Purge, Parse, Patch: Designing in a Point Cloud

The impact of digital technologies on the production and representation of architecture was originally a formal one. Parametric spline curves suddenly became feasible formal reactions to postmodern and deconstructivist ideas using calculus-based drafting and modeling software engendering two decades of formal explorations ranging drastically in scale. These experiments led to novel ways of thinking about the representation and making of architecture (at the scale of fabrication). Beginning around the turn of the 21st century another digital trajectory surfaced with the growing accumulation of large data sets and the technical capability to not only organize, but also distribute the information, allowing for more interactive and collaborative design processes. These large data sets exist in the realm of formal experiments, but more specifically refer to databases generated through GIS systems, building information modeling, and remote sensing technologies such as Lidar.

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In addition to formal experimentation, technical improvements have produced new frontiers in how design interfaces with and forms the built environment. For example, integration of interactive technologies can produce real-time experiential changes based on data input. These technologies have transformed the production of practice and have significantly altered modes of practice; the emerging landscape is organized according to infrastructure enabling mass participation, which challenges established methods of working and requires new sets of design tools and skills. In their introduction to *Collective Intelligence in Design* in the September 2006 issue of *Architectural Design*, Christopher Hight and Chris Perry elaborate on the repositioning of design practice according to a different model of societal organization, one in which power is exercised through the use of information rather than through physical space.[1] In this scenario, the traditional division between fields of design practice is replaced by a much more ambiguous collective of trans-disciplinary ways of seeing and acting upon the built environment. 'Collective Intelligence' refers to working collaboratively through the ease of information exchange, but also suggests design work that encompasses a broader spectrum within the design disciplines in response to increasingly complex and global design problems.

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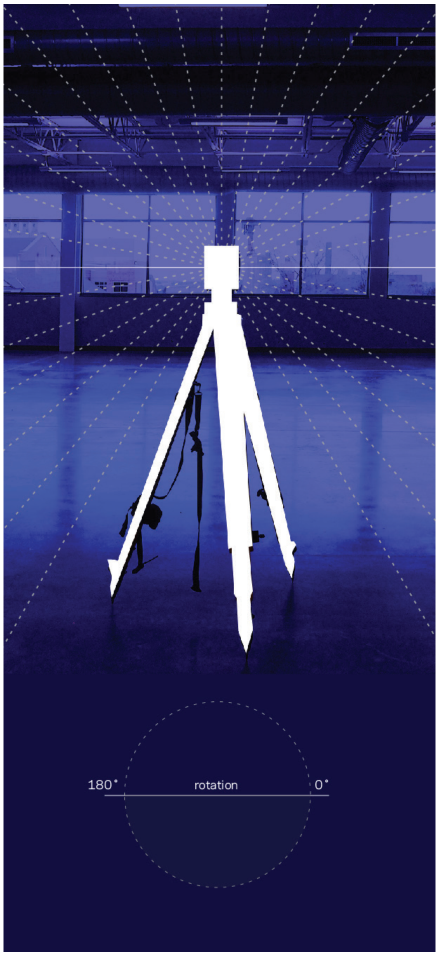


Figure 1. *High Definition Scanning Tool*, by Sara Lum.

BIG DATA TECHNOLOGIES

Building information modeling, geographic information systems (GIS), and remote sensing technologies such as 3D laser scanning are no longer new technologies, but data exchange between software interfaces and practitioners has become significantly less complicated. Building information technologies and its simulation and analysis capabilities allow for a more seamless workflow from the 'virtual to the actual,' outdating the traditional method of the imagined design drawings delivered to and built by the builder.[2] As a result of working through building information modeling, a fourth dimension, time, is introduced into the design and construction process, enabling the architect to be in a more central position, in some ways returning to the role of master builder.[3] The representational gap between design conception and construction continues to narrow as the size of associated data sets expands.

The closing of the representational gap challenges the abstract role traditionally played by design drawings, an abstraction which may be unwelcome in the construction process, but which often provides a manageable landscape to tackle complex challenges in design. While big data seems to capture every imaginable quality necessary for design it often ignores the fleeting and ephemeral qualities of the built environment that even the slightest abstraction of drawings left room to imagine and communicate. When communicating a project using these information-based tools the question is no longer how much data and information is enough, but how much data is too much? Big data tools and workflow methods require new skills and modes of thinking through design problems; design becomes in part a process of purging, parsing and patching relevant information together. This is particularly true for design tools such as GIS and Lidar, also known as 3D laser scanning.

LIDAR AND REMOTE SENSING TECHNOLOGIES

Light Detection and Ranging, or lidar, is a remote sensing technology that projects thousands of laser pulses per second and calculates distance by measuring the return time of the reflected light pulse. The result is a measurable three-dimensional digital point cloud model ranging from thousands to millions of points. Large-scale 3D scanning is made possible by laser technologies developed in the 1960's with a rich history in fields such as archeology, engineering, physics, and the military, but until recently the use of this technology was not as commercially viable.[4] The history of utilizing remote sensing technologies to understand spatial environments dates back to the 1970's with government programs such as Landsat 1 through 7, an initiative started in 1972 offering views previously unseen of the earth's surface. This was also just after Roger Tomlinson developed the first functioning GIS software, or Geographical Information System, allowing for spatial visualization of data and geographical information.[5] Over the past 30 years, the Landsat program has collected a continuous photographic record of the earth's surface and through mapping has revealed much about growing cities and changing landscapes alike. Using photogrammetry and other techniques this data can be used to learn from and act upon the built environment. Remote sensing technologies contribute to how designers understand and act upon their environment; one needs to look no further than how initial site information and studies are conducted via Google Earth's aerial and street view tools. One of the primary examples of designers using remote sensing technologies to understand and communicate ideas about space is the use of satellite imagery by Charles and Ray Eames in the groundbreaking film, "Powers of Ten;" the final version was completed in 1977, five years after the Landsat program began and 24 years before the release of Keyhole Earthviewer 1.0, the first software version of what later became Google Earth.

Advancements in measurement and optical tools—remote sensing, photography, microscopes, telescopes—generate novel ways of looking at the world from the expansiveness of the universe to details unseen by the naked eye. As adopters of such tools architects are challenged to innovate methods and approaches to how technological developments, in this case metrology devices, will be used and ultimately affect the design and construction of architecture. The built environment is unequivocally tied to the process of design; the tools and processes used to capture, interpret and design have a measured impact on final outcomes. Lidar, also called high definition scanning or 3D scanning, alters traditional means of collecting, interpreting and representing data, and can be utilized for multiple scales of application and at different moments during the design process.

3D SCANNING AS A TOOL

Despite architecture's slow adoption of 3D scanning other industries have been experimenting with and incorporating it into their workflows. This includes professionals and researchers in engineering, preservation, manufacturing, forestry, crime scene investigation, disaster relief, and the oil industry. In all cases, accuracy and time are important reasons for adopting high definition scanning. In his 2014 SPAR International Conference keynote address, Magnus Rönnäng, technical expert for Volvo Cars Groups, described Volvo's virtual manufacturing simulation process. Now, instead of attempting to maintain robust and labor-intensive BIM models, Volvo uses high definition scanning to update physical models of their plant for redesign and clash detection simulation of the manufacturing process directly within the point cloud.

Serious investigations about the design and representational implications of 3D scanning in architecture are important for thinking about the future of this tool within practice and academia beyond its purely practical utility. To date there is limited precedence of the study of 3D scanning in architecture; most experimental use has taken place in peripheral fields. In addition, much experimentation within the discipline has been focused outside of the United States in locations containing more historic structures. One team of designers leading critical 3D scanning experiments is London-based ScanLAB Projects, comprised of the duo Matthew Shaw and William Trossell. ScanLAB Projects has scanned an impressive variety of physical spaces and approaches each project with an innovative perspective exploiting the broader implications of 3D scanning related to the surveying, interpretation and representation of data. In "Digital Doppelgängers: Future Scanscapes," which was included in *High Definition: Negotiating Zero Tolerance*, the January 2014 issue of Architectural Design, Shaw and Trossell elaborate on the use of 3D scanning as a design tool. They suggest that while 3D scanning collects large data sets, the data is almost exclusively quantitative even if experimental methods of collecting data with the scanner are utilized. The qualitative aspects of space—temperature, atmosphere, sound—are extremely difficult if not impossible to capture and measure using a 3D scanner. The last paragraph of the article asks, "If a digitized version of space is uncanny yet cannot compete with the real, how can it enhance it, provoke it, change the way it is used?"[6]

Projects that utilize 3D scanning from large scale (building) projects to small scale projects (person) tend to use the data as a way to understand and adapt to specific site conditions. Utilizing high definition scanning as simply as a documentation tool for site and historic structures is underestimating its potential within both professional and academic projects. Perhaps more transformative than the incredible accuracy of 3D scanning is its potential to exploit time as a variable. The ease and quickness of high definition scanning allows for a more accurate capture of three-dimensional space over a period of time, which opens up a range of possibilities to exploit time as a fourth dimension within the design processes. Some experiments are focused on scanning across time to track changes to structures, movement and ephemeral elements such as smoke. Experiments focusing on accuracy deal more with scanning detailed objects and difficult spaces to capture, including historic structures. What remains to be explored further is how point cloud data can be used to generate novel ideas about space and for purposes beyond pure documentation? At what point is the data a practical tool and at what point is it a point of departure for design? The extreme accuracy and amount of data collected from high definition scanning is beyond any conceivable amount of information achievable using a tape measure. Can parts of the data be used to generate tool paths for fabrication? Can specific points be extracted to generate spaces specific to scans of movement? Is there a moment of data abstraction—of purging, parsing and patching information together—that generate design strategies? It is the play between reality, abstraction and simulation that is particularly interesting related to utilizing 3D scanning in design processes.

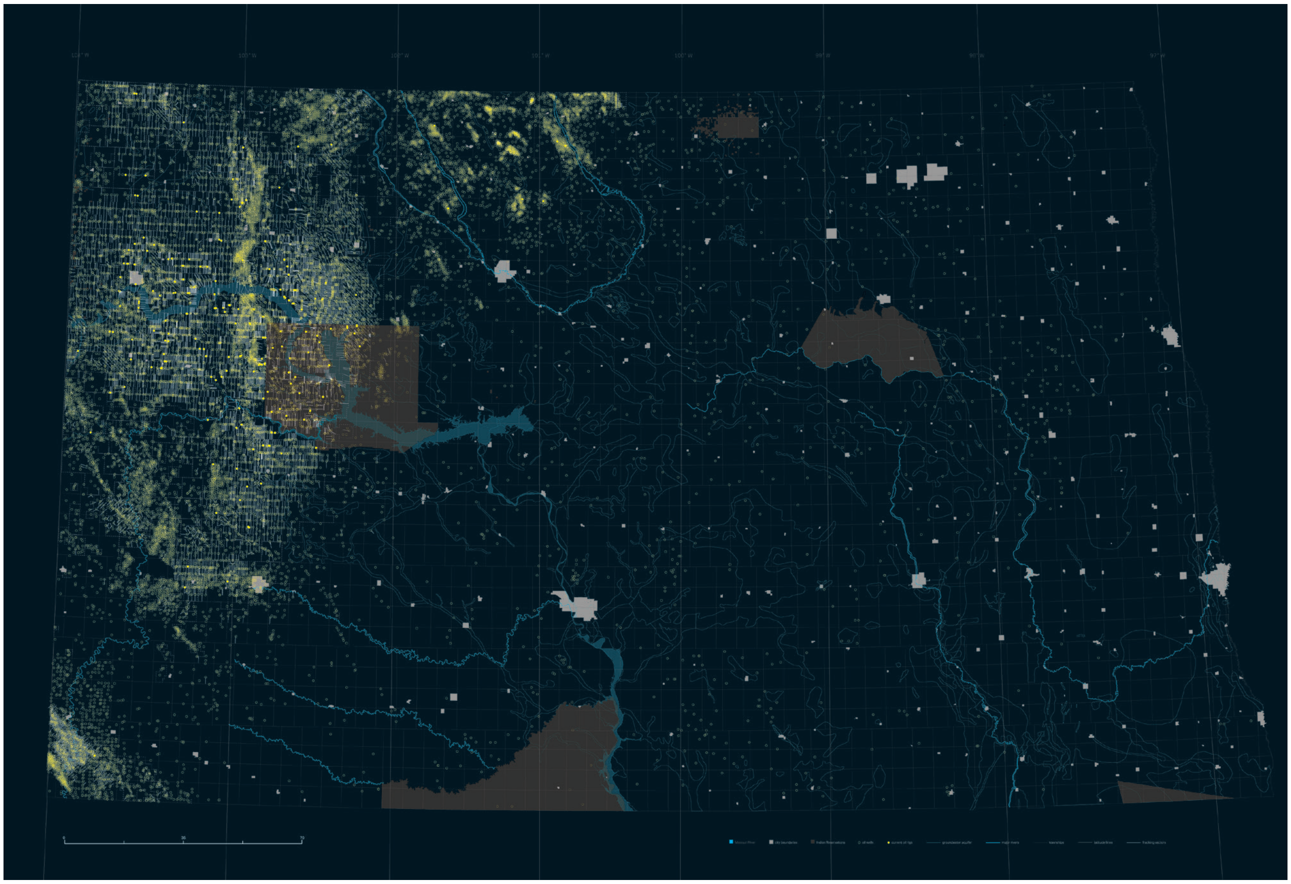
EXPERIMENTS IN MAPPING AND 3D SCANNING

Inspired and elaborating on methods of investigation ScanLAB and others are conducting I have been working on a few projects through research and teaching utilizing high definition scanning and GIS technologies as tools. The projects operate at different scales, problematizing distinct variables of the tools and the way the data is used. Currently the work exists at various levels of completion dependent on the time scale for each project. The projects to be discussed include *Narratives of the Bakken*, *Point Pavilion*, *Scripting Scans* in collaboration with Jason Wheeler for a jewelry collection called *Snow Li*, and two building workshop courses taught utilizing 3D scanning as a design tool.

NARRATIVES OF THE BAKKEN (MACRO)

Narratives of the Bakken is a project in progress utilizing a multi-disciplinary research method to study place and the politics of space in the Bakken oil fields of the Williston Basin in western North Dakota. The oil discovered in the Williston Basin is the largest accumulation of oil discovered in North America since 1968 when the Alaskan Prudhoe Bay field was identified. Specifically, the research is being conducted on the Fort Berthold Indian Reservation, currently one of the most active drilling locations in the region. The prosperity brought by the oil boom presents significant social, environmental, and infrastructural challenges for this rural region, not to mention a very uncertain future. Additionally, the land politics on tribal lands are even more layered than already complex mineral and surface rights ownership laws. The project's goal is to document and make visible a multi-faceted narrative of site: one part physical and another part social through physical documentation (3D scanning), analytical research (GIS mapping and diagramming), and ethnographic studies (in person interviews).

Gaining access to a drilling site has been the most difficult challenge of the project. High definition scanning is more labor intensive and dependent on physically



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occupying a location than photography. Private drilling companies in the Bakken have almost shut down outside access to oil sites completely. However, the circumstances of tribal lands make this area slightly more open and accessible to researchers. Missouri River Resources, which is the first Tribally chartered energy company in North Dakota, has agreed to one of the company's first drilling sites, which will begin work in Spring 2015, to be the site of investigation for my research. The over 1,300 wells drilled on Fort Berthold before Missouri River Resources was started were drilled by private companies leasing land from the Mandan, Hidatsa and Arikara Nation.

Through this research the variable of time is both part of the interest and the limitation. Scanning an oil site over time offers a glimpse of the life cycle an empty landscape undergoes during oil extraction; it makes a process not typically accessible visible in a spatial way beyond what is possible through photography. The logistics of gaining access and scanning at different moments in time is particularly difficult in a place that has such drastic weather patterns and seasons when most scanners should not be used below freezing temperatures and accuracy can be hindered by natural elements such as wind. This approach to 3D scanning unless coupled with other research methods also carries similar risks to using the scanner simply for historical documentation.

At this scale of research, GIS becomes a powerful data mining and mapping tool to pair with site-specific point cloud data and humanities-based research. Large-scale mapping offers glimpses of how oil sites aggregate and mark the landscape, in addition to showing surface and mineral rights ownership patterns. On privately owned land in the Bakken surface and mineral rights are often owned by

Figure 2. *Narratives of the Bakken: Fracking Futures*, by Sara Lum with GIS assistance by Daniel Renner. Data from http://www.nd.gov/gis/ and https://www.dmr.nd.gov/oilgas/.

different people; tribal lands can be tribally or individually owned in addition to being designated trust land or fee land. Multiple maps and diagrams are being used to communicate both the physical and political variables acting on (or underneath) the site over time. All of the data is extracted from publicly accessible GIS databases. In addition to the "real" data of the scans and the "abstracted" data of the mappings, interviews with surface and mineral rights owners, oil company workers, and other stakeholders reveal social complexities of the area. The research will be communicated and later utilized to suggest landscape-based design opportunities bringing attention to the history and environmental, social and political changes taking place on Fort Berthold.

Another trajectory emerged in the project related to housing in the oil fields. An abandoned school from the 1960's is being turned into housing for oil workers; it has been scanned and will be re-scanned throughout the process of its transformation aiding in design research studies related to temporary housing typologies in the Bakken region.

The methods for both trajectories of the project attempt to study three-dimensional time-based changes visually accessible through the use of the 3D scan-

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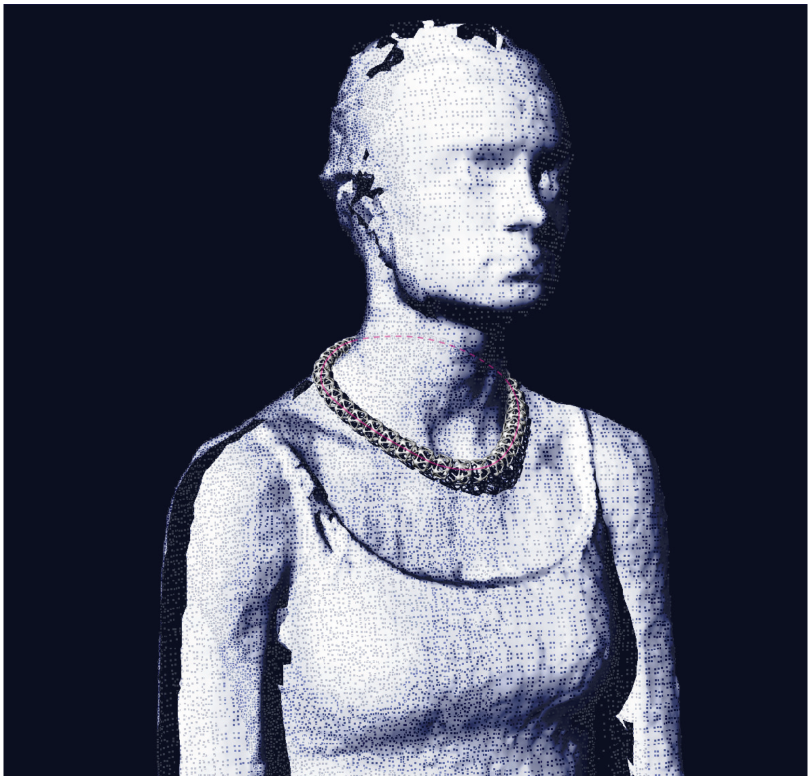

ner. The project uses qualitative research methods to inform the quantitative approach of high definition scanning in order to develop innovative research methods to record an important cultural history and inform future design decisions. In this case the data is used as a record (3D scanning) and to communicate larger patterns (mapping).

SCRIPTING SCANS (MICRO)

Scripting Scans, a project in collaboration with Jason Wheeler, uses 3D scanning

Figure 3. *Scripting Scans* by Jason Wheeler and Sara Lum.

to extract data for site specific, or body specific, jewelry designs based on the exact proportions of human figures. Utilizing a point cloud of a human figure generated from a 3D scan, a grasshopper script was generated to determine optimum jewelry sizing dependent on the input point cloud for a jewelry collection by Jason Wheeler, *Snow Li*. For the early experiments, high definition scanning was used, but we are currently exploring the possibility of utilizing another remote sensing technology such as photogrammetry for data input. In this case, individual customers would be able to download a photogrammetry app, such as Autodesk's 123D Catch and upload a body capture of 36 photos, which would output a mesh to be used in a similar fashion to the high definition point cloud in the grasshopper script. While the current script bases the length of each necklace on a curve extracted from the point cloud, one of the future goals is to design a script utilizing more data from the point cloud than one curve to generate specific jewelry or apparatus.

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Similar to the macro scale project the accuracy of the data for *Scripting Scans* is not a generator, but a documentation of an existing condition. While valuable in its own way, the data itself is not being used as a creative tool, but as a highly accurate record of site used for design applications very specific to the body. While these types of experiments are valid, experiments with 3D scanning in design need to shift beyond the tool as a record of space. How can a point cloud

Figure 4. *Point Paviliion* process scan of the Architecture, Math and Engineering Building at South Dakota State University by Sara Lum.

be used to generate new spatial models? Can the data be parsed and extracted to develop tool paths for fabrication? Can scanning movement and other temporal phenomena lead to novel ways of generating design ideas?

POINT PAVILION (MESO)

The *Point Pavilion* is a project to be built in the Spring of 2015 as a part of a building shop course called *SCANtoFAB* focused on utilizing point clouds extracted from 3D scans to design and fabricate a small pavilion for the center of our new building and studio space at South Dakota State University. The students in the building shop will participate in fabricating the pavilion, but will develop their own small scale experiment using scanning to design and fabricate as well. They will all need to use the scan of the space or additional scans collected and create a light aperture altering and interacting with one of the windows in the space. Instead of using the scans as a site study the students will be required to use the extracted data in a deliberate way to design. Using grasshopper and other tools they will analyze, purge and reuse some of the information in the design process. Digital Fabrication tools such as the laser cutter and CNC will be used for prototyping and fabrication.

TEACHING BIG DATA (3D SCANNING)

While it has been clear for some time that the processes of the next generation of architects will be driven by a set of constraints related to big data, it is still unclear how these challenges will be taught within an academic setting. Thought processes and teaching related to digital fabrication and parametric design have produced a cohort of young professionals equipped with specific technological

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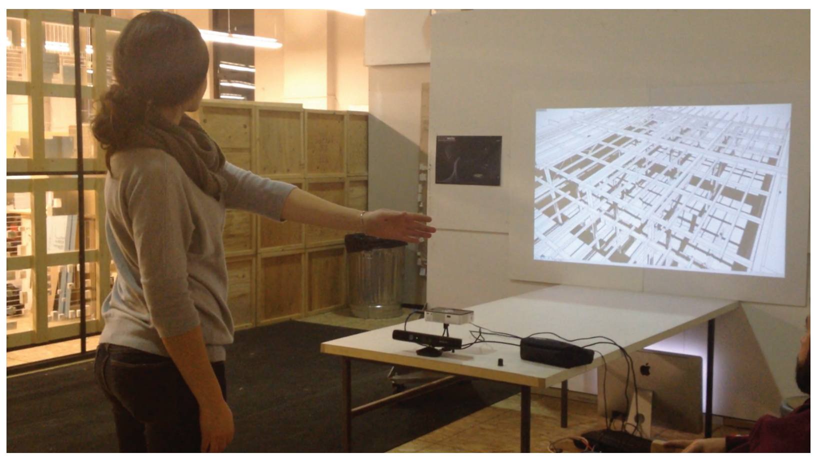

proficiencies, but these skills are often still intricately tied to an exclusively authorial design process. Processes associated with big data, while inherently digital, are based on collaborative processes and the management of massive amounts of information. In contrast to formally focused digital design processes, a process of purging, parsing and patching information to be communicated is required. What data is relevant? How should it be organized? In what form is it useful for design? The challenge of simulating the conditions to learn how to manage information for design in an academic setting is in part simply having the computer capacity to engage with large data sets, as well as having the type of projects that facilitate such processes of design. The professional world creates the sense of urgency and necessity for utilizing information-based tools such as remote sensing technologies and building information modeling nonexistent in academia.

Figure 5. *Interactive Scanner* by Josh Wagner and Rythm Unnown for *Surveying, Mapping and Scanning* taught by Sara Lum.

Methods of incorporating large-scale 3D scanning into the classroom were experimented with in a Fall 2013 building shop course title *Surveying, Mapping and Scanning*, but the course was taught before a 3D scanner was purchased. High definition laser scanning was introduced through a hands-on, research based approach; the theoretical and historical framework of the workshop was based on fundamental surveying and mapping methods. The goal of the assigned coursework was for the students to research, experiment and question the limits of 3D laser scanning technologies as a representational tool. Subsequently, a series of incremental project exercises, titled how low can you go, asked students to research 3D laser scanning and its associated inputs and outputs, build a 3D laser scanner as inexpensively as possible, and experiment with collecting, manipulating and representing data collected from their machine. The final project challenged the students to consolidate their findings into a focused experiment to "properly misuse" the tool—their own or the department's scanner—and to represent their findings.

The most successful projects included a laser scan system built for $5, a hologram contraption built as a representational method for 3D scan data, a study scanning light, and a laser scanner built using a Microsoft Kinect connected to a 3D modeling environment and used to interact with a computer model through body movement. By isolating variables of 3D laser scanning in a design research environment the device's tolerances were exploited to reveal opportunities for implementation in the design process, which will be experimented with further in the Spring 2015 building shop. *Surveying, Mapping and Scanning* isolated the front end of 3D scanning related to how the technology works and ways it can be extracted, manipulated and represented. *SCANtoFAB* strives to extend beyond representational experiments and investigate how the data can actually be used to design. To understand and be critical of the relationship between design tools and the built environment is valuable to students entering a profession with many technological approaches; having the critical thinking skills to creatively implement new design tools in the profession is more important than mastering any one particular technology.

Building information modeling and its associated inputs, including 3D laser scan data, problematize representation. Abstraction is traditionally inherent in architectural drawings; the gap between a drawing and constructed reality is often seen as a projective gap that allows for creative interpretation and imagined futures. Abstraction is not inherent in 3D scan data because of its incredible accuracy; in this case it must be thoughtfully constructed during the process of collection, manipulation and representation of the data. Large data sets associated with 3D laser scanning require important processes of purging, parsing and patching of information. These processes illicit questions in need of continued exploration. How much data is too much data? What does this mean for design processes and workflows? What does this mean for representation? And most importantly, how does high definition scanning inform design? It is clear designing in a point cloud calls for new skill sets, but even more important investigations remain regarding the long-term implications of designing in a point cloud and its potential to generate novel ways of thinking about the design of future spaces. This is the goal of the work presented and its future iterations.

ENDNOTES

1. Christopher Hight and Chris Perry, introduction to *Architectural Design: Collective Intelligence in Design* 76(5), ed. Christopher Hight and Chris Perry (2006), 5-9.

2. Manuel DeLanda, "Philosophies of Design: The Case for Modeling Software," in *VERB Processing: Architecture Boogazine*, ed. Jaime Salazar (Barcelona: Actar, 2002), 131-143.

3. Richard Garber, "Optimisation Stories: The Impact of Building Information Modelling on Contemporary Design Practice," *Architectural Design* 79(2), ed. Richard Garber (2009), 6-14.

4. Matthew Shaw and William Trossell, "Digital Doppelgangers: Future Scanscapes," *Architectural Design* 84(1), ed. Bob Sheil (2014), 20-29.

5. Jessica Aguirre, "The Unlikely History of the Origins of Modern Maps," *Smithsonian.com*, June 2, 2014, accessed September 19, 2014. http://www.smithsonianmag.com/history/unlikely-history-origins-modern-maps-180951617/?no-ist.

6. Shaw and Trossell, "Digital Doppelgangers: Future Scanscapes," 20-29.