Hello, World: The Exploration of a Component-Based, Systemic Approach to the Physicality of Digital Infrastructure

by

Elizabeth Ellen Powell

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ABSTRACT

This thesis explores the interrelationship between digital and physical environments by investigating the Fabrication Laboratory typology as a new form of digital infrastructure. The research conducted herein examines the apparent disparity between the architectural manifestation of digital infrastructure, and the ephemeral cultural perceptions of virtual environments. As an analogous form of digital infrastructure, Data Centers are analyzed to identify design parameters for the development of a Fabrication Laboratory prototype that will align virtual perceptions with the physical infrastructure that supports its operation. The tectonic expression for the prototype is a derivative of the speed by which technology is changed, positing a highly adaptable architecture through the development of a component-based, systemic approach to the design. The fitness of the prototype is then tested through its application to a site in Halifax, Nova Scotia. Through these investigations the ambition is to establish an architectural language of the digital age.

ACKNOWLEDGEMENTS

It is with great admiration and the utmost respect that I thank my supervisor Cristina Verissimo, my advisor Eric Stotts, and my thesis-preparation studio professor Niall Savage. Their perceptiveness, expertise, and provocation gave form to the foundations of this work.

Additionally, I give thanks to Omar Gandhi Architects, Lydon Lynch Architects, Gair Williamson Architects, LeBlond Partnership Architects + Planners, and VIA Architects for the inexplicable quality of experiences I gained while working with their firms during my two academic work terms, and during the seven-year hiatus I took from my studies between the first and second semesters of the master's program.

Lastly, but perhaps most importantly, I thank my husband Aaron Scot Outhwaite. Anecdotally, he was the first person I met when I began Architecture school in 2004, and he has been by my side, goading me on, ever since.

CHAPTER 1: INTRODUCTION

> Ours is a brand-new world of all-at-onceness. 'Time' has ceased, 'space' has vanished. We now live in a global village ... a simultaneous happening. (McLuhan 1967, 63).

This thesis explores the interrelationship between the virtual and the physical, by investigating the architecture of Fabrication Laboratories as a new approach to the typology of digital infrastructure for urban environments. Our digital culture is the manifestation of countless linkages, branching out rhizomatically in all directions. Through digital networks we are connected to each other and the collective body of knowledge that has been digitally catalogued with near infinite speed. Time and distance are virtually collapsed to the now. Coupled with our 'smart' device culture, digital environments are transposed onto the physical environment (see Image 01). But, this portable hardware is only the tip of the 'digital iceberg'. The unseen physical underbelly of digital infrastructures exist in stark contrast to this virtual ephemera, and the methods by which these typologies are tectonically conceived do little to support the reality of an ever changing technology.

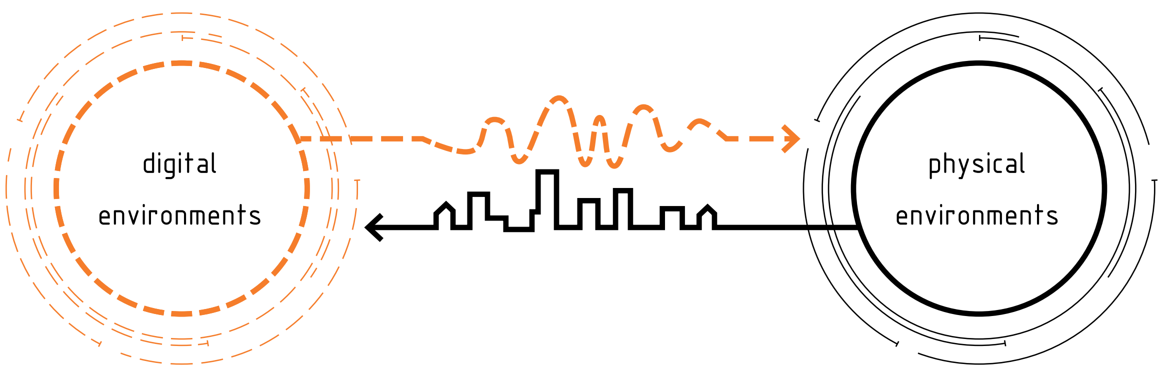


Image 01: Diagram representing the transposition of digital environments onto physical environments

The cultural ideology of upgradeability, and the ephemeral experience associated with the digital environment provides an existing framework from which to base a new architectural example. I believe that the existing notions of flexibility and 'real-time' responsiveness can be telegraphed into the built environment, and through this some of the invisible processes of urban life can be made tangible and present. By exploring an architectural approach that embraces *change* as fundamental to its manifestation, a new typology for digital infrastructure can be developed to express digital culture through a physical environment.

The issues surrounding the current approach to digital infrastructure are clearly represented in the form of Data Centers, which are the physical manifestation of the internet. They are buildings filled with thousands of computer hard-drives for the purpose of processing, storing and transmitting the information of the world. Since the proliferation of the internet through the World Wide Web in the late 1980's, digital stores of information have grown exponentially. Moving from a distributed network of individual computer terminals linked together, to rooms dedicated to server farms, the physical structures of the internet have now morphed into purpose-build structures (see Image 02); data has become infrastructure.

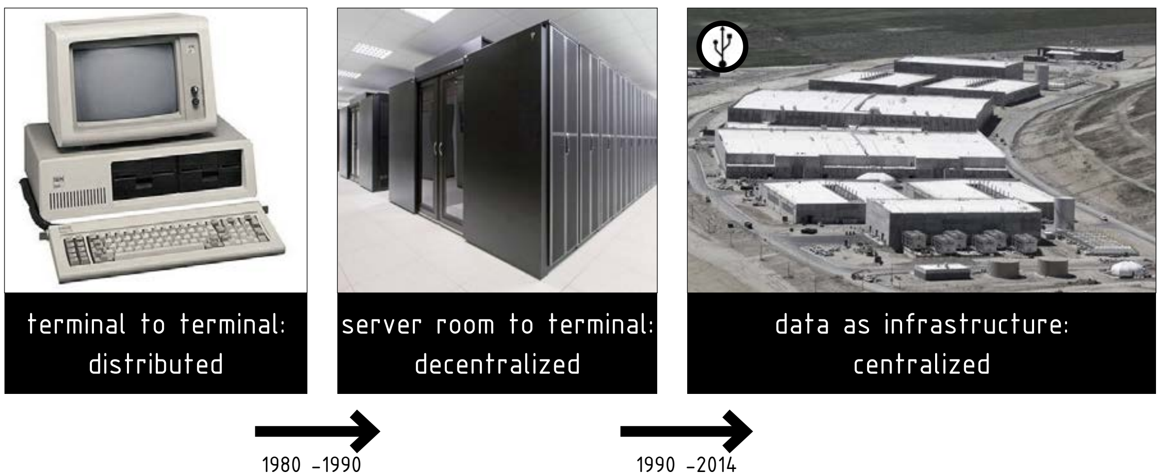


Image 02: Photographs representing the physical stages of evolution in digital infrastructure. The image on the left is an example of the IBM 5150, one of the first personal computers on the market (Hardwidge 2012), shown here as analogous to the beginnings of the digital infrastructure growth. The middle image shows the server tower hardware of a typical server room (Soft 2009). The right image shows the Utah NSA Data Center (Bowmer 2013), at the time one of the largest data centers in the world.

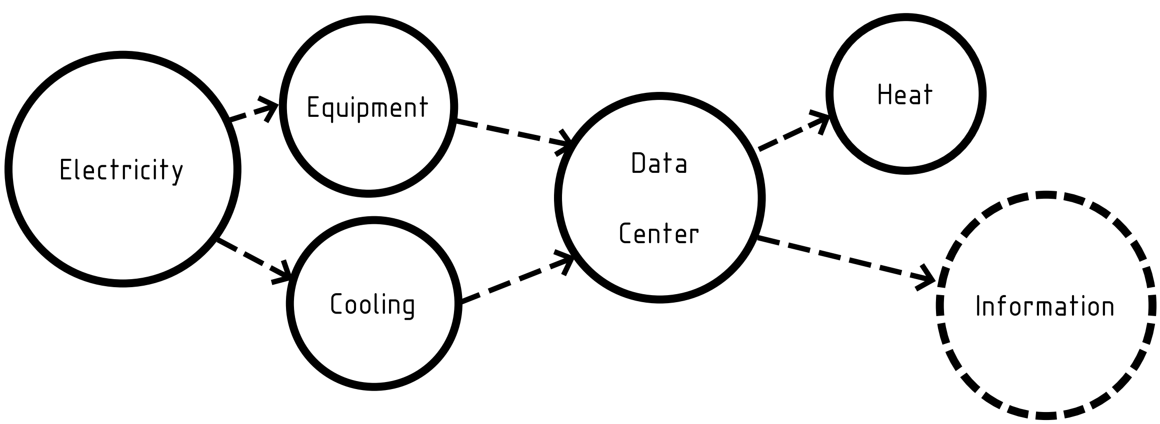


Image 03: Process flow diagram showing the typical inputs and outputs of a data center. (data from May 2012, 58)

As one of the primary forms of digital infrastructure, Data Centers serve as a case study for exploring a new model of digital infrastructure. As a typology, these buildings are typically closed-off from the public, guarded, and grossly energy intensive (see Image 03). Image 04 to Image 06 show one of the two existing Data Centers in Halifax, located on North Street. Far from being tectonically representative of the digital cultural it supports, the heavy brick and concrete facades are marred with the scars of technological upgrades and changing uses within the building throughout the years (see Image 07 – Image 09).

Image 04:   Images of the North Street Data Center in Halifax, Nova Scotia. (Google Maps 2014a)

Image 05:   Images of the North Street Data Center in Halifax, Nova Scotia. (Google Maps 2014b)

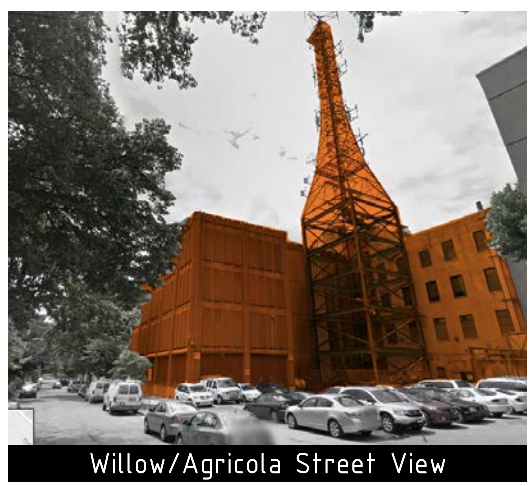


Image 06:   Images of the North Street Data Center in Halifax, Nova Scotia. (Google Maps 2014c)

Image 07: Photograph of North Street Data Center taken from North Street at Agricola Street. Items highlighted in orange show the bricked over windows, mechanical upgrades and architectural additions to the building. Halifax, Nova Scotia, 2014.

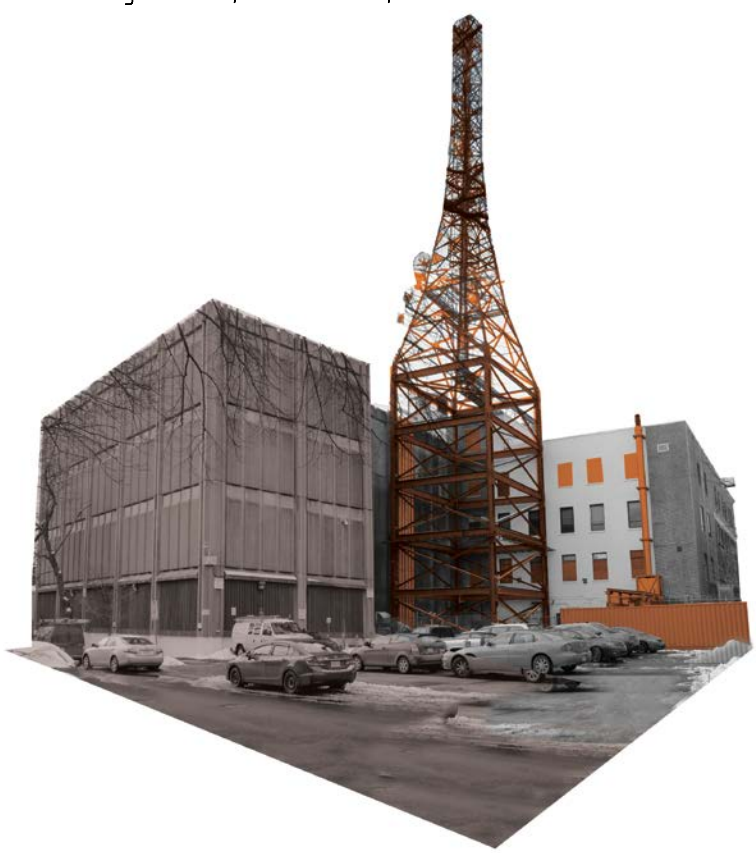


Image 08: Photograph of North Street Data Center taken from Willow Street at Agricola Street. Items highlighted in orange show the bricked over windows, mechanical upgrades and architectural additions to the building Halifax, Nova Scotia, 2014.

This is a traditionally conceived building that was converted to integrate new technology. Windows are boarded-up, mechanical and electrical systems are tactlessly dropped onto roof tops and available landscapes, and a once aesthetically conceived facade is mauled into new functionality. The buildings housing the North Street Data Center serve as a cautionary example of the ravages a rapidly changing technology have on statically conceived buildings.

Image 09: Photograph of North Street Data Center taken from North Street at Robie Street. Items highlighted in orange show the bricked over windows, mechanical upgrades and architectural additions to the building Halifax, Nova Scotia, 2014.

Programmatically, the relationship between virtual and physical that I will explored in this thesis is the translation between concept and actualization by means of a Fabrication Laboratory, or Fab Lab. More than simply a facility of 3-D printers, laser cutters and C.N.C. machines, Fab Labs offer a means of direct translation between digital information and physical objects. Furthermore, educational spaces, work spaces, and exhibition spaces are added to the program set to allow people to collectively plug-in and engage with their digital environment (see Image 10).

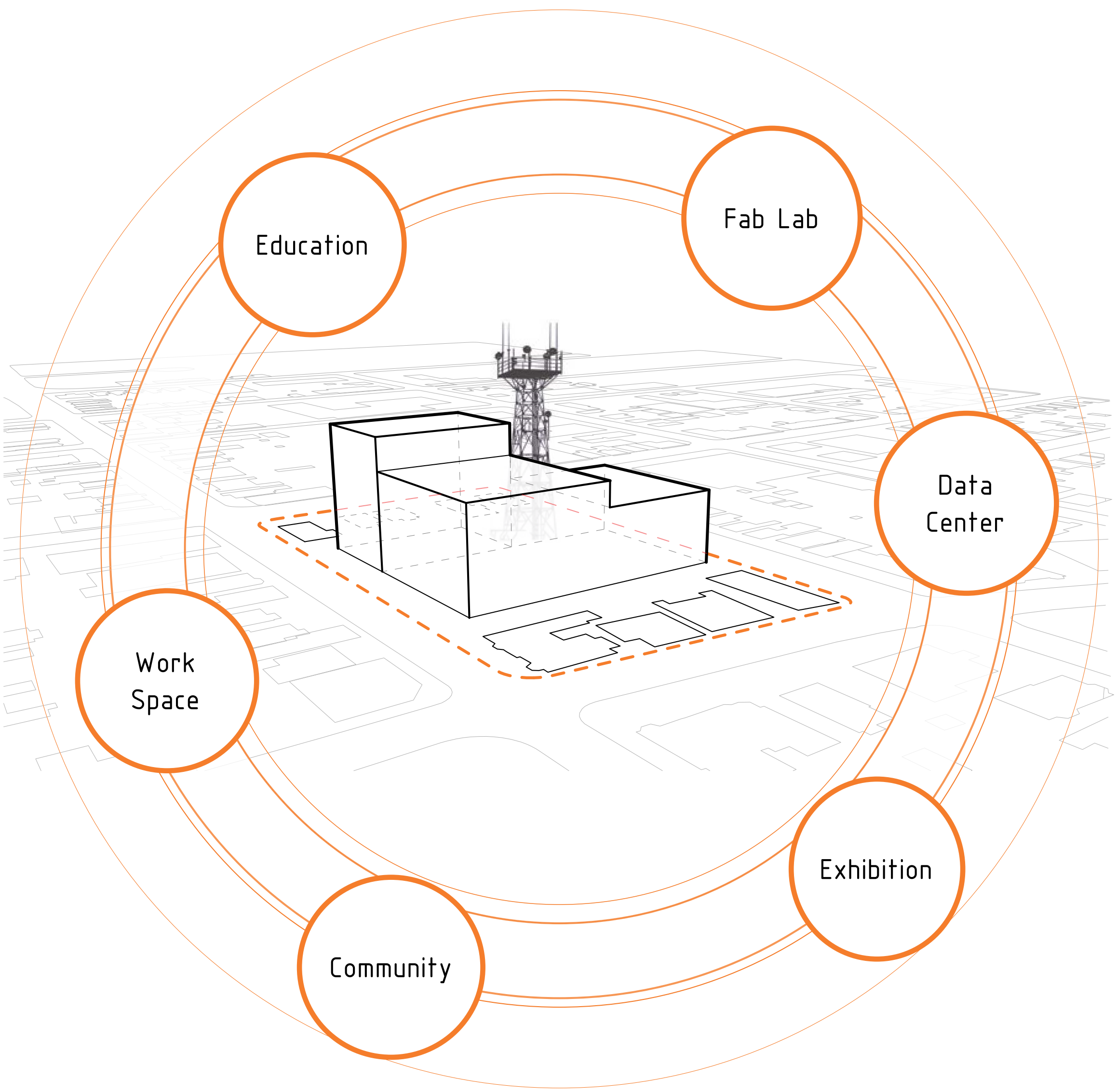


Image 10: Diagram showing program set (data from Nova Scotia Geomatics Center 2012)

Moving toward a definition of the methodology for siting the program set, a consideration is here made of the fact that digital manufacturing technologies are becoming more accessible to the general public. And, while this is true, the systems requirements for such equipment predicates the availability of a garage-type space within the home. A comparison between low and high density residential parking structures (the garage and the parking stall, respectively) reveals that while the primary parking and storage functions are met at both densities, the alternative functions of the garage as a loud space, work shop, or a place to start a small business are not available in the urban core (see Image 11 and Image 12).

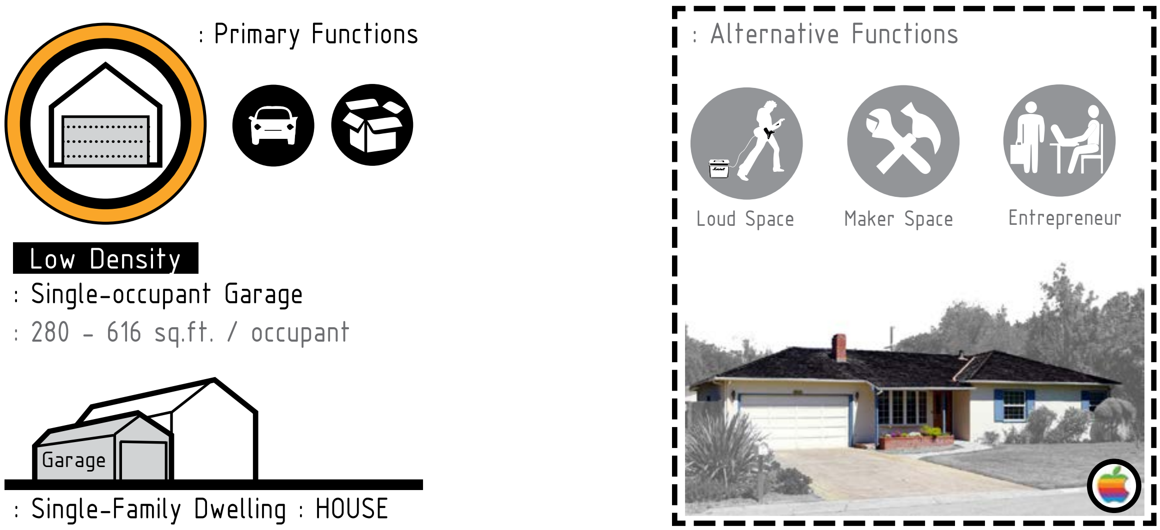


Image 11: Diagram representing primary and alternate functions of low density residential garage. Image of garage shows the example of where Apple Computers was founded (Caulfield 2012)

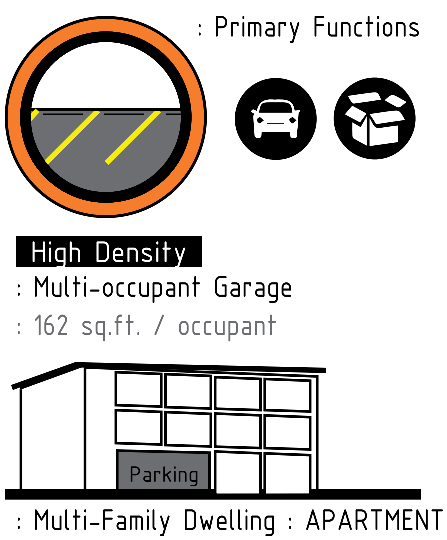
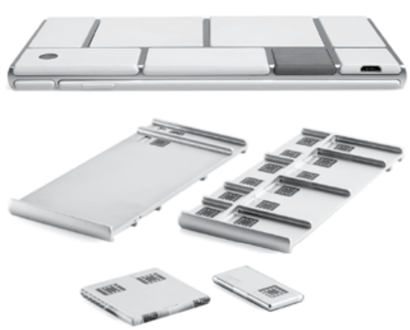
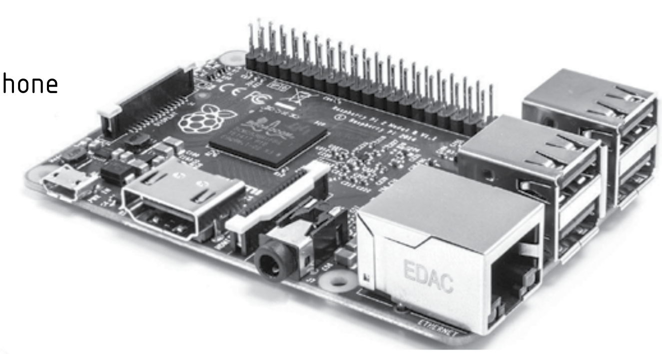


Image 12: Diagram representing primary functions of high density residential garage.

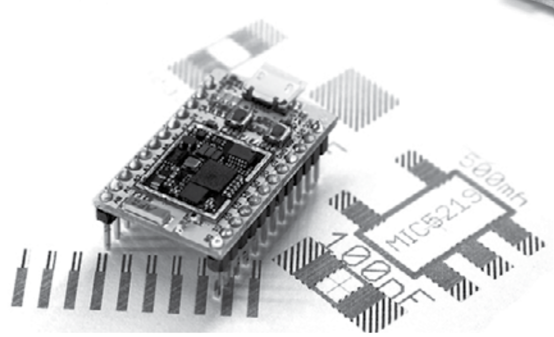
The design focus of this thesis will be on the development of a prototype Fab Lab that will respond to the indeterminacy of digital infrastructure. The prototype is designed to adapt to the environmental and urban conditions of site, the changing programmatic needs of the Fabrication Laboratory, and the inevitable building-system upgrades that will affect this typology. In approaching this design challenge, influence is drawn from the existing model of component-based, open-architecture that is common to the development of digital hardware. This model is designed on a principle of flexible and upgradable components that are plugged-into, and systemically supported by, a universal manifold. The tectonic expression of objects designed with this approach - such as the Google Modular Phone (see Image 13) - become derivative of the speeds by which the technologies are changed. This component-based, systemic approach to design is herein utilized for the development of the Fabrication Laboratory prototype.



google's modular component-based phone



open-architecture printed circuit board



component-based open-architecture approach

Image 13: Examples of a component-based open architecture approach in computer hardware development. Top image shows Google's modular phone (ProjectAra 2014), middle image shows Raspberry microcontroller (Raspberry Pi 2015), and the bottom image shows a computational hardware component developed by Spark IO (Supalla 2014).

The fitness of the prototype developed with this methodology is then tested through its application to a site in Halifax, Nova Scotia. The site for Beta testing the prototype is located on the existing parking lot of the Robie Street Data Center. This is a predominantly residential neighborhood, with light-commercial along the ground level areas of Robie Street and Agricola Street. The proposal inserts the cultural programs of the Fab Lab, Education Space, Work Space and Exhibition Space to the existing Data Center program. In using the principles of a component-based, systemic approach for the development of an architectural prototype for digital infrastructure, this thesis seeks to align ephemeral virtual perceptions with the physical infrastructure that supports its operation.

Image 14: Axonometric drawing of North Street data center, showing location of the Proto_Site. (data from Nova Scotia Geomatics Center 2012)

1.1 Hardware: Digital Infrastructure

1.1.1 Digital Infrastructure History

Today, cities are blanketed with a seemingly invisible 'cloud' of wireless networks, connecting individuals to the people and information of the world (see Image 15). These are fluidly dynamic systems, with an endless stream of software updates, hardware upgrades and wave after wave of innovative posturing. Mark Shepard refers to this as an age 'ubiquitous computing' (Shepard 2011, 14), wherein everything from cities, buildings, cell phones, and refrigerators are connected into the digital network. While it may be enticing to focus entirely on the here and now, Antoine Picon cautions against the temptation to only look at the present (Picon 2010, 16). Suggesting instead that the roots of an information-based society can be traced back throughout human history.

As an example, communication infrastructure has long impacted the shape and organization of the city as a means of distance based information exchange. Beginning thousands of years ago with the use of smoke signals and drums, as an early form of optical and ocular telegraphy, to peer-to-peer human or pigeon couriers, and the purpose-built construction of the semaphore network originating in ancient Greece (see Image 16), the progression of information exchanged dramatically changed with the invention of electricity. Electrical systems afforded the invention of the electric telegraph in 1838, that led to a massive global undertaking for the construction of underwater cable systems in the mid 1800's (see Image 17). This electrical telegraph cable network connected the world with previously unfathomable speed, spreading information and knowledge that would unify a global culture.

Image 15: Radio telescope (Wallpaper Vortex 2014)

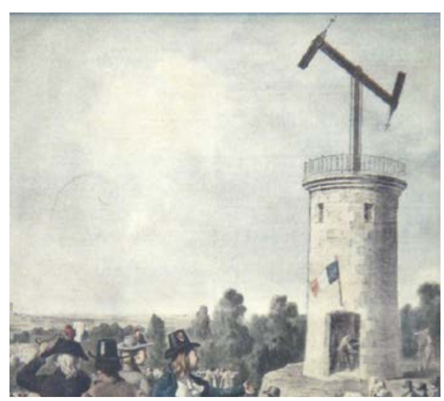


Image 16: Painting by unknown author, *Chappe Semaphore*, 1793 (Wikimedia 2015)

Image 17: Underwater telegraph cables throughout the world in 1901. (International Telegraph Bureau 1901)

The original underwater telegraph network has been superseded with a submarine fiber optic cable network (see Image 18), and these wired telegraph networks have laid the groundwork for the advancement of the wireless communication technology that has become synonymous with the current global communication networks. With the advent of the computer in the mid 20th century, and the invention of the internet in 1969, global communication systems have quickly moved from the analog to the digital. With the computer at the helm of the communication infrastructure, the networks that once simply broadcast, were now capable of transmitting, storing and processing information all at once.

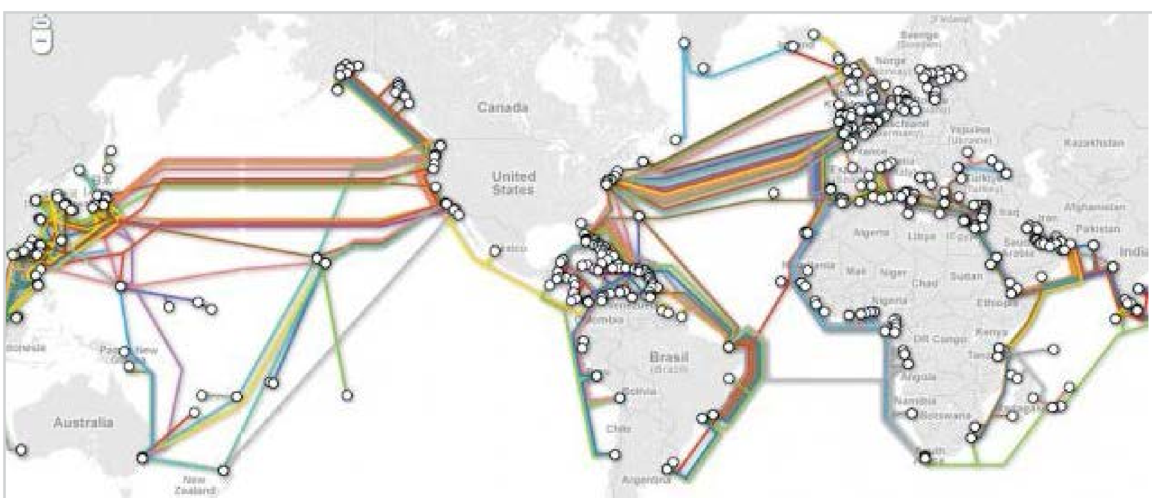


Image 18: Submarine fiber optic cable network in 2014. (Telegraphy Submarine Cable Maps 2015)

In the beginning, the digital networks had little impact on architecture. The internet existed in the form of a distributed network of computers terminals connected directly to other computer terminals via telephone lines. Apart from an increased electrical load on a building, there was no significant impact on the architecture. Since the widespread proliferation of the internet between 1980 – 1990, the need to store digital information has grown exponentially, leading to the introduction of rooms dedicated to this purpose. These server rooms have specific climatic requirements, but had not significantly impacted the architectural language. Then, in the early 1990's, due to the continuous growth in storage needs, the server room was transitioned into a purpose-built server building, and the data center was born. (see Image 19)

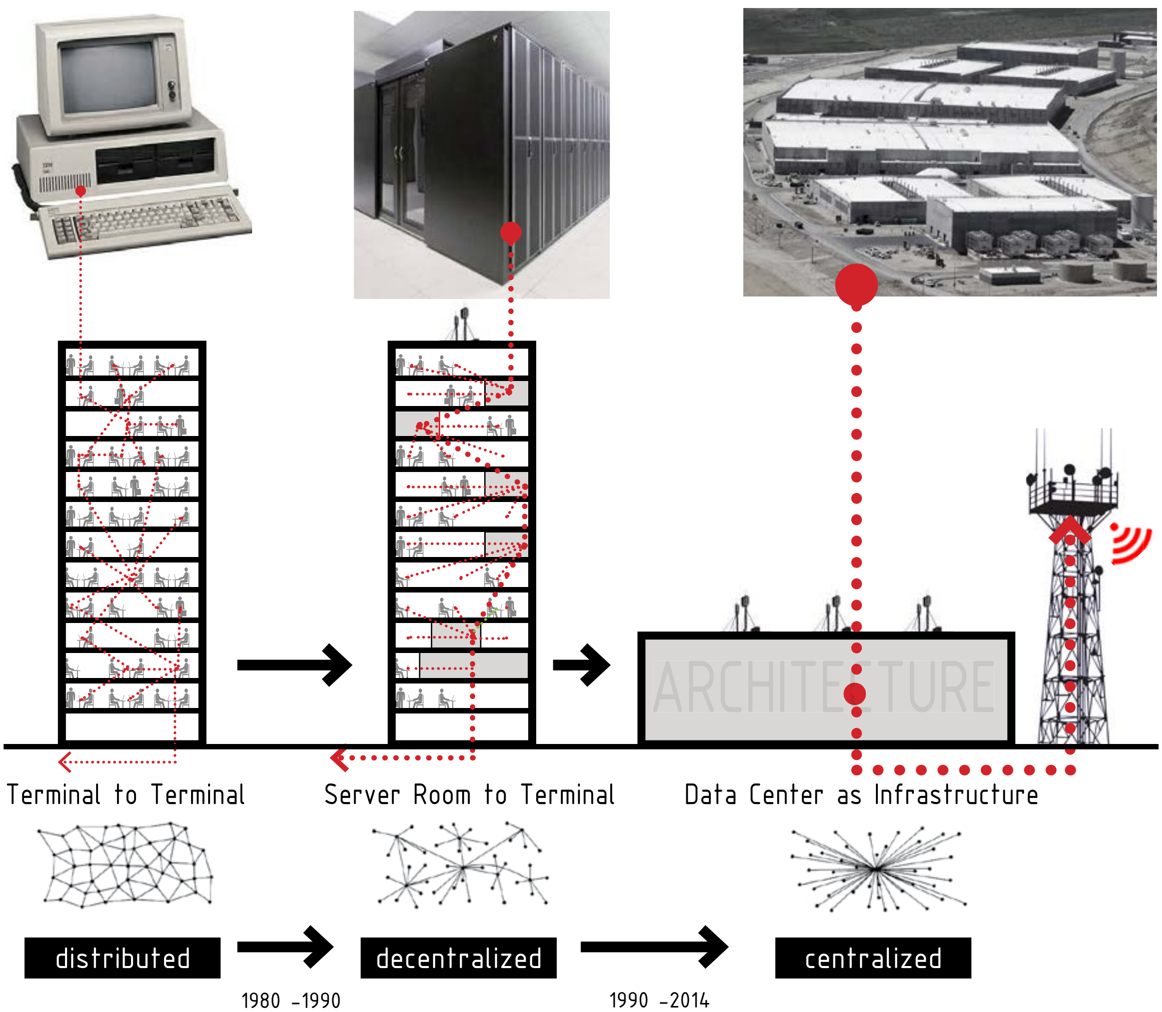


Image 19: Photographs representing the physical stages of evolution in digital infrastructure and diagrams showing the impact on architecture. The image on the left is an example of the IBM 5150 (Hardwidge 2012), representing terminal to terminal connections between computers. A stage that has little impact on the architecture. The middle image shows a typical server room (Soft 2009), that begins to alter the program of buildings. The right image shows the Utah NSA Data Center (Bowmer 2013), an example of the transformation of information into architecture.

1.1.2 Digital Reality: Physical Impact of Digital Infrastructure

> The networks … are less immediately perceptible than traditional objects. … A wireless network needs for instance computers or cell phones to become fully present to its user. (Picon 2010, 119)

Today there are over 3350 data centers in 103 countries worldwide (see Image 20). In 2012 they were reportedly accountable for 30 billion watts of electrical usage annually, roughly equal to the output of 30 nuclear power plants (Glanz 2012). While it is relatively easy to obtain this broad stroke information on data center power consumption, it is very difficult to obtain a clear picture of the consumption of specific facilities. Most data center operators are unwilling to report on their power usage, as the technology within the facilities is highly secretive in a competitive market, and they fear that with hard data their competitors would be able to reverse engineer their systems. Regardless of the trade secrecy, current projections predict that this global energy output for data centers will triple by 2020, so as to satisfy our cultures ever increasing appetite for data (May 2012, 55). This is an incredible outlay of resources for a building typology commonly referred to as a 'cloud computing' facility; a marketing nomenclature that obfuscates the truth of the physical impact of data centers.

Within the Data Center typology the energy inputs are allocated towards two main functions. Primarily, the energy is used to run the equipment, and secondarily to cool the facility (see Image 03). Data center efficiencies are based on their Power Usage Effectiveness (PUE), which is the ratio of the total facility power draw, divided by the power used to operate the IT equipment (May 2012, 60). Subsequently, the goal for these facilities is to operate at a PUE of 1.00. This is to say that for each watt of energy used to run the equipment, the facility will require one watt of energy to maintain climatic conditions. With this in mind, the two main considerations for a potential data center site are the proximity to a continuously reliable energy source, and the availability of free natural cooling. For free cooling, proximity to a large body of water such as the ocean, and naturally cool air as is characteristic of northern climates, are preferable.

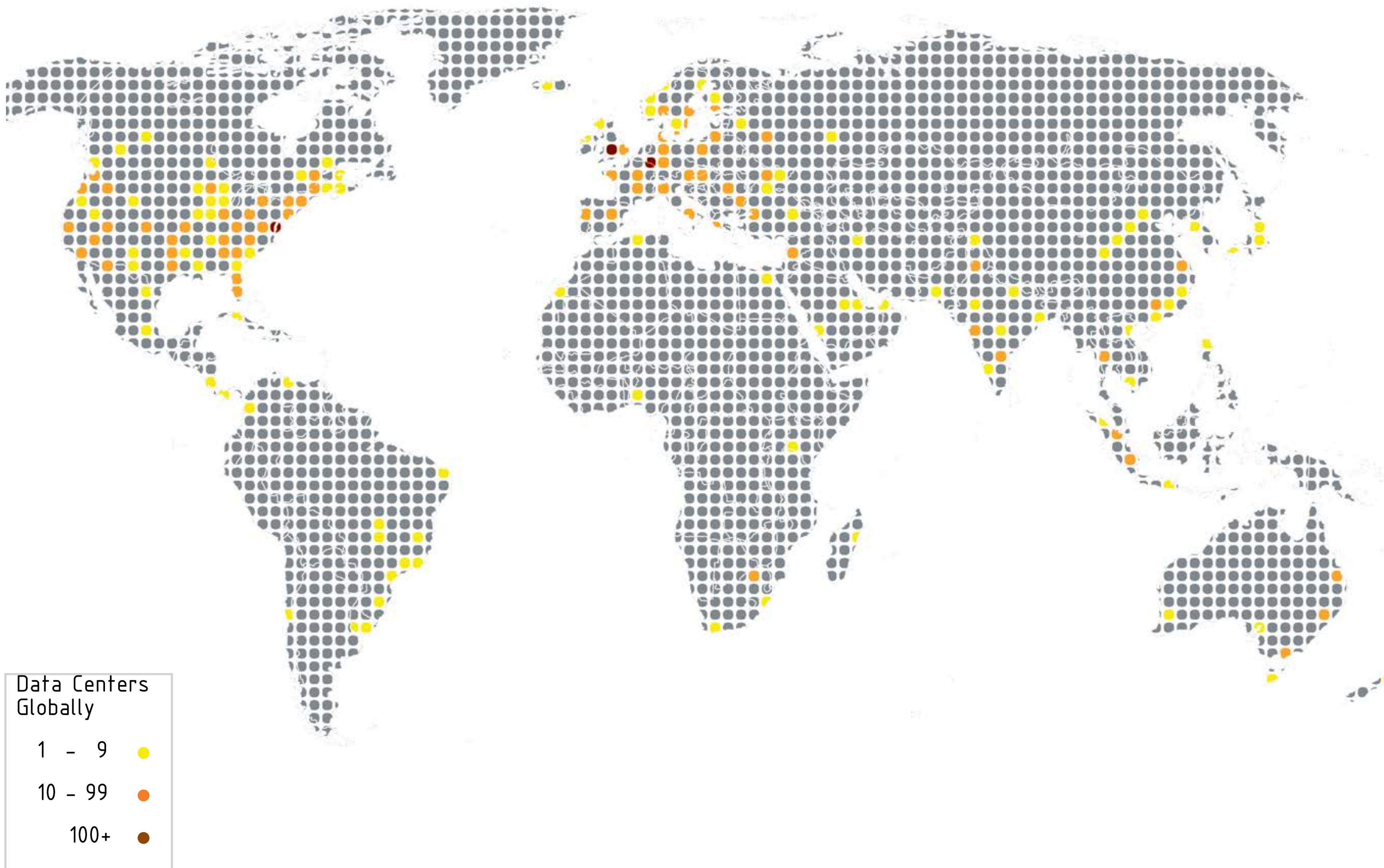


Image 20: Infographic showing distribution of colocation data centers worldwide (data based on Data Center Map 2014)

Image 21: Dresden Row Data Center in Halifax, Nova Scotia. (Google Maps 2014d)

Image 22: Dresden Row Data Center in Halifax, Nova Scotia. (Google Maps 2014e)

Image 23: Dresden Row Data Center in Halifax, Nova Scotia. (Google Maps 2014f)

In Nova Scotia there are four data centers, with two on the peninsula in Halifax. One facility is on North Street, between Robie Street and Agricola Street (see Image 04 on page 3). The other is located on Dresden Row (see Image 21 to Image 23). These buildings are materially heavy (made from brick and concrete), closed-off from public access, and - especially in the case of the North Street data center - totally lacking a human-scaled haptic expression. Architecturally speaking, they are of the same aesthetic language as the AT&T Long Lines building, at 33 Thomas Street in Lower Manhattan (see Image 24). Much like the North Street data center, the Long Lines building in New York was a former telephone switching station converted into a data center. In his essay in the book titled

Data Space (May 2012, 12), Jacob Reidel describes the formal traits of the Long Lines building as: "...unbroken blank facades, highly-secure perimeters, and the ability to operate off-the-grid (in the case of the Long Lines buildings, this was in order to allow the national long distance telephone network to continue operations in the event of a nuclear attack)" (May 2012, 13). Reidel suggests that these are the hallmark traits of most data centers, but questions the validity of this fortress-styled architectural expression as a representation of the physical embodiment of the digital 'cloud' system it contains.

The question of an architectural expression of the digital infrastructure is pervasive in this thesis. Herein, the goal is to align the outward physical expression of a building with the ephemera of the digital cultural functions occurring within.

Image 24: AT&T Long Lines Building, Manhattan (Green 2012)

1.1.3 Digital User Interface

> The digital has become indistinguishable from the deeply experiential. (Picon 2010,157)

In 1970 architectural theorist Nicholas Negroponte – the founder of MIT's Media Lab – published a prophetic book titled, The Architecture Machine (Negroponte 1970). At a time before ubiquitous computing, the internet, and the personal computer revolution, Negroponte was exploring the interrelationship between architecture and digital environments. Using simplistic versions of the contemporary computer, Negroponte accurately predicted many trajectories of the digital revolution. A predominant early focus in their work was the development of a common language between people and computers. Drawing influence from interactions between people travelling to foreign lands, wherein the language barrier creates communication challenges. Negroponte noted that in these settings people would rely on hand gestures and facial expressions to bridge the language gap (Negroponte 1970, 9). Subsequently, Negroponte postulated that the common language that would allow people and computers to interface would be gesture-based. Furthermore, his saw the one-way interfacing (people to computers, not computers to people) as limited, and worked towards an intelligent machine that could observe and interface with the user.

One of the early experimental installations Negroponte and the Media Lab completed at MIT was the self-organizing, behavioural-sensing environment installation titled 'Seek' (1970) (see Image 25). Within the Seek installation, an collection of cube modules was created as an environment for gerbils. As the gerbils interacted with the environment, the computer would observe and record behaviour patterns using a series of sensors. A robotic arm would then move the cube modules to morph the space, adapting as a result of gerbil interaction. Despite the work bordering on the esoteric, the reciprocal sensor/response interface between living organisms, environment, and computers would lay the groundwork for architectural work that would follow in the years to come.

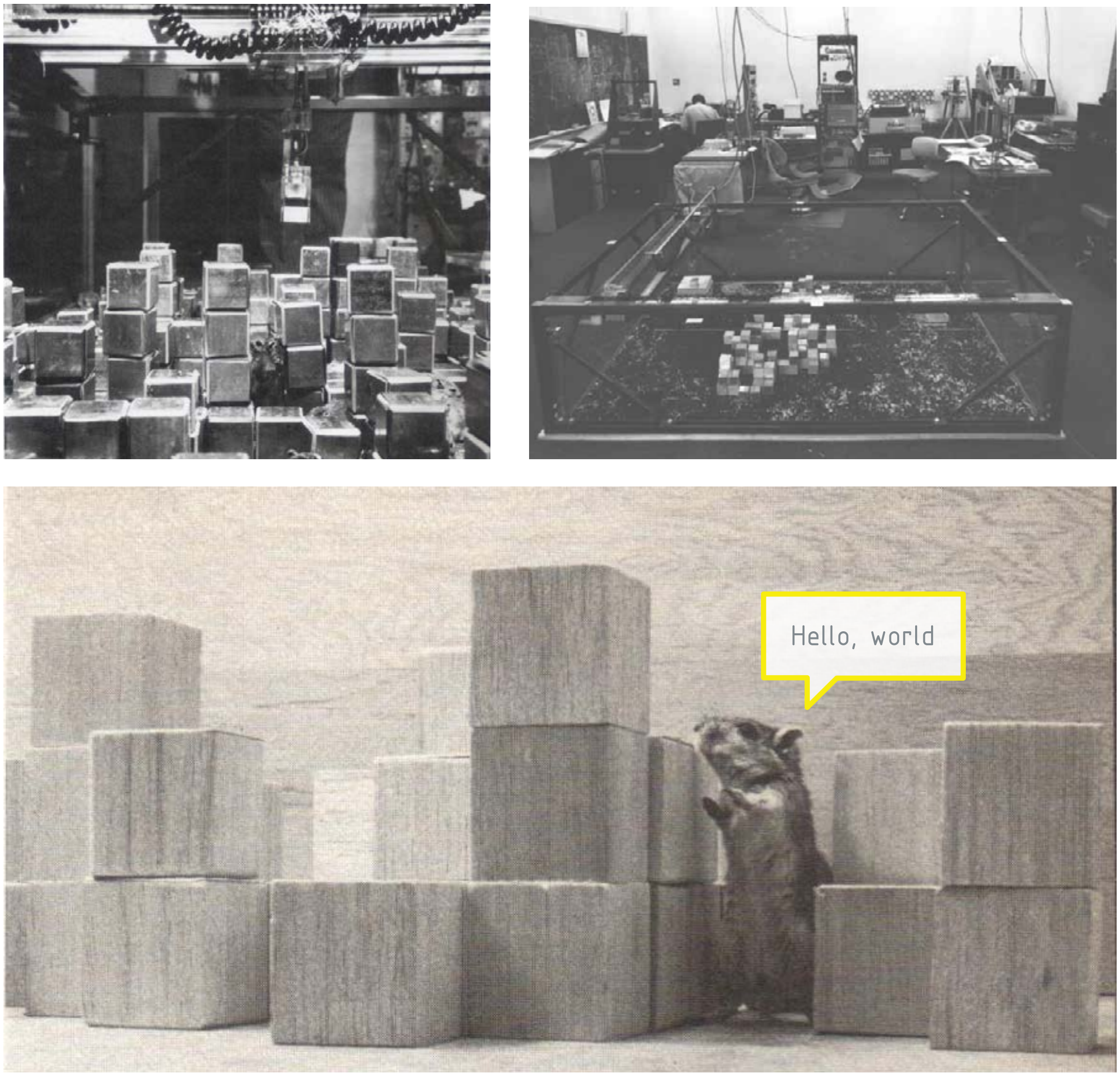


Image 25: Images of Nicholas Negroponte's self-organizing, behavioural-sensing environment installation titled 'Seek', exhibited at the New York City Jewish museum in 1970. (Hoggett 2010)

Today the tangible connection to digital networks come in the form of the devices used to plug-in to the system. These are computers, cell phones and other smart devices. Antoine Picon speaks about this relationship, suggesting that only through interaction with the aforementioned devices, will the wireless network becomes apparent to the user (Picon 2010, 119). This suggests that the digital network is made physical by user interaction. Thereby, if digital environments are to be made tangible in the physical environment through the medium of architecture, then the architecture must be interactive.

Image 26: Images of the Bloomberg Interactive Communication Experience installation in Tokyo, by Klien Dytham Architecture. (Klien Dytham Architecture 2009)

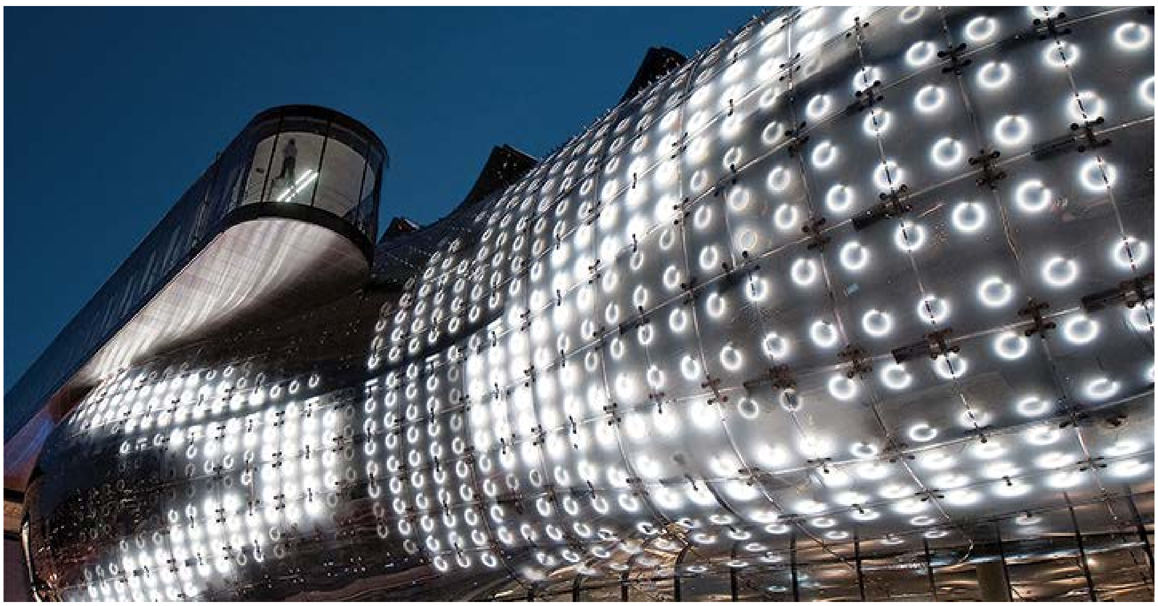


Image 27: Images of Kunsthaus Graz, center for contemporary art in Graz, Austria by Peter Cook and Colin Fournier (Cook and Fournier 2003)

This type of interaction has been explored in various forms by architects since the early iterations done by Negroponte and the MIT Media Lab. In Image 26 and Image 27 two such examples are shown. The Images above are from an exhibition in Tokyo, by Klein Dytham Architecture. The installation is an example of sensor/response characteristics that translate gestural movements into a light response on the screen wall pictured. Below is a more formally architectural example by Peter Cook in Graz, Austria. This facade is designed to act as an urban screen for the display for artistic productions. This thesis explores this dialog using building systems that integrate a sensor/response interface between digital and physical environments.

1.2 Software: Digital Programming

1.2.1 Digital Perceptions: Virtual Ephemera

> Inside the computer is of course not inside myself, but it is not outside either… when I am sitting at a computer, I feel like I'm wading in the water's edge, that I am being linked with another world. (Ito 2011, 118-119)

Virtual environments hold an elusive quality of fluid indeterminism in the collective imagination. Perceptions of boundary, scale, tectonics, and materiality are dramatically different than those in the physical world. For every second that passes in natural time, 100 hours of video are posted to YouTube. Every square inch of the planet earth has been photographed from space, and we are now able to oscillate our mental position between astronaut view, and street view, zooming fluidly with the scroll of a mouse wheel, or a pinch of the fingers (depending on the use of touch screens),for nearly every city on the planet. Scales of time and distance in a computer environment become hyper-versions of their physical counterparts. Antoine Picon extends this idea into the architectural realm, observing that in this exaggerated computer environment forms appear to: "… float without definite dimensions" (Picon 2010, 124). He goes on to suggest that our digitally enhanced viewpoint of the world gives rise to a cultural context for the reception of architecture that blurs the lines of scale and dimension. Picon cites projects such as Renzo Piano's Kansai Airport (see Image 28 and Image 29) as exemplary of an architecture that blurs the lines of scale. François Roche's firm R&Sie(n) explores architecture in a similar manner. Their theoretical project titled "I've Heard About", and their installation titled 'Hypnosis Chamber' are rendered so as not to reveal the exact scale (see Image 30 - Image 31). This thesis draws influence from the digital perception towards an expression of architecture.

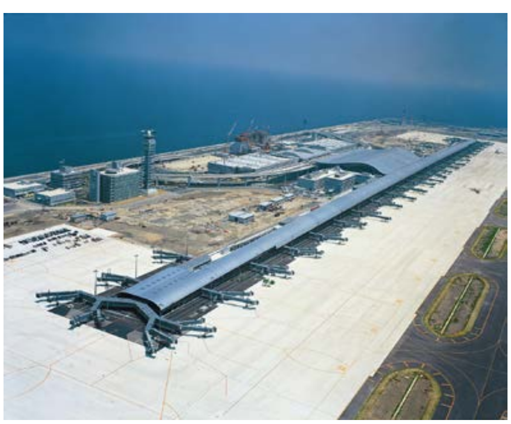


Image 28: Images of Kansai Airport by Renzo Piano. (Kamon 2011)

Image 29: Kansai Airport by Renzo Piano (Kansai-international-airport 2015)

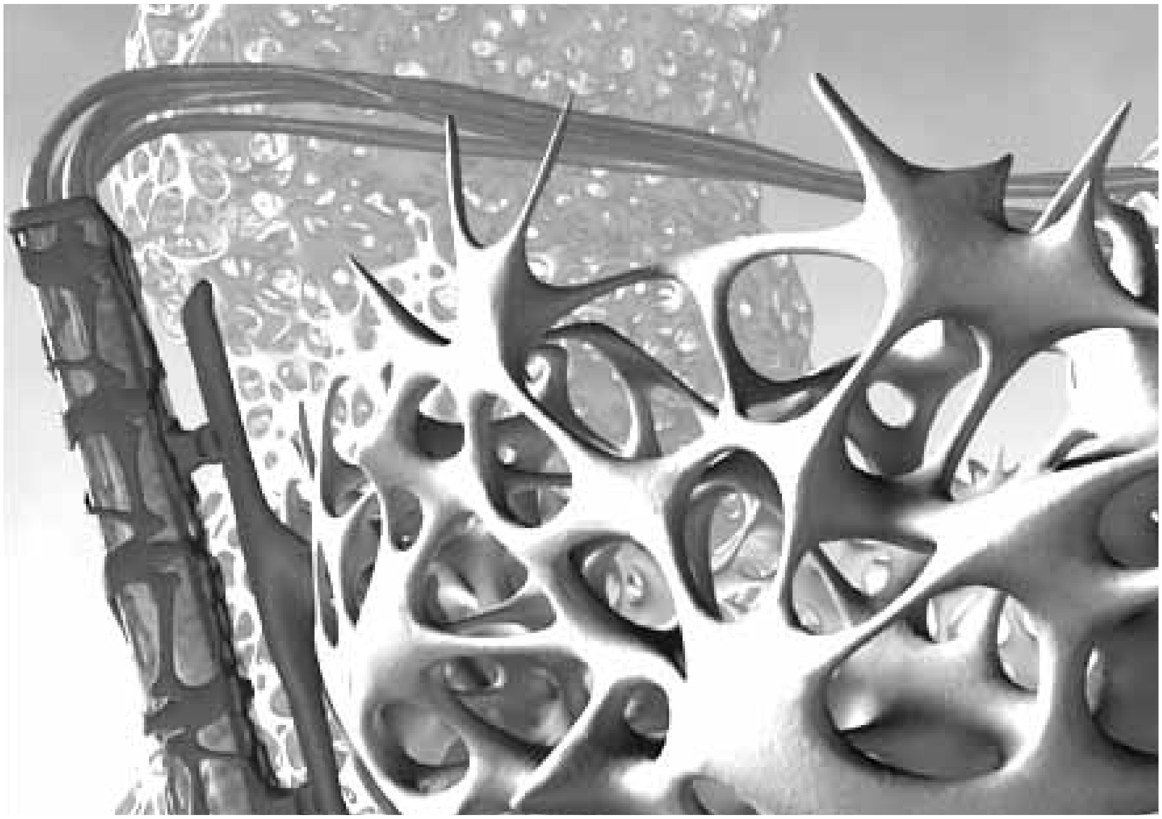


Image 30: Rendering of 'I've Heard About' project by R&Sie(n) and Benoit Durandin (R&Sie(n) and Durandin 2006)

Image 31: Rendering of 'Hypnosis Chamber' project by R&Sie(n) and Benoit Durandin (R&Sie(n) and Durandin 2005)

1.2.2 Fab Lab: Idea to Actualization

> Coupling employs interventions that also operate extrinsically, sometimes at a territorial scale. Easily replaced or upgraded, these infrastructures double as landscape life support, creating new sites for production and recreation. (Bhatia et al. 2009, 9)

Fabrication Laboratories, or Fab Labs, were first conceptualized at the Massachusetts Institute of Technologies (MIT) Center for Bits and Atoms by Neil Gershenfeld in 2001, as an outreach project to provide the means of creating widespread access to digital production methods. Initially coupled with a grassroots group, the Fab Lab project facilitated the implementation of digital manufacturing technologies across the globe. These facilities contain flexible manufacturing equipment such as laser cutters, CNC machines, rapid prototypers (3D printers), printed circuit board milling and microprocessor design, assembly and testing stations. Today there are over 450 Fab Labs worldwide, with a mere six facilities in Canada (see Image 32).

Neil Gershenfeld describes the impact of this ongoing project, as fostering "personal expression with technology", and as "locally developing solutions to local problems" (Gershenfeld 2006). Fab Labs blur the lines between digital and physical environments, and in doing so, provide the tools to develop digital ideas into physical realities. The introduction of a Fab Lab within the scope of the program for this thesis provides a space for direct and tangible engagement with digital environments within a community.

In Image 33, the program spaces are organized as an allegory from idea to actualization. Progressing from Idea Conceptualization, to Idea Refinement, to Idea Actualization, the program set is organized to foster a translation between the digital and the physical. Work spaces, educational spaces and exhibition spaces are added to the program set to supplement the development of the allegory between idea and actualization (see Image 34).

Collectively, these programs provide space in the urban center to both 'plug-in' to digital environments, as well as creating a new form of productive space. While places to collectively plug-in to the digital network already exist in the form of cafes and libraries, the publicly-accessible *productive* spaces in the city are limited.

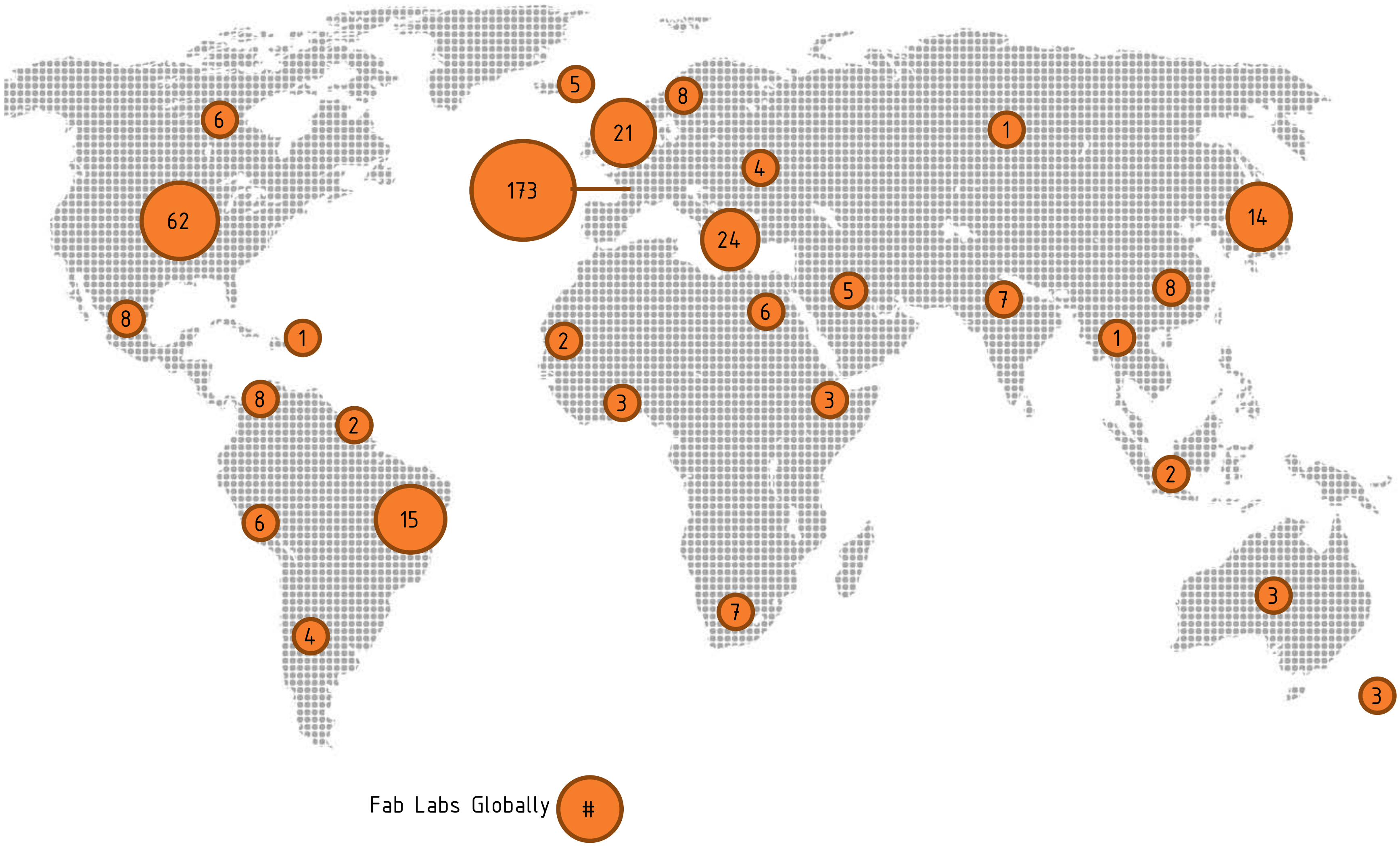


Image 32: Diagram depicting distribution of Fabrication Laboratories globally (MIT Center for Bits and Atoms 2014)

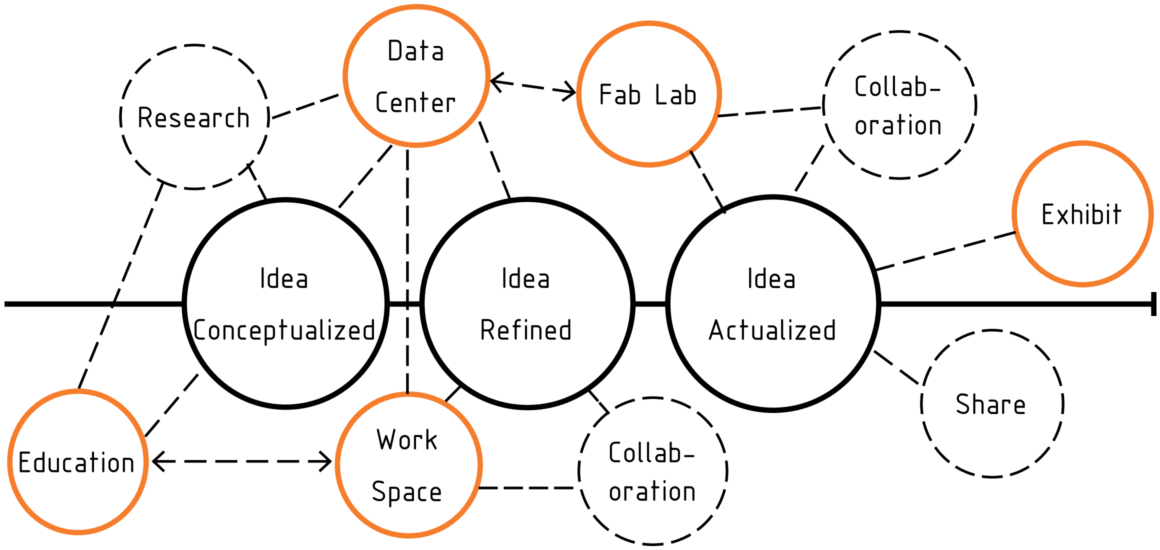


Image 33: Diagram depicting program spaces in relation to workflow between idea to actualization

Image 34: Images depicting program spatial characteristics. Fab. Lab. (Formlabs 2013), Data Center (Soft 2009), Work Space (Findlay 2012), Education (Diller Scofidio and Renfro Architects 2006), and Exhibition (Moxis Design 2011).

1.2.3 Urban Garage: Density and Cultural Production

> Computing is not about computers anymore. It is about living. (Negroponte 2014)

The inclusion of the Fab Lab to the thesis program-set elicits a number of considerations to the design. As this technology is becoming increasingly accessible to the general public, it calls into question the relevance of a typology dedicated to this program. Furthermore, the speed by which this technology changes sets flexible parameters on both the size of the program spaces, as well as the modifiability of the mechanical and electrical systems. To what extent the architecture will be made adaptable will be explored later in this thesis as a tectonic response to the program, but the first question will be addressed here as a question of site.

It is true that the technologies that comprise the Fab Lab are being made affordably available to the general public, and it would not be difficult to imagine a 3D printer in every home. However, laser cutters, or CNC milling machines are far less likely. The systematic requirements of these technologies (air handling, dust control, etc.) predicate the availability of a modifiable garage type space within the home. The garage typology presents a unique functionality that is not rendered equally across the varium of residential densities in a city. Which is to say, that while all garages have parking, not all parking spaces have the functionality of a garage.

In the case of the single-family dwelling, a garage provides the primary functions of parking and storage space, as well as the alternative functions of a loud space, maker space, or entrepreneurial space (see Image 11). In contrast, apartment buildings with parking stalls do not provide the alternative functions of the garage within the limitations of the shared garage space (see Image 12). Additionally, apartment living is commonly a compressed version of its single-family dwelling counterpart. Spaces within living units are typically smaller in apartment structures, and thereby less accommodating for bulky equipment.

It is telling that many of the companies that shaped the digital revolution were started in garages. The house in Image 11 was owned by Steve Wozniak, who built one of the first private computers and, with Steve Jobs, started Apple Computer within the garage pictured. Additionally, Google, Amazon, and Hewlett Packard can trace roots back to the garage. Musical groups such as Nirvana, Metallica and the Beatles were formed in garages. Product companies such as Mattel, or visual media 'imagineers' such as Walt Disney were founded in garages. The alternative functions of these often overlooked spaces serve a vital role for the messy, noisy and innovative creativity of a culture. This is especially true for youth culture, who crave individual spaces, but can rarely afford them (hence, garage bands). The manifestation of the garage in dense urban setting as a single-purpose car storage facility serves none of these alternative functions that have proven vital for cultural production.

Turning back to the original question of the validity of the Fab Lab typology in the city, it becomes evident through an analysis of density (see Image 35) as related to garage typologies, that the urban core is in need of publicly accessible creative, alternative space. Regardless of the technology used to manufacture, there is a pressing lack of noisy, messy, creative space in the urban center. This thesis will seek to remedy the perceived deficiency by defining this quality of space for the urban center of Halifax, so as to foster a creatively productive culture.

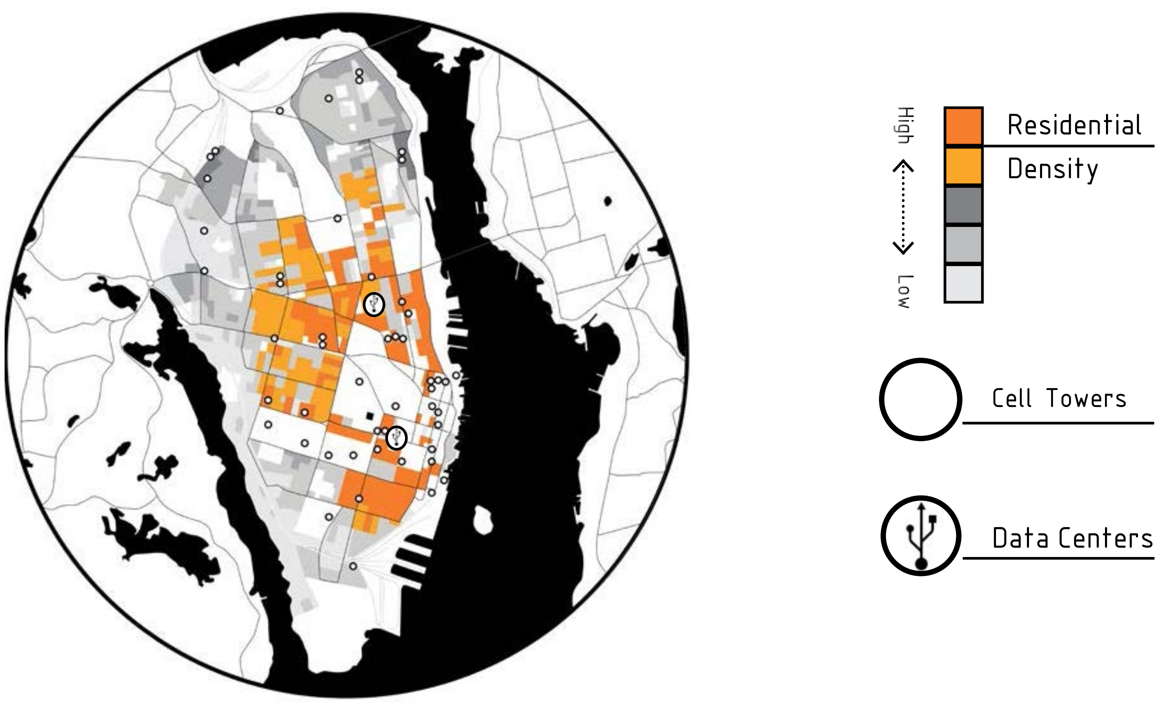


Image 35: Map comparing residential density to information infrastructure in Halifax, Nova Scotia (data from Nikkel 2014) (data from Data Center Map 2014) (data from Nova Scotia Geomatics Center 2012)

CHAPTER 2: DESIGN

2.1 Proto_Type: Designing for Indeterminacy

The design of a prototype for the Fabrication Laboratory, and the digital infrastructure typology in general, is challenged by indeterminacy at many scales. The speed by which the technology is changed presents a unique design parameter, wherein the spatial and service requirements are by necessity not fixed. Unlike the design for more traditionally conceived typologies such as residential, wherein the equipment – appliances, furniture, etc. - come in standard sizes that tipically vary within inches, the scale of variety in Fabrication Laboratory equipment is much greater. The typical piece of digital fabrication equipment - C.N.C. Machines, 3D Printers, etc. - come in widely variable scales, that not only vary in sizes measured by feet, but in their mechanical, and electrical system requirements (see Image 36 and Image 37). Furthermore, the spatial/system requirements for the fabrication equipment will change over time, as machines are upgraded, replaced or removed. For the Fabrication Laboratory prototype this is of particular importance. While a specific machine, and its resultant program space, may suit the needs of the users for a period of time, different quantities, types, and/or versions of machines may be required at some time during the life of the project.

This issue of indeterminacy associated with digital infrastructure is not a problem limited to architecture. Computer scientist have been addressing the issues of *change* and

Image 36: Other Machine Co. 'Othermill' desktop C.N.C. machine (Other Machine Co. 2015)

Image 37: Northwood Manufacturing Company 'FA1212FT' C.N.C. machine (Northwood Machine Manufacturing Company 2012)

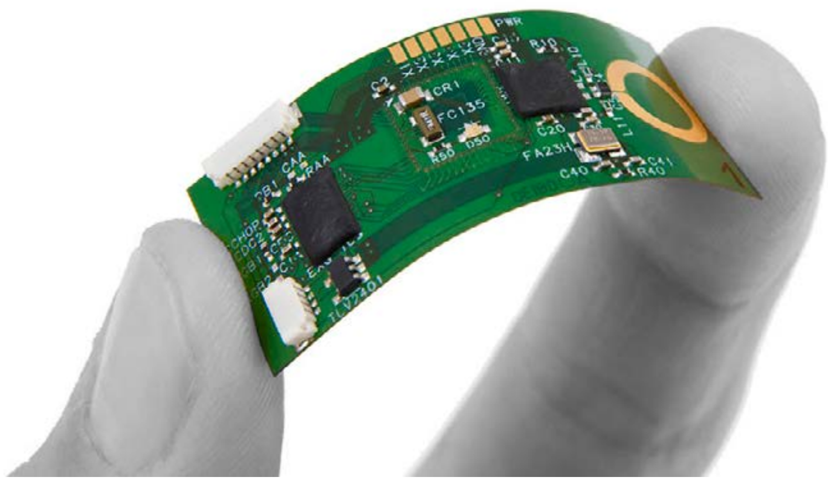


Image 38: Flexible printed circuit board (Flexible Printed Circuit Board 2015)

upgradeability as a foundational structure of computer hardware design for decades. An example of this can be seen in nearly every computer in use today, in the form of the printed circuit board. (see Image 38) The printed circuit board is a component-based piece of open-architecture, wherein the board is a multi-functional manifold for the support of many different parts of the computer. This manifold is designed to provide all the necessary mechanical, electrical and structural requirements of the respective parts that are plugged into its surface. Printed circuit boards are the backbone of modern computing, and the flexible functionality of this part serve as foundational design principle to this thesis.

Subsequently, the prototype design is conceived as a series of discrete, and interchangeable components that, when assembled, form the Fabrication Laboratory typology. For this, the components are categorized as the Support Systems (see Image 39: page 29), Programming Components (see Image 44: page 34), Responsive Tectonics (see Image 57: page 47), and Skin Performance (see Image 63: page 55). This hierarchical categorization of the Fabrication Laboratory typology into a system of components, serve as the design guidelines for the implementation of this typology onto a specific site.

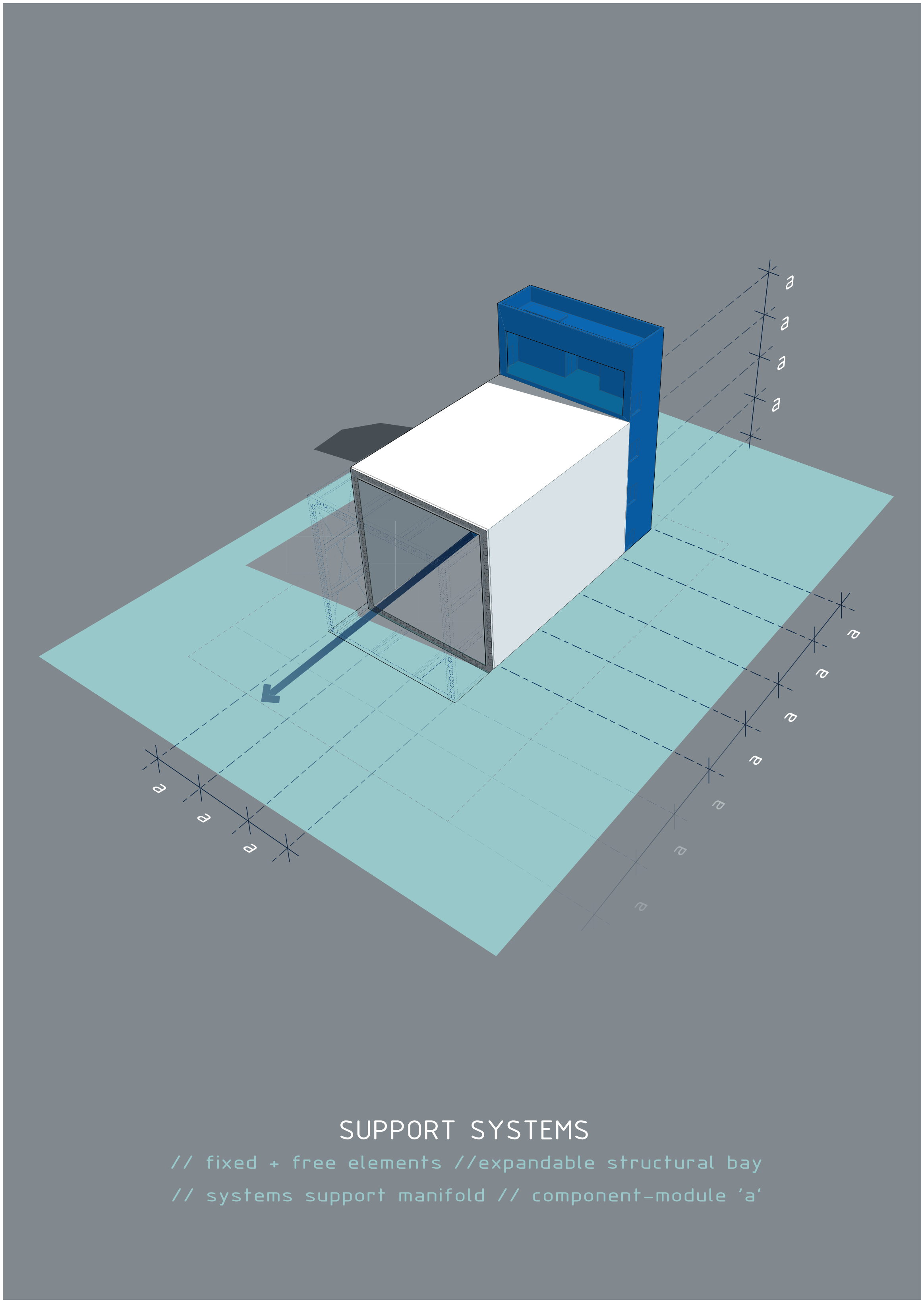


Image 39: Support systems diagram depicting the modular and expandable support manifold, and fixed service tower.

2.1.1 Support Systems

Utilizing the component-based, systemic principles of the printed circuit board, the design of the Fabrication Laboratory is centralized around the idea of an expandable support manifold. This manifold is the primary structural, mechanical and electrical support for the flexible and interchangeable, program modules, and the sensory/responsive outer skin components (see Image 39). All of the components that form the Fabrication Laboratory prototype system are connected to this support manifold in some way.

The manifold is designed as a linearly expandable structural bay system that provide the subsequent building components the structural, mechanical and electrical support required by each element (see Image 40). The structure of the manifold is perforated for the distribution of the mechanical and electrical systems (see Image 41), and designed to freely allow these systems to be upgraded throughout the life of the project. As an expandable structural bay, the size of the Fabrication Laboratory can be adjusted to suit the dimensions of a specific site. Furthermore, if a selected site can support expansion, the building can be made larger with the addition of more bays.

The form of the Structural Manifold, is a derived from an analysis of the Fab Lab program. For this, the program is separated into two categories; the fixed and the free (see Image 42). The free categorization of the program set denotes those programs that are expected to change over the life of the building, thus requiring the mechanical and electrical upgradability of the manifold. This set of programs are divided into two sub-categories, the light-industrial manufacturing program spaces (3d printers, C.N.C. machines, etc.), and the commercial and assembly public program spaces (gallery, offices, etc.). The manifold is formed to provide separation between these two sub-categories (see Image 43). Thus, creating a protected interior volume for the containment of the louder manufacturing spaces.

In contrast, the fixed program spaces include the permanent features of the building, such as the stairwells, washrooms, and elevators. To provide delineation between these spaces, the fixed program is organized into a support tower that is situated at one end of the manifold. This tower orients the growth of the project on its site, and serves as an access point for the upper leves of the program volumes (see Image 40).

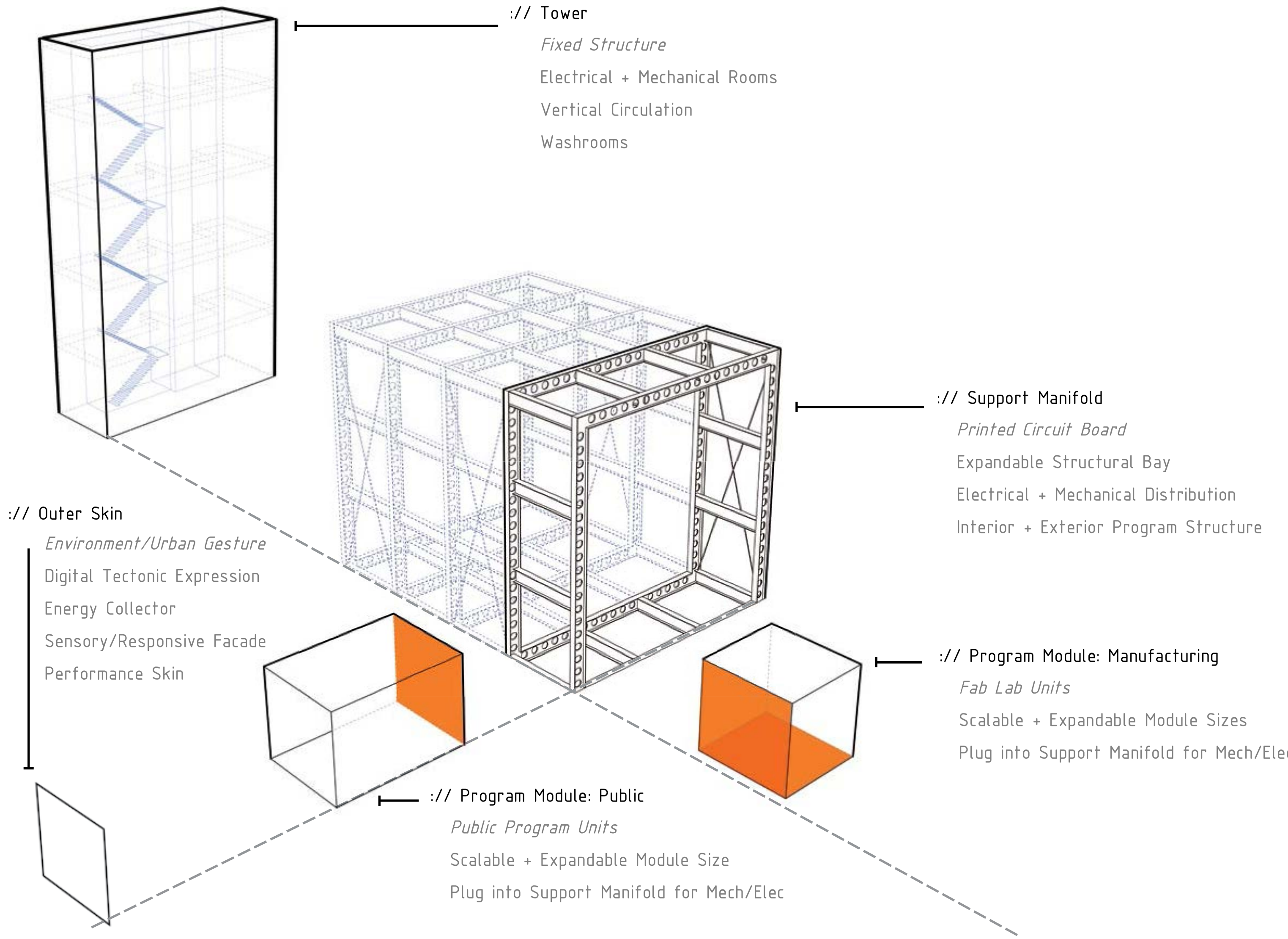


Image 40: Exploded axonometric drawing showing relationship between tower, support manifold, program modules and performance facade

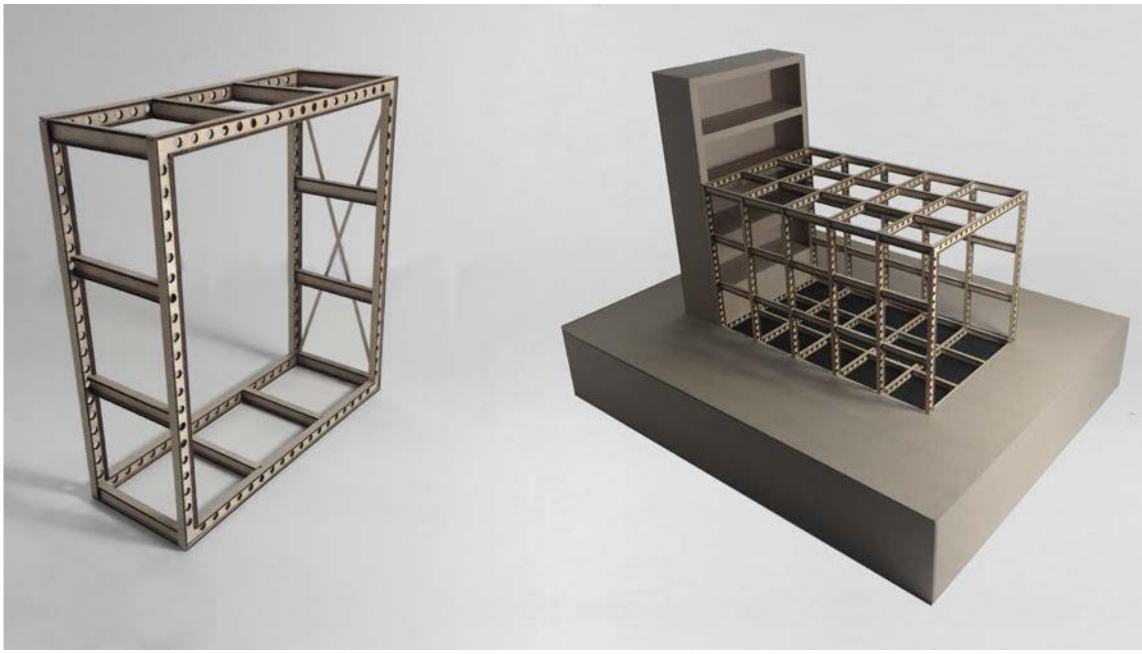


Image 41: Physical model showing the form and perforated structure of the support manifold, and expansion of the bay system.

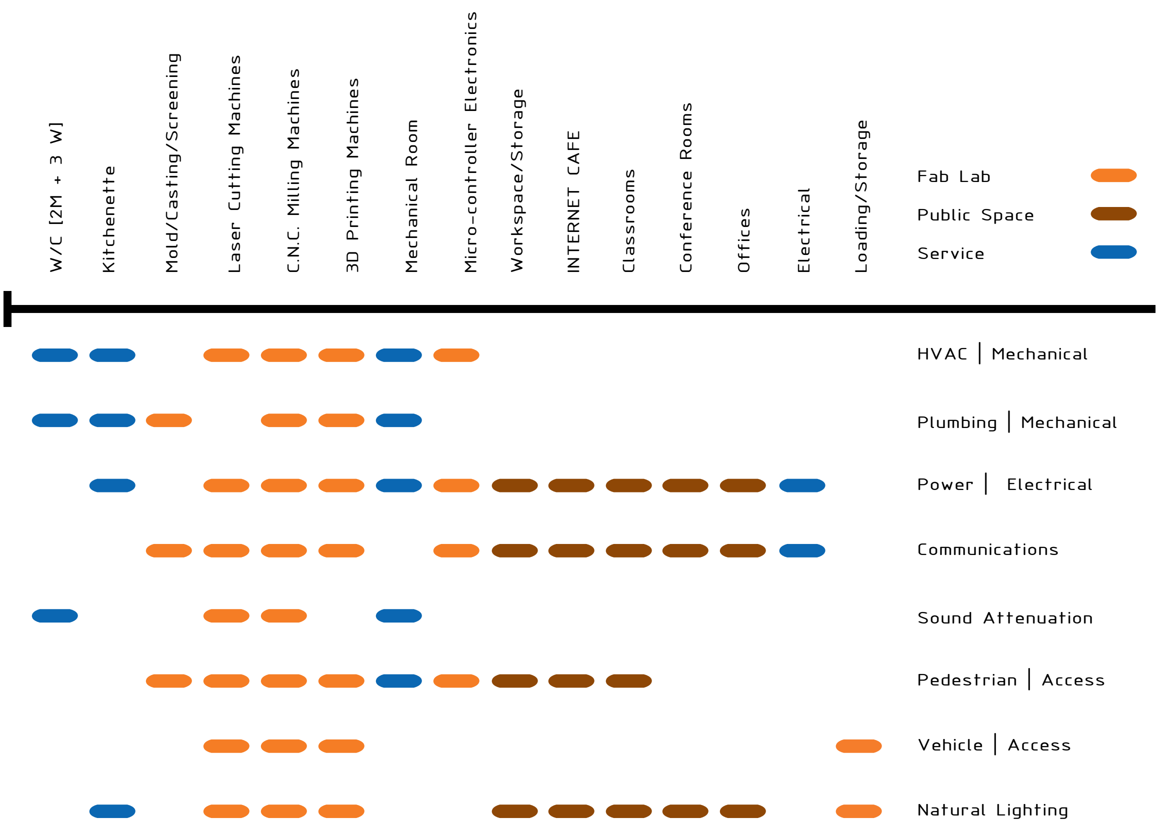


Image 42: Fixed and free program set requirements organized in terms of systemic requirements.

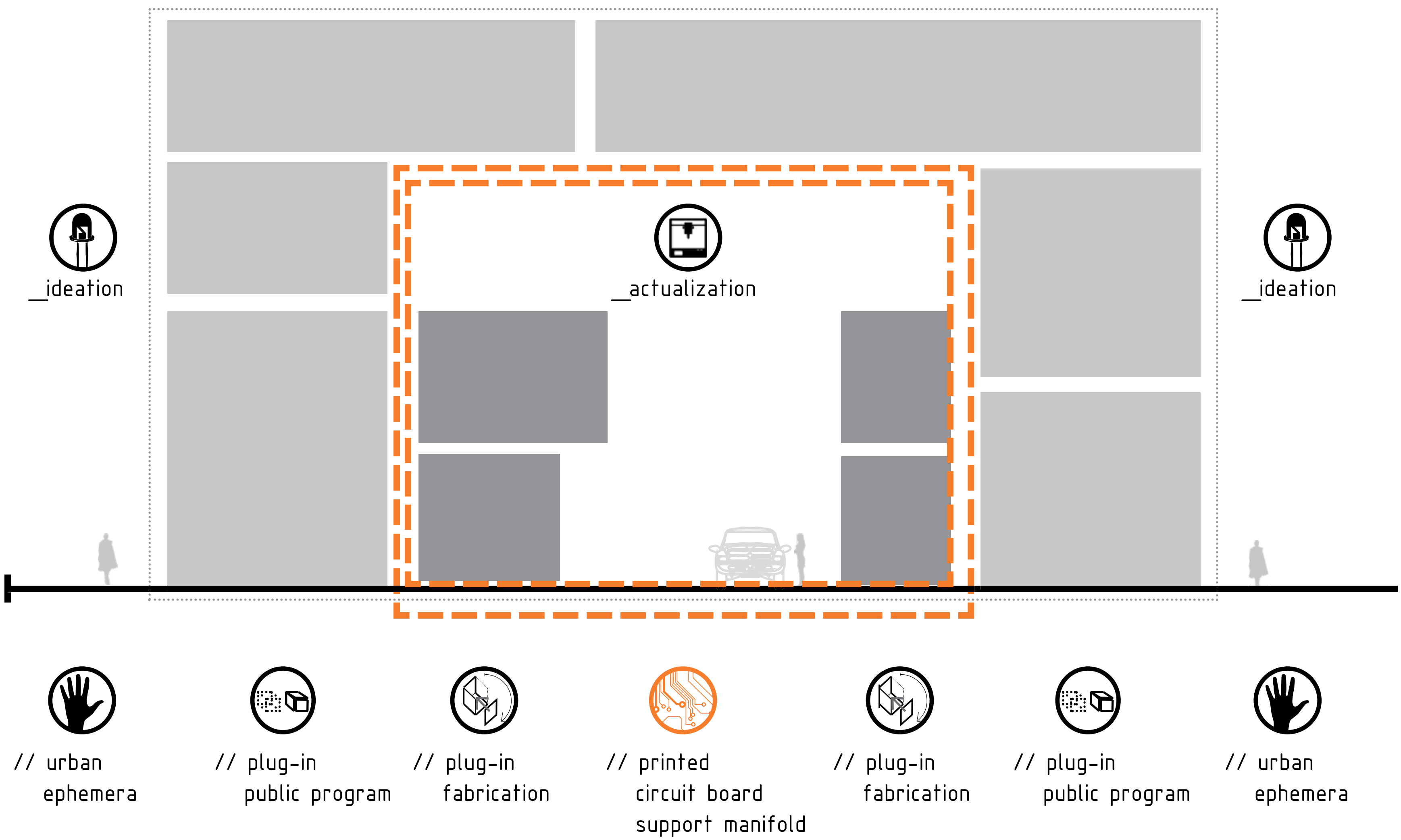


Image 43: Sectional diagram depicting relationship between support manifold and the public and manufacturing program spaces

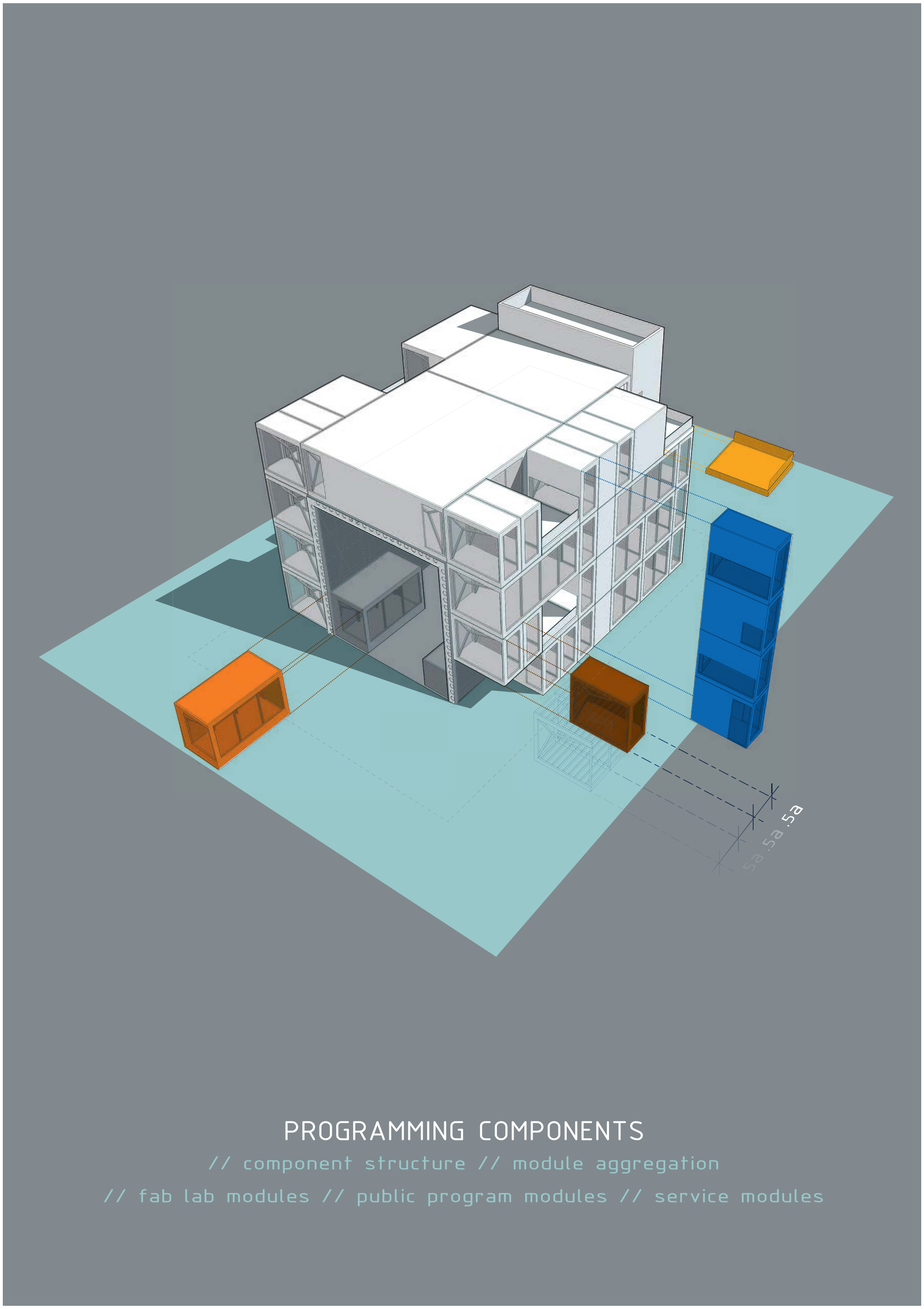


Image 44: Programming components diagram depicting the program modules in relation to the support manifold and tower. The module types, expandable structural system, and aggregation are highlighted.

2.1.2 Programming Components

Similar to the support manifold, the program modules are built on a repeatable structural component. This structure is designed as a light-weight truss that cantilever the program modules from support manifold (see Image 47). Unlike the manifold, the structural elements are used to form self-contained modules, rather than an open expandable bay (see Image 45 and Image 47). The dimension of the modules range from extra-small (10'-0") to extra-large (60'-0") (see Image 47). The modules are then aggregated on the surfaces of the manifold as dictated by site and programmatic requirements (see Image 44 and Image 46).

Program modules are classified into four types (see Image 47). The standard modules that can be scaled to fit the programmatic requirements of either the Fabrication Programs, and the public programs. The roof top modules, which vary in both width as well as depth; a variation that allows larger open spaces to be placed on the roof of the manifold. The open terrace modules that provide areas to engage with the outer skin at the upper levels of the building. The final module type is the service module, that provides stairwell and washroom services, additional to those provided in the fixed tower space. The last type becomes important when the support manifold is expanded, and the requirement for additional washroom and vertical circulation service space is necessitated (see Image 48).

One possible aggregation of the program modules is demonstrated in the floor plans shown in Image 49 to Image 53, and in the corresponding section shown in Image 54. Circulation between modules is located adjacent the face furthest from the manifold. This arrangement allows for the surface of the program modules that plugs-into the support manifold to utilize the mechanical and electrical services, as highlighted in orange on the plans and section.

As the interior of the support manifold is a light-industrial space, vehicular access is necessary. On the Ground Level floor plan (see Image 50) the central corridor of the Manufacturing Space is reserved for vehicular access, and an open workshop space. Image 55 shows a rendering of the interior of the Fab Lab, wherein the program modules are plugged into the support manifold, and the central corridor is used for the assembly of large scale projects. Image 56 shows an exterior rendering of the large garage-style doors that provide enclosure to the manifold, and vehicular access to the manufacturing space.

Image 45: Physical model of program modules showing varium of module sizes.

Image 46: Physical model of program modules showing one possible aggregation of the modules on the support manifold.

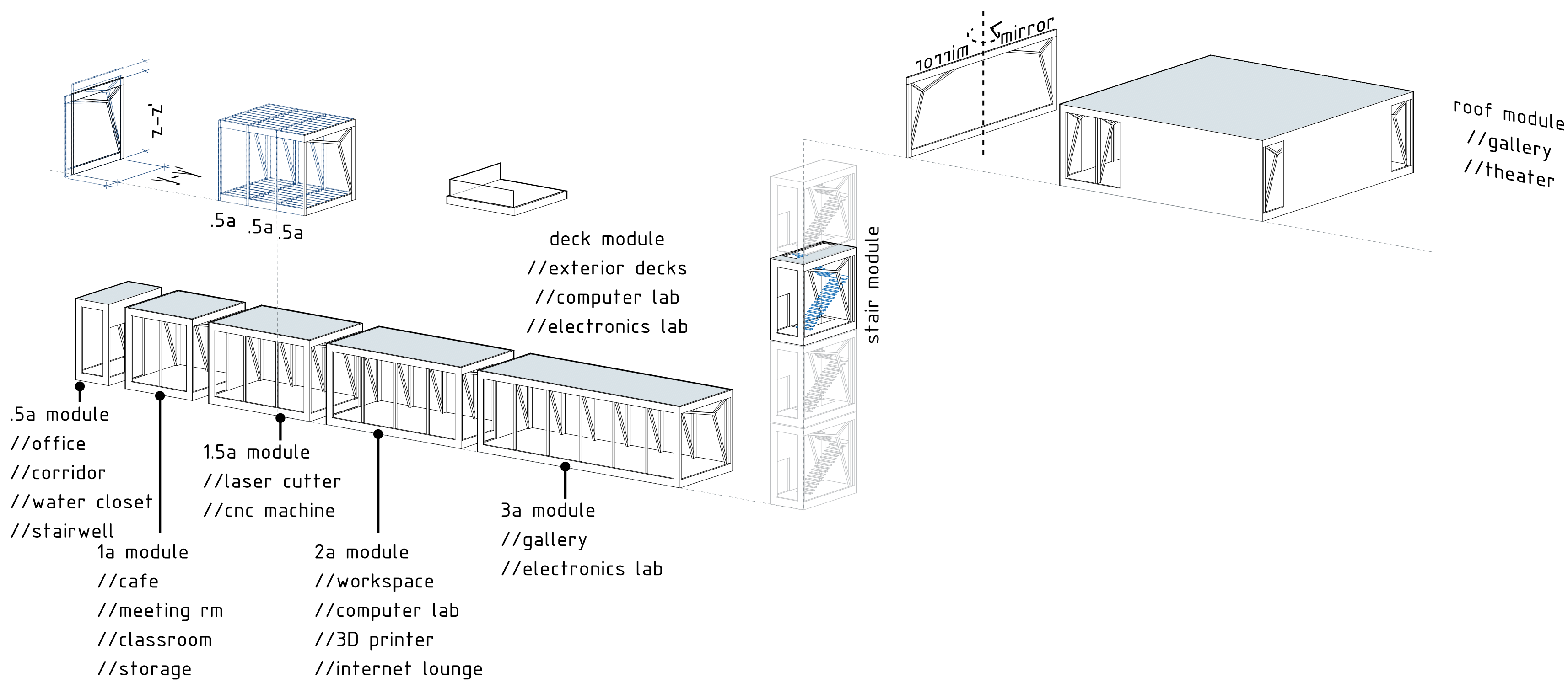


Image 47: Program module diagram depicting variation of form, aggregation, and program uses

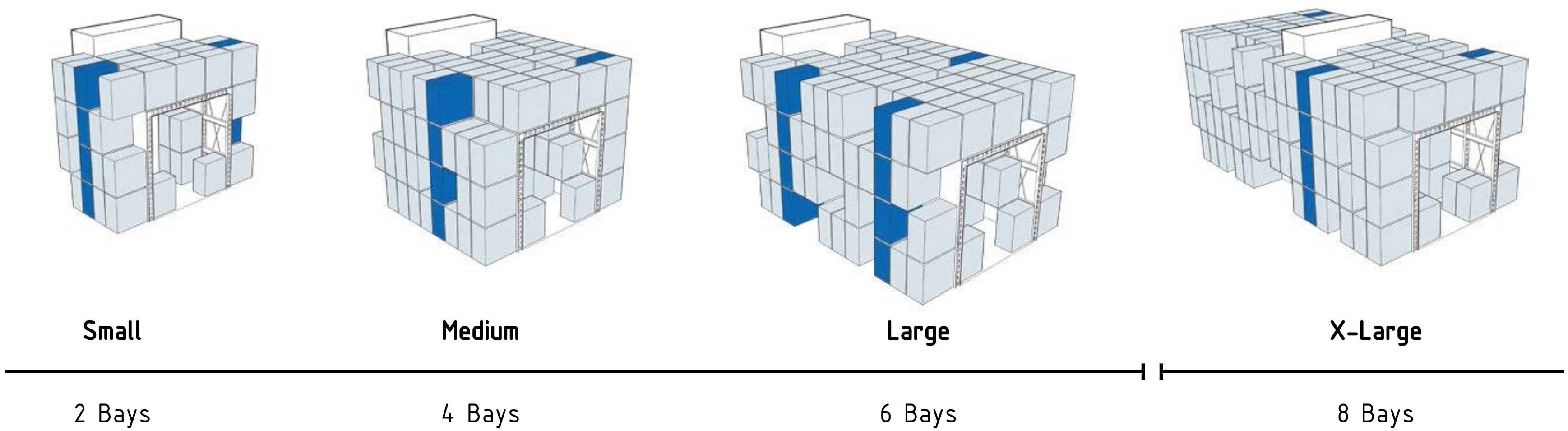


Image 48: Axonometric drawings showing growth of support manifold from small to extra large, with additional service program modules

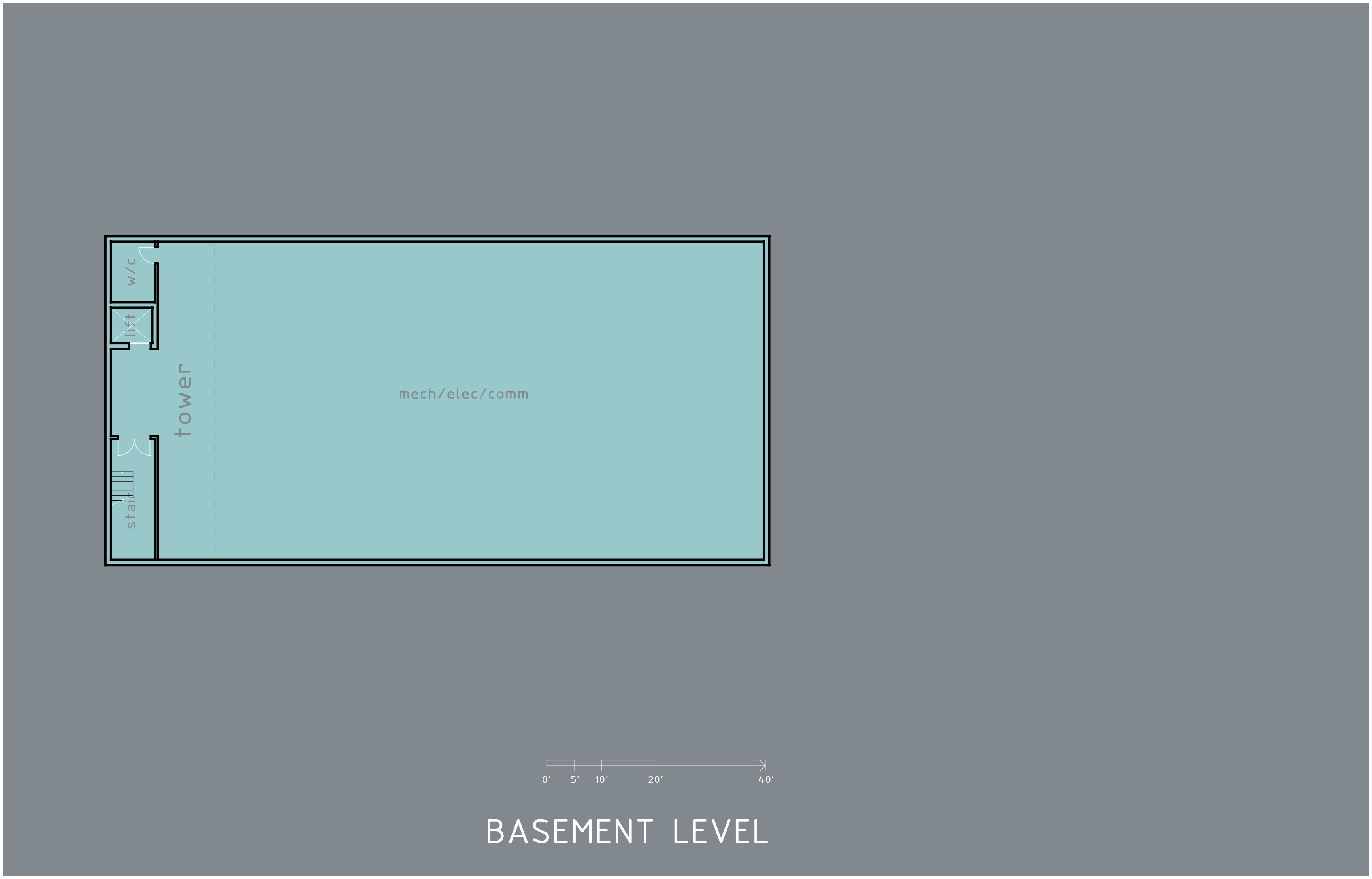


Image 49: Basement level floor plan example

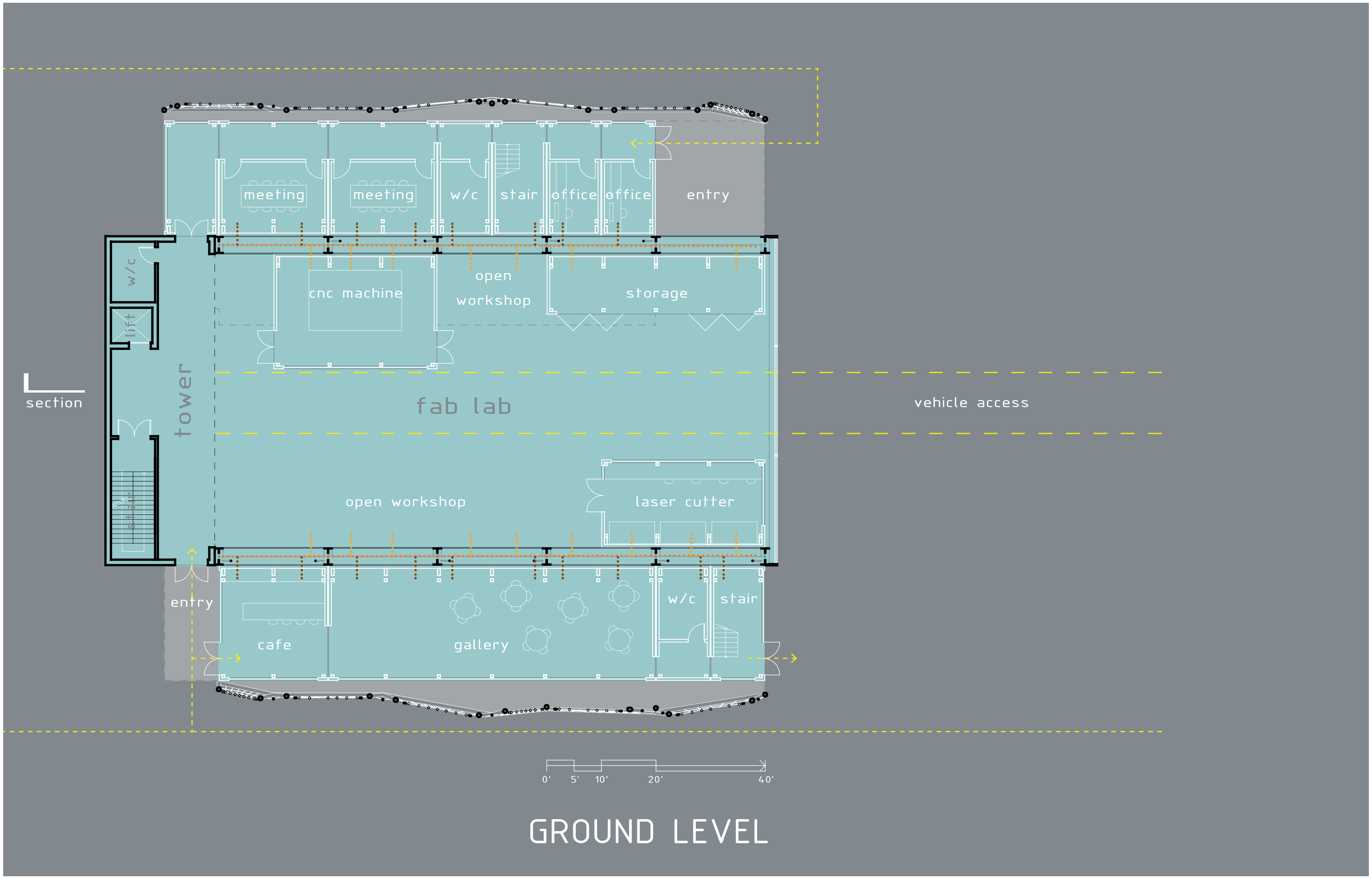


Image 50: Ground level floor plan example

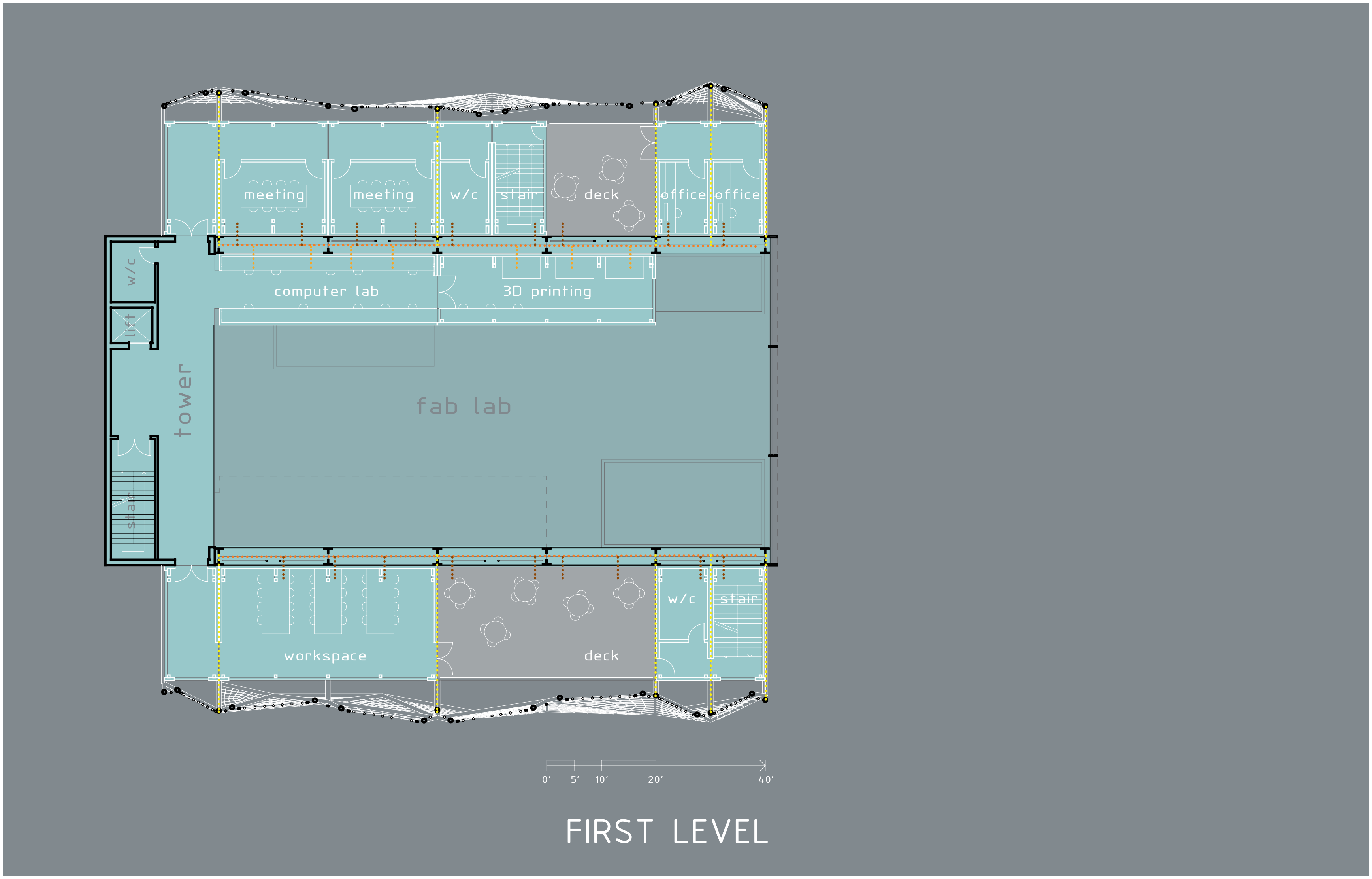


Image 51: First level floor plan example

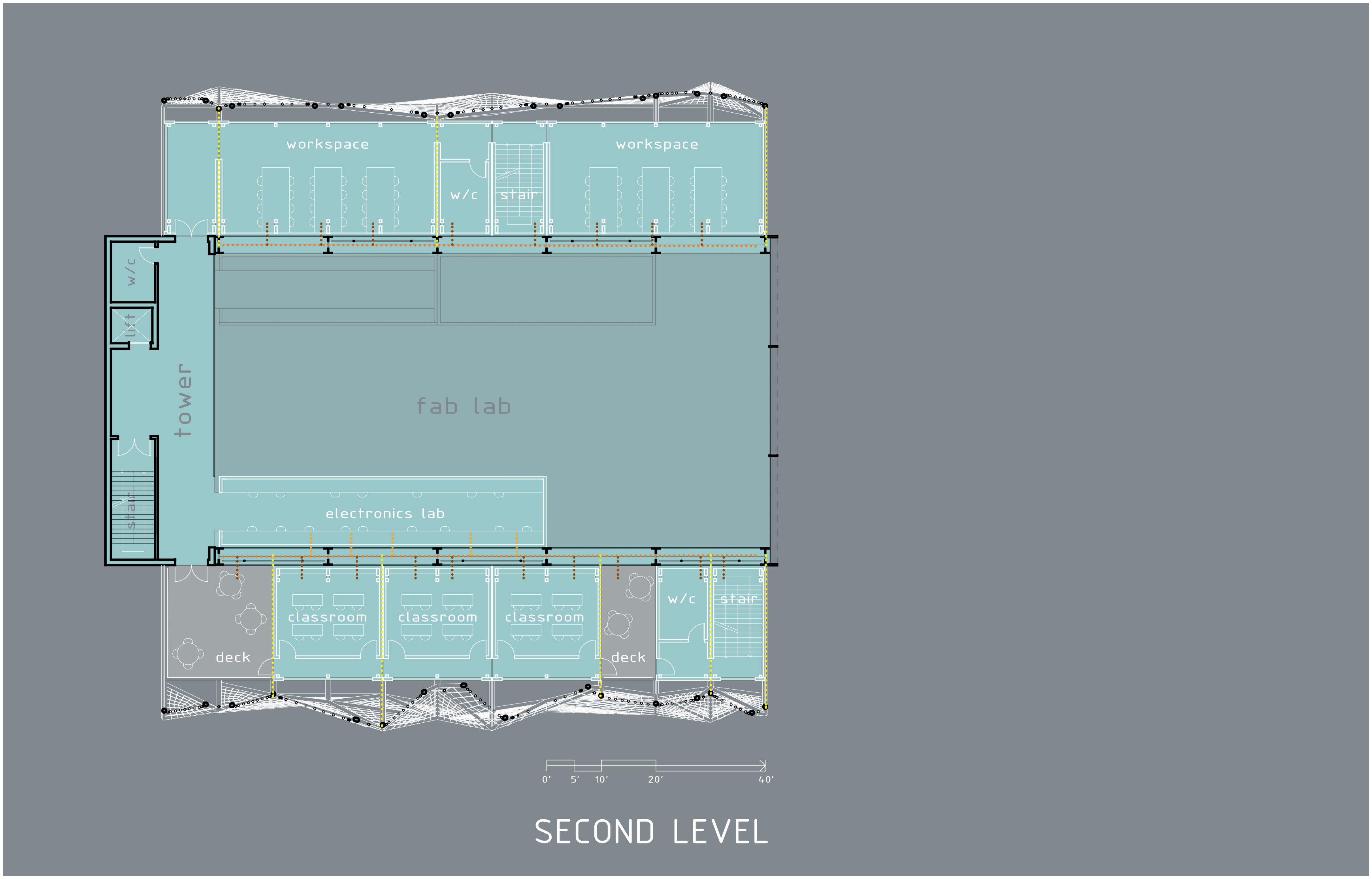


Image 52: Second level floor plan example

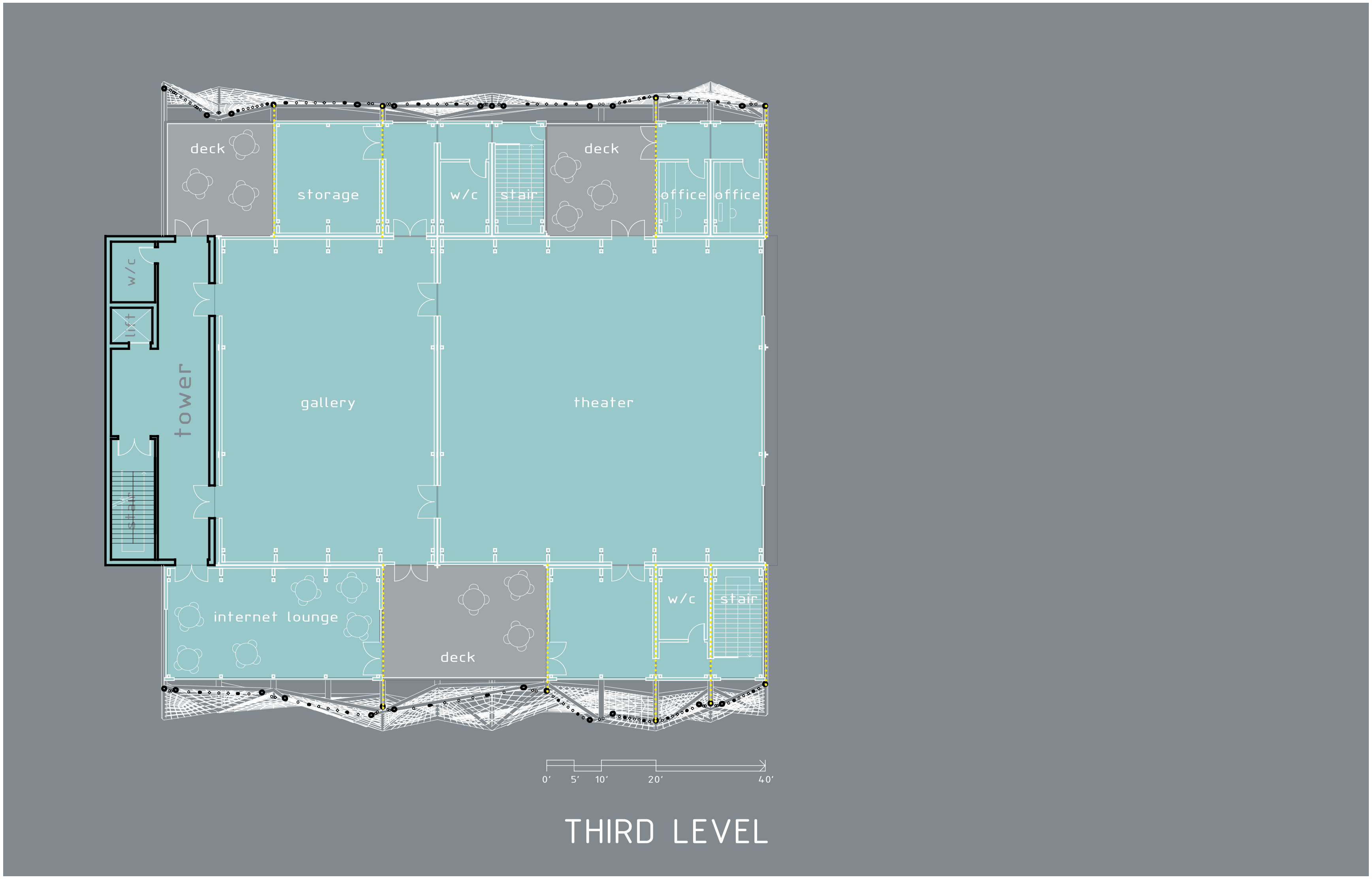


Image 53: Third level floor plan example

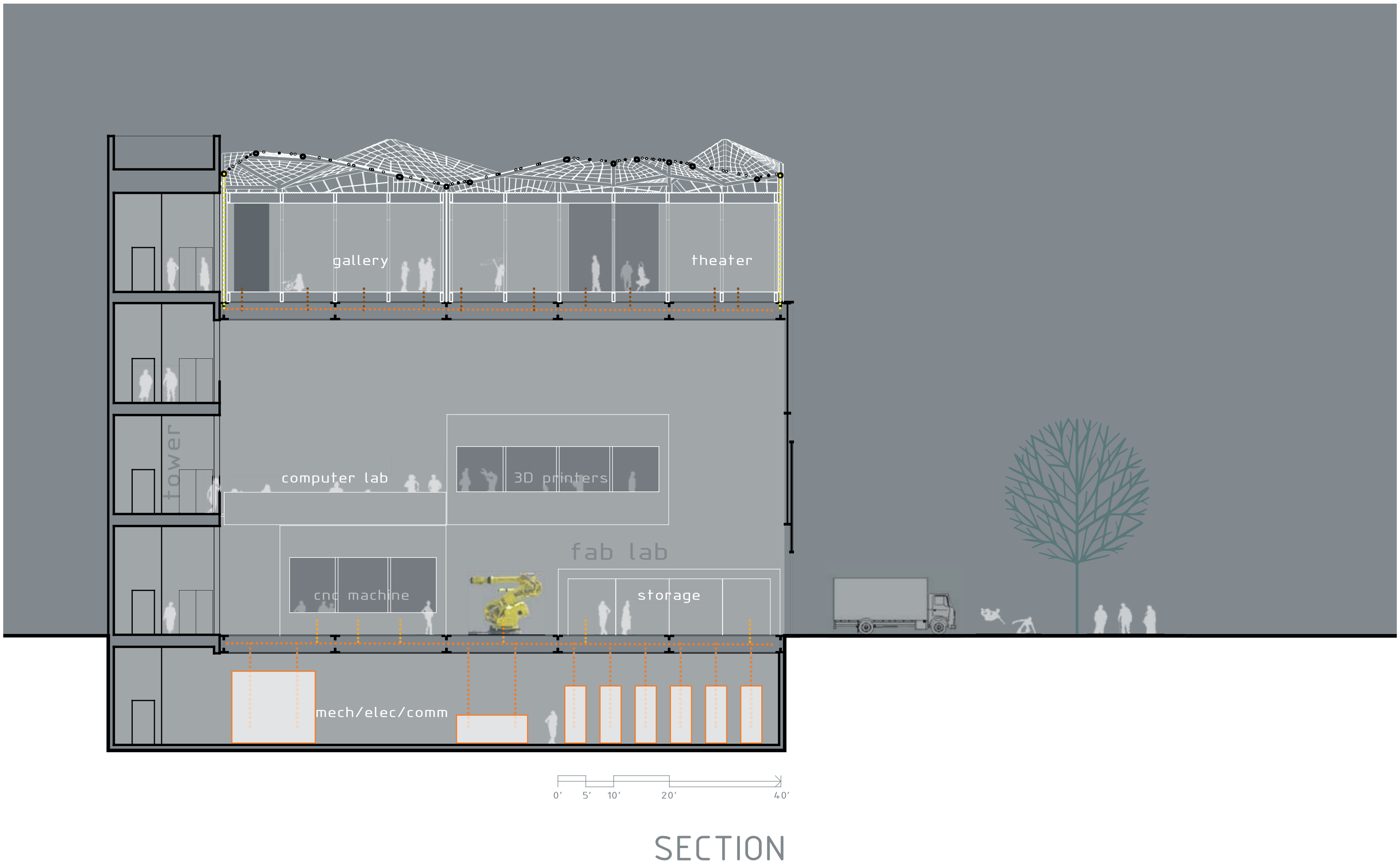


Image 54: Section (Section marker shown on Ground level floor plan example)

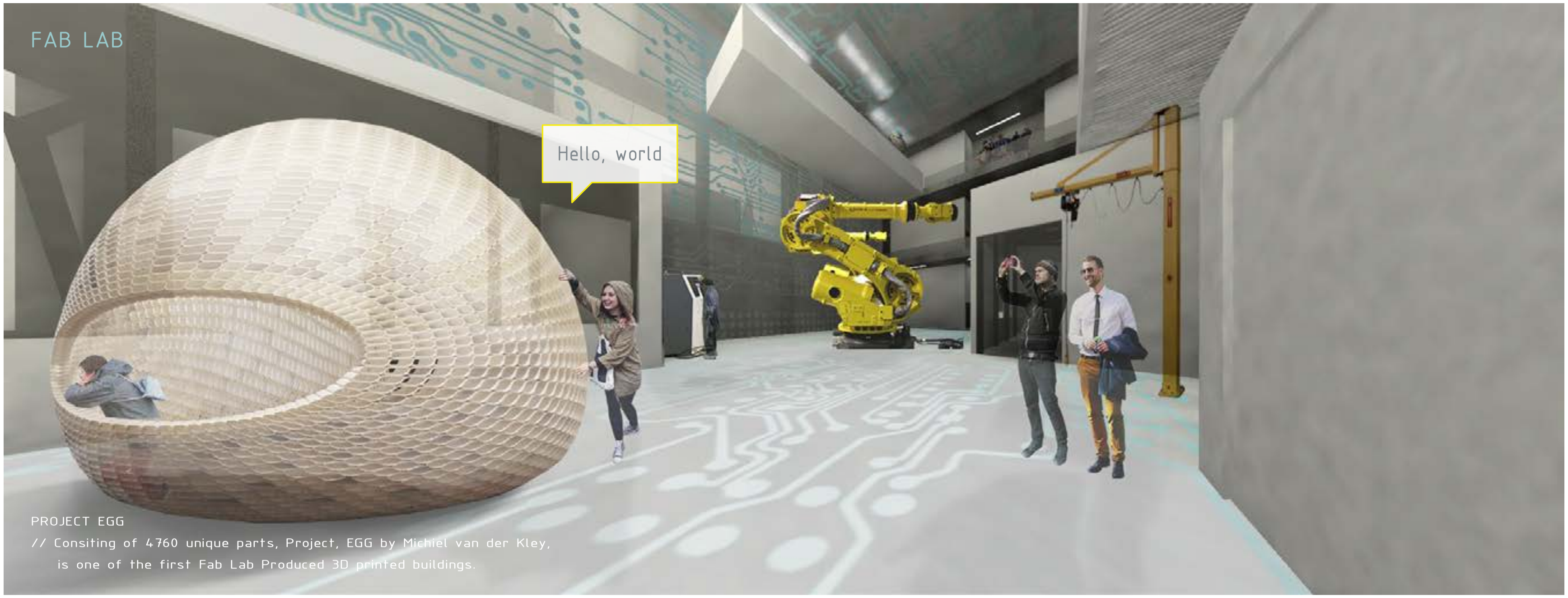


Image 55: Rendering depicting interior of manufacturing space, and relationship between support manifold and program modules

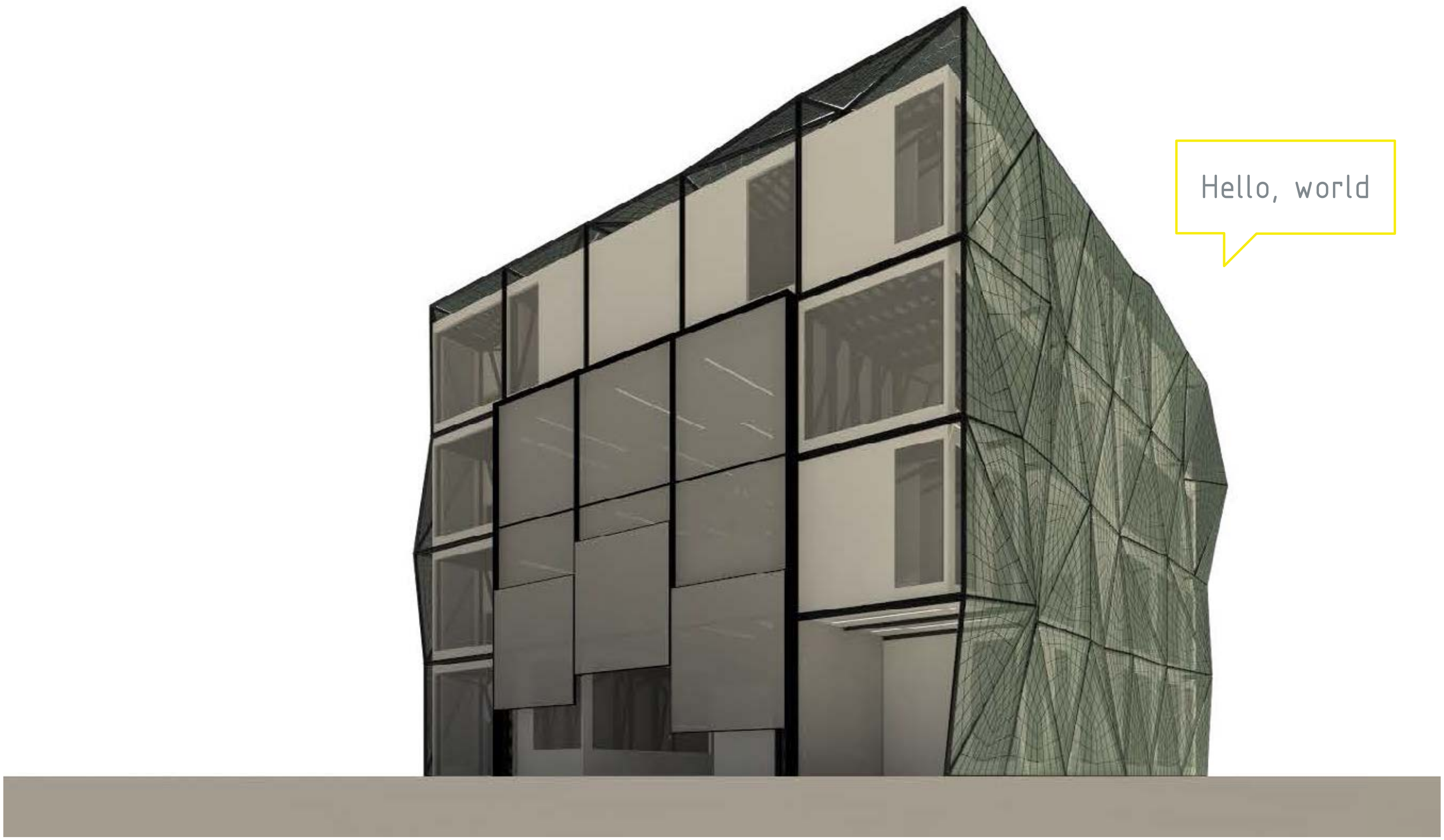


Image 56: Rendering depicting manufacturing space operable garage door facade

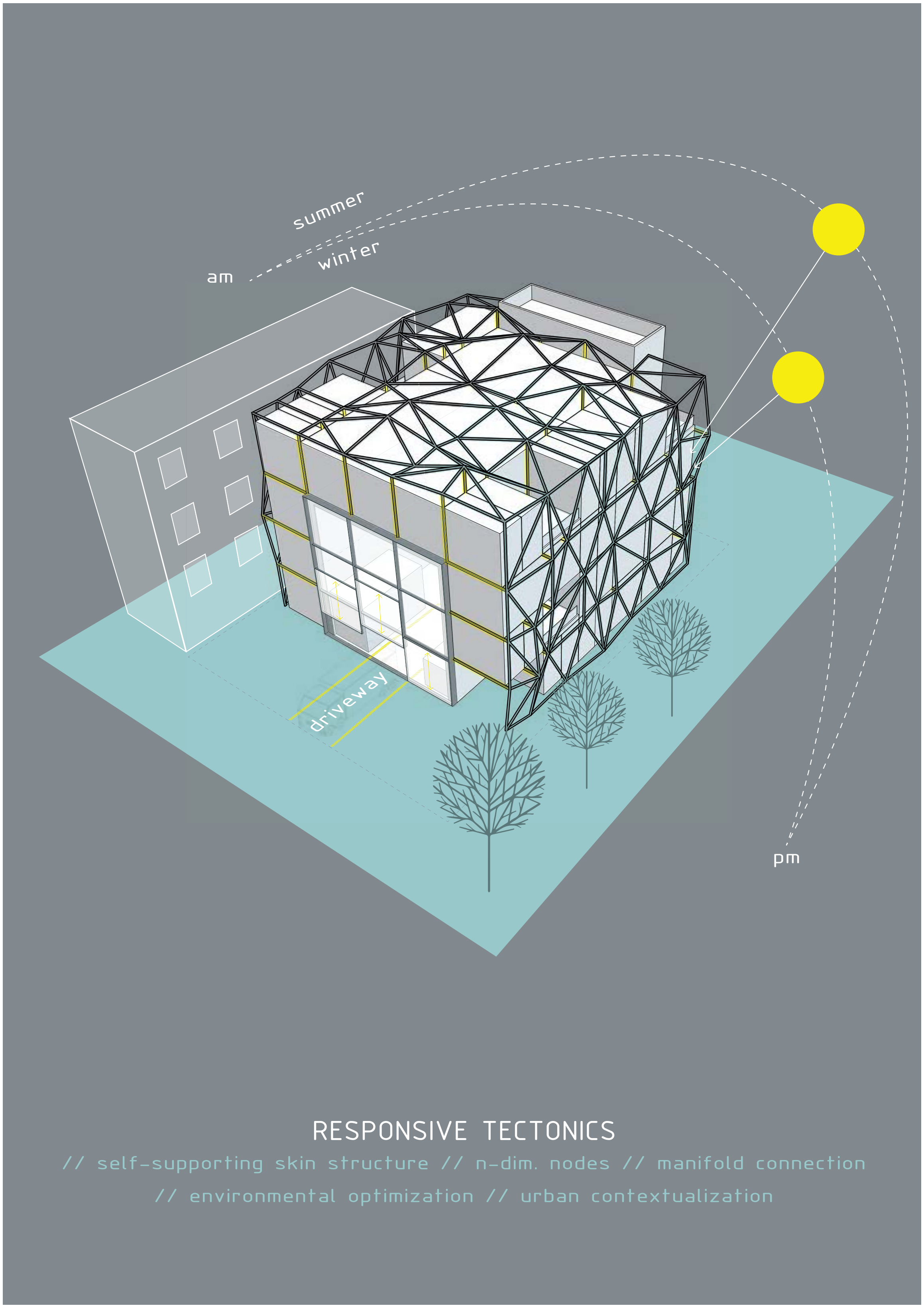


Image 57: Responsive tectonics diagram depicting the formation of the outer skin in a response to environmental and urban conditions, through a self-supporting, flexible-node, grid structure. This is connected back to the support manifold via support conduits at program module junctions.

2.1.3 Responsive Tectonics

The tectonic expression for the Fabrication Laboratory is manifest in the form of an environmentally and urbanistically responsive outer skin (see Image 57). As with other forms of digital infrastructure, the Fabrication Laboratory is a particularly energy intensive typology. The computers and machines that fuel its operation create a large deficit of energy in the form of electrical power input and cooling load. Thereby, the functions of the outer skin are to perform as a real-time, sensory-responsive solar shade, energy collector, and an interactive urban gesture.

In the design of the prototype - where the site specifics of environment, proximity to neighbouring structures, and the relationship to other urban conditions are unknown - the ability for this outer skin to adjust and formally adapt is critical. As an example, the design of a responsive outer skin for a small, shaded, windy site at the urban core will vary greatly from a large, well-lit, suburban site. The former might opt for a formally cubic, wind-actuated, piezoelectric façade, and the latter a solar collector, formally articulated to maximize solar accumulation. This situational indeterminacy is addressed by separating the outer skin into two constituent parts; the grid structure, and the performance skin. While these have a concomitant relationship, the design for the components can be conceived as separate entities. The latter of which will be addressed in greater detail the next section (see Image 63: page 55).

The formal articulation of the outer skin is responsive to three site specific relationships. These are the relationship between the building and the environment, the building and people within and around the building, and the building and its neighboring structures (see Image 58). In situations where the building is located adjacent to a neighboring structure that has the ability to take advantage of the outer skins solar shading and energy collection properties, it is possible to extend the skin to encompass both structures (see bottom diagram in Image 58).

The outer skin is designed as a formally-adjustable, light-weight, self-supporting manifold - the grid structure - that is infilled with an environmental and gesturally responsive performance panel - the performance skin. This arrangement allows the form of the building to be changed in response to local conditions, while at the same time allowing the infill panels to be readily changed as technology progresses. As the outer skin performs as an energy collection device, the grid structure connects back to the inner support manifold via support conduits (see member indicated in yellow in top drawing of Image 59).

To create a grid structure capable of achieving a multitude of different formal articulation, the system is conceived as a series of flexible nodes, that connects simple structural lengths, and the support conduits (see top drawing of Image 59). Formal complexity then becomes a product of the variation between support conduits, which results in a variation and quantity of the structural lengths. Further articulation of the form is achieved by varying the placement/quantity of the nodal connections.

If the lengths of the structural members is consistent, as can be seen in Image 60, the resultant skin is manifest as a planar, rectilinear grid system. Adjusting this system, so that the number of nodes is consistent with the previous example, but the length of the structural members is varied, the resultant grid-form is as shown in Image 61. Further formal articulation can be achieved by varying both the length of the structural members and reducing the number of nodal connections, as demonstrated in Image 62.

Comparison of these forms through a solar analysis shows that the watt-hours per meter squared is increased with the first formal articulation. At the same time, the number of unique lengths in the structural system increases from 3 to 107. In the second formal articulation, the number of unique elements is reduced to just 82, but provides slightly less solar accumulation than the first formal manipulation. By analysing the formal options of this system, a site specific solution can be created to optimize the energy production of the outer skin based on local conditions.

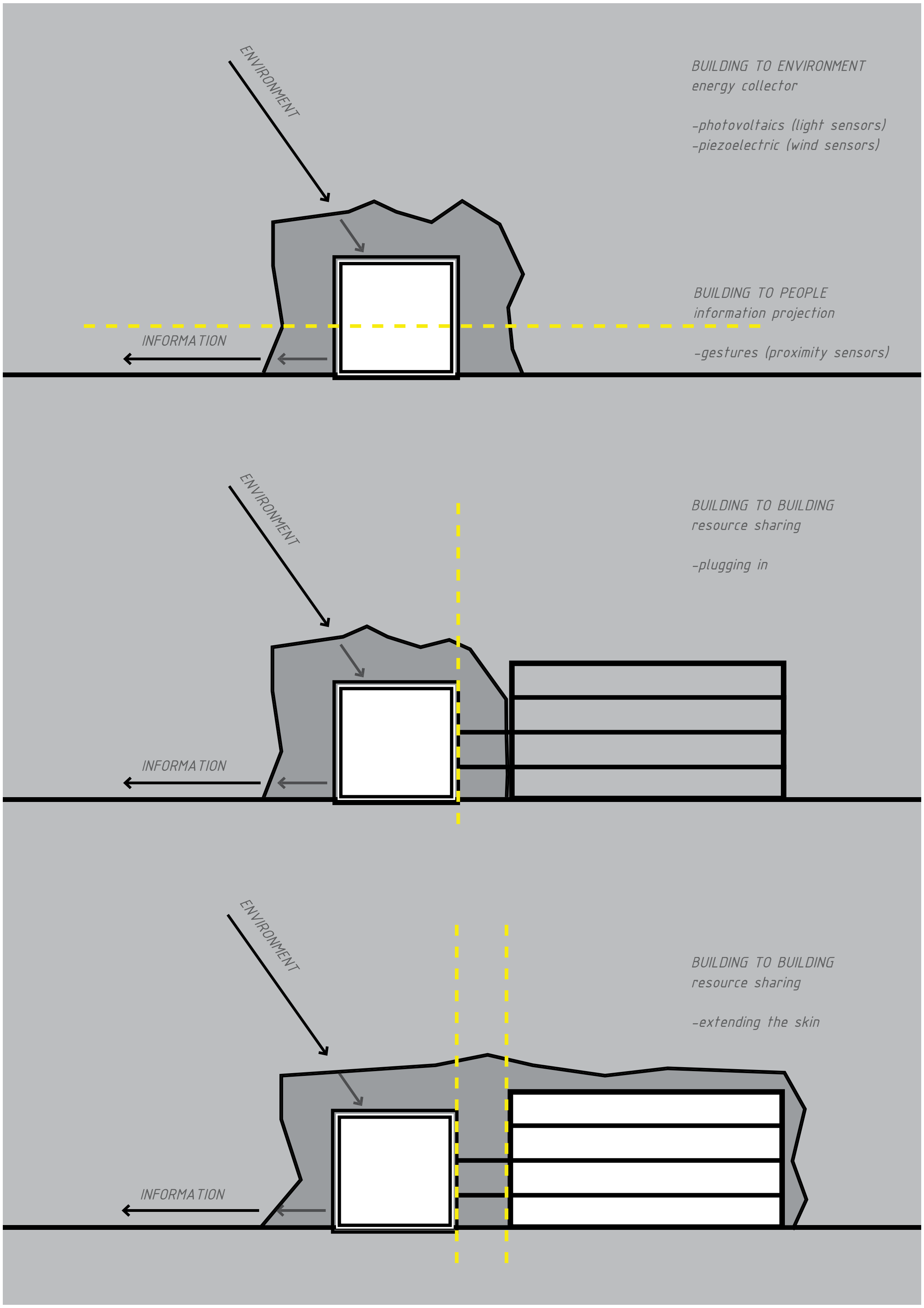


Image 58: Diagram depicting relationship between performance skin with the environment, people, and other buildings.

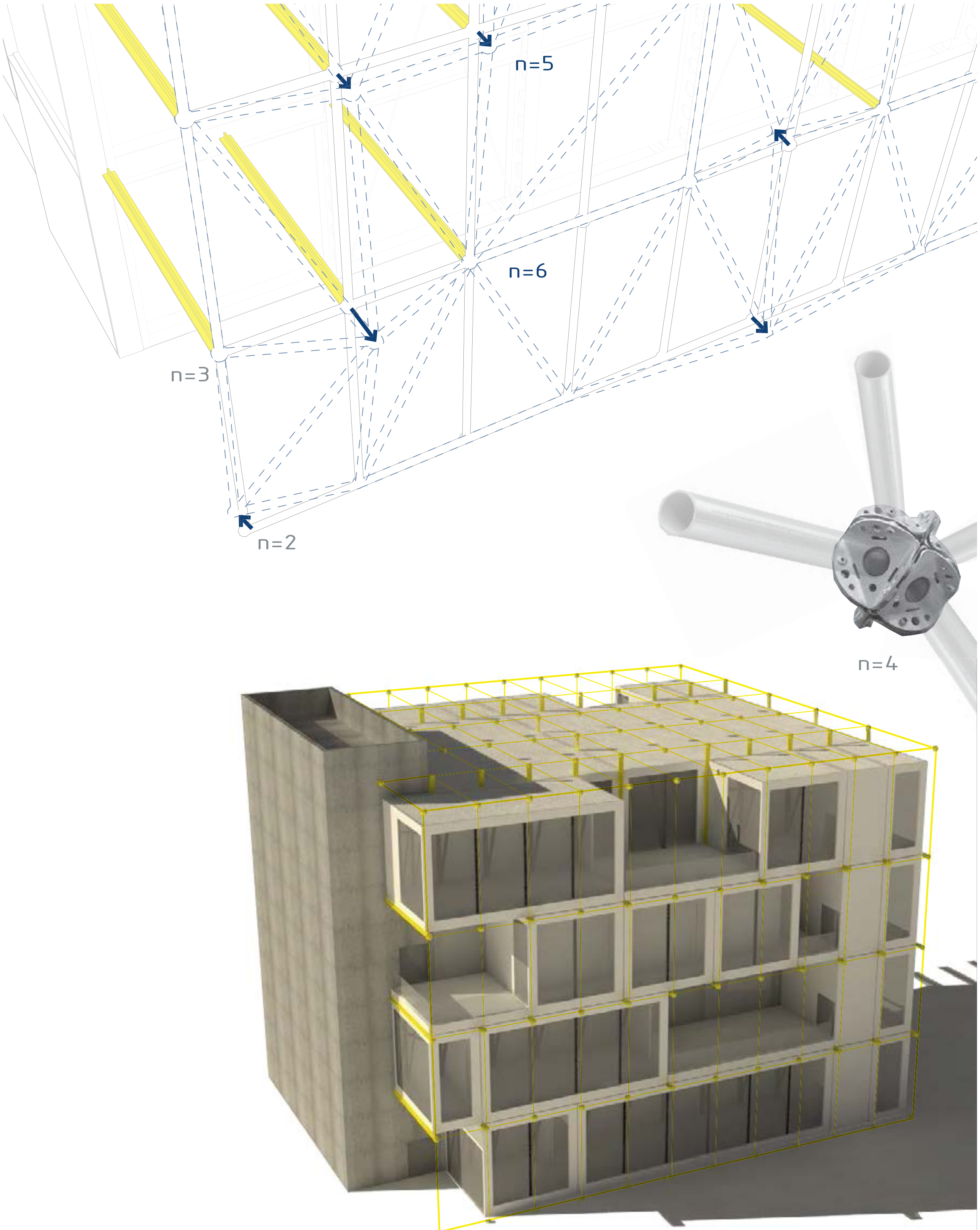


Image 59: Drawing and rendering depicting the mode by which the grid structure components are used to create formal variation. In the top drawing the support conduits, that are used to bring energy collected in the facade back to the support manifold, are highlighted in yellow. If the length of these members are changed from a consistent dimension - as indicated by the arrows - formal variation of the grid structure is achieved - as indicated by the dashed lines. The bottom rendering shows the relationship between the support conduits and the program modules, at the junction points between the modules. The image of the node demonstrates the complexity in the system comes from the flexible node, which connects together simple structural lengths.

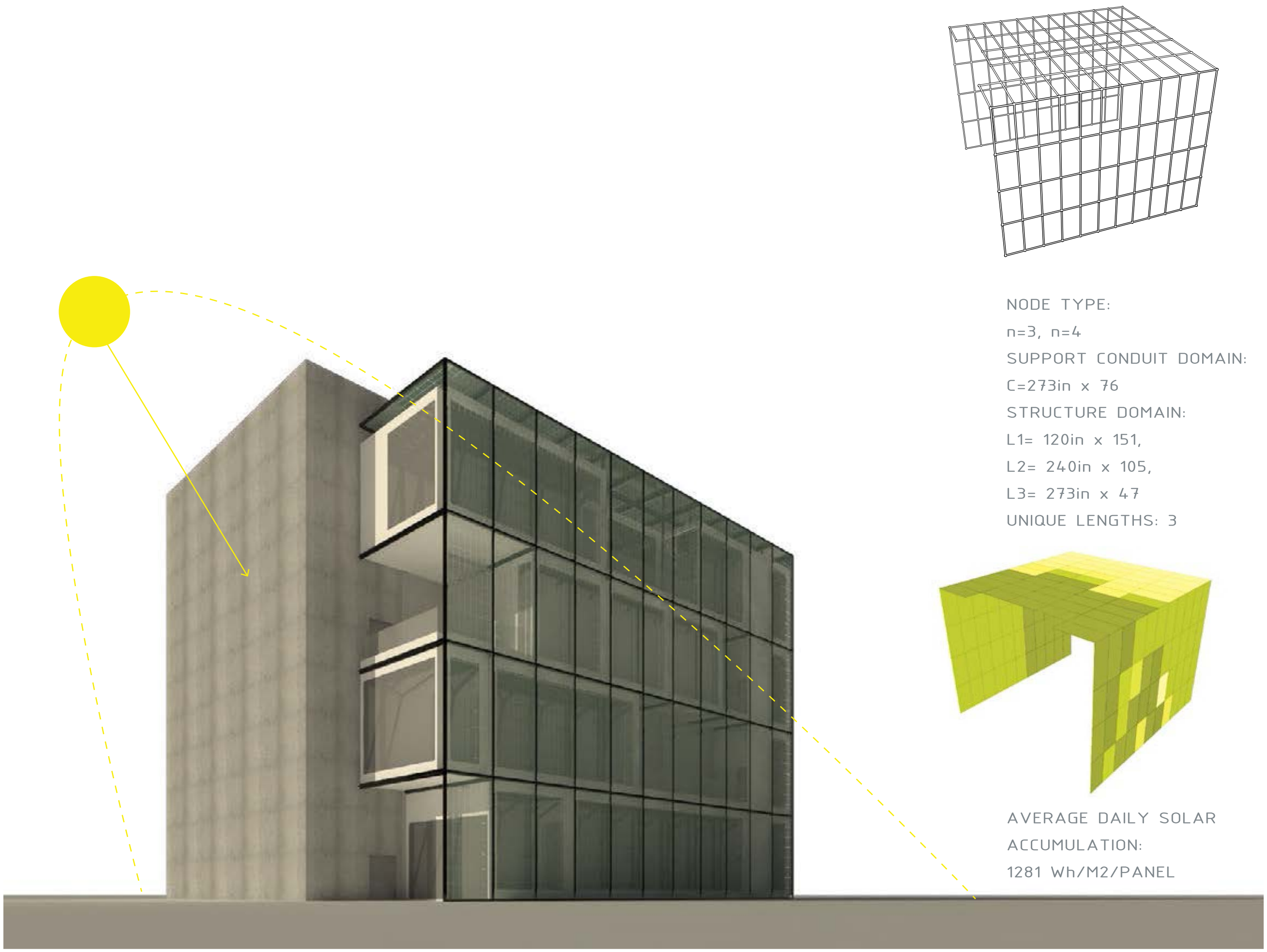


Image 60: Formal manipulation 1: rectilinear grid

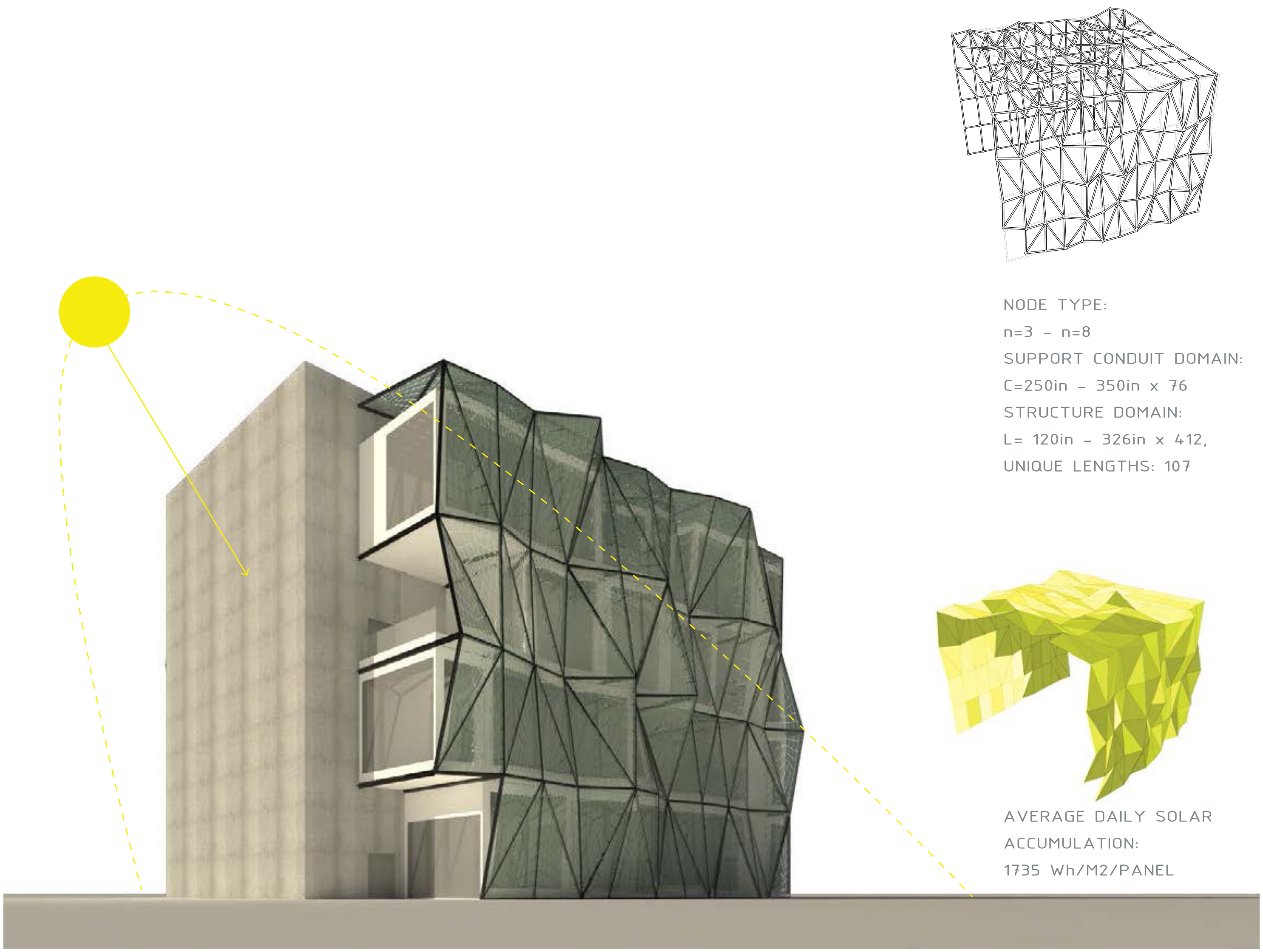


Image 61: Formal manipulation 2: triangulated rectilinear grid

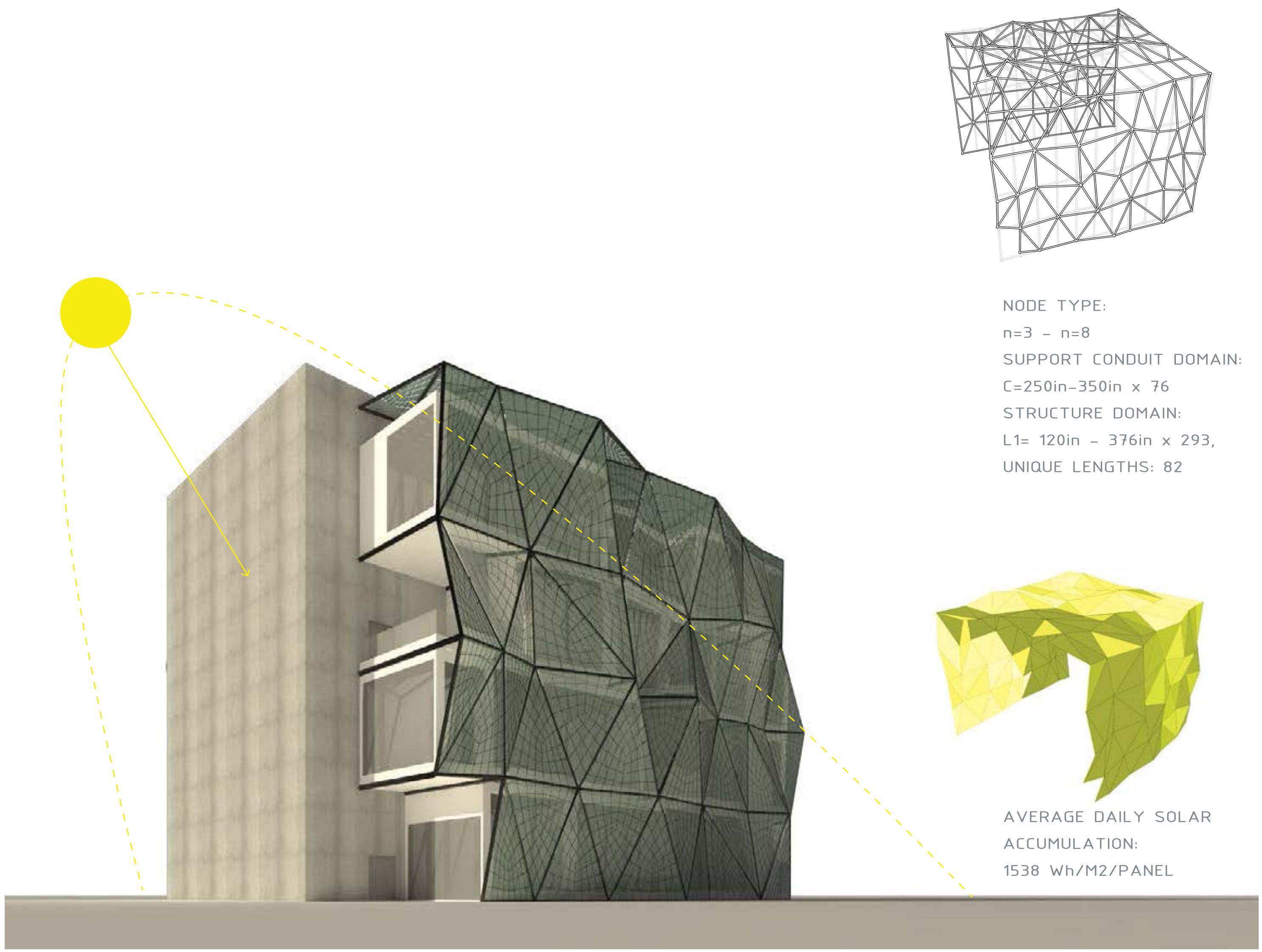


Image 62: Formal manipulation 3: triangulated grid

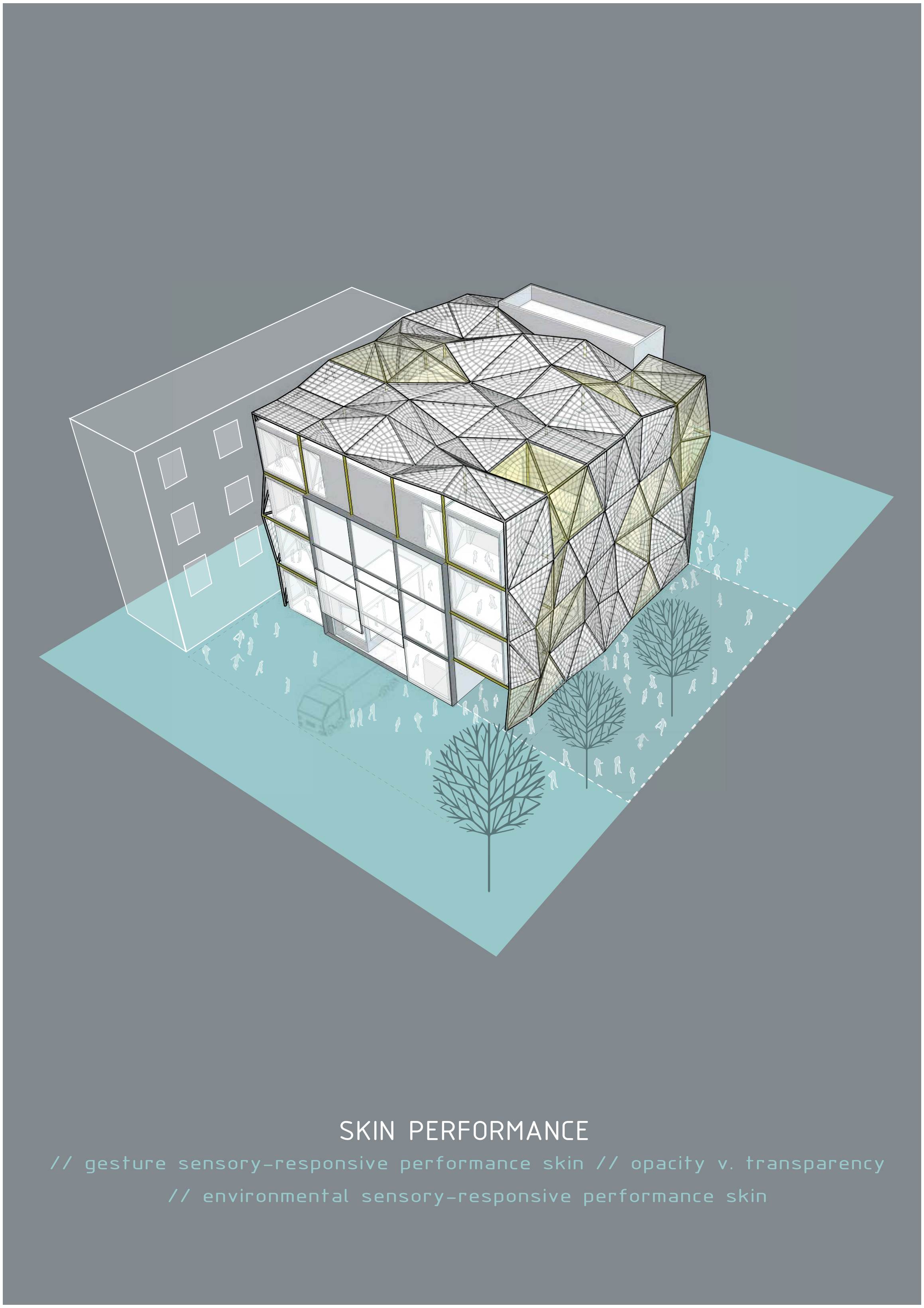


Image 63: Skin performance diagram depicting the environmentally and gesturally responsive performance skin panels that are plugged into the grid structure, which together, comprise the outer skin system.

2.1.4 Skin Performance

As the infill panel into the grid structure, the performance skin component is designed to function as real-time, sensory-responsive, solar shade, energy collector, and an interactive urban gesture (see Image 63). Utilizing sensors as part of this facade elements – such as light sensors, occupancy sensors, motion detection sensors – a panelized system is designed to respond in real-time to changing conditions in both the environment, as well as the interactions with people inside and outside the building.

Experimenting first with the principles of gestural interaction, a sensory/responsive study was conducted to demonstrate the translation between information and materiality. In the model shown in Image 64, a series of light sensors are built into a living planted medium of moss. These sensors are connected to a single-board microcontroller, which is coded to translate the light level data collected from the light sensors, as a response in the form of an LED light array. As the moss is touched, and the light sensors shaded, the single-board microcontroller processes this information and creates a response in the LED array by turning off sections of the lighting. This study demonstrates the means by which gestural interaction can become part of an ephemeral facade.

A second study is conducted to demonstrate the principles of an environmental responsive facade (see Image 65). In this study, the wind is utilized to create a kinetic response in the facade panels. If this motion was combined with a piezoelectric energy collection device, the motion caused by the wind could be used to generate energy for use back in the building.

From these studies, a strategy for the classification of responsive facade panels is derived for use in the design of the performance skin. These panel types are classified as static panels that input, translate and display information, simple movement panels that move in direct response to environmental forces, and mechanical movement panels that input, translate and move panels in response to either gesture or environmental stimulus (see Image 66). In the left photograph of Image 66, an example of static panels is demonstrated in Jakob MacFarlane Architects FRAC Center, completed in 2013 in Orléans, France. The FRAC Center uses LED lights imbedded into the panels to create an ephemeral display in the facade. An example of simple movement can be seen in the work of artist Ned Kahn, in the center photograph of Image 66. In this project titled Turbulent Line, completed in 2000 in Brisbane, Australia, Kahn uses the wind to create kinetics in the facade panels. Lastly, in the right photograph of Image 66, an example of mechanical movement panels is demonstrated in the work of Mark Goulthrope, of dECOi Architects, installation titled Aegis Hyposurface. In this project, a series of motion detection sensors are used to activate motors, that are used to create kinetic movement in the facade. Dependant on the local environmental conditions, and the potential for urban interaction on a site, these methods of translating environmental/gestural input into a responsive facade become guidelines for the design of the performance skin.

For the development of the outer skin component, the gestural and environmental types of sensory inputs are mapped onto an axonometric drawing of the grid structure. Image 67 shows the relationship between location on the facade, and the type of interaction at that position. At the ground level, where pedestrian/occupant interaction occur on both sides of the facade, the inputs are gesturally based. At the upper levels, where occupant interaction occurs on only one side of the facade, the inputs are both gestural and environmentally based. On the roof of the building, where no gestural inputs are unlikely occur, the inputs to the facade are purely environmentally based. Image 68 shows a rendering of a digital model demonstrating an example the dynamics of the facade elements at the ground level.

As one of the primary functions of the performance skin is to produce energy for the building, an analysis of an actuated façade panel section is shown in Image 69. The comparison between the static-state of the panels, and the actuated-state of the panels shows an increase in solar accumulation of the facade. Thereby, if the panels are imbedded with photovoltaic cells, a kinetic facade will increase the energy production potential of the facade.

Another function of the performance skin is to act as a solar shading device for the program modules, so as to decrease the cooling load of the building. In the sectional rendering shown in Image 70 (refer to Image 71 – Image 73 for enlarged drawings) the light transmittance through the performance skin is demonstrated. In this example a simple movement, wind-actuated piezoelectric facade is combined with a Motorized Movement, proximity-sensory facade that opens to create views into and out of the building as people approach the windows. This combination of sensory responsive panel types creates a condition where the tectonic expression of the building is the sum of the dynamics of environmental energy collection, and the interactions between people and the building.

Putting all of the components of the Fabrication Laboratory together, the interaction between the systems is represented in Image 74. While the building is designed to allow the systems that support its operation to be freely changed and upgraded through the life of the building, this sectional diagram describes one example of the flows of energy through the building. Starting at the outer skin, the dynamics of the facade panels can be either closed or opened (refer to item 1 and 3), to either block solar gain in the summer or allow solar gain in the winter. The panels also act as energy collection (refer to item 2), in this example as a solar energy photovoltaic collection device. This energy is then transferred back to the support manifold, via the support conduits between the junctions of the program modules, for redistribution. The heating and cooling system is based on a Geothermal Hydronic system (Moe, 2012), that uses water piped in the floors and ceilings of the program modules. In this example, chilled water is pumped into the floors to cool the air in the spaces, and as the air gains heat it naturally rises and warms the water in the pipes in the ceiling. This warmed water is then sent back to the geothermal unit in the basement through the support manifold to be naturally chilled in the ground, and once chilled, is redistributed (refer to item 4, and the blue and red distribution lines). As the building is filled with an abundance of heat generating computers, and pieces of fabrication equipment, a strategy is developed to deal with the potential excess heat that may not be handled by the geothermal system. In this case, excess heat can be converted into steam through a heat exchanger, and used to run a steam turbine generator. Thereby, excess heat put-off by the equipment in the building is recycled back into electrical energy for use in the building.

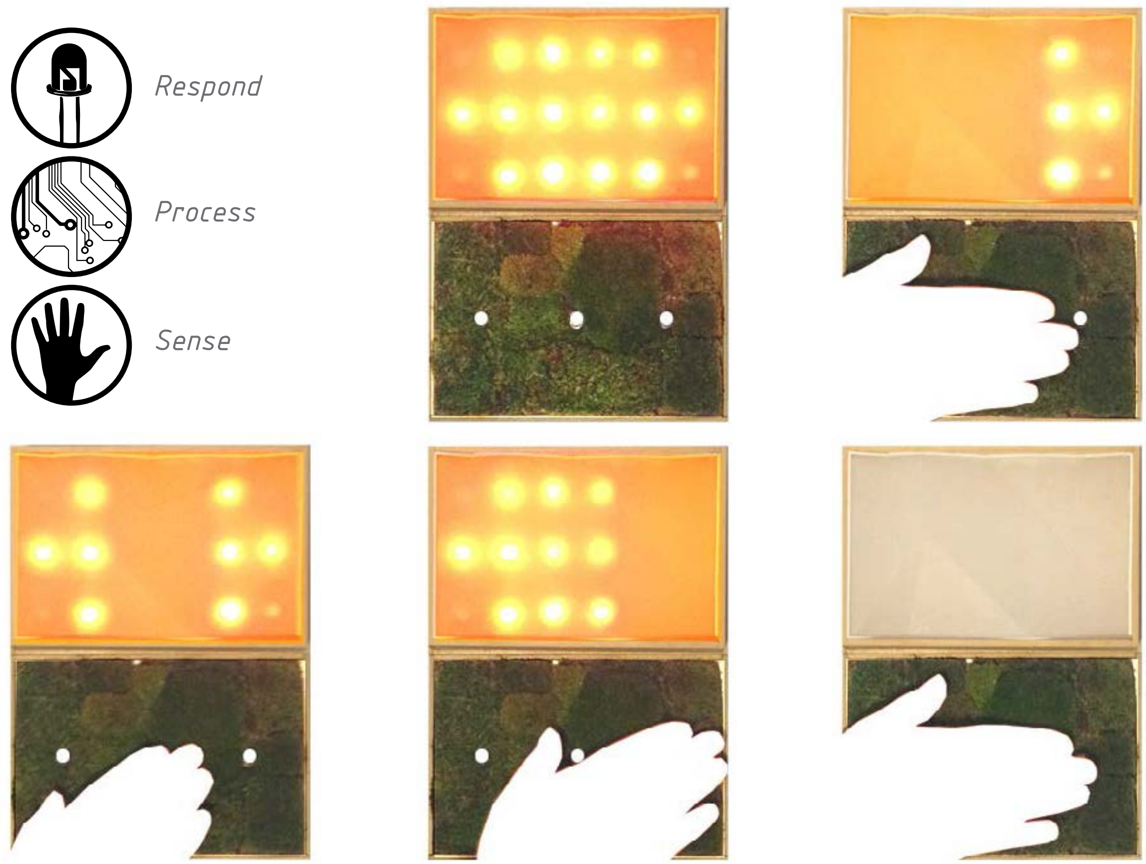


Image 64: Gesture-responsive, static panel study, demonstrating a gesture-based sensory input, that is translated into a LED light-responsive facade panel. As the hand is moved across the three light sensors, the LED array creates a real-time response in light.

Image 65: Environmental-responsive, simple movement panel study, demonstrating a wind-actuated facade.

Static Panels	Simple Movement Panels	Mechanical Movement Panels
LED Responsive Facade	Wind Actuated Facade	Gesture Sensory, Motor Actuated Facade

Image 66: Images depicting sensory/responsive facade panel types. On the left, static panels are demonstrated in Jakob MacFarlane Architects FRAC Center project (Boreal 2013), simple movement panels are demonstrated in artist Ned Kahn's Turbulent Line facade (Burrows 2012), and mechanical movement panels are demonstrated in the right image in dECOI Architects Aegis Hyposurface installation (Burry 2001).

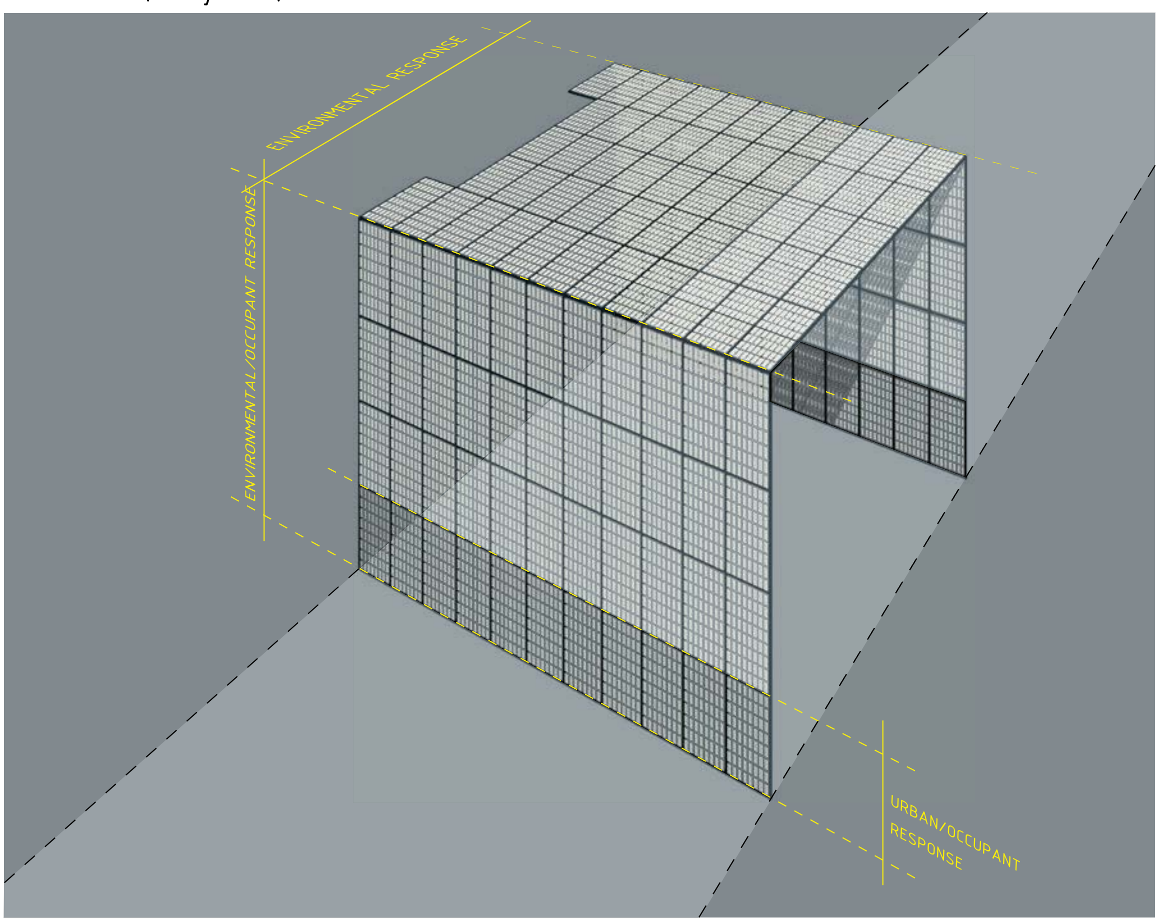


Image 67: Axonometric drawing of outer skin mapping environmental and gestural sensory/ responsive facade elements.

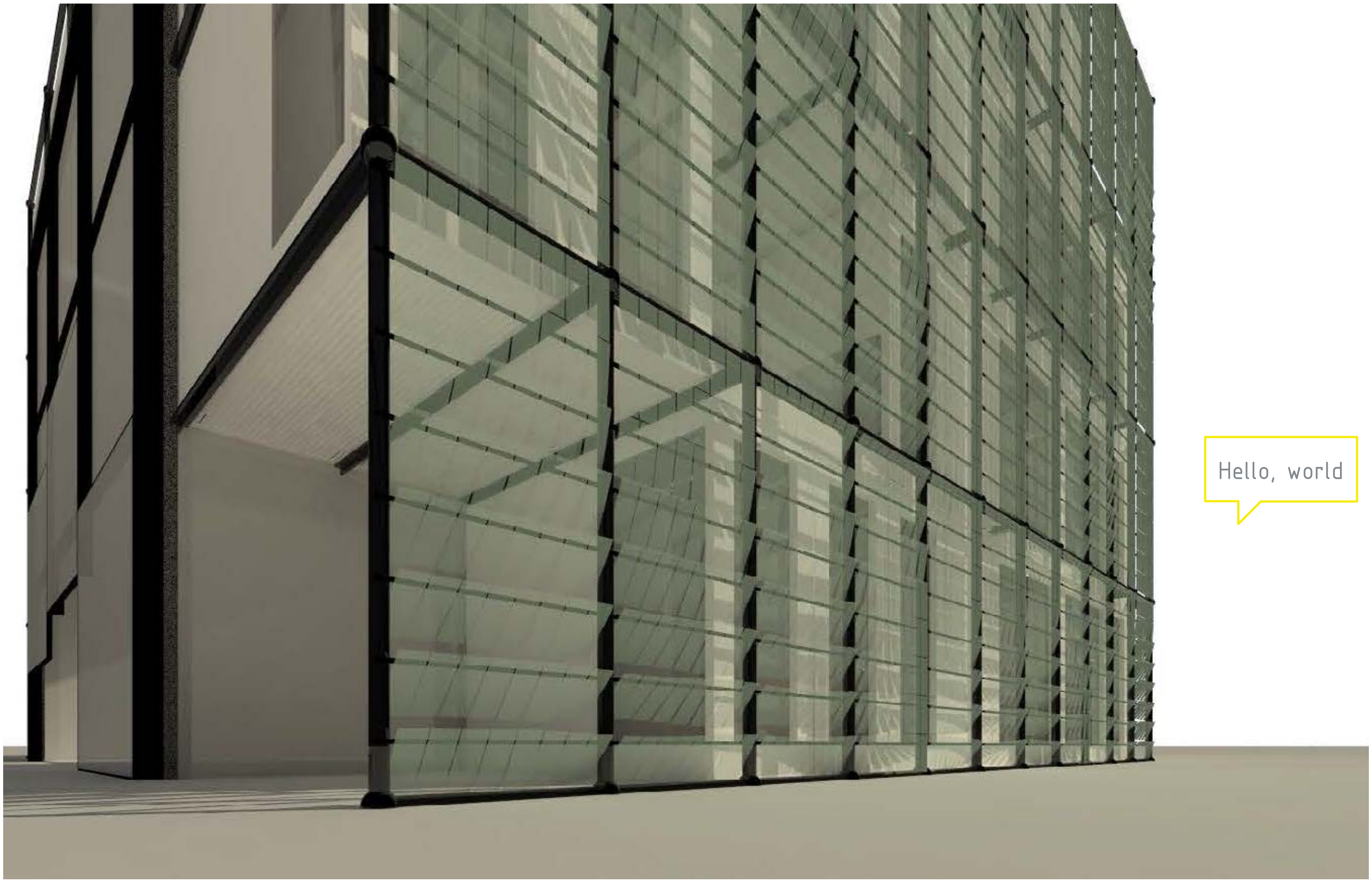


Image 68: Street level rendering depicting variable porosity of actuated facade panels

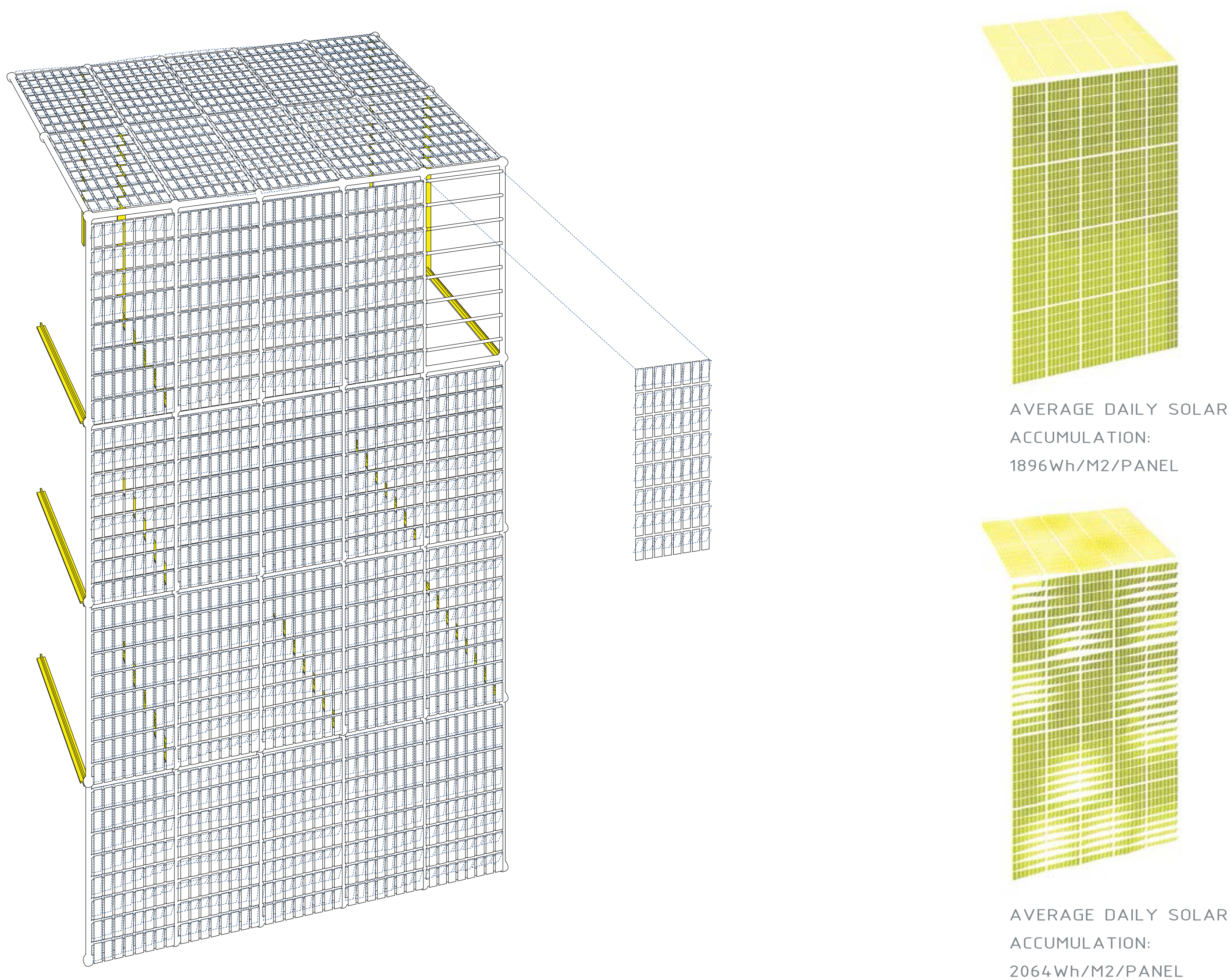


Image 69: Exploded performance skin detail showing actuated movement, and the resultant solar accumulation

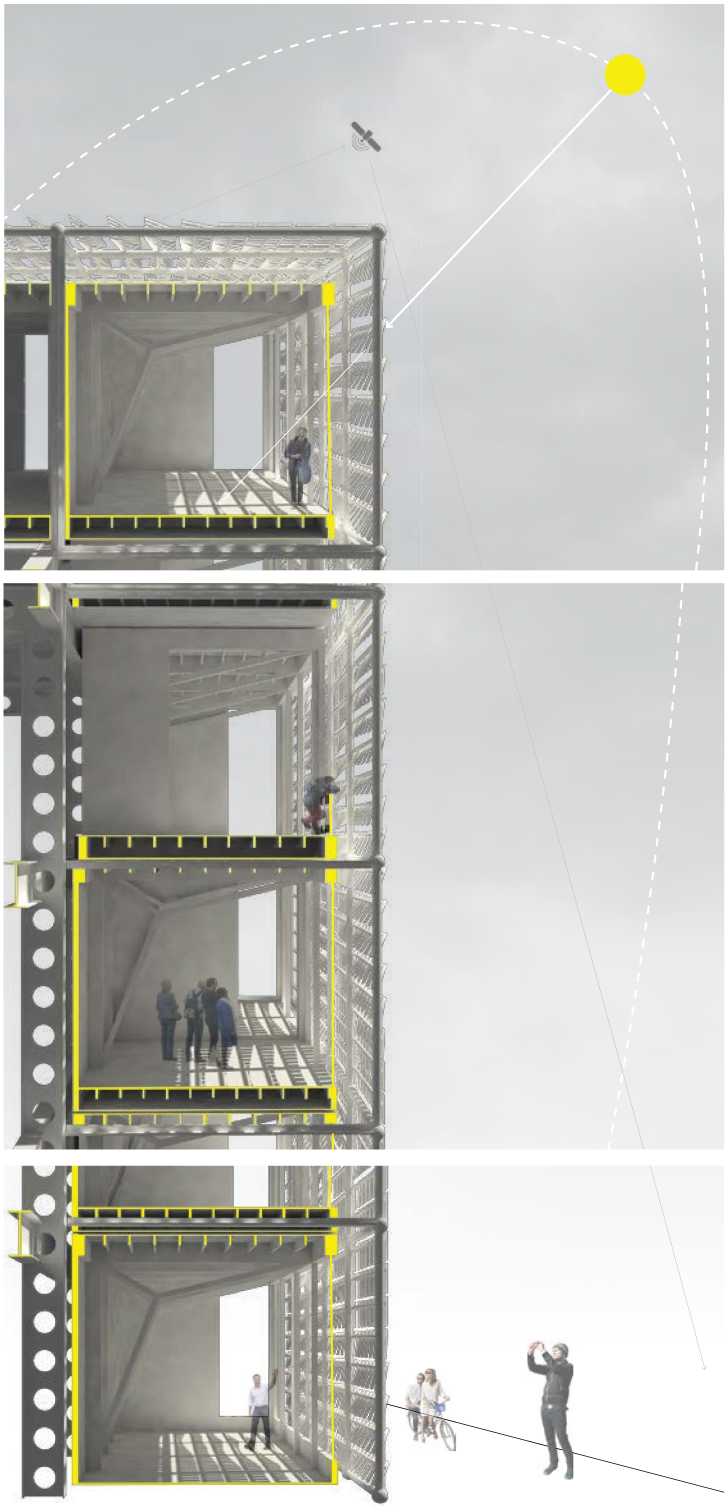


Image 70: Sectional rendering through public program modules and performance skin, depicting environmental and gestural actuated movement of facade panels (see Image 71 to Image 73 for enlarged images)

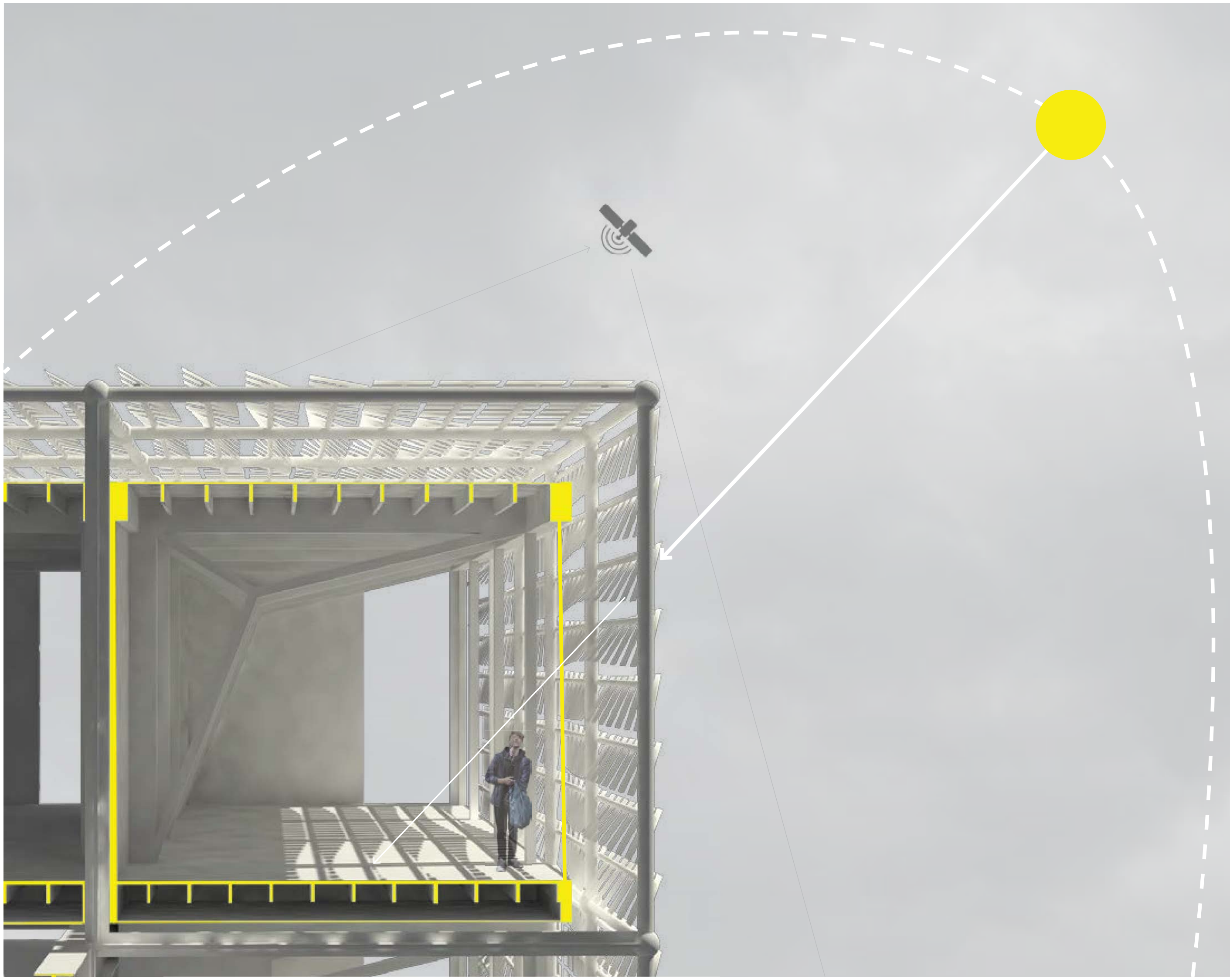
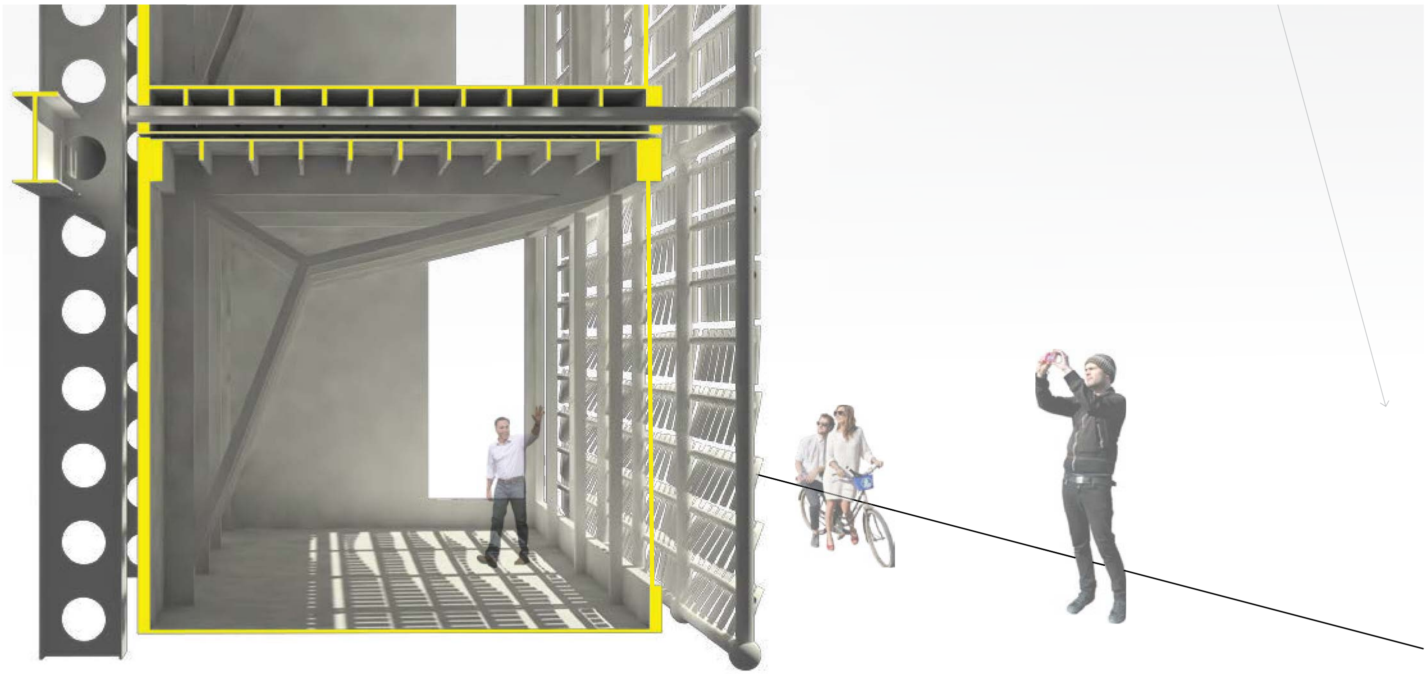


Image 71: Enlarged sectional rendering through public program modules and performance skin at third level.

Image 72: Enlarged sectional rendering through public program modules and performance skin at first and second levels.



SENSE PROCESS RESPOND

//sensory environments // responsive facade

Image 73: Enlarged sectional rendering through public program modules and performance skin at ground level.

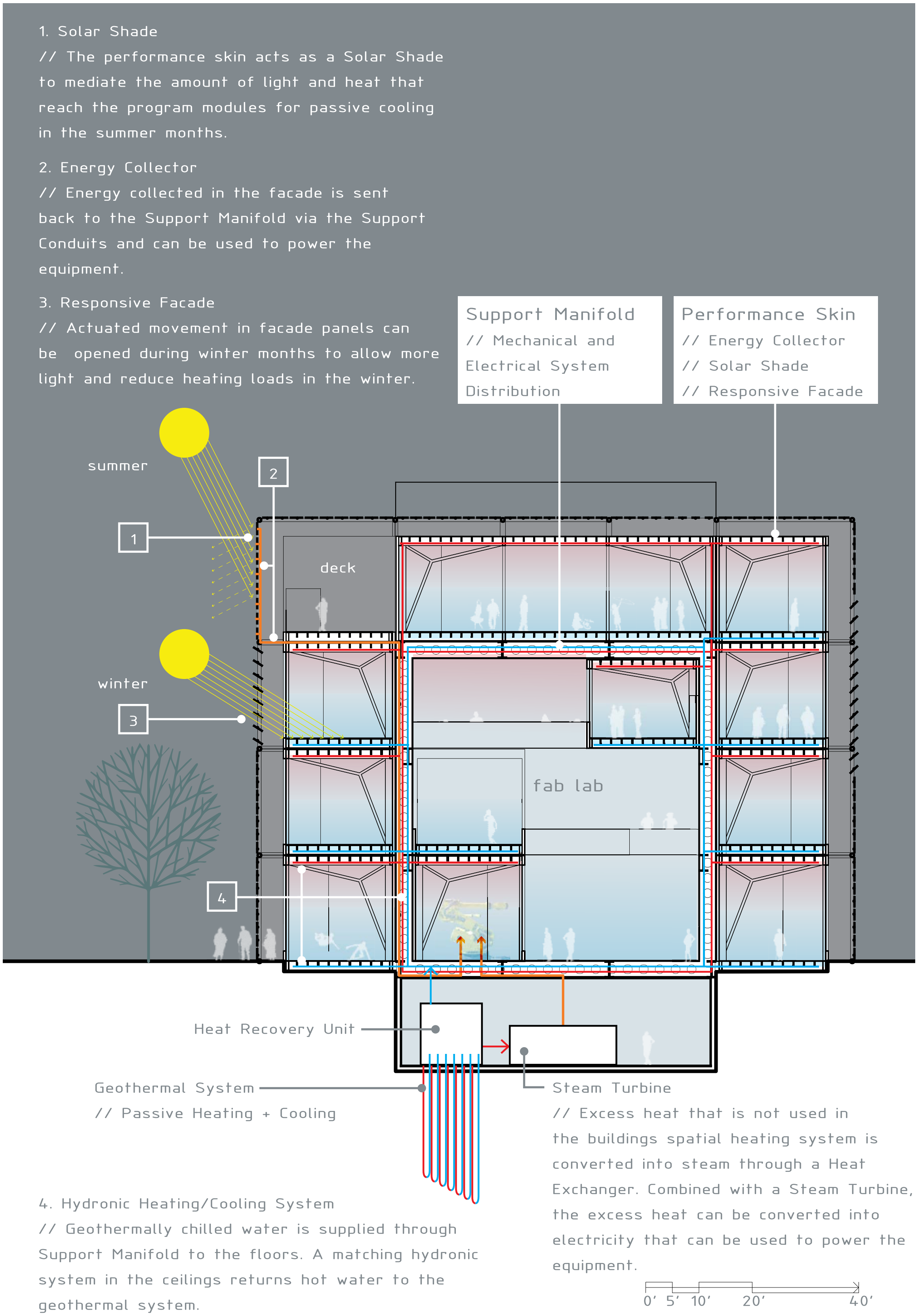


Image 74: Sectional diagram showing passive heating/cooling, and electrical recycling strategies.

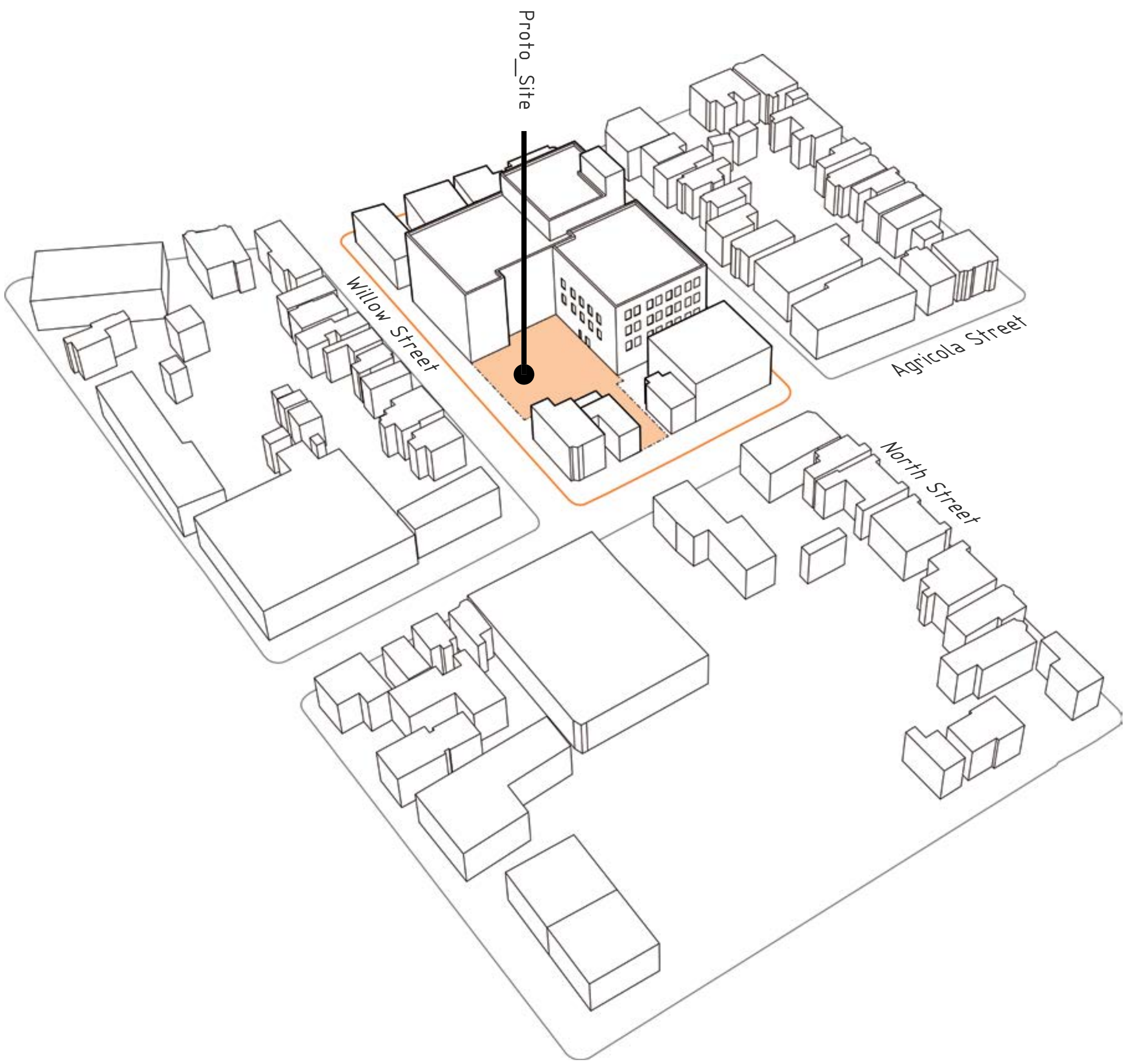
2.2 Proto_Site: Beta Testing

2.2.1 Sense: Site Specificity

For testing the prototype, the site of the aforementioned Data Center on North Street in Halifax is chosen (see Image 75). For this the open parking-lot on the Willow Street side of the property will be used to locate the Fabrication Laboratory. Access to this site is available from a gap between buildings on the commercial Agricola Street (see Image 76), and the predominantly on the residential Willow Street side of the property (see Image 77). This is a tight urban infill site measuring 110' (33.5 Meters) by 80' (24.4 Meters), with many surrounding structures. In preparation for the occupation of this site, consideration is given to the existing windows, entryways and mechanical equipment of the Data Center, that will remain and be incorporated into the design (see Image 78).

Image 79 shows a shadow study of the site for the morning, noon and afternoon shade conditions of the parking-lot, during the December, March and June equinoxes. This analysis shows that the site is predominantly shaded, and likely not an optimal candidate for a solar energy collection facade component.

Placing the tower along the blank concrete facade of the Data Center, and expanding the support manifold towards Agricola Street, various sizes of the Fab Lab are tested (see Image 80). The axonometric drawing on the left of Image 80 demonstrates a small two-bay support manifold. The middle image shows a four-bay system on the site. This is the maximum size that the site can support as is. However, if the Bridge Brewing Company building were to be demolished, as in the example in the image on the right, and its program incorporated into the Fab Lab in the form of a program module, the support manifold can be expanded to a seven-bay system.



PROTO_SITE

// urban surroundings // site access // solar analysis

Image 75: Digital massing model of Proto_Site and surrounding areas.

Image 76: Agricola Street site access

Image 77: Willow Street site access

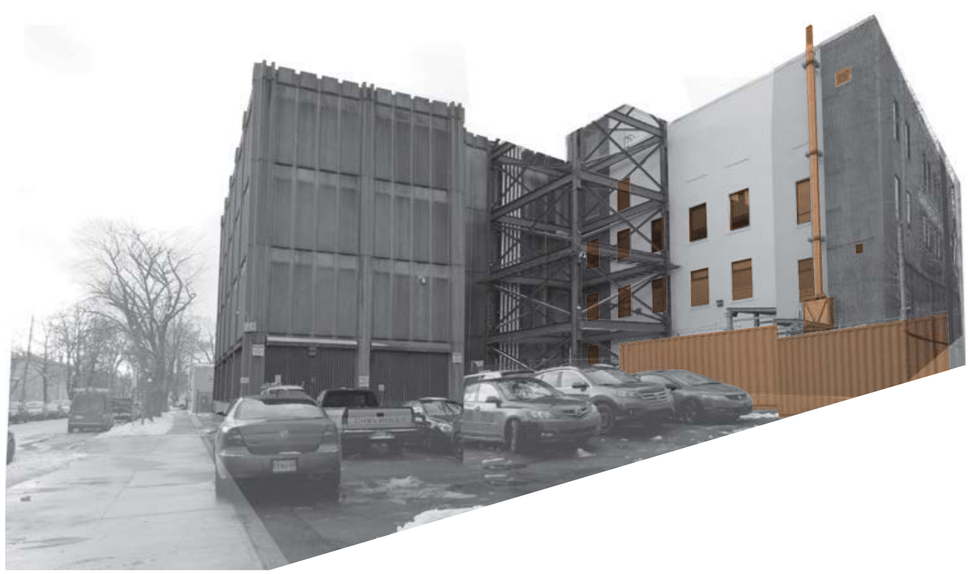


Image 78: Existing data center fenestration and mechanical equipment

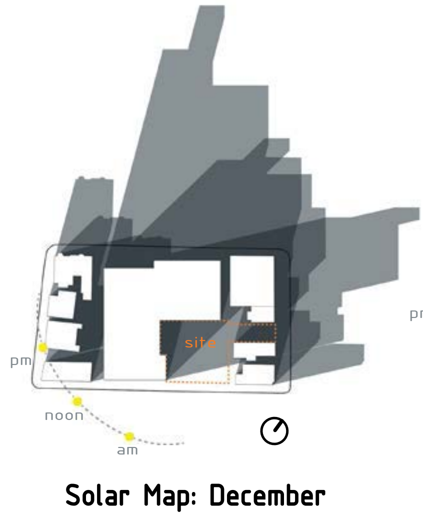


Image 79: Shadow study of the Proto_Site, showing morning, noon, and afternoon shade conditions in December, March, and June.

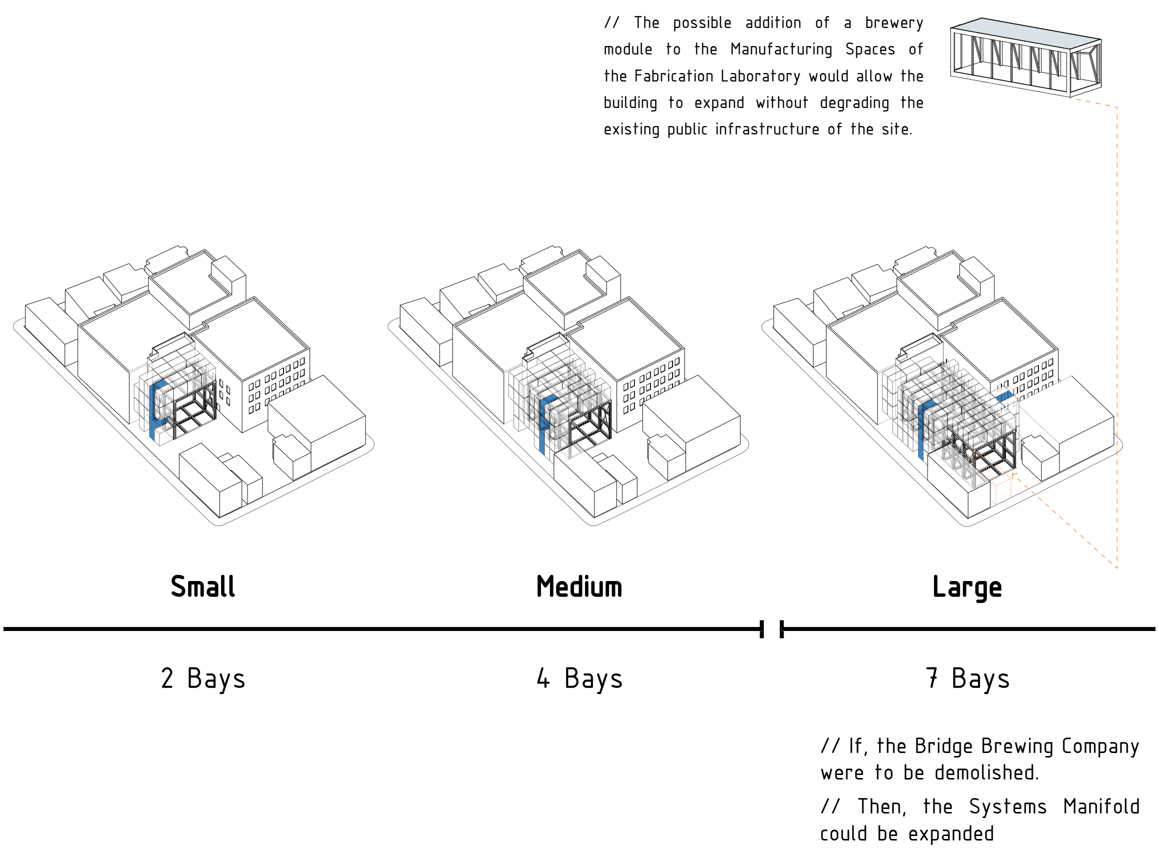


Image 80: Axonometric drawings testing small, medium and large support manifold on site

2.2.2 Response: Component Specificity

Placing the prototype on site (see Image 81 and Image 82) the tower is located on a portion of blank façade on the Data Center, and a four-Bay support manifold is expanded outward toward Agricola Street (see Image 81 and Image 83). This orientation of the Fabrication Laboratory makes use of the existing gap between buildings on Agricola Street (see Image 76) as the vehicular access point for the Manufacturing Spaces, as well as providing future potential for expansion of the support manifold, if the Bridge Brewing Company building is demolished. The form of the tower is modified from the prototypical rectangular plan form, to adjoin with the preexisting geometry of the Data Center (see floor plans in Image 88 – Image 92).

The public program modules are then aggregated on the Willow Street side and top of the support manifold (see Image 81 and Image 84). The space between the support manifold and the Data Center building is utilized as a light-well for the existing Data Center windows, a corridor for the existing Data Center access doors, and as a stairwell for access to the Fabrication Laboratory roof top program modules (see floor plans in Image 88 – Image 92). This breeze-way connects the Data Center to the Fab Lab, and through the support conduits, could potentially allow the Data Center to make use of the support manifold and mechanical/electrical spaces of the Fab Lab (see Image 93).

The grid structure of the outer skin is then tested in its various formal articulations (see Image 81 and Image 85). Through a solar analysis of this highly shaded site, it can be demonstrated that little solar gains are made through the articulation of form on this site. As such, the rectilinear grid form is chosen and an alternative method for energy collection in the facade is explored.

As such, a simple movement, wind-actuated, piezoelectric façade element for energy collection. This is designed in conjunction with a mechanical movement, occupancy-sensory, gestural facade element. Thereby creating a performance skin panel that is moved by the wind when the building is unoccupied, and as Program Spaces are occupied, the facade mechanically opens to provide connection between inside and outside (see Image 81, Image 86 and Image 87).

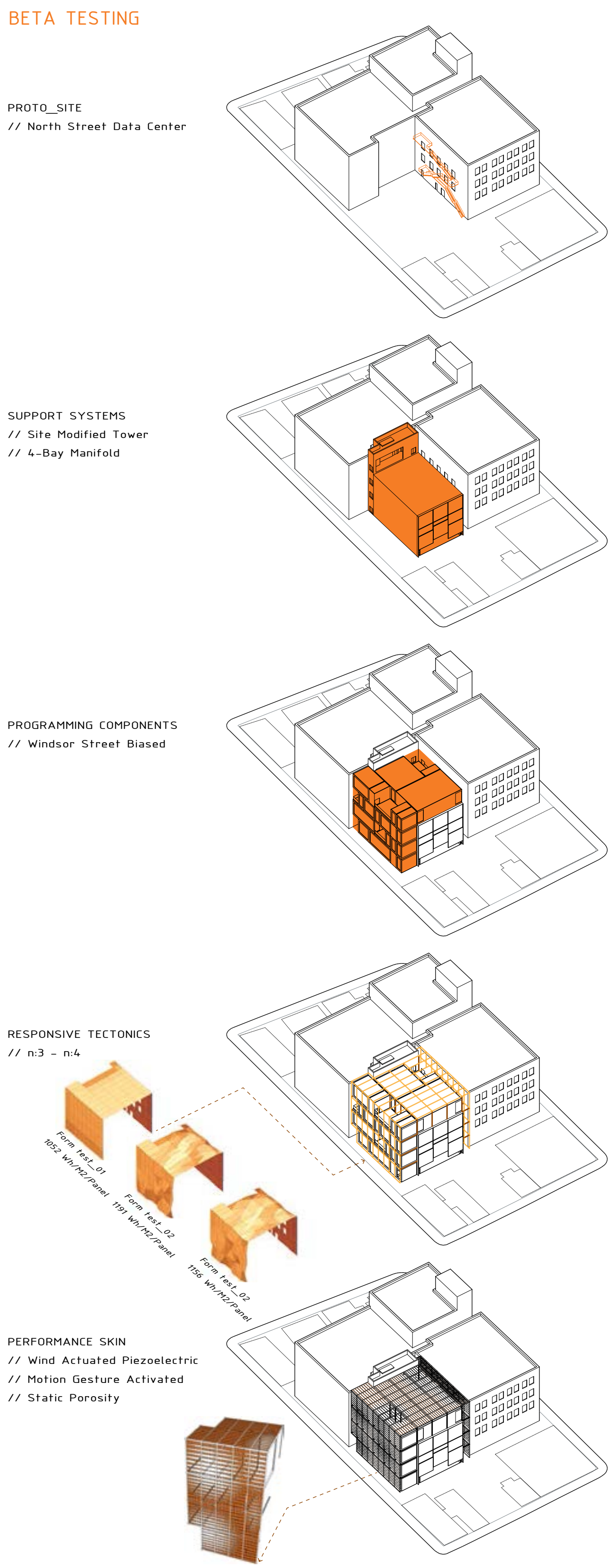


Image 81: Overview of axonometric drawing series depicting the testing of the four prototype design principles on the Proto_Site (see Image 82 to Image 87 for enlarged images).

BETA TESTING

PROTO_SITE

// North Street Data Center

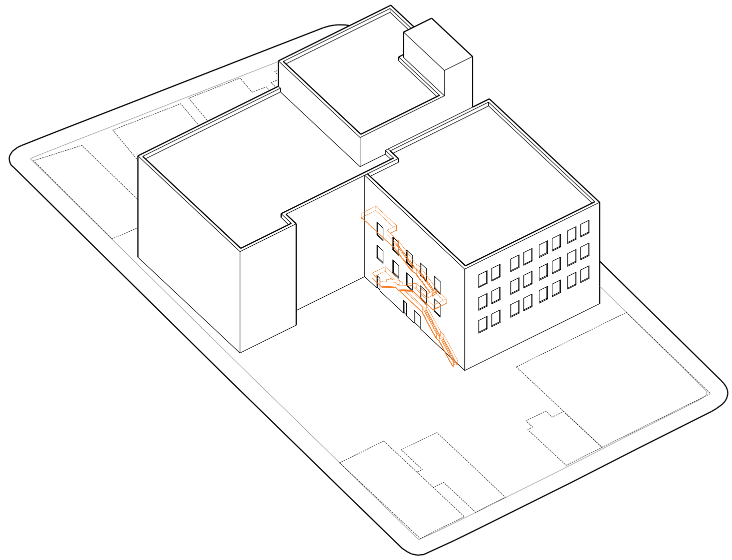


Image 82: Axonometric drawing depicting Proto_Site existing conditions, and proposed atrium stairwell.

SUPPORT SYSTEMS

// Site Modified Tower

// 4-Bay Manifold

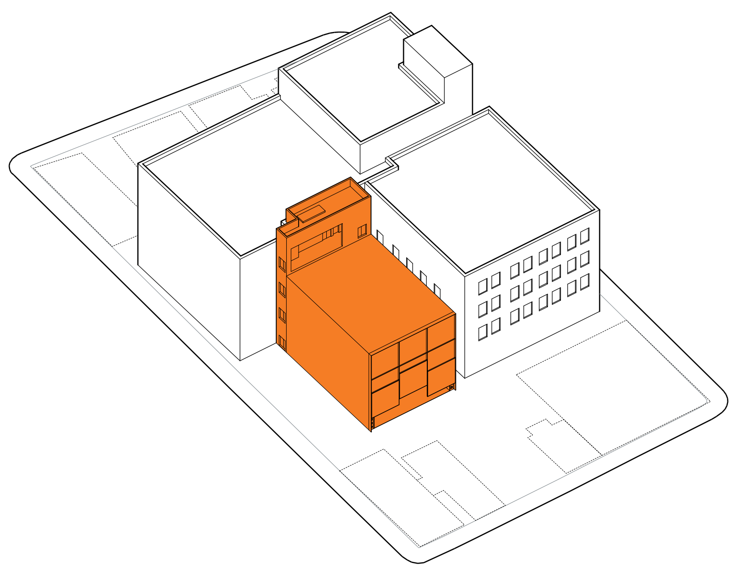


Image 83: Axonometric drawing depicting Proto_Site with addition of site modified tower, and four-bay support manifold. Size selection of the proposal is based on maximizing number of bays, without demolition of Bridge Brewing Company Building (see Image 80).

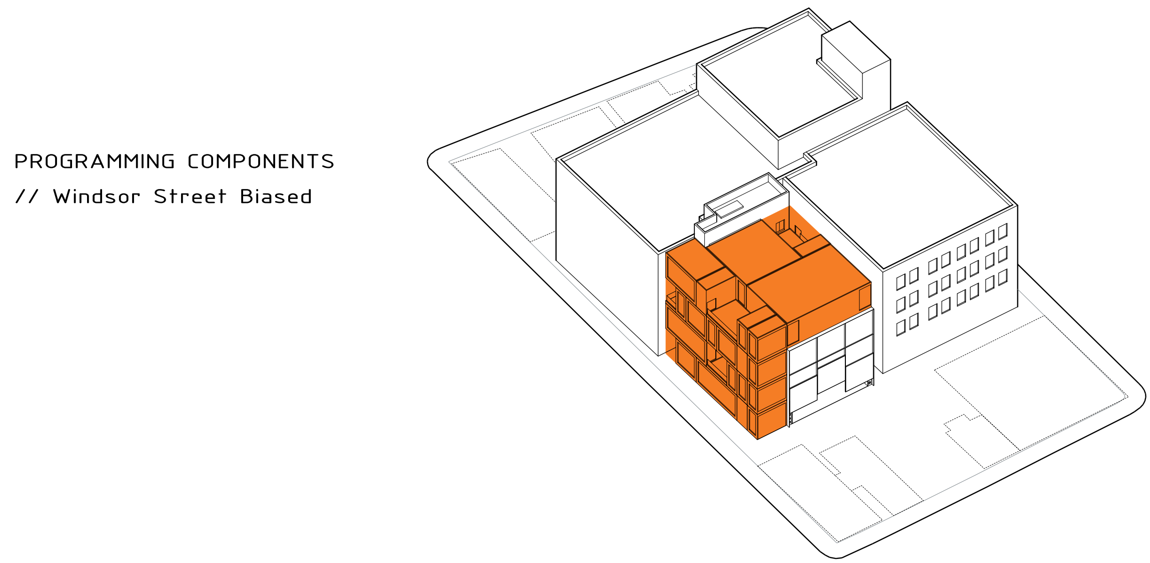


Image 84: Axonometric drawing depicting Proto_Site with addition of program modules. Due to the limiting parameter of the site depth, and the proximity to the existing data center's Windsor Street facing windows, public program modules are aggregated on only one side of the support manifold.

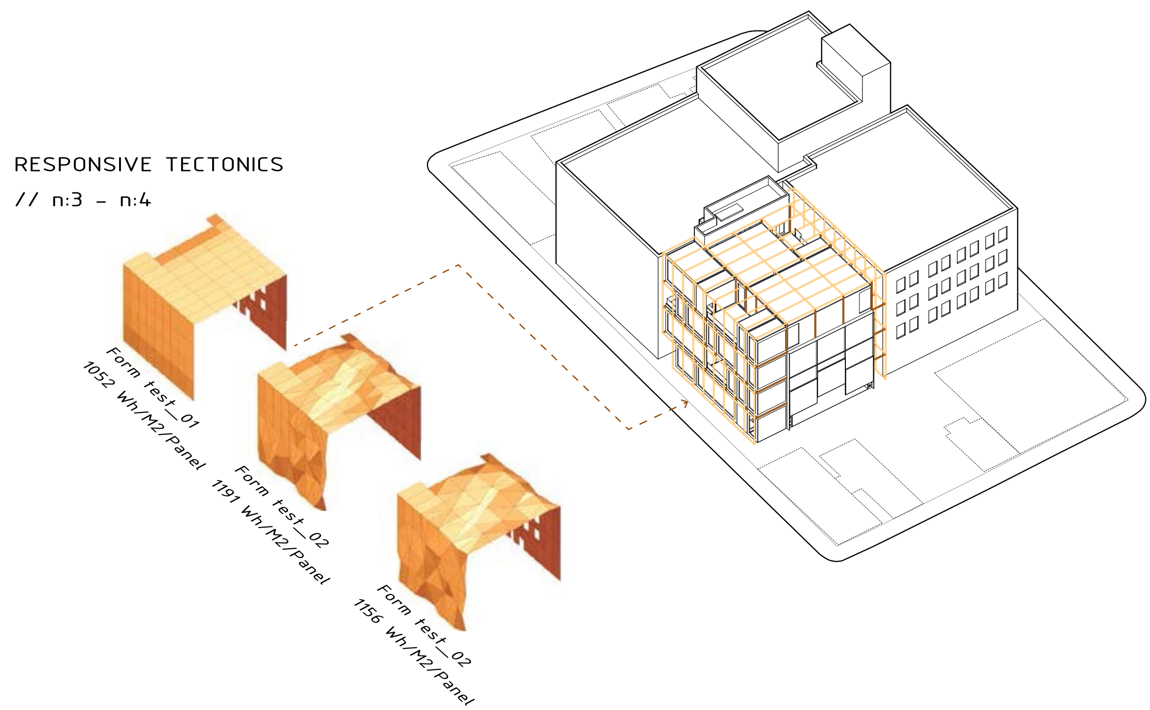


Image 85: Axonometric drawing depicting Proto_Site with addition of grid structure of the outer skin. The solar analysis to the left show the testing of three formal manipulations. As the site is predominantly in shade, as shown in Image 79, the solar gains of the formal manipulations show little differentiation. As such, the rectilinear grid form is selected, and an alternative to a solar-based performance skin panel is explored.

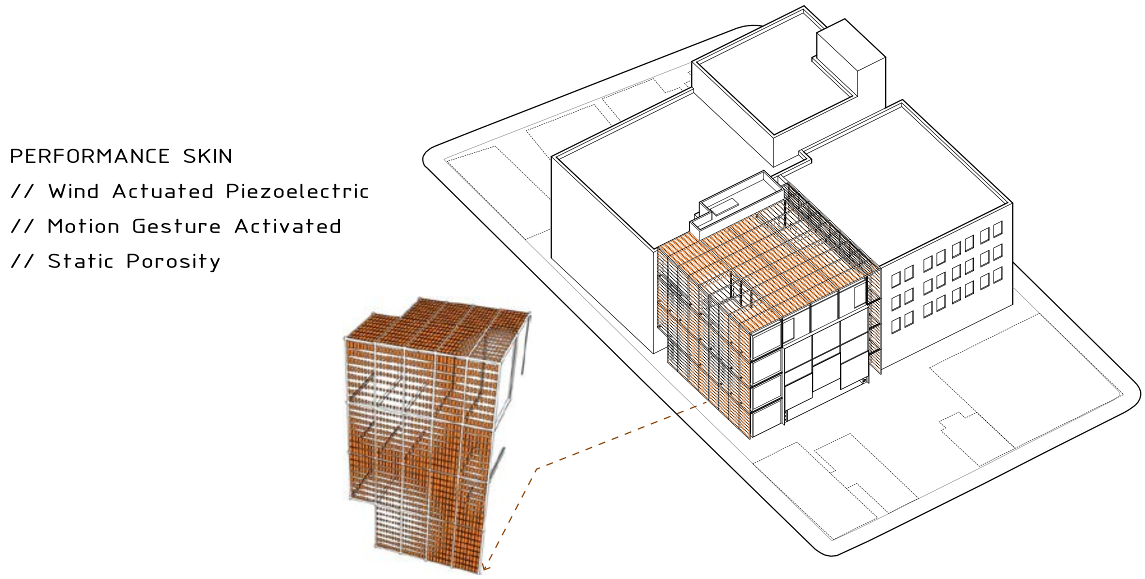


Image 86: Axonometric drawing depicting Proto_Site with addition of *performance skin* panels. Due to the limitations of solar on the site, a *simple movement*, wind-actuated piezoelectric panel is selected for energy collection. This is designed with a mechanical movement, occupancy sensory, gesturally responsive system.

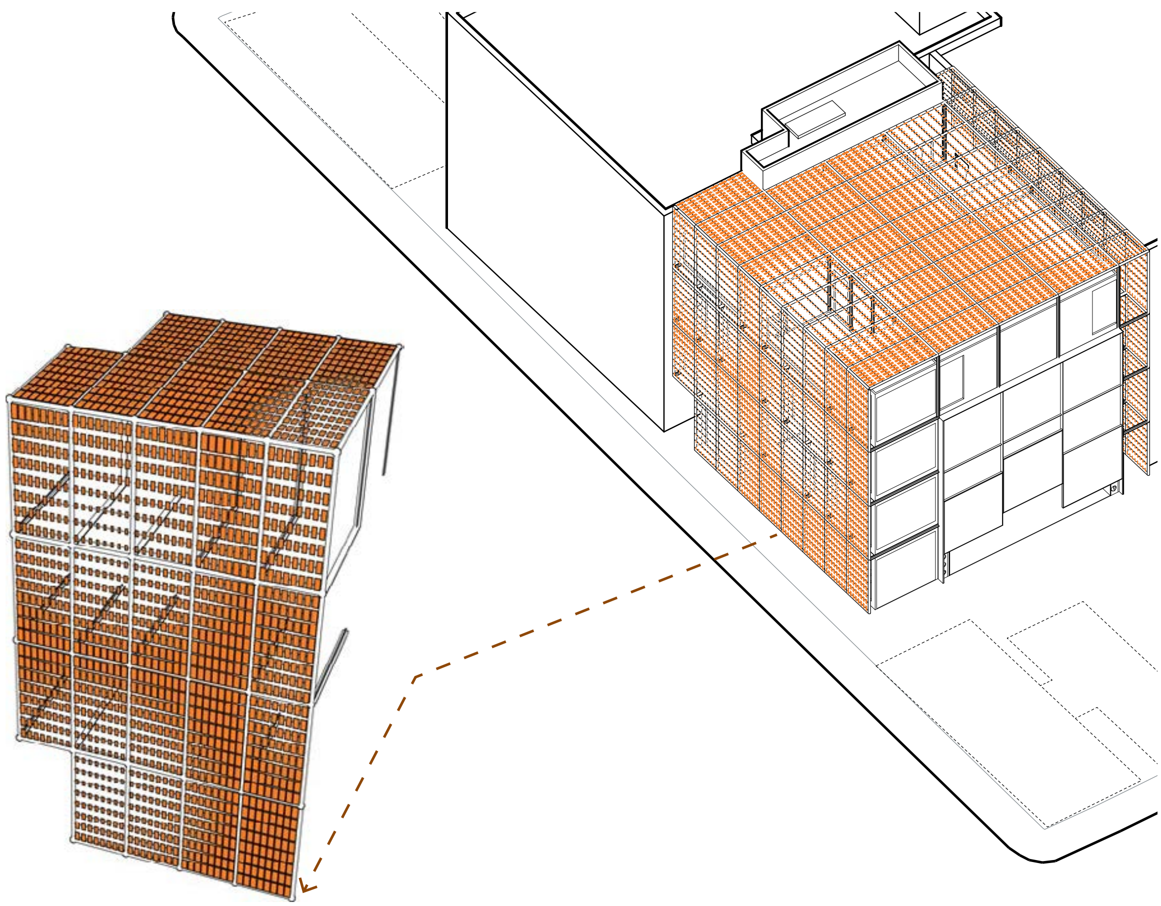


Image 87: Enlarged view of Image 86 to show detail.

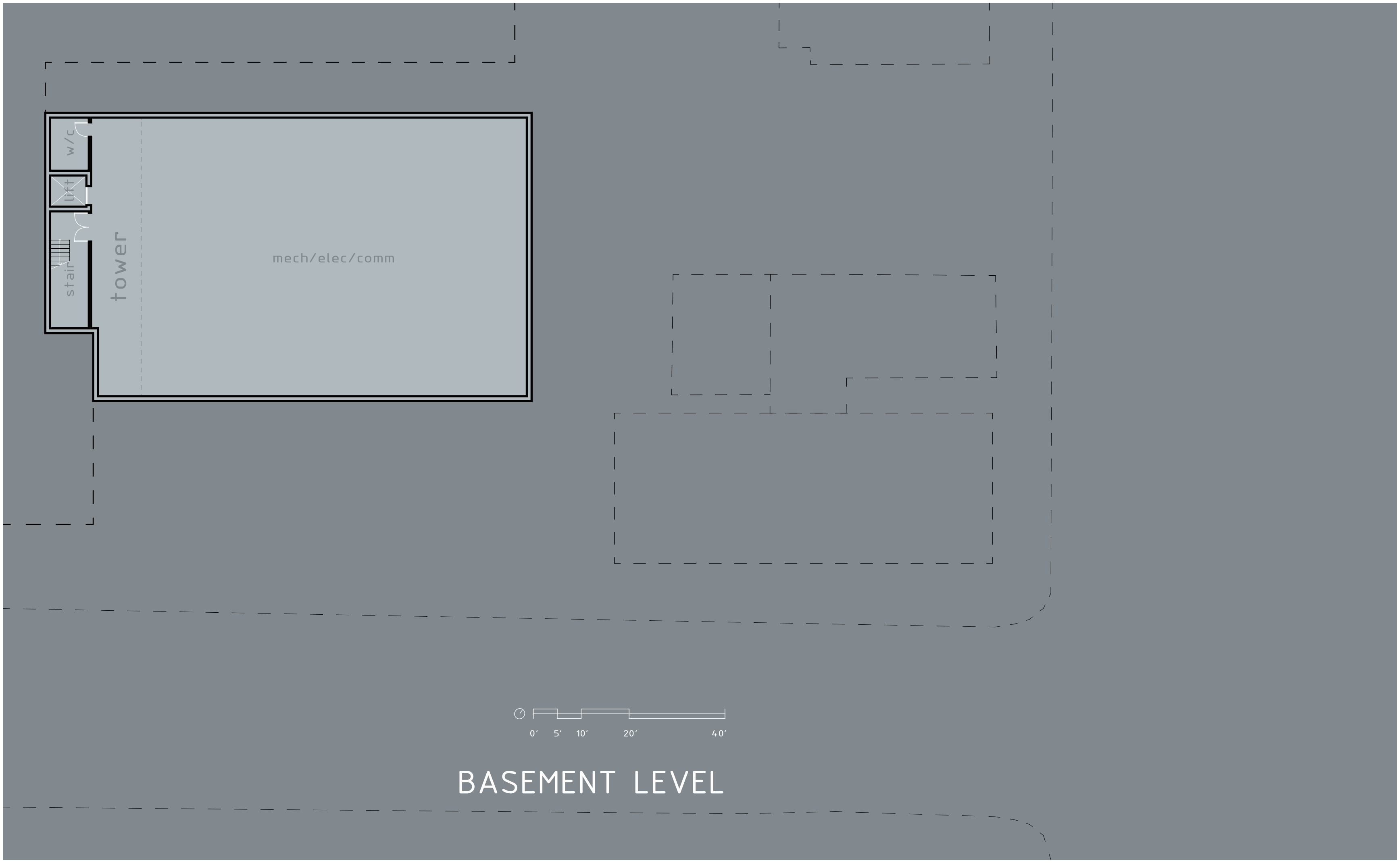


Image 88: Basement level plan of Proto_Site

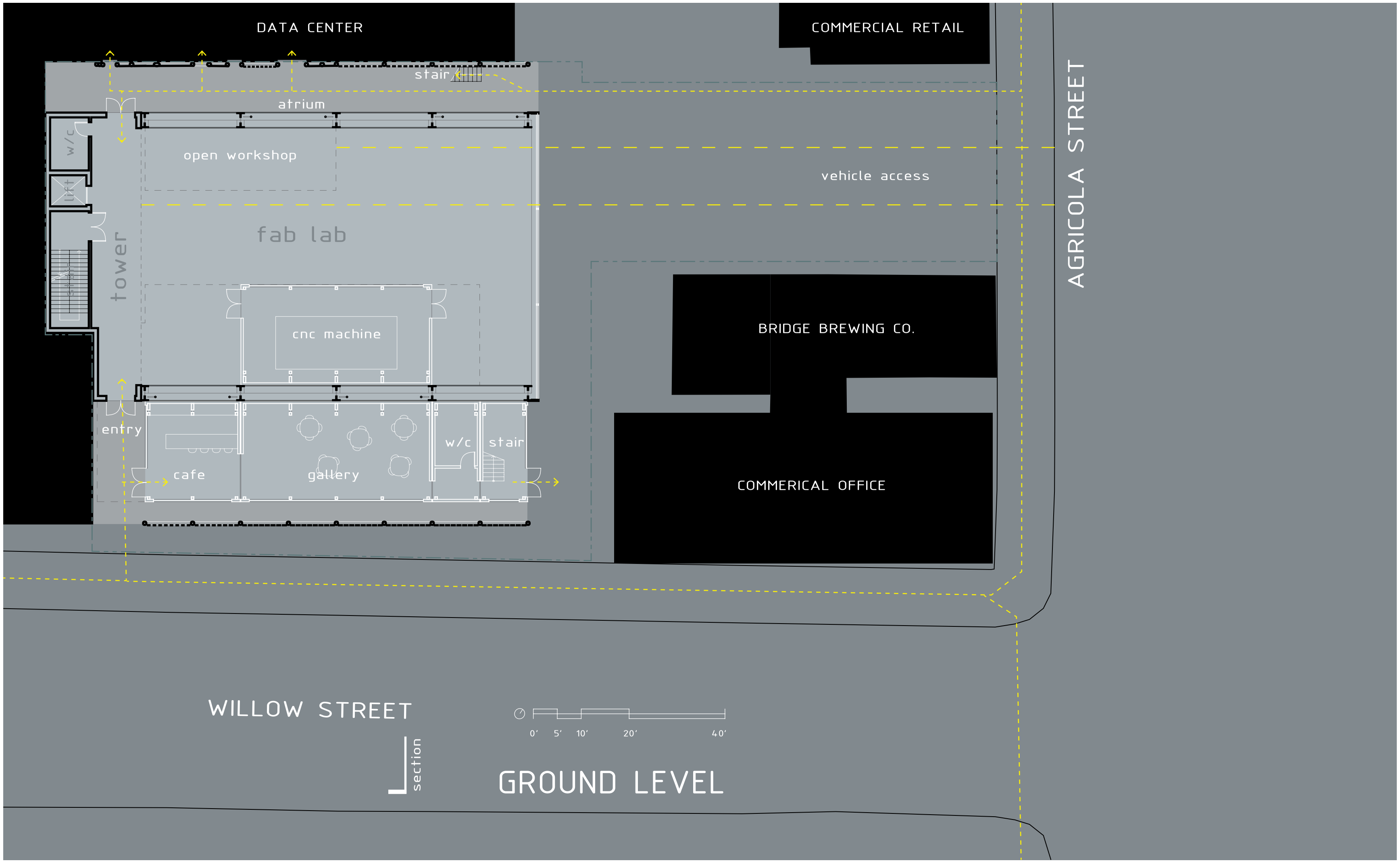


Image 89: Ground level plan of Proto_Site

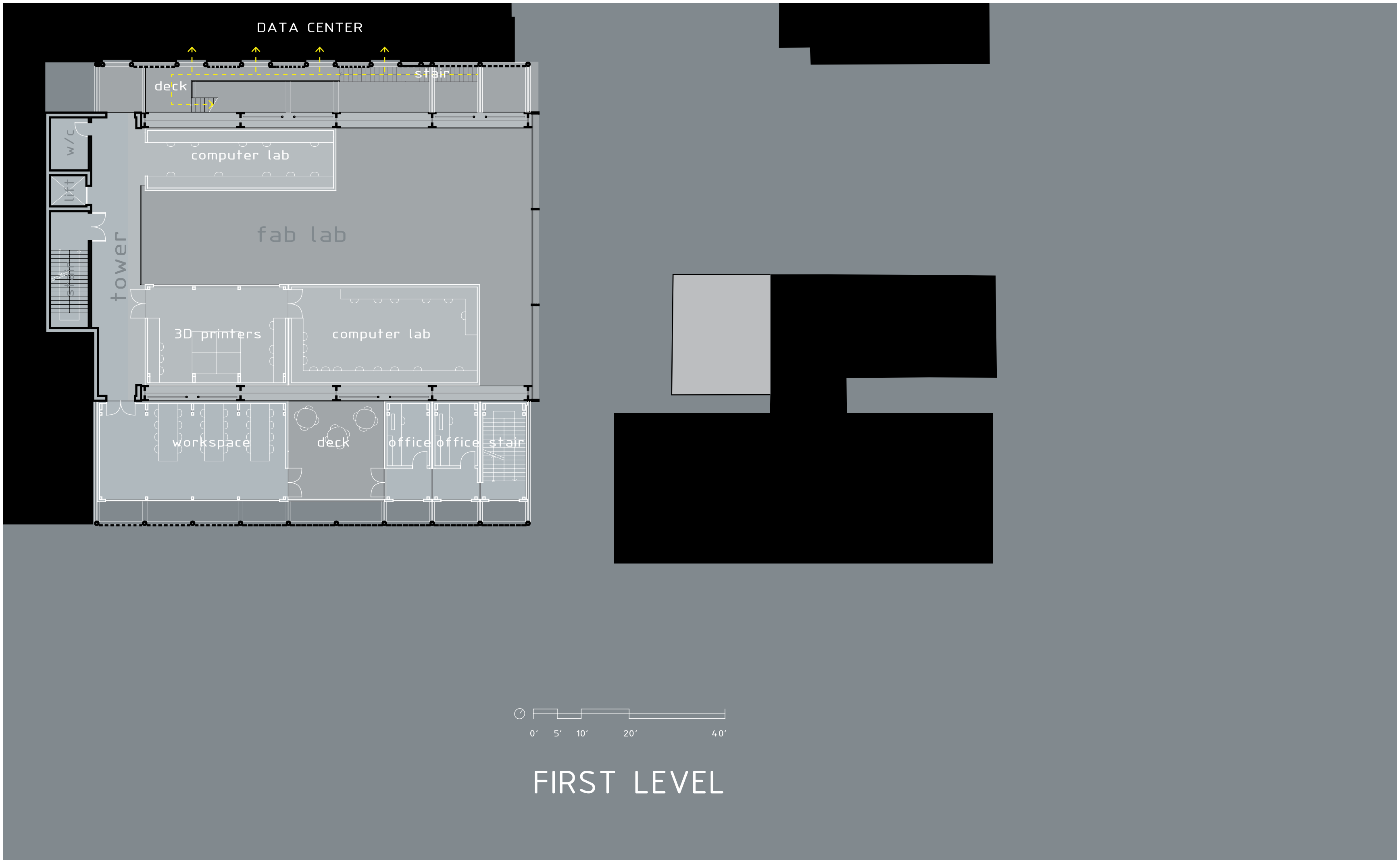


Image 90: First level plan of Proto_Site

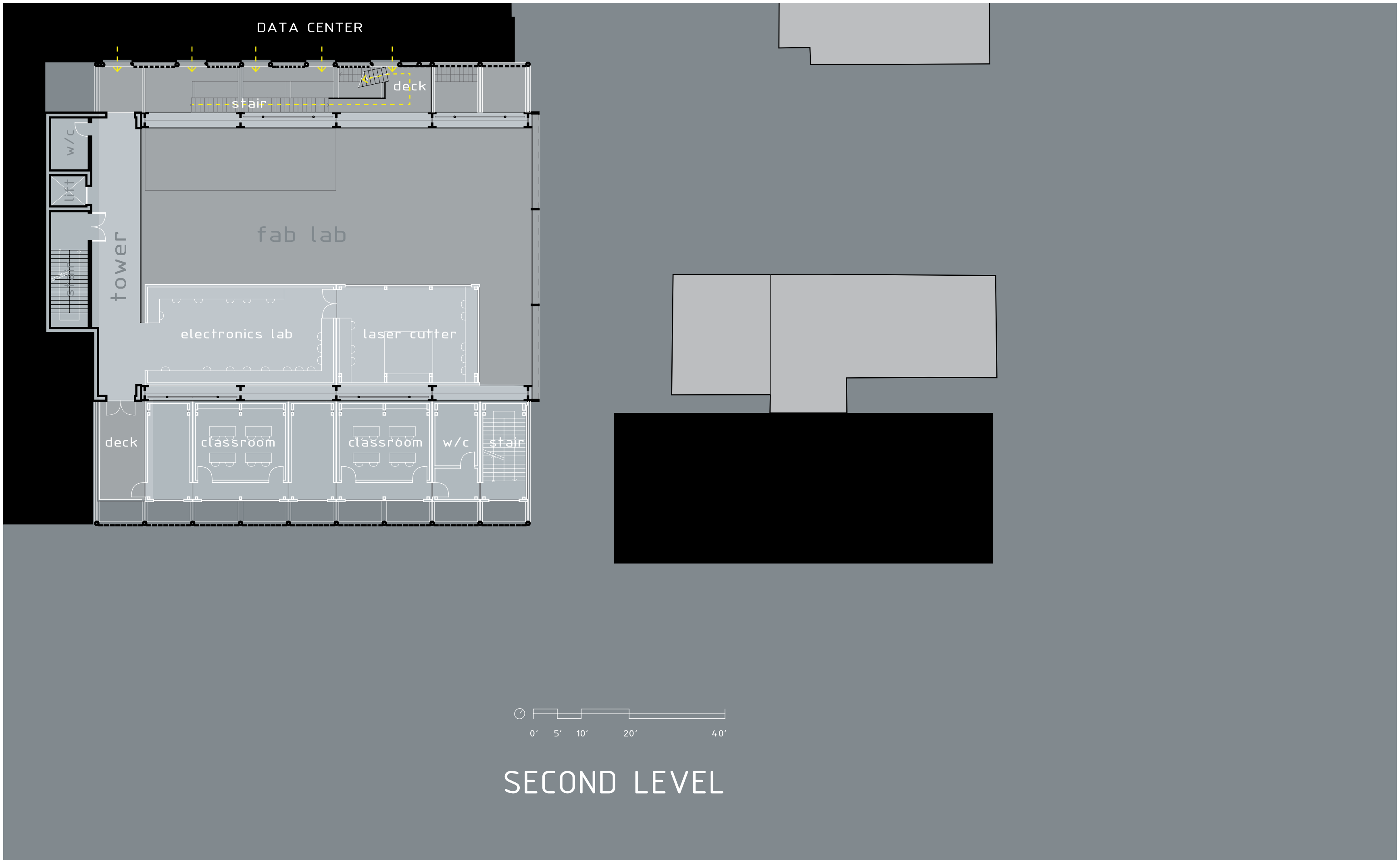


Image 91: Second level plan of Proto_Site

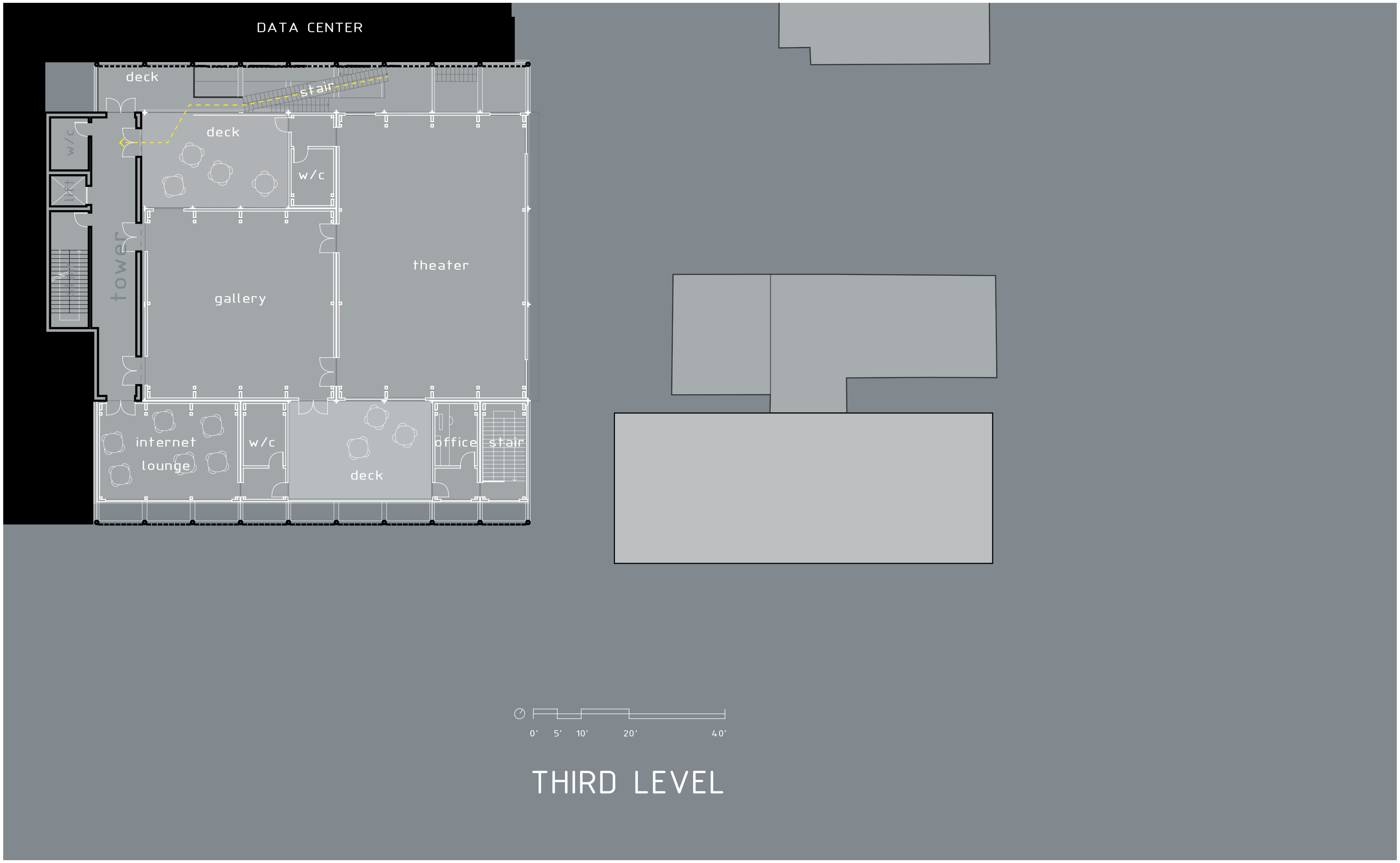


Image 92: Third level plan of Proto_Site

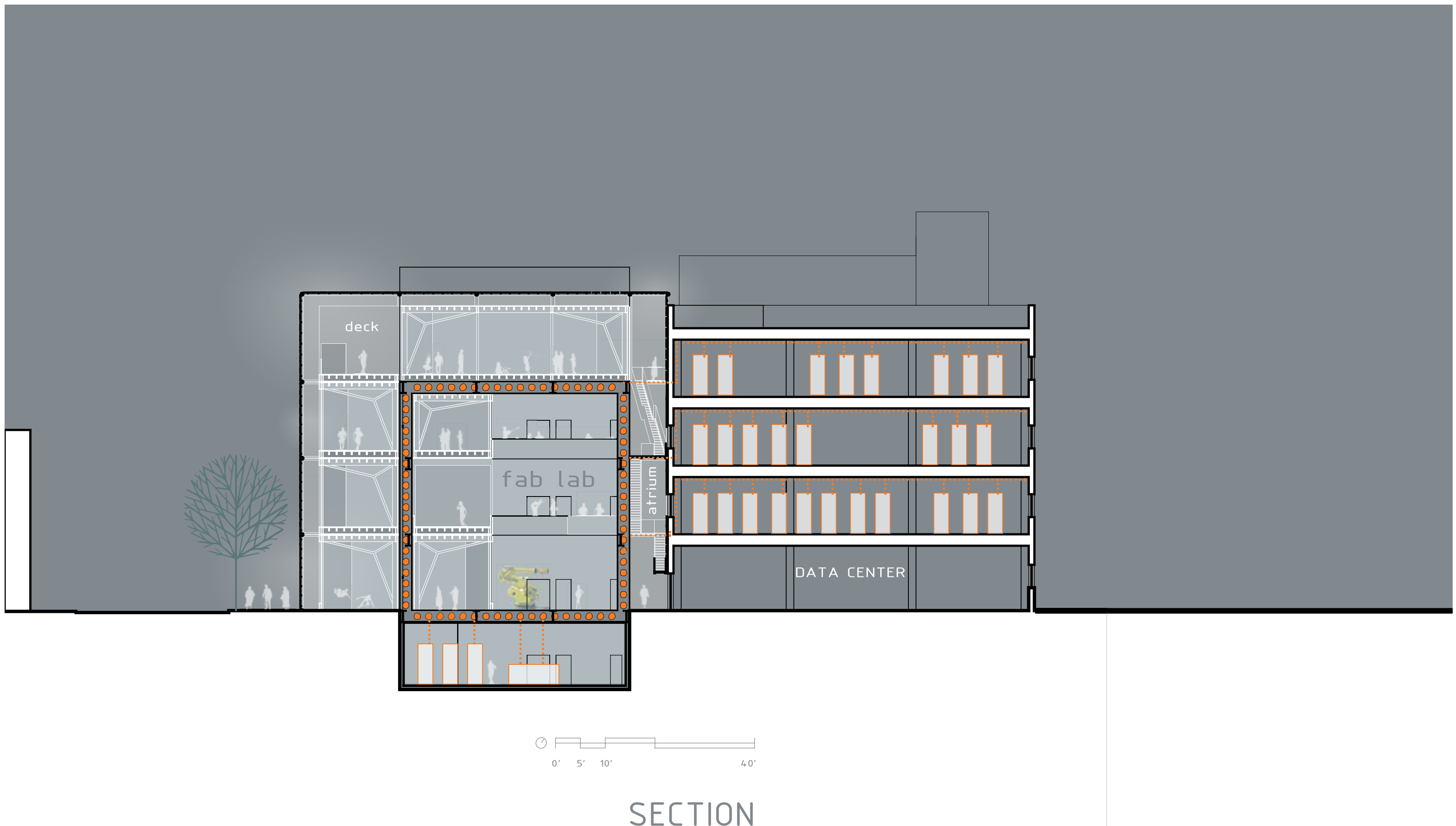


Image 93: Section of Proto_Site (Section marker on ground level plan)

CHAPTER 3: CONCLUSION

3.1 Component-Based Systemic Approach

> Computers plug us into a fluid, eminently variable world that gives a special intensity to some of our sensations and the decisions they lead to. (Picon 2010, 152)

The exploration of a component-based systemic approach to the physicality of digital infrastructure conducted within this thesis, addresses the issues discovered in this typology, by embracing change as fundamental to the design. Looking back to the technologically marred facades on the traditionally conceived construction of the North Street Data Center, (see Image 07: page 4 to Image 09: page 5) it is possible to see the advantages of this approach. If a Fabrication Laboratory, designed with the methodology proposed in this thesis, required upgrades to program, mechanical or electrical systems, the tectonics expression of the building would not be affected. Simply, the components would be removed, replaced, or added upon, and the system would adapt freely to the new conditions.

Through the initial development of a prototype for the Fabrication Laboratory, the subjects of indeterminacy that affect the design for the systems, program, environment, and urban conditions were brought to the forefront. This decision led to the design of a system of components that would not only have the capacity for program and system component adaptions, but would be capable of responding to the specifics of a site. While the Fabrication Laboratory is developed as a universal prototype, the resultant form and performance of the tested building is individualized by the specifics of site.

In Section 2.2: Proto_Site Beta Testing, the site specific adaptations of the prototype are tested on a highly constrained urban infill site, in the core of Halifax. The fitness of the prototype is measured by the ability for the component system to adapt to the conditions of a specific site. In this scenario, the prototypical form of the tower is adjusted to integrate with existing neighbouring forms, the symmetrical aggregation of program modules becomes asymmetrically biased to maintain access to the Data Centers existing doors and windows, and the outer skin is formally and responsively adapted to local environmental conditions. The digital rendering in Image 94 shows the concluding form of the prototype, as adapted for this site.

From this adaptation of the prototype to a site, it is plausible to suggest that the Fabrication Laboratory prototype could be applicable on a wide variety of sites. Image 95 shows the application of the prototype a more open, urban site on the Halifax waterfront. Unrestricted by neighbouring structures, this rendering demonstrates a seven bay system, using a static panel, photovoltaic energy collector and LED gestural response. Presuming, for the sake of the example, that height restrictions limit the scale of the building vertically, the rendering demonstrates the ability for the prototype to be adapted for a multitude of urban conditions.

As a result of developing a component-based system, there is an inherent opportunity to use the component elements as separate from the system-whole. Image 96 demonstrates a 3D printer program module is installed in the parking stall of an apartment building (see Image 12: page 7, and section 1.2 Software: Digital Programming: Urban Garage: Density and Cultural Production). The performance skin shown in this example uses a micro-algae panel, that can be used to remove the carbon dioxide from the air, and produces oil, cellulose and oxygen. This example exhibits the wider applications of a component-based systemic approach to the development of digital infrastructure, and provides another means of adding more cultural production spaces to the urban core.

Lastly, building upon Antoine Picon's postulation, as discussed in section 1.1 Hardware: Digital Infrastructure: Digital User Interface, that digital networks only become apparent to users through interaction (Picon 2010, 119), the gesturally interactive elements of the outer skin can be seen as the development of an architectural language that tangibly expresses the ephemeral qualities of an otherwise invisible digital environment. In this sense, the design of a sensory/responsive outer skin for the Fabrication Laboratory creates a tectonic expression that aligns digital cultural perceptions with the physical infrastructure that supports its operation.

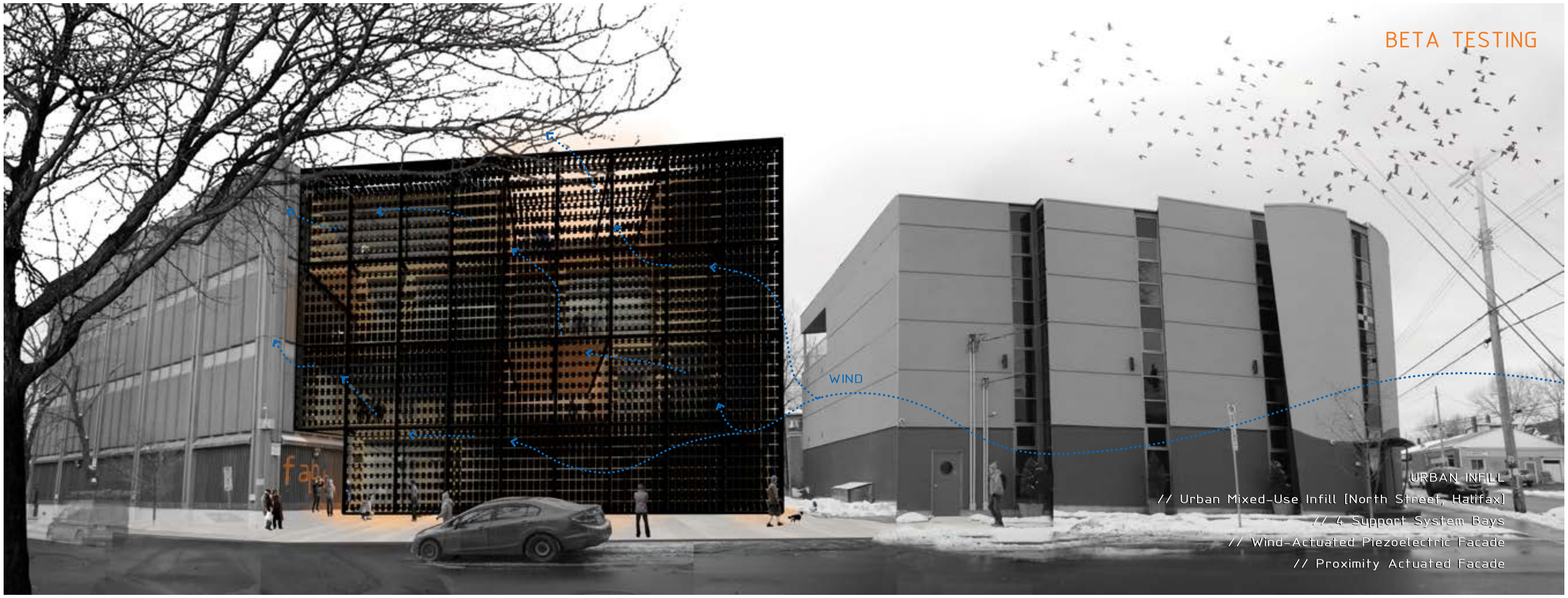


Image 94: Digital rendering showing of the concluding form of the prototype, as adapted for the North Street Data Center site.

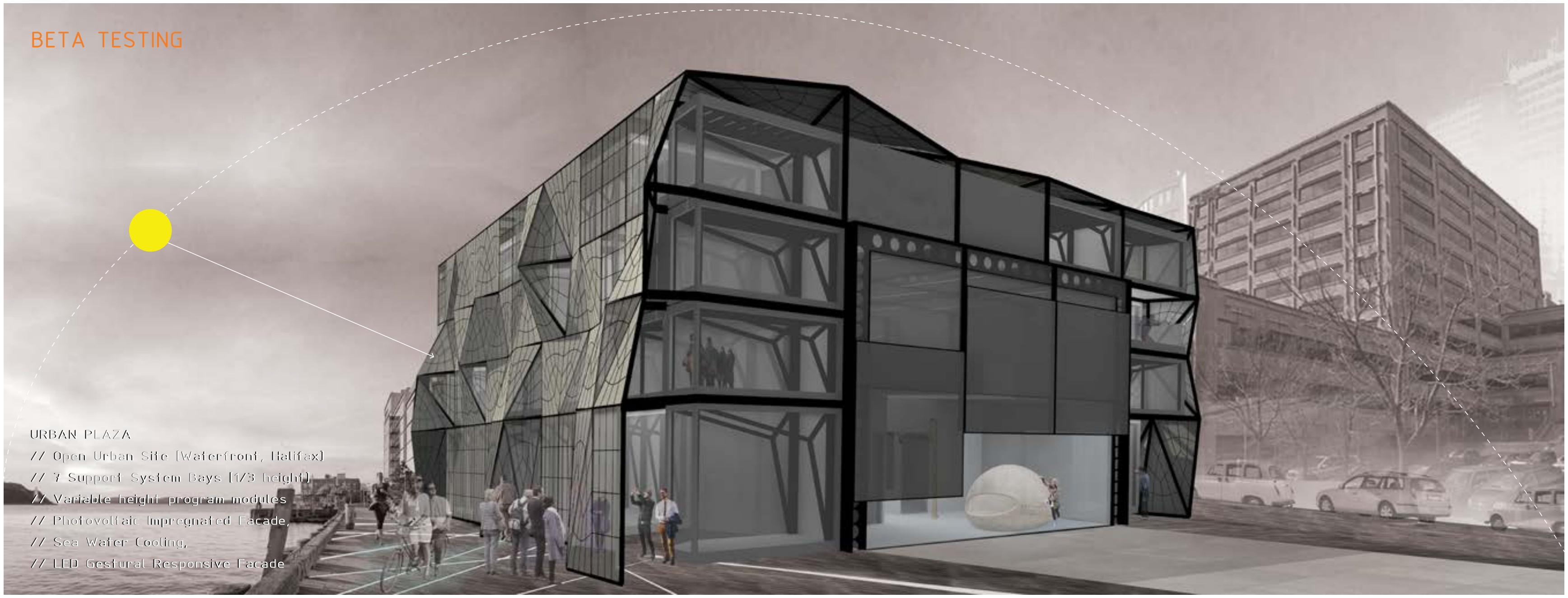


Image 95: Digital rendering showing the concluding form of the prototype as adapted to a site on the Halifax Waterfront.

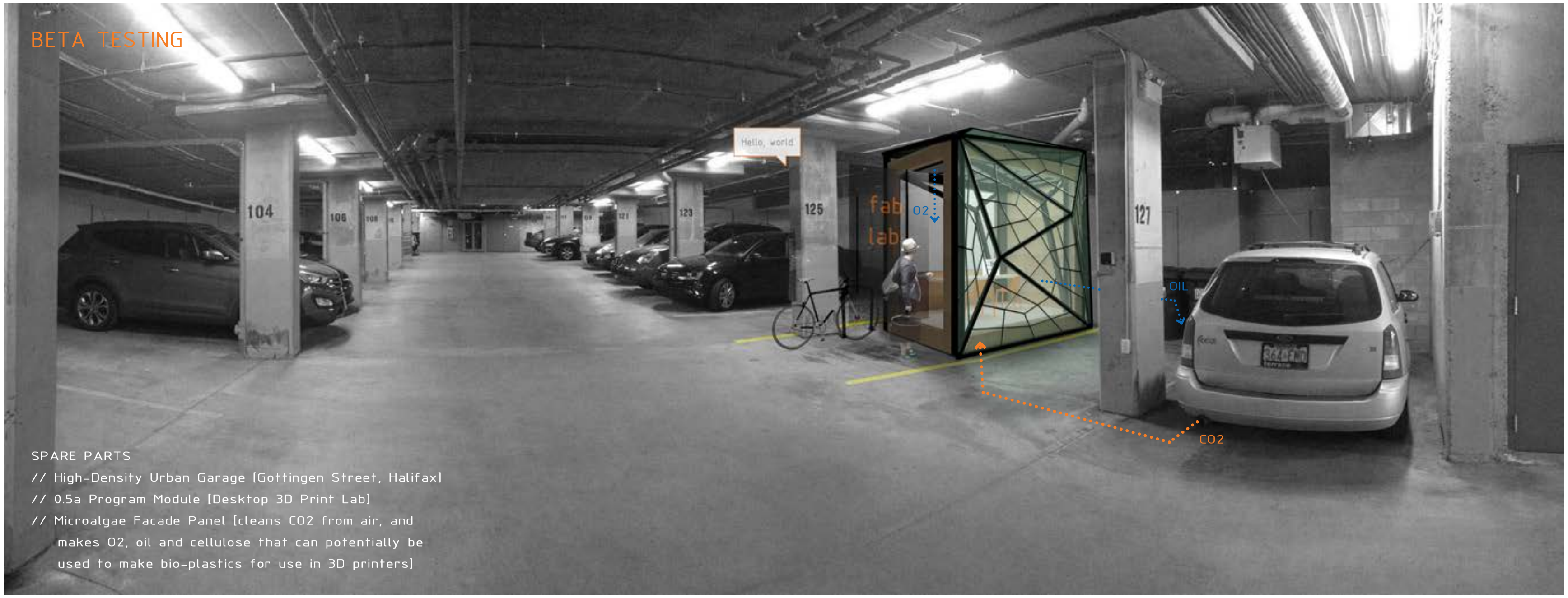


Image 96: Digital rendering testing the adaptability of the components to be used separately from the Fabrication Laboratory system-whole in a high-density residential parking garage

APPENDIX: HELLO, WORLD

Image 97: The above image is of a drawing describing the title name of this thesis in the context of the work. This panel was pinned-up as part of the thesis defense, as an introduction to the work.

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