

HP2: The Design of a 3D-Printed Partition for the Healthcare Environment

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ABSTRACT: As of 2012, the methods in which the construction industry fabricates a non-load bearing partition are virtually the same as 100 years ago. This process and assembly is perpetuated by a construction culture that thrives on convention. Sheet building materials are nominally controlled, assembly definitions are outlined through building codes, and trades continue a system of apprenticeship where techniques are passed down through generations. This is further complicated with a construction process that is the mediator between the conception of the designer and the built artifact. The aim of this research was to reconceive the conventional construction techniques of the partition in high performance, technology-specific locations; an area that begs for development within a contemporary fabrication environment where new cnc technologies are able to translate mass-customized form into full scale, built assemblies.

HP2 was a design research project into the potential of a fully digitally fabricated, high performance interior partition placed within the healthcare environment. Initial research indicated areas where design could assist in more effective delivery of healthcare. For example, altering the ways healthcare providers enter and exit the room, as well as the way air is moved through the room could better protect patients in these facilities. Additionally, research aimed to integrate the inclusion of digital form generation and fabrication techniques to consider the partition of tomorrow – one that allows synergy between the form, space, and various building systems.

The design process investigated areas of acute care patient rooms, structural surfaces, architectural wall infill (poche), narrow spectrum sanitary lighting, adjustable and variable perforation, and patient room air ventilation. This process culminated in the manifestation of a 3d printed scale mockup of the partition with all systems present. Current projections of this project speculate on the potential of large scale 3d printing as a means to establish better connections between the high technology systems being requested and a fabrication technique which is supportive of that endeavor.

KEYWORDS: healthcare, fabrication, monocoque, 3d printing

INTRODUCTION: LIGHT GAUGE PARTITIONS AND THE CONSTRUCTION INDUSTRY

As of 2012, the methods in which the construction industry fabricates a non-load bearing partition are essentially the same as 100 years ago; repetitive structural members spaced equally with a modular, mass produced surface applied and finished on the construction site. While there are most certainly variations on this theme that might respond to contextual conditions such as materials (wood vs. steel studs), systems and their routing, budget, or temporality, this system has seen very little significant change.

The physical artifact of a partition is most often an assemblage of various materials and components, each serving a specific function. This might include materials such as drywall or wood panels and componentry such as aperture, hardware, mechanical vents and diffusers, electrical/data devices, grab bars, or lighting for example. Each of these elements is designed in isolation and is flexible enough to accommodate diverse contextual conditions. The system referenced is also a product of a dated manufacturing culture – one that foregrounds mass production and modularity, and in turn, sameness. This process and assembly is perpetuated by an entrenched construction culture that thrives on convention and tradition. Sheet building materials are nominally controlled through market demands such as 16" increments and consistent thicknesses. Partition assembly definitions are outlined through building codes and laboratory testing specifications that quantify traits such as fire spread and resistance, acoustical transmission, and structural load deference. Further more, although often unmentioned, the building trades continue a system of apprenticeship where techniques are passed down through generations adding to a quasi-institutional knowledge in the construction industry. Lastly, this context is further complicated with an communication and translation process that is the mediator between the conception of the designer and the built artifact. The

actual assembly of the partition is often times at least 2 levels removed from its conception through contract documentation, to contractor or shop drawing, to fabrication by trades person. This composite condition became the context of the critique and the basis for this research project.

1.0 THE HEALTHCARE CONTEXT

The healthcare environment is one of the largest growing industries today with populations living longer and care needs growing proportionally with that age. It is expected that the healthcare industry will produce nearly 4 million jobs over the next ten years and will see an annual increase of 3.0%. This increase is followed closely by the construction industry that is projected to see annual increases in the range of 2.9%. (Thomas, 2012) Rapid growth and significant linkage between both industries suggests that status quo will not meet the growing needs of both, and that healthcare environments are ripe for new designed responses. Increased care will dictate more space for patients and increased patients will require need for more workers.

Initial research, as a result of this project, identified several areas where design might assist in the delivery of healthcare and the quality of spaces it occurs within. The design process gathered healthcare industry literature as well as interviews with various specialized design professionals. This information was reviewed and analyzed to identify areas in which design might offer a more efficient and effective space for both the caregiver and the patient. Additionally, the overlap of these areas provided for hybrid conditions that could, through their juxtaposition, enhance both scenarios. As a result, the acute care patient room, and more specifically the partition that exists between two rooms, was selected as a locus for testing design strategies both for its ubiquity and simultaneous possession of the various topics in which the research indicated potential.

Room types position the components of the restroom, healthcare professional, and the patient in various places to create synergistic opportunities and desired adjacencies. (e.g. Fig. 1). While opinions vary across the United States, our research and interviews determined that the outboard room type was optimal for its connections to the corridor and efficiency in healthcare delivery. This type allowed for the nurse's station to be located in the corridor providing more area at the corridor wall for of a door and window thus increasing visual connections from the nurse's station. This connection meant care providers could perform most of their rounds without having to enter the room, thus decreasing the times in which air and surface contaminants could enter the patient room. The only pronounced negative trait of this room type is a reduction in the amount of exterior wall and resultant window to the outside, but that was seen as possessing less significance with regards to the overall function of the patient room.

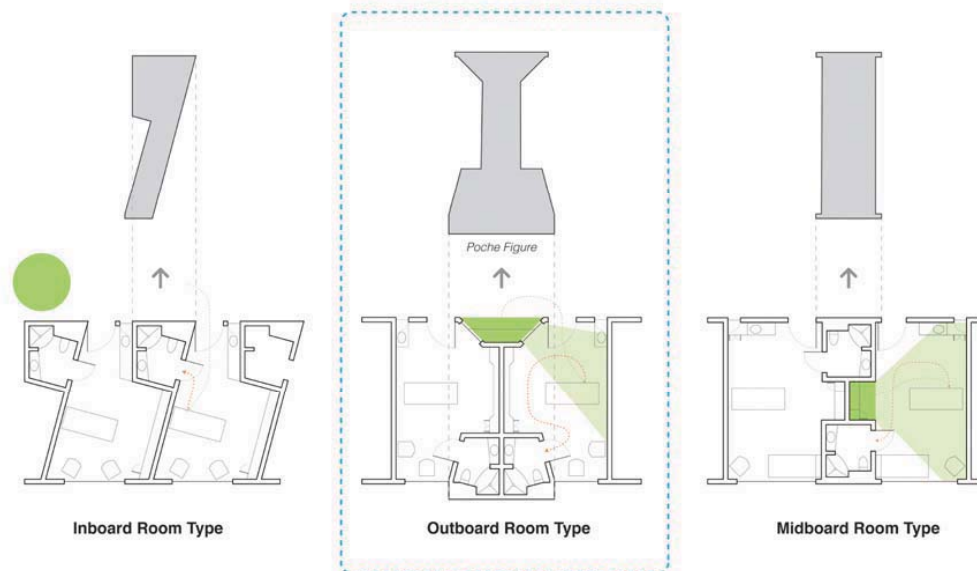


Figure 1: Patient room typology. Source: (Author 2013)

The entry into the acute care patient room presents the highest potential for contamination of room air and surface. When a user enters the room from the corridor, airborne contaminants in the adjacent corridor have opportunity to migrate in the wake of a moving person. Typically, room ventilation is planned to create

positive air pressure in the room so air moves toward the corridor when the door is opened. Additionally, healthcare workers who might sanitize when leaving one room are immediately prone to contamination when entering the next room through contact with surface and hardware. This room entry plays an important role in keeping the patient safer with regards to air and surface-borne contaminants and research gathered through this project indicated that altering the ways healthcare providers enter and exit the room, as well as the way air is moved through the room could better protect patients in these facilities. (e.g. Fig 2)

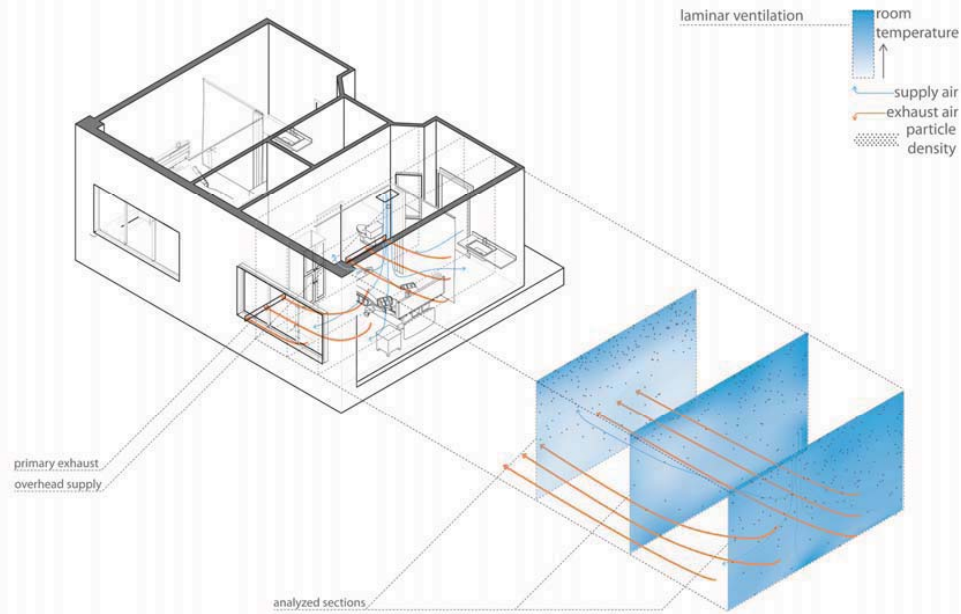


Figure 2: Patient room ventilation analysis. Source: (Author 2013)

Building systems within a healthcare facility typically move vertically in areas where they are able to be aggregated and decrease the distance to delivery. Often this means poche space within the restrooms contains a high amount of water, air and electrical systems. As a result of positioning the restroom towards the exterior wall, the vertical systems that are feeding multiple floor levels in the facility are also located toward the exterior wall. This core of systems, which includes the supply of fresh air to the patient room, provides excellent placement for responding to desired airflow directionality decreasing the infiltration of airborne contaminants into patient rooms. (e.g. Fig 3)

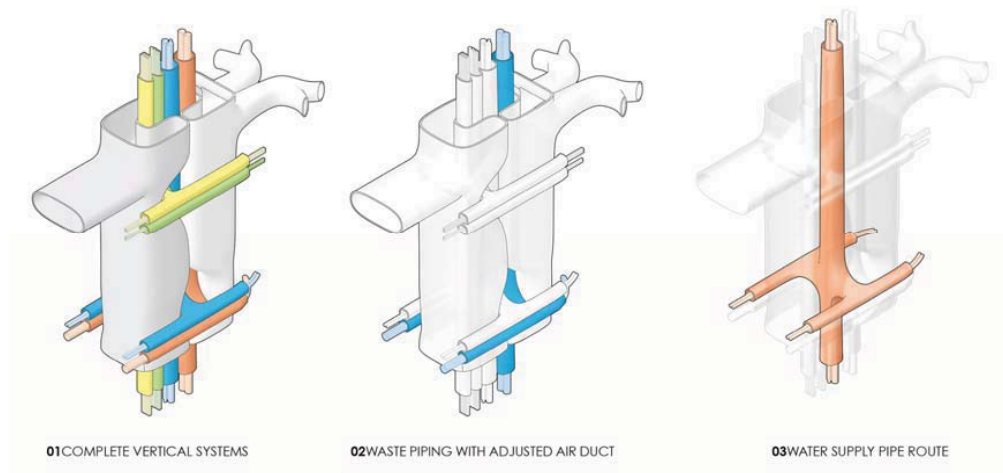


Figure 3: 3d printed building systems diagram. Source: (Author 2013)

2.0 DESIGN STRATEGIES

HP2 was a design research project into the potential of a fully digitally fabricated, high-performance interior partition placed within the healthcare environment. The aim of this research was to reconceive conventional construction techniques of the partition in performance and technology-specific locations such as healthcare facilities. The design process investigated areas of acute care patient rooms, structural surfaces, architectural wall infill (poche), narrow spectrum sanitary lighting, adjustable and variable perforation, and patient room air ventilation. The previous subtopics became catalysts in the development of the design research project contained within.

Architectural poche, a representational technique which dates back deep in the history of architecture and its representation, typically infills the space between the lines indicating the outside wall surface. For the purposes of this project, poche was manifest at two scales – in its traditional sense within the interior of the partition, and at the scale of the larger object located within a field. (e.g. Fig 1) The interior volume of the wall where, typically, repetitive structural member are located was cleared to make way for more efficient routing of internal systems. This was achieved through the repurposing of the wall surface to be structural – a monocoque. At the larger scale, the collective composition of the partition as it moves from the nurse's station at the corridor through the patient room and encompasses the restrooms was seen as an object in the space with specific demands and functions with potential to be redefined through alternative constructional logic and retooled systems delivery.

In an effort to reduce consumption of materials, and eventual relocation to a landfill when these materials have outlived their usefulness, change in the construction technique is necessary. With new fabrication technologies available, the use of traditional construction systems (i.e. studs and drywall) is not as relevant. New fabrication systems allow for customized partitions that offer more flexibility than was possible in mass-produced sheet goods. One of these, 3d printing, is rapidly increasing in accessibility and feasibility and seems, at this point, to only be limited by the size of equipment used to fabricate. Materials available for printing are also increasing becoming more diverse, economical, and performative with regards to strength, transparency, maintenance, tolerance, and sustainability. Several groups, including Objet and D-Shape, are investigating large format 3d printing and the potential of mass customized architectural assemblies. Printing full-scale architectural components or parts in addition to the full envelope are no longer fictional narratives but rather attainable goals.

The traditional partition is a product of the 20th century, a timeframe of manufacturing defined by mass production of materials and products. This partition type does not allow for difference outside of a few variables. Any deviation outside of these variables results in the increase of cost and labor for manipulation. Mass customization on the other hand establishes a more robust set of parameters resulting in higher degree of performance specificity. 3d printing allows this specificity through variation in formal conditions and material options. Initial prototypes were mocked up in ABS plastic to test flexibility, strength, form, and proportion. Future studies will investigate the potential of a reusable, corn-based material that can avoid the landfill of traditional construction materials by being reconstituted. For modification of 3d-printed construction, portions of the wall can be removed, processed, and reused to create an infill panel. To extend this logic further, entire partitions can be processed when they outlive their use and be recycled into new constructions.

The inclusion of systems into this new fabrication typology begins with the surface and its diversity of parameters including material, thickness, and orientation. The surface is a ubiquitous condition in the built environment where a high percentage of those surfaces are single use and highly underutilized. Surfaces exist in extremely diverse ranges of materials, contours, scales, thicknesses, and workability. These parameters are typically selected based on a determined use and performance standard with regards to durability, maintenance, acoustics, transparency, initial workability, and aesthetic manifestation.

Monocoque is a term derived from the Greek word combination that translates to 'single shell.' First introduced through aircraft construction in early 20th century, it offered an ability to integrate what was previously two systems, structure and skin and developed a hybrid which simultaneously performed the duties of both with reduced weight and comparable strength. The potential of monocoque construction in the partition displaces the structural role of the wall to the surface thus releasing the interior of the wall, the poche, to allow for freer movement of systems and the ability of those systems to work synergistically. Even more, where the space is not needed for systems, it can be completely removed and the surface itself can perform the duties of structure and separation. Acoustical concerns are addressed through cellular materials that isolate sound and decentralize vital air space into a dispersed network of air pockets. In turn, this can decrease weight in the partition construction depending on material selection.

Within aforementioned strategies and technologies, the design began with inventory of the context and analysis including function, anthropometrics, and systems integration. Critical anthropometric wall sections (nurse station, sanitation area, task surface, etc.) were established to address use requirements through pushing and pulling the wall surface, accommodating various technical concerns. (e.g. Fig 4) Surface design was generated through analysis of various performance markers that are parametrically manipulated through the use of software. Unlike mass produced sheet goods, variables such as wall thickness can be differed based on what they are tasked with doing. Surface geometry was analyzed and parametrically controlled in ways that added material where necessary, and lightened the skin where not needed. Additionally, surface thickness can delaminate to create structural conditions and cavities for the transmission of air, water, waste, or power. Effective delivery of ventilation, coupling of systems to encourage synergistic transference, and integral systems printing including circuitry and ventilation were opportunities present with a new fabrication technique. Ventilation routing, which required the most poche space allocation, was conceived of as a morphing volume that was sometimes independent and other times grafted into the surface through delamination.

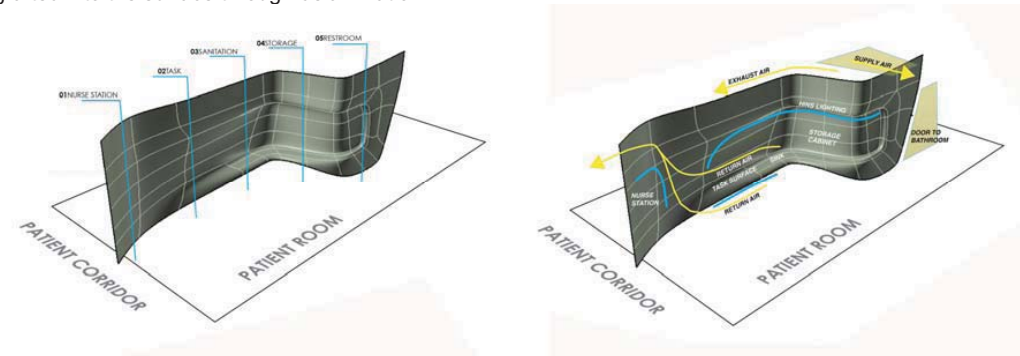


Figure 4: Critical anthropometric sections and performance criteria of the partition. Source: (Author 2013)

A series of prototypes were generated looking into the performative aspects of perforations on the architectural surface with the goal of eliminating elements such as the light and air diffusers. (e.g. Fig 5) This perforated strategy would be integral into the surface and variable based on local need. For example, where the surface of the partition needed to breathe more, the size and frequency of the perforations could be parametrically controlled to increase or decrease airflow. This condition would also work for variable lighting conditions allowing for light to be delivered at the appropriate intensity to the point of need and fade away where not necessary. These investigations also prototyped the effect that these surface manipulations would have on the potential of the surface to contour based on set criteria. (e.g. Fig 6) The use of perforations and surface manipulations were also seen as a way to integrate sanitation of air and surface. High intensity narrow spectrum (HINS) lighting is a recent development that is highly effective in the sanitation of air and surface. (ScienceDaily, 2010) This light type can be integrated into architectural spaces and assist in maintaining a cleaner environment without large amounts of space internally. The coupling of this technology with 3d printed surface conditions with variable perforations offers incredible opportunity to manifest a hybrid surface that performs relative to strength, contour, and delivery of building systems.

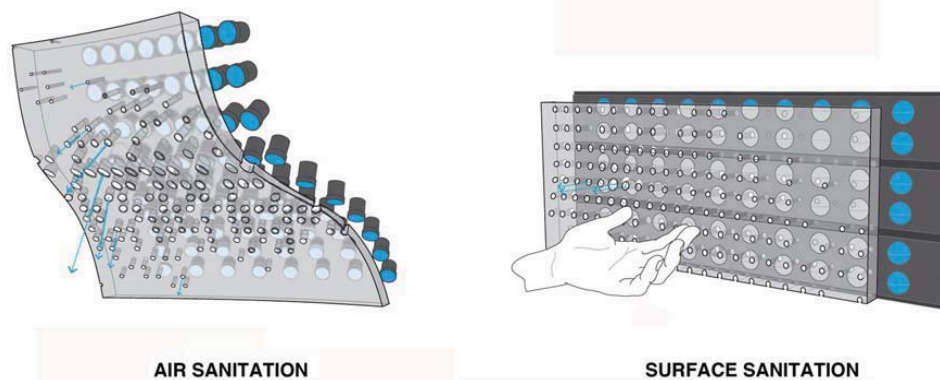


Figure 5: Surface and light sanitation through perforations incorporating HINS lighting. Source: (Author 2013)

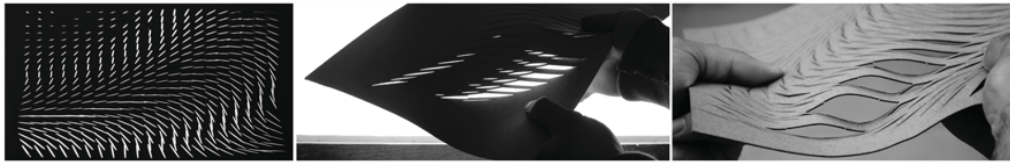


Figure 6: Initial surface perforation studies from parametrically defined patterns. Source: (Author 2013)

CONCLUSION

To this point, this process has resulted in the manifestation of a 3d printed scale mockup of the partition with all systems routing present. Current projections of this project speculate on the potential of large scale 3d printing as a means to establish better connections between the high technology systems being requested and a fabrication technique which is supportive of that endeavor. Additionally, future studies will determine the viability of reusable materials in the 3d printing process allowing prolonged use and flexibility through the life of the partition. This proposal suggests that fully integrated partition design might best be served through a fabrication technique that is offering more control and precision from conception to realization. The future trajectory is to test fabrication at full scale with 3d printing technology, focusing on areas of high systems concentration. By dissolving this division of systems and encouraging exchange, This design research project aspires to break disciplinary boundaries in turn redefine the future of high performance, technology-specific partition design.

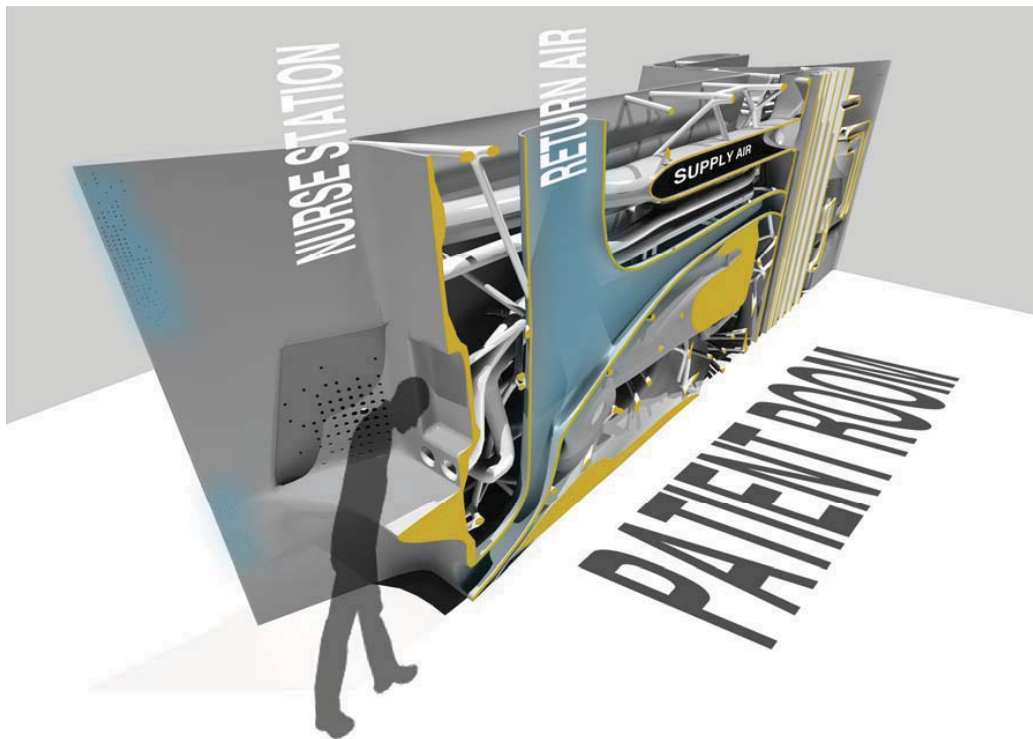


Figure 7: Sectional render of partition design. Source: (Author 2013)

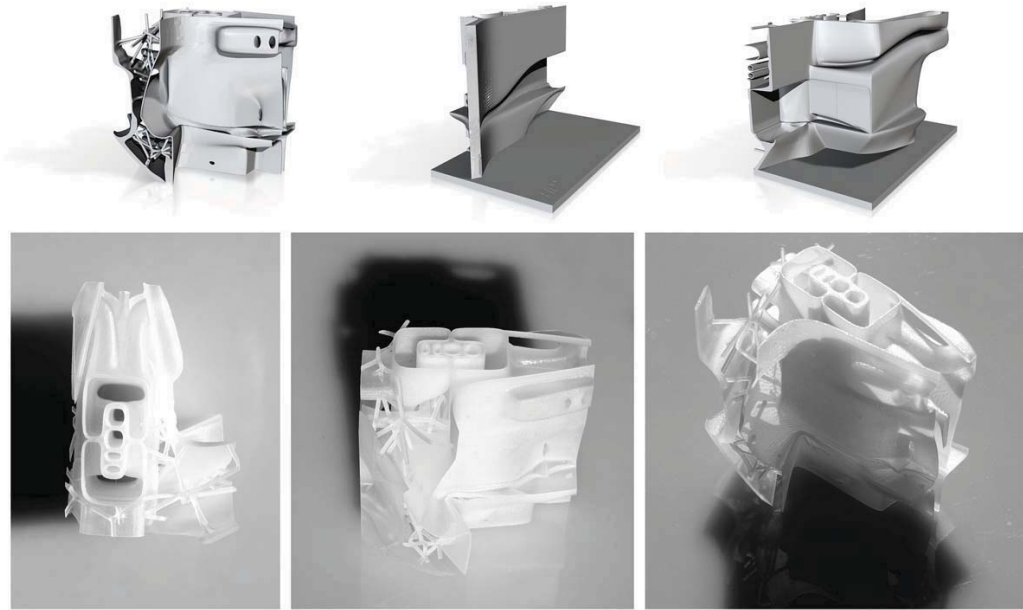


Figure 8: 3d print prototypes fabricated from ABS plastic. Source: (Author 2013)

REFERENCES

- Thomas, G. Scott. "Health care projected to be decade's hottest industry for jobs." *On Numbers Business Journal Exclusive*. March 16, 2012. <http://www.bizjournals.com/bizjournals/on-numbers/scott-thomas/2012/03/health-care-is-projected-to-be.html> (Accessed 20 Jan 2013)
- University of Strathclyde. "Light technology to combat hospital infections." *ScienceDaily*, 16 Nov. 2010. Web. 19 Jan. 2013