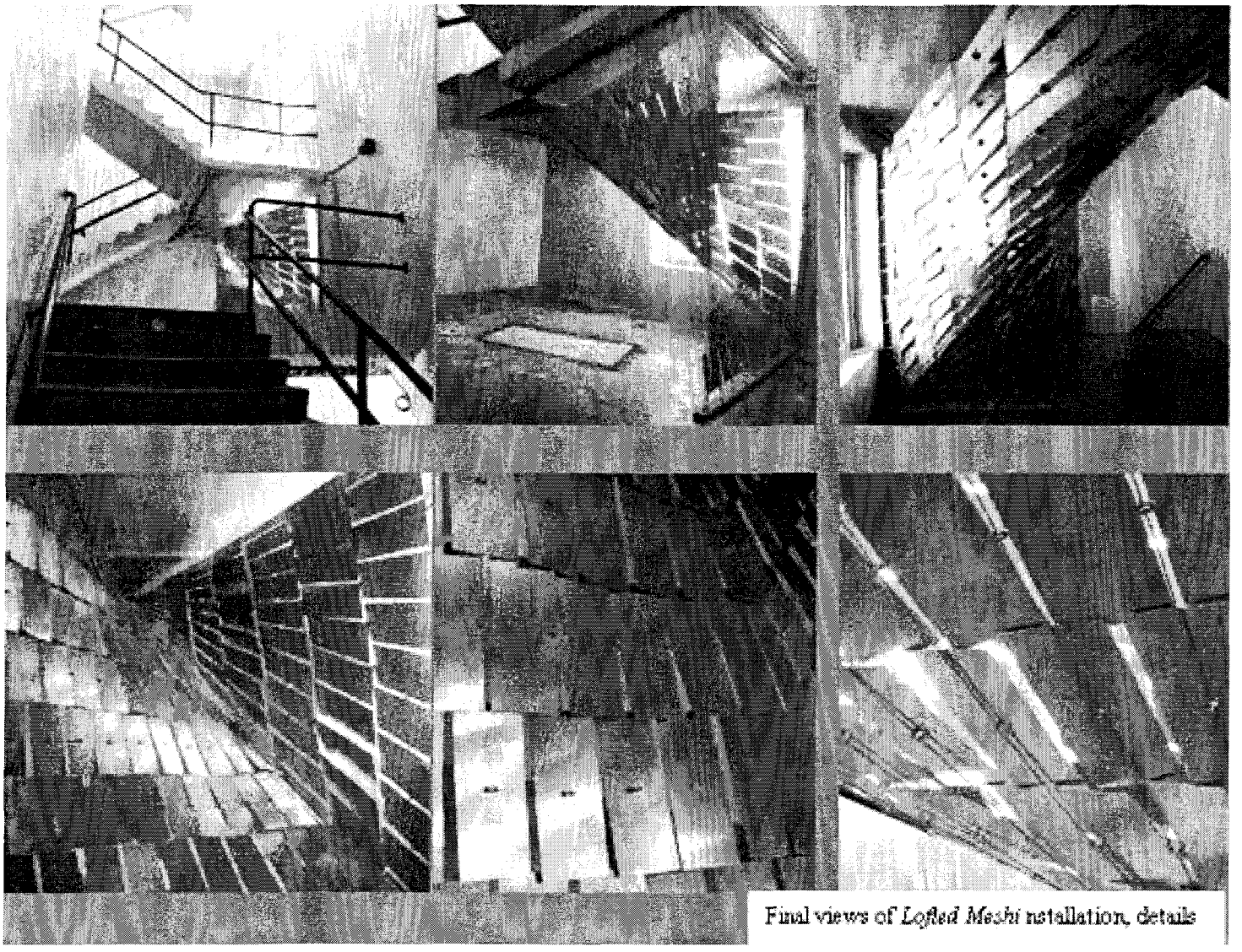
This group worked intimately with the dimensional constraints imposed by standard doors and the human body. The design is a permutated volume derived from what the students termed the 'threshold aura' of a person traveling up the stair. They began by modeling a simple volume that filled the space between the standard door height of 6'-8" above the first floor and the second floor. From this, a warped surface was created by deforming the exterior surfaces along the path of travel based on the 'aura' of a person and the 6'-8" dimension. To emphasize the floating quality of the ceiling, the project uses an existing railing to cantilever from the second floor, and suspends the volume below. The students employed a ribbed waffle framework for this structural purpose, as well as to accommodate the geometric complexity of the volume.

The ceiling surface itself is designed as a light transmitting fabric shell. It is sewn together from pieces cut from a template made from the developed surface of the exterior. The project acts as a hovering shroud into which one enters when moving along the stair.

Lofted Mesh considers the idea of threshold at several levels. It forms a light threshold between the window and the dark space of the stairwell. It also acts as a threshold to a new semi-



Left to right: site model, light ray model, lofted mesh computer model, detail mock-ups, waterjet cutting template.



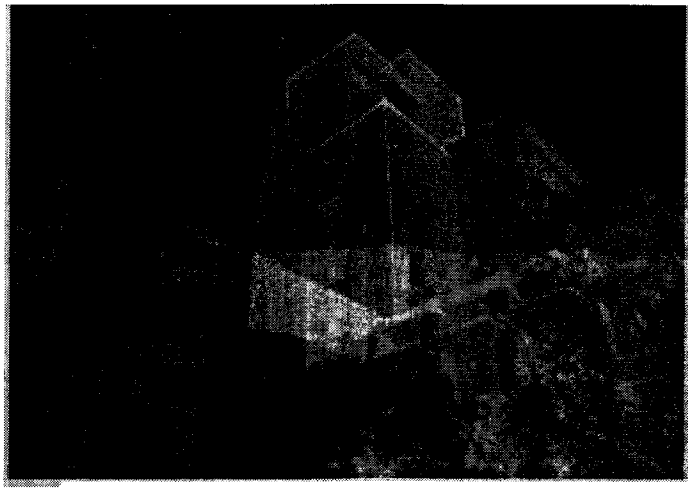
Final views of Lofted Mesh *installation, details.*

enclosed space under the existing landing, and introduces perceptual and perspectival depth into this confined corner. The design is inspired by an interest in projected light rays entering one of the two windows. The students modeled lines indicating sun angles at different times of year and day, inscribing them in the space. The space itself is located at a juncture in the fire stair that joins the two different building geometries. This particular configuration affords a small area under one of the stairs outside the path of egress. This became the project site. The projected geometries are extrapolated to extend across this area, and subsequently adjusted to draw upon existing and projected site edges, such as the window edge and that of the stair landing.

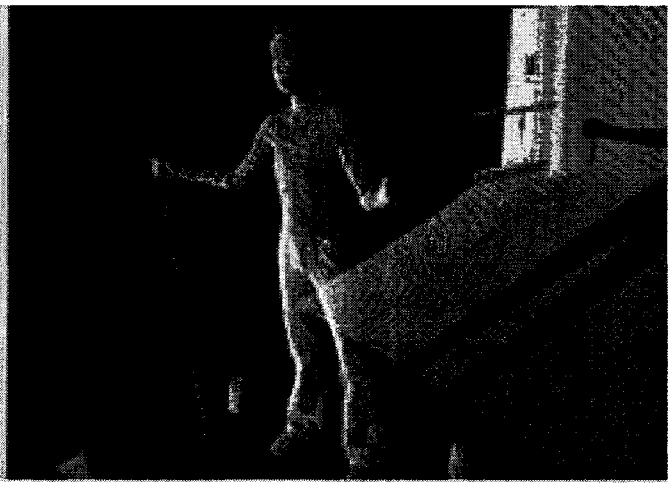
Construction proceeded along a similar path. Formalizing the idea of light rays, the students developed a system of structure and skin that reiterates the geometry of the projected lines, and creates a mesh-like surface that both screens and reflects the sun. The lofted form is expressed through the converging shingle pattern of waterjet cut aluminum sheets. The project creates an illusion of visual depth when seen from the stairs below, and contrary to the initial emphasis on sun lines and angles, produces a shimmering, indirect light in the stairwell space.

PROJECTS: *THICK SKINNED*

Skinned Surface employs laser scanning to bring together the body and the environment. The project is thought of as a continuous skin that deforms to accommodate the body, and views out toward significant pieces of the site. The scanner itself can capture physical data accurately from as far as fifty meters, and generates a point cloud of the physical information. Students used this capability to model near and distant site boundaries. This data was then used to develop volumetric



CYRA laser scan of site



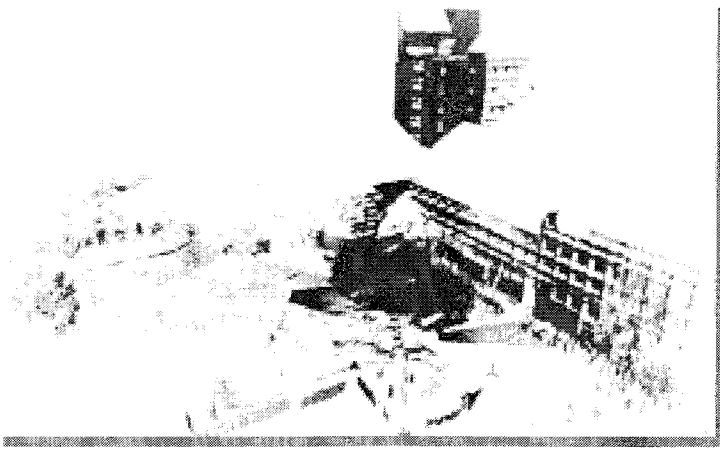
CYRA laser scan of body.

cones of vision that sculpt the interior surface of the project. The scanner was also used on a more modest scale to digitally capture the body. This data was also used to shape the surface to accommodate a viewing subject. The imperative to develop a 'double negative' transformed in this case from one of solid and void, to skin and surface. From the exterior, the intersecting voids read as an object housed within an implied rectilinear volume. Construction of the skin is currently being developed as a structural waffle made of plywood covered with plastic sheet.

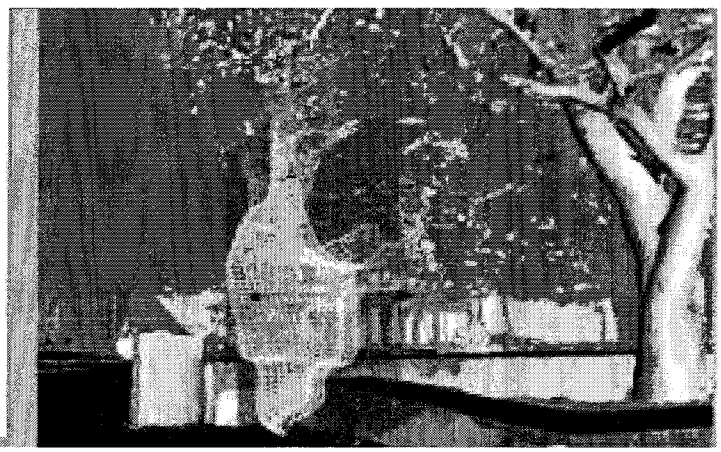
Motion Map begins to define more precisely and literally what several of the *Fabricating Space* projects articulate from the previous semester. That is, how can form frame and echo movement of the body? This project is generated from the intersection of several paths sculpted by the transitory positions of the body in motion. The phenomenological and experiential dimension of the assignment is interpreted here as movement over time. The design process charts the positions of a person traveling along several paths created around the site. An existing collection of benches and planters serve as props on which to sit, lean, climb, and lay, and characterize the different nature of the paths.

In order to accurately map the many body positions, this group worked with MOCAP, a motion capture technology used in the animation and gaming industries. They simulated the physical attributes of the site, and recreated the paths of travel while wearing a suit that locates LED's at key points of the body – feet, knees, hips, arms, shoulders, head. The motion capture software tracks the LED's and translates them into a digital point cloud. The students used this data to derive volumetric outlines of the body while in motion. They lofted a volume around splines that connect the key body points from one position to the next. This not only affords a precise map of the body, it also directly engages the technology, and implies a method of construction.

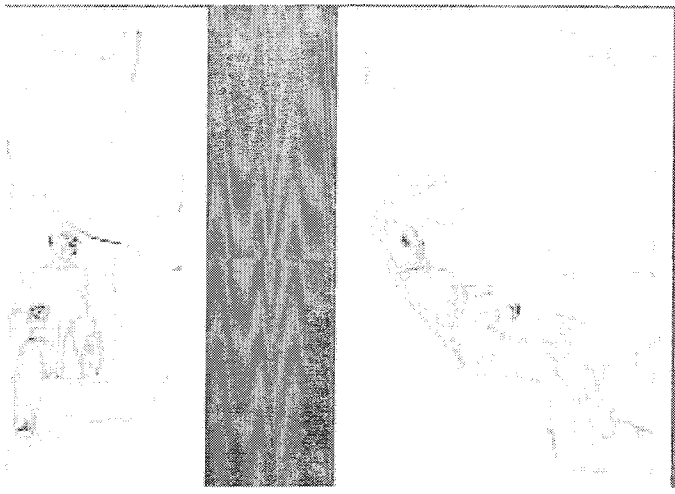
The 3D Print below describes the literal intersection of the volumetric paths. This describes the spatial and formal basis of the design which is currently being refined and simplified. As with each of the previous projects, the 3D Print does not reveal a system of construction; it is homogeneous. However, the



Cone of vision volumes derived from scanned site.

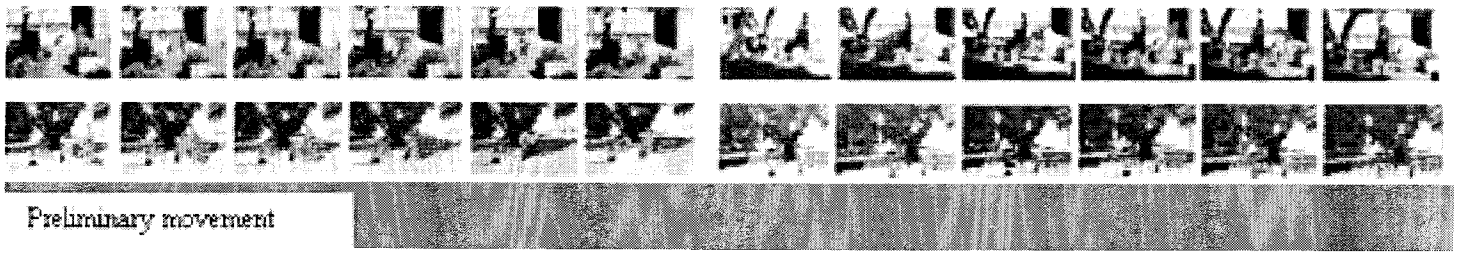


Intersection of cone of vision volumes.



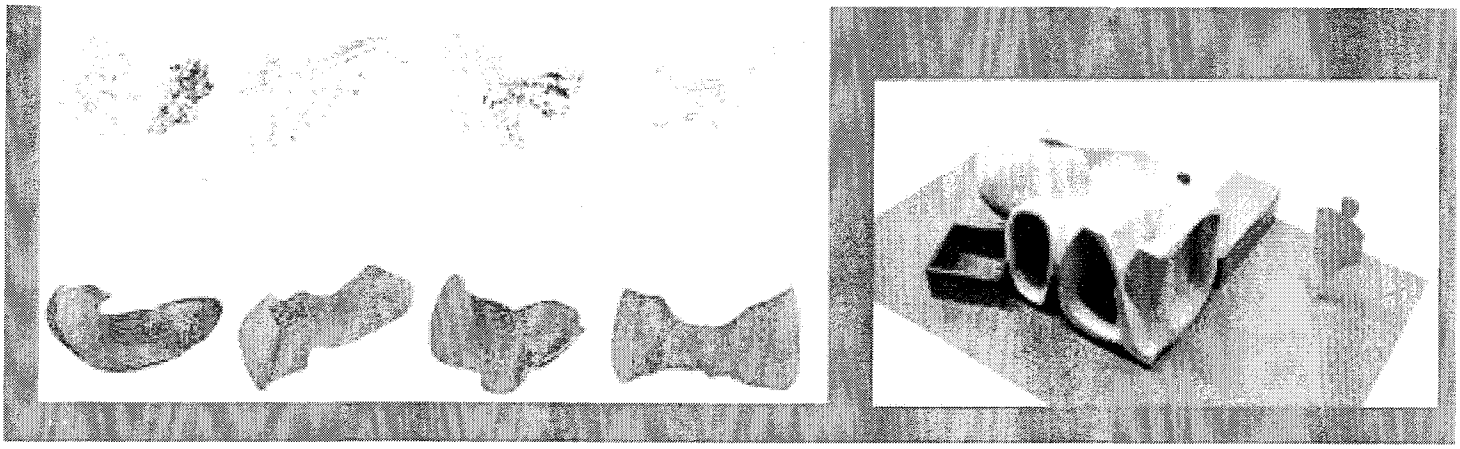
Surface wrapped around body void and cone of vision voids

Surface of void.



Preliminary movement.

Motion Capture stills of 'sitting'.



MOCAP generated point cloud. joint splines. lofted body motion volumes.

3D print of intersected volumes.

lofted computer model suggests a technique that can take advantage of the CNC technologies at hand, namely two-dimensional cutting. The students are currently working with unfolding the surface into shapes that can be cut two dimensionally, and developing a foam structure whose internal baffles articulate the splines, the cross section of the volumes at the exterior face, and the intersection of the paths. This project, and the one previous, will be built in the coming months.

CONCLUSION

Throughout both seminar processes, the technological particulars provided constraints that geared the evolution of the designs, and the manner in which they enabled or limited body-space manufacture. The addition of using the new input technologies in *THICK SKINNED* in particular, fostered ways of mapping the dynamic interplay of the body with space, and laid the groundwork for future investigations. The built projects in *FABRICATING* SPACE suggest how these investigations can be strengthened architecturally by mediating shifts in language, scale and material throughout the design process. By cross-pollinating CAD/CAM practices with something both as multi-faceted and mundane as the body, students were able to engage new media as an extension of their own everyday experience. In this case, the digital enabled re-conceptualization of the relationship of the subject to architectural space and form, and challenged the preconceived assumptions of both.

[1] RESOURCES: Z-Corp 3D Printer, Integrated Manufacturing Laboratory, Department of Mechanical Engineering;Waterjet cutter, Lawrence Berkeley National Laboratory, Design and Engineering Shop; CYRA Laser Scanner, CYRAX, Sausalito, CA; Motion Capture technology, **MOCAP**, Emeryville, CA

[2] Michael Heizer's earthwork sculpture from 1969 *Double Negative*, as discussed in Craig Scott's article, "Space, Other Space: Double Negative as Spatial Practice", *Dimensions 13*, University of Michigan, College of Architecture + Urban Planning, 1999, pp. 94-103 served as introductory material to this topic.