PROCEEDINGS

INTERSECTIONS DESIGN & RESILIENCE

2018 INTERSECTIONS SYMPOSIUM

American Institute of Architects

Association of Collegiate Schools of Architecture

The American Institute of Architects

ACSA

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ABOUT THE SYMPOSIUM

The American Institute of Architects (AIA) and the Association of Collegiate Schools of Architecture (ACSA) are dedicated to the INTERSECTION of Education, Research and Practice. Since 2015, we have offered ***Intersections Symposium***, a series of research sessions derived from a competitive, peer-review process, which address a specific theme. This Proceedings addresses design and resilience through the lens of technological, social, and ecological perspectives and is the product of the 2018 ***Intersections Symposium on Design and Resilience*** held June 22, 2018, at the AIA Conference on Architecture in New York City.

We want to thank our co-chairs Julie Kim and John Folan; our moderators: Billie Faircloth, Shawna Myers, and Alan Ricks; our presenters: Michelle Laboy, Whitney Moon, Vera Parlac, Cordula Roser Gray, Julie Larsen, Sandy Stannard, their co-authors and students, and our special guest Bryan Lee. Without their contributions, there would be no Intersections and sharing of this important work.

Nissa Dahlin-Brown, EdD, Assoc. AIA, Director of Higher Education, AIA

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About Our Theme - Design and Resilience

JOHN FOLAN
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> *"Resilience is the intentional design of systems that have capacity to adapt and sustain vitality in response to stresses or disturbances. Resilience 1) is multi-scalar, 2) benefits from redundancy, 3) anticipates dynamic futures, 4) equitable, 5) non-absolute, and 6) predicated on understanding of condition."*

The working definition referenced above is the thread that we used to tie together the content of four sessions and frame discourse at the 2018 AIA Intersections Symposium on Design and Resilience. Three separate, but related, contextual frameworks - Technological, Ecological, and Sociological - provided a platform for a fourth discussion that addressed synthesis and action. Offered as part of the 2018 AIA Conference on Architecture and curated in collaboration with a cohort of moderators, this format represents a radical departure from previous Intersections Symposia. With an articulated mission of bridging the gaps that exists in education, research and practice, the Intersections Symposium is a joint venture between the AIA and ACSA. The move to construct the 2018 symposium as a constellation of sessions delivered throughout the programming of the AIA Conference promised to broaden discourse and make a forum more accessible to the voices who will reinforce the connections between practice and the academy.

Consistent with that aspiration, the sessions were conceived of and structured as forums for discussion. Presentations were abbreviated and the content oriented toward illustrating major themes, either consistent, or in opposition with one another. The moderators for each session were empowered to calibrate the conversation around thematic content contained in this volume, but were asked specifically to avoid making this a platform for dissemination of published content. The moderators selected for the thematic sessions are leading practitioners in the areas of technology, ecology and social justice, representing the practices of Kieran Timberlake, Kennedy Violich Architecture, and MASS Design Group respectively. Beyond being well respected design practitioners with domain expertise, all three architects represent practices that have research units, remain engaged in contemporary educational pedagogy development, and address the breadth of topic scope with different hierarchical priority. In this form, the symposium sessions positioned themselves as units that could stand autonomously, or relate across a broader discourse. The content of this volume includes six projects, each reinforcing actionable models for systems of architecture as they relate to ecological, technological, and sociological resilience. Presented here in comprehensive form, the writing underscores thematic content discussed in New York City on June 22, 2018. Across all three sessions, and the associated writing included in this volume, we see consistent themes in systems, place, scale, and metrics emerge. The evidence of that consistency was affirmed as moderators and participants convened to speculate on actionable opportunities for both practice and the academy. The lenses through which opportunity was explored in discourse, and which is affirmed in the cases/writing finds its bearing in the session synopsis which follow.

Framing Technology and Resilience How can technology aid our search for design and resilience? In what ways are we proposing innovative resilient design solutions via the integration of data, sensors, biomimicry, materials development and testing, structural innovations, energy modeling, artificial intelligence, augmented reality, and virtual reality? Is there current research occurring in academic studios and labs that can impact professional practices?

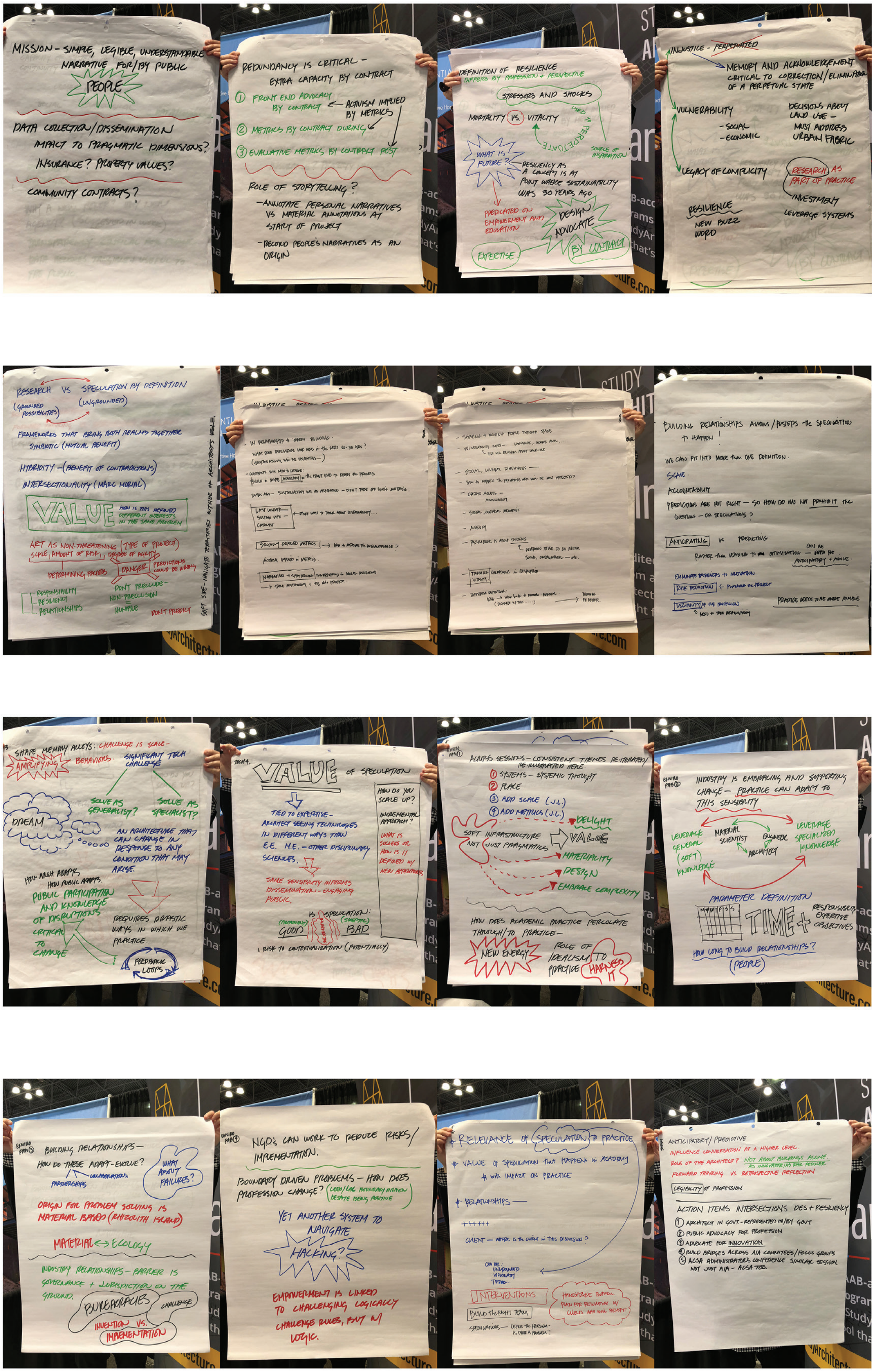
Led by **Billie Faircloth**, AIA, Kiernan Timberlake, the authors addressed design issues, while engaging citizens and other stakeholders, to showcase cutting edge research in adaptive building systems, material sciences, environmental, urban ecology, adaptation and embedded technologies, particularly as they relate to climate change, resiliency and sustainability. One of the projects offers strategies for resilient communities that face challenges and opportunities to live with water. These strategies include urban hydrology management, citizen-engaged science, visualization strategies, data and sensors, and urban prototyping (Cordula Roser Gray, AIA, Tulane). The second project shares the results of several senior research studios focused on material technologies, kinetics, synthetic biology and robotics in architectural systems and how technology can empower architecture to connect spaces, users and environment as one path to resilience (Vera Parlac, U. of Calgary).

Framing Ecology and Resilience How do we design more resilient habitats? What theories, systems, materials, and/or processes are being explored that embrace these challenges and advance resiliency and sustainable use? What new opportunities might present themselves as we innovate and explore solutions to these critical issues?

The selected projects for this session address ecological design and resilience through infrastructure, materials, fabrication, building performance, aesthetics, and parametric tools. Facilitated by **Shawna Meyer**, AIA, Kennedy & Violich, the authors presented compelling cases for how nature informs design and produces resilient structures that please the senses and save the planet. The audience heard two different strategies for leveraging ecology to produce different scales of products. One of the projects combines innovative design strategies with advanced R&D concrete mixes and fabrication techniques. The resulting concrete modules encase mangrove seedlings, while concrete fins below water create new ecological habitats (Julie Larsen, Assoc. AIA, Syracuse). The second research project presents student research using parametric design tools, multi-modal methods, and performative material systems as part of a larger design challenge (Sandy Stannard, Cal Poly). In each example, “performance” goes beyond the basics, informed design, and identifies an environmental necessity - need for water, need for cleaner air - based on the project situation.

Framing Social Resilience Communities around the world are struck with sudden shocks and disturbances due to social, political and environmental change. What does design and resilience mean for those who inhabit our built environment? How can design and construction impact educational outcomes? The spread of disease? Poverty? Policy? Security? How do we engage stakeholders in the design and resilience process?

MASS Design’s **Alan Ricks**, AIA, joined by Colloqate’s Bryan Lee, facilitated an interactive discussion about social justice, equity, and inclusion. The audience heard two very different proposals for addressing social resilience and design in communities. At one scale, pneumatic technology, mobility, sociability, and environmental responsibility through the design and fabrication of a prototype nomadic inflatable structure offer answers to a community need (Whitney Moon, U. Wisconsin). The second project in Boston focused on urban resilience for the homeowner by addressing the existing urban fabric of repetitive, residential buildings that architects have historically neither designed nor studied. Through a data-model developed from publicly available information, an online app was created to simulate comfort, energy use, response to natural hazards, etc. (Michelle Laboy, Northeastern U.) Both of these projects reinforce the idea that social resilience addresses changes resulting from environmental, social or political stresses. Fundamental to both projects is the engagement of stakeholders in the process.


MISSION - SIMPLE, LEGIBLE, UNDERSTANDABLE NARRATIVE FOR/BY PUBLIC
PEOPLE
DATA COLLECTION/DISSEMINATION
IMPACT TO PRAGMATIC DIMENSIONS?
INSURANCE? PROPERTY VALUES?
COMMUNITY CONTRACTS?
REDUNDANCY IS CRITICAL - EXTRA CAPACITY BY CONTRACT
ROLE OF STORYTELLING?
DEFINITION OF RESILIENCE
STRESSORS AND SHOCKS
MORTALITY VS VITALITY
WHAT IS FUTURE?
DESIGN ADVOCATE
EXPERTISE
BY CONTRACT
MEMORY AND ACKNOWLEDGEMENT
VULNERABILITY
LEGACY OF COMPLICITY
RESILIENCE NEW BUZZ WORD
RESEARCH VS SPECULATION BY DEFINITION
HYBRIDITY
INTERSECTIONALITY
VALUE
DANGER
VALUE OF SPECULATION
DREAM
FEEDBACK LOOPS
GOOD BAD
DELIGHT
VALUE
MATERIALITY
DESIGN
EMBRACE COMPLEXITY
NEW ENERGY
HARNESS IT
INDUSTRY IS EMBRACING AND SUPPORTING CHANGE - PRACTICE CAN ADAPT TO THIS SENSIBILITY
PARAMETER DEFINITION
TIME+
HOW LONG TO BUILD RELATIONSHIPS?
(PEOPLE)
BUILDING RELATIONSHIPS -
WHAT ABOUT FAILURES?
MATERIAL ↔ ECOLOGY
BUREAUCRACIES
INVENTION VS IMPLEMENTATION
NGO'S CAN WORK TO REDUCE RISKS/ IMPLEMENTATION.
YET ANOTHER SYSTEM TO NAVIGATE
HACKING?
EMPOWERMENT IS LINKED TO CHALLENGING LOGICALLY CHALLENGE RULES, BUT W/ LOGIC.
RELEVANCE OF SPECULATION TO PRACTICE
INTERVENTIONS
ACTION ITEMS INTERSECTIONS DES + RESILIENCY

Framing Resilience: The Wrap-Up Our vision for this symposium leveraged the partnership between the American Institute of Architects (AIA) and the Association of Collegiate Schools of Architecture (ACSA) to extend discourse at the intersection of education, research, and practice. As we considered the structure for the 2018 Intersections Symposium, we saw an opportunity to further strengthen the tie between the academy and practice via brokered engagement between an invited moderator, the authors, and the audience. We envisioned three interactive discussions, each led by a leader in the profession whose own efforts bridge research and practice. While the content of the accepted authors' papers directed the structure of the discussion, the moderators framed the respective conversations with a series of provocations designed to elicit open and lively dialogue between the authors and the audience. In a final wrap-up session, the three invited moderators and co-chairs engaged in an open discussion with each other and the audience on the nature of research, practice, and technology framed through ideas of resilience.

Each of the three sessions foreground a discreet lens – technological, ecological, and sociological. Taken collectively, however, the projects all asked us to reconsider the residual impact on the user and on the environment. The question of value-added ultimately rose to the surface.

- What is the value of speculation?
- Is it "living in a dream" to imagine an architecture that can change in response to environmental conditions?
- How does academic practice thread into practice?
- How can the profession leverage industry relationships when governance and jurisdictions present barriers?
- Where are the opportunities to exploit the differences between research and speculation, or, in other words, between grounded possibilities and ungrounded ones?

Are they really so very different in the end? Given the lively and energetic debate between an audience of practitioners and the authors, it was clear that this topic was timely and relevant to contemporary discourse in schools and in practice. The desire to find ways to build relevance to risky experimentation and implementation resonated across the discussions. Critical to continuing the dialogue is building relationships to start a feedback loop enabling new models of practice and of education. We must continue to challenge the role of the architect, as not just about buildings, but about innovation and risk. The issues raised in this symposium and in these proceedings are just the beginning of a conversation that should continue.

As co-chairs of the 2018 Intersections Symposium, we would be remiss if we did not recognize the efforts of our predecessors. Nothing is achieved in a vacuum and the ability to reconsider the format has been the privilege of having charted territory to build from. Without the support of the American Institute of Architects and Association of Collegiate Schools of Architecture, and their foresight in providing a platform for this exchange, the work of everyone represented in these proceedings would not be possible. We would like to express our gratitude to co-conspirators in the production of this volume, Eric Wayne Ellis, ACSA Director of Operations and Programs, and Nissa DahlinBrown, AIA Director of Higher Education. Without their efforts and support, the diversity and scope of what is discussed would not have been as broad or focused in setting the stage for future Intersections Symposia.

John Folan and Julie J. Kim, Co-Chairs

CHAPTER ONE
DESIGN FOR SOCIAL IMPACT AND RESILIENCE

ALAN RICKS
MASS Design Group

Who do we design for? When we consider the public as the principal stakeholder new questions arise about both the process as well as the product to be delivered. In this ambiguous terrain who determines the brief and the program? And who is able to make decisions? The approaches can vary widely from the delivery individual objects, spaces, and building to new models of community engagement, as well as access to knowledge, tools, and data. This gamut of outcomes stems from an aim to demand that all our communities gain equitable access to services and well-being delivered through well-designed environments. Activists, academics, and practitioners are finding new ways to engage and serve constituencies previously cut off from the benefits of design services.

Resilient Homes Online Design Aide: Connecting Research and Practice for Socially Resilient Communities

DAVID FANNON
Northeastern University

MICHELLE LABOY
Northeastern University

Resilience in architectural research, discourse, and practice tends to focus on physical aspects of the built environment. Much of the discussion within this technological domain of resilience resolves around singular, unique, and high-value facilities: ignoring the vast fabric of buildings where most people live. However, studies in socioecological resilience suggests that resilience in the built environment must address people and systems, not merely property. Transitioning to this focus will both require and result in broadening architecture's interest and influence beyond the normal physical boundaries of the built environment. To effectively engage this broader scope, new tools must enable new modes of public outreach, information sharing, data analysis, decision support, and ultimately create new knowledge. This paper describes the motivation, development, and preliminary findings of one such tool, the Resilient Home Online Design Aide (RHOnDA). This results suggest a cycle of participatory architectural research to advance socioecological resilience.

INTRODUCTION

Studies in socioecological resilience suggest that resilience in the built environment is fundamentally about people and systems, rather than property.[1] While architects contribute important work by building resilience of individual buildings as shelter against specific hazards, and adapting them to new conditions, improving urban resilience must also address the existing urban fabric of repetitive, residential buildings that architects have historically neither designed nor studied. Carpenter et al.[2] formulated resilience assessment as relating object(s) and hazard(s), succinctly asking "resilience of what to what?" but uncertainty about both the object (individual structures comprising the urban fabric) and the hazard (the broad array of short- and long-term hazards) complicates such assessment of resilience in the built environment. Thus, evaluations of and interventions in social resilience require a fundamental shift in architecture research and practice; from performing highly-specific, detailed analysis of an exceptional object for an expert audience (elements of our prior research and teaching) to identifying a broadly applicable set of generic probabilistic trends and communicating them to the widest possible audience (the subject of this article).

Embracing this approach demands new definitions of the architectural project that combine rigorous research with social engagement, including new methods for analysis and modeling, as well as new methods and tools of communication. RHOnDA—the Resilient Home Online Design Aide—is an example of this type of work. To better understand and improve the resilience of existing residential buildings, we adopted a sampling and modeling approach of randomly-selected buildings within broad types to represent the entire urban fabric of a city, simulated their performance and trained a machine-learning algorithm to tailor generic information to any specific home of that type based on user inputs. The results of this modeling and analysis are presented in an interface that gives access to a national database of risks and socio-ecological factors of resilience, making publically available data accessible and customized to a user's location, household, and building type; and providing clearly explained and illustrated recommendations and opportunities for action. This new method of outreach and communication leverages and expands public agency in the resilience of the built environment.

Engaging with the existing urban fabric expands the conventional physical and social boundaries of Architecture: improving social resilience for individuals and communities while broadening design to areas of the built environment not ordinarily considered. More than a publicity program, public engagement and empowerment are inherent features of these new disciplinary tools. Because feedback from users generates new knowledge and directions for researchers and practitioners it effectively connects research, education and practice to build social-resilience.

NOT JUST A BUILDING: BUILDING FABRIC

Academic and practice-based research into the resilience of the built environment follows the contours of the academic and professional discourse, considering only the unique and high-value assets as "Architecture." Conversations about resilience within architecture tend to focus on singular buildings designed for specific hazards. This is important work, as it tests ideas and develops methods for assessment, and possible design solutions. However, it depends on a client with both the desire and ability to investigate and incorporate these designs, and is inherently specific, detailed and unique. This work is in line with the general focus of the academic and professional discourse: the few rigorous estimates available are decades old, but suggest between 2% and 5% of buildings worldwide are designed by architects, with higher totals in some countries like the UK.[3] More recent data for the housing sector aligns with those figures: the design of housing constitutes only 4% of the billings from the top ranking architecture and engineering firms in the United States;[4] and architects only design about 2% of the houses in the United States.[5] As a result, the insurance industry dominates research about resilience for the residential building stock, and understandably focuses on hazards to property as measured by greatest economic cost. Similarly, climate adaptation planning often emphasizes risk assessment at urban scales to guide new construction, with little agency over existing structures. Taken together, there is scant attention to the existing residential fabric, even though it represents a vast proportion of buildings and provides dwellings for most Americans. We believe the repetitive nature of this urban fabric could be modeled, to generate regionally specific but broadly applicable knowledge and inform programs for mitigation and adaptation with widespread benefits.

LOW-DENSITY URBANISM

Fabric buildings are not a uniquely urban phenomenon: most new development in the United States occurs on the fringes of cities: in suburbs and exurbs, a landscape dubbed—and dismissed—as urban sprawl. Drawing on a range of sources, Ellen Dunham-Jones estimates that approximately three-quarters of new US construction occurred in what she describes as a "a vast landscape almost entirely uninformed by the critical agendas or ideas of the discipline."[6] While increased global urbanization means that 55% of people worldwide live in cities,[7] more than half of the US population lives in suburbs. A 2017 analysis based on 2016 census data suggests that the overall trend from the end of the 20th century still continues, noting that "the fastest growth was in the lower-density suburbs of large metros, with midsize and smaller metros growing more slowly and non-metro counties lagging."[8] Even the narrative of urban revival seems to be primarily a product of wealthy, well-educated moving to particular neighborhoods, than a general trend.[9] While these demographic shifts within neighborhoods also warrant study, the college-educated millennial seems likely to be the exceptional homeowner able to hire (or to be!) a professional who can evaluate resilience as part of renovating the home.

Urban is to us, the urban agglomeration, not just the dense core or inner ring suburbs; it is urban problems extrapolated across areas of low density. When it comes to addressing issues of resilience, the need for tools may be greater in non-urban areas without sufficient density to support the planning and programmatic resources of a large city. Certainly, suburban and even rural areas have a greater percentage of homeownership than cities. Distributed ownership is a challenging characteristic for resilience in the built environment, as it requires action by thousands of more-or-less well informed independent actors, each with their own motivations and agendas. In this milieu the contemporary model of architectural practice as a service for elite clients has little to offer. Whether the cause or effect of their disconnect from architectural discourse, suburban

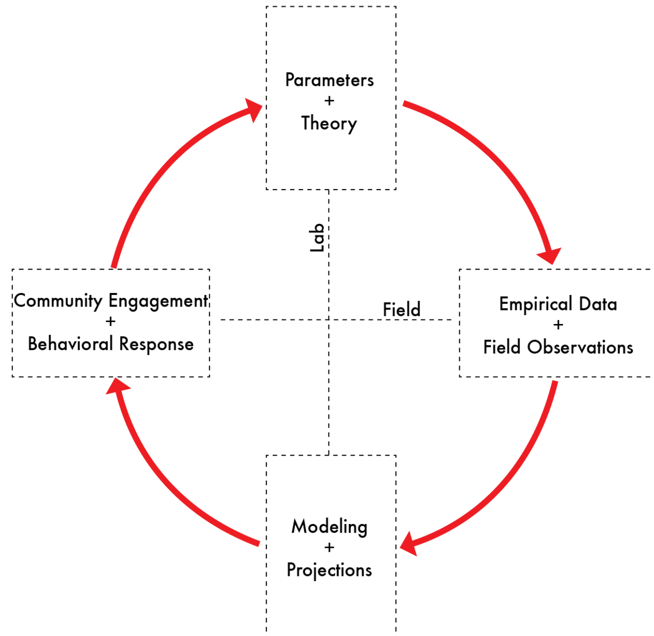


Figure 1: Conceptual diagram of feedback loop between academic research and community engagement, building social resilience in architectural research and practices (by authors).

homes are perceived as standardized, formulaic, market-driven[10], yet this very consistency simplifies assessment and renders findings more generalizable to a larger population. Furthermore, for architects to affect social resilience requires engaging with the very same economic and cultural systems that generate this environment, to influence them through research, advocacy and collaboration.

THE ROLE OF THE ARCHITECT IN SOCIAL RESILIENCE

Our point is not that architects have limited scope in the design of buildings, but rather, that the role of architects is not merely to design buildings. In this case, developing new tools expands the discipline to engage the social, economic and political systems operating in the existing built environment that are not currently part of the discourse. In the design for resilience, architects are sometimes cast as "information managers" or "creative individuals" interpreting the brief of a project and allowing the free flow of information between stakeholders.[11] In this role, architects can advance social resilience by creating a feedback loop of information from research to practice to users, back to researchers and other actors of the built environment: informing reorganization and adaptation. (See Figure 1)

The work here lies not in discovering new techniques in the design (or even re-design) of particular buildings, but rather in the realm of public education, communication and policy. Bosher described the research challenge of

Figure 2: Building typologies defined and modeled for RHOnDA based on City of Boston database and sampling, include: single-family home, triple-decker, duplex, row house, and low-rise multi-family building (by authors). This methodology exclude building types of 5 stories or more.

resilience as one of implementation, technology transfer and diffusion– not of generating new knowledge per se—using existing frameworks, that are sufficiently flexible and reconfigurable to enable users to appropriate them for their own requirements and contexts.[12] To that end, we developed a methodology that can be applied in almost any region of the country to bring high-quality research to a wide audience that could not normally access sophisticated analysis, expertise and judgement to make good on these findings. It translates building-specific research into generalized probabilistic trends, and then tailors and communicates those findings to the situation of specific users. This tailoring to make the information useful and accessible to individual people depends on gathering information. Consistent with the non-expert audience and goal of wide adoption, the interface gathers just enough information; asking users very basic questions to input into the model and anonymizing it for user privacy. In addition to driving the user tailoring, this information represents a valuable body of data about individual households for future research.

SAMPLING AND ZIP CODE DATA

One benefit of a repetitive built environment is that it becomes reasonable to use statistical approaches to evaluate general trends. Sampling from a relatively repetitive environment avoids the need for finely-resolved information about each property, with a commensurate, but acceptable, reduction of fidelity in the results. To that end we clustered the assessor data into groupings or types, for example single family, or row houses as illustrated in figure 2. These five to six types (depending on city) were held to be sufficiently similar that findings from one could be generalized across the type with only minor adjustments (for example scaling by floor area). We then drew samples of each type from the assessor's data and developed a detailed data model of each of the sample buildings, including systems information, year of construction, size, envelope characteristics and so on. We analyzed the performance of each sample building using these data and looked at the findings across the sample as representative of the whole type in that city. This process has been repeated in three cities with different building stock, climate, and risks. In some cases where precise values were unknown, a range of data consistent with the findings in the type were used. This process allows for some degree of uncertainty. The samples then yield generalizable multi-variable algorithms, so any other house of the type (even one we did not model) may be approximated.

While sampling provides information about the vulnerabilities of each property type, evaluating and responding to risk also requires understanding the hazard. While there is a great deal of data publicly available from both government, Industry and NGO sources—including FEMA, NOAA, DOE, SurgingSeas, Insurance Institute for Business and Home Safety—we observed that available hazard data is both highly dispersed across those multiple sources and generally directed at an expert audience. We addressed these challenges by classifying hazards into twelve types (e.g. high winds, power failure, high-heat, storm surge). We then identified the best data sources available for each and converted all the data to a spatial constant spatial resolution of zip code. While this is an imperfect geographic measure, the resulting zip code-based national database addresses multi-hazard resilience, and, critically, can translate those hazards into localized risks.

NOT JUST MULTIPLE BUILDINGS: SYSTEMS

Determining hazard by combining information about the home and the risks it faces, while useful and certainly temptingly architectural, are only a small part of the challenge of resilience. Working to conceptualize and measure resilience, a team of researchers at the Multidisciplinary Center for Earthquake Engineering Research (MCEER) developed a model that organizes the factors affecting resilience into four mutually-exclusive and collectively-exhaustive domains, dubbed the Technical, Social, Organizational, and Economic domains.[13] The technical domain includes the physical infrastructure of the built environment. The organizational focuses on the structure for procedures and policy that govern both the technical environment (such as building codes) and human relations (such as emergency management plans). In contrast, social relates to the attributes of the human population such as age, health, and affluence. Affluence is one manifestation of the broader economic domain, which relates to both economic resources and instruments like insurance, as well to the economic drivers of resilience, such as natural resource availability, innovation,

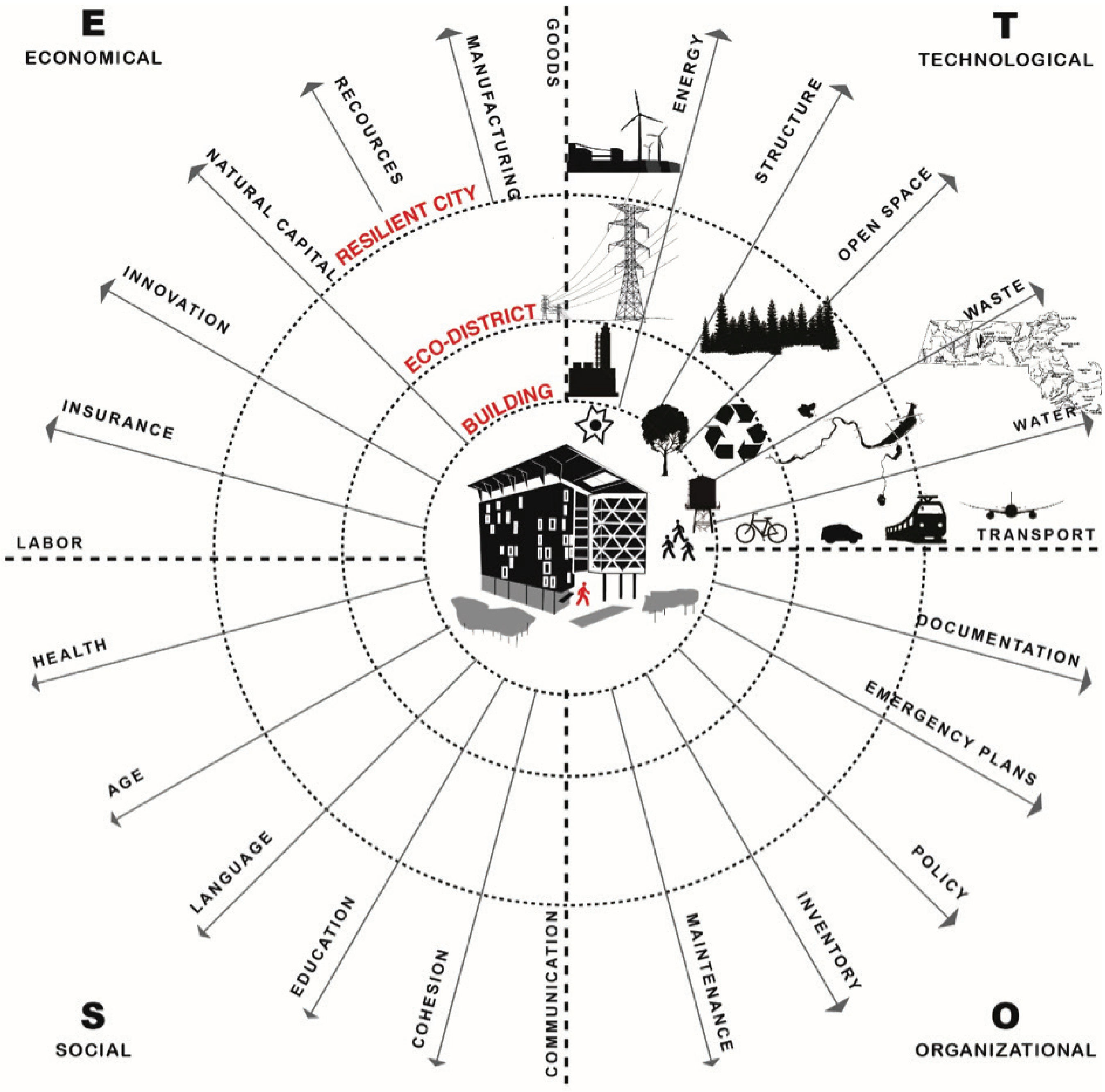


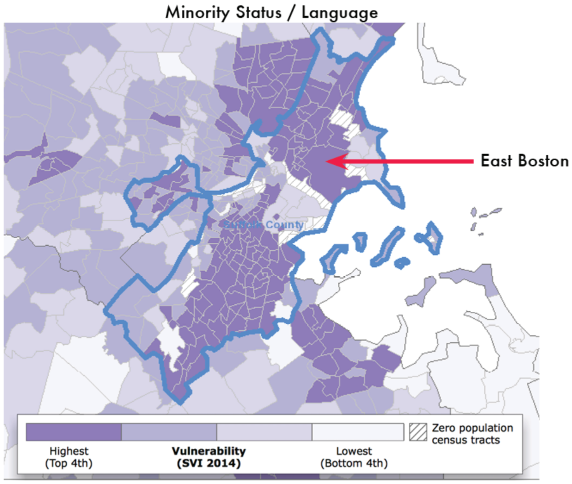
Figure 3: Domains of resilience (image by authors, first published in: Michelle Laboy and David Fannon, "Resilience Theory and Praxis: A Critical Framework for Architecture," Enquiry: A Journal for Architectural Research 13, no. 2 (December 11, 2016), https://doi.org/10.17831/enq:arcc.v13i2.405.

and manufacturing infrastructure. The diagram in Figure 3 illustrates these domains across multiple scales, from people to buildings to districts to cities and regions.

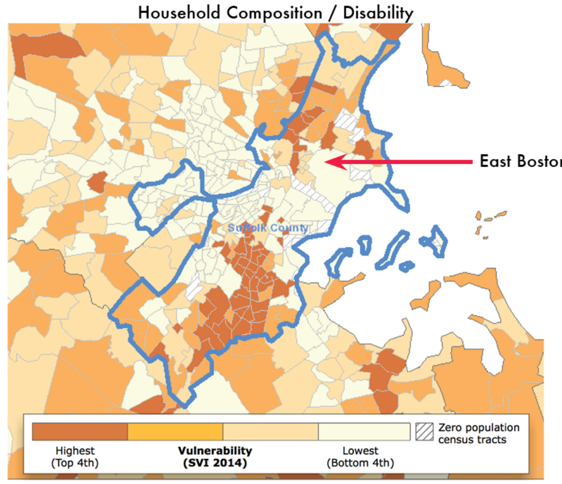
In the TOSE model, system resilience is not necessarily controlled by the lowest common denominator: increased resilience in one domain may offset fragility in others. However, fragility in any domain places additional demands on the others, possibly causing constructive interference and cascading failure. The model is sometimes criticized for focusing on human systems, and not adequately incorporating natural phenomena and ecosystems and their reciprocal influence on the resilience of the human environment. Such an anthropocentric view of resilience is particularly acute in the built environment. Architecture—like engineering—tends to focus almost exclusively on the technical domain, and ideas

Boston, MA (Suffolk County)

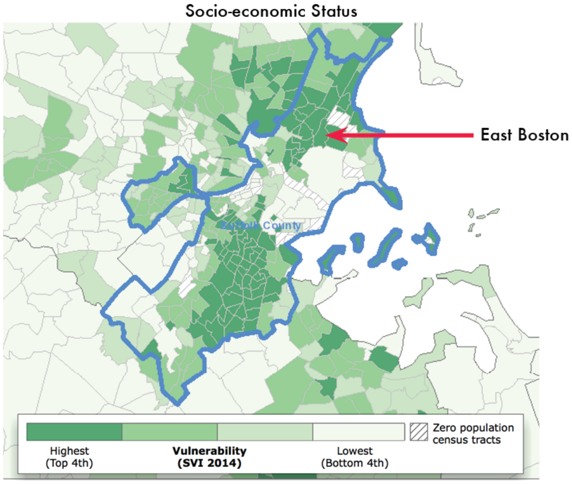
Minority Status / Language



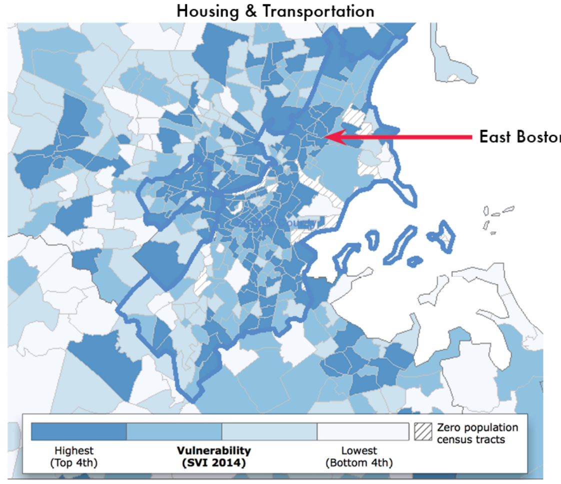
Household Composition / Disability



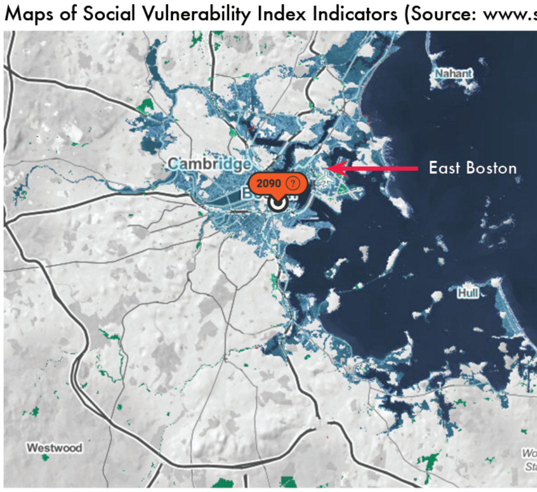
Socio-economic Status



Housing & Transportation



Maps of Social Vulnerability Index Indicators (Source: www.svi.cdc.gov)



Maps of Coastal Flooding: 10% accrued probability over 7ft by 2090, Unchecked Pollution Scenario (Source: Surging Seas, Climate Central)

Figure 4: Comparison of Social Vulnerability Indicators and Coastal Flood Risk in the City of Boston (Suffolk County, MA).

of property protection. However, because architects design social environments and systems, and because resilience is about interdependent systems, we can and must engage with the other three domains. The limitations of focusing on one domain are not merely theoretical or idealistic: social and physical vulnerabilities often overlap. Figure 4 shows maps of social vulnerability index (from the CDC) and coastal flooding from sea level rise (from Surging Seas), showing that the most socially vulnerable populations are disproportionately affected. The flooding in New Orleans after hurricane Katrina offers one example from a tragically-large body of research showing the convergence of vulnerability hazard[14] and the ethical dimension of spatial design.

The increased frequency and severity of hazards requires approaches for people to shelter in place, and thrive in this new, risky, normal. In response, we need to map and communicate risks across all domains and multiple natural hazards. The temptation is to treat each hazard in isolation as a technical problem, while treating them in conjunction, using the lens of the household, connects the physical home and the people dwelling in it. To that end, in addition to natural hazards, we added socio-ecological factors of resilience, including community factors, for example accessibility and social vulnerability (income, disability, demographics).

METRICS: HOW TO ENGAGE SYSTEMS OUTSIDE TECHNICAL

The complexity of socio-ecological resilience in the built environment is well documented.[15] The challenge lies in defining and measuring performance and in considering trade-offs. Too often, resilience is described as a new buzzword replacing sustainability, or assumed to be in opposition with it; that “stronger” necessarily implies more environmental harm. While resilience sometimes demands excess capacity, and sustainability sometimes seeks optimization, both offer architecture transformative new dimensions to assess our work, including social and ecological aspects. A 2017 paper addresses the concordance, reviewing seven frameworks for evaluating resilience and identifying 88 unique resilience strategies in five broad thematic groupings. Of the strategies, 35 were positively correlated with sustainability, and only 14 were negative. The remaining 39 were conditional on the particular circumstances.[16] Such findings motivate the present work, which hopes to clarify the contingent strategies as positive or negative for specific homes.

One key feature of enabling social resilience is education, about the hazards and about steps to mitigate them, the so-called resilience strategies used as recommendations in the RHONDA tool. Over one hundred recommendations were drawn from an extensive literature review of research papers, insurance industry guidelines, new building codes and standards, and government programs. These were combined using expert judgement into simple descriptions and illustrations accessible to a non-expert audience, tagged by climate zone, risk, and construction type; and cross-linked with others that either reinforce or contradict them. For example, recommendations for continuous insulation cross-reference with fire hazards if the products used are flammable. The response to the questions about the home, occupants, their expectations and preparedness determine if each recommendation applies. Extensive reference sources and citations offer additional information and assistance, so users can dive more deeply.

The design question is how to make this mass of possible recommendations accessible, and not overwhelming. We developed multiple ways to enter and filter the recommendations from a dashboard that summarizes resilience indicators at the household and community level; designed to interactively visualize complex data, like flooding probabilities over the years specific to the home. Results can be searched and sorted by hazards, physical or time scale, or other user priorities. These recommendations are also graded by level, for example, flood risk may be a high priority for a new home in a low-lying area, but the recent construction might render energy upgrades for passive survivability unnecessary.

NOT JUST SYSTEMS: PEOPLE (FUTURE DIRECTIONS FOR THIS WORK)

While serving the needs and desires of clients who hire them, architects’ primary professional duty is to protect the Health, Safety, and Welfare of the public.[17] The profession continues to expand the understanding of that obligation beyond mere compliance with the building code to encompasses environmental sustainability (e.g. 2030 challenge); health (e.g. WELL standard); and increasingly in preparing for and recovery from natural hazards. As detailed previously, nascent efforts have yielded several standards for resilience, but these remain primarily technical in orientation, and expert in application,[18] without addressing the essential complexities of socio-ecological resilience. As ever, incorporating social forces into architecture demands forms of social engagement beyond the conventional architect-client relationship, and tools beyond the public meeting.[19] Understanding the architectural problem of resilience in this way militates for a new participatory model; the true measure of effectiveness comes through users, both individuals in their own homes and especially groups and communities. Unlike normal dissemination of findings, or a public information program after the fact, public engagement is an inherent feature of working in the domain of social resilience in which the public both learns about and shapes the built environment. Developing this tool became a mechanism to engage with diverse groups and communities to address what might be called the triple bottom line of resilience.[20]

COMMUNITY GROUPS (PEOPLE)

Neighborhood of Affordable Housing, Inc. (NOAH) like many community development organizations, focuses on issues of housing, environmental justice and community planning.[21] NOAH is focused primarily in East Boston, an economically challenged and majority minority area of the city located between the Harbor and Massachusetts Bay, and built on historic marsh fill, that faces significant risk for coastal flooding and sea level rise (see Figure 4). Because of the intersection of risk and social vulnerability, we engaged with the staff to develop early conceptual directions that would respond to the specific community and developed a plan for specially-trained youth workers to go door to door and help residents navigate the tool and interpret the results. In addition to the pragmatic benefits of multi-lingual, technically-savvy young people extending the reach of these tools, the very act of the survey builds social and community bonds. With some training these young people become resources in their community, while themselves developing research and leadership skills. As researchers, we are collaborating with NOAH in pursuing sources of funding to do this work as part of the evaluation of the impact of the tool. As a future stage, we can even image the tool becoming a platform for social connections and two-way communication. For example, if the evaluation identifies a home susceptible to heat is occupied by particularly vulnerable resident, a forecast for a heat event could prompt an alert, directly to that resident, as well as via phone or in person, perhaps even by same youth worker. This personalized outreach connects the resident to the community, and to community resources and services, such as transport to a neighborhood cooling center. While there are undeniable benefits to enabling stronger ties, this approach would require the tool to store results, rather than anonymize them, with the attendant privacy and security concerns. As part of our ongoing engagement we participated in their community design workshops for flooding protection at an infrastructural scale, to understand the motivations, concerns and interests of the community in design; and are planning a future workshop with community members particularly focused on flooding protection of homes using RHOnDA.

INSURANCE & FINANCE (BUSINESS)

As described above, the insurance industry constitutes an important—in some ways dominant—actor in the resilience of the urban fabric, which suggests that the discipline of architecture should understand and engage with these economic systems if we are serious about building resilience beyond the technical domain. For understandable reasons, insurance companies worry most about the risks that they insure, and which have the greatest likelihood of financial harm. The National Flood Insurance Program distorts the market by insuring high risk properties against catastrophic losses that private homeowners policies do not cover.[22] Thus private insurance is concerned less about coastal flooding than, say, leaky plumbing; as evident in the work of the Insurance Institute for Business & Home Safety, an industry-funded research and communication organization.[23] In meetings with leading insurance companies, it became clear that fire, although not a natural hazard, was of particular concern, especially in sustainability improvements. The financial incentive of reduced risk is real but difficult to assess without knowing a great deal more about the homes. Similarly, mortgage lenders have a real interest in ensuring that the valuable asset of a home survives the term of a loan. In fact, the Multihazard Mitigation Council of the National Institutes of Building Sciences proposed the "resilience mortgage" as one of the best strategies to increase resilience of the residential fabric,[24] and called for new tools to enable these public-private incentive programs. Recommendations included software tools, and perhaps a new workforce position for a resilience evaluator—much like a home inspector or energy auditor—who would conduct a software-assisted walkthrough home-visit. In preliminary discussions with industry representatives, it was suggested that tools like RHOnDA could serve to mediate information exchange between homeowners and businesses about their property, clarifying coverage, evaluating risk and incentivizing mitigation either in advance of or conjunction with the on-site evaluation.

PLANNING AND POLICY (GOVERNMENT)

The third thrust of socio-ecological resilience lies in policy, which includes incentive programs and regulations that are part of climate mitigation and adaptation planning occurring at many levels of government. We engaged the Climate Preparedness Task Force of the Metropolitan Mayors Coalition of Greater Boston, a group convened and supported by the Metropolitan Area Planning Council which works to coordinate the climate mitigation and adaptation activities of fifteen member-municipalities in the Boston area, ranging from urban to suburban, as well as state and federal agencies[25] After a presentation to the task force, we began hosting workshops in specific communities to understand users, and ways the tool might be customized to best meet their needs and demographics. For example, Cambridge has high-resolution hazard data and many available programs, however, citizens find it difficult to find, interpret, and understand their eligibility. Instead of the general, and slightly generic recommendations, a customized web tools could deliver links to specific local programs, for tree planting, PV installation, HVAC upgrades and so on. This interface between people and policy promotes even greater organizational and social resilience within communities.

CONCLUSION

A resilient built environment depends not only on the technical domain, but the social, organizational, and economic one as well. Architecture, with fundamental responsibility to shape the interaction between humans and our built environment is uniquely able to promote socio-ecological resilience. This can be done not only through better fundamental research and design, but especially by developing new tools for the discipline to explore and test the impact of new forms of participation with architecture's public. Building social resilience needs to be focused on people, which includes not just educating and empowering the public that will need to adapt their homes and neighborhoods in place, but also better preparing the discipline of Architecture itself to lead, reorganize and redesign buildings, cities and infrastructure in uncertain futures. Architecture research can expand the tools of architectural practice, and in turn, that engagement with community-based practices can enable a feedback loop of information to inform new directions for research and thus new guidelines for practice.

ENDNOTES

1. Michelle Laboy and David Fannon, "Resilience Theory and Praxis: A Critical Framework for Architecture," *Enquiry: A Journal for Architectural Research* 13, no. 2 (December 11, 2016), https://doi.org/10.17831/enq:arcc.v13i2.405.
2. "From Metaphor to Measurement: Resilience of What to What?," *Ecosystems* 4, no. 8 (December 1, 2001): 765–81, https://doi.org/10.1007/s10021-001-0045-9.
3. Constantinos A. Doxiadis, *Architecture in Transition* (New York: Oxford University Press, 1963), 69–77, https://archive.org/stream/architectureintr002017mbp#page/n73/mode/2up/search/percent.
4. Building Design + Construction, "2016 Giants 300 Report: Ranking the Nation's Largest Architecture, Engineering, and Construction Firms," July 19, 2016, https://www.bdcnetwork.com/2016-giants-300-report-ranking-nations-largest-architecture-engineering-and-construction-firms.
5. Duo Dickinson, "Architects Design Just 2% of All Houses–Why?," *Common Edge*, April 7, 2016, http://commonedge.org/architects-design-just-2-of-all-houses-why/.
6. Ellen Dunham-Jones, "Seventy-Five Percent: The Next Big Architectural Project," *Harvard Design Magazine* 12, no. Sprawl and Spectacle (Fall 2000), http://www.harvarddesignmagazine.org/issues/12/seventy-five-percent.
7. Department of Economic and Social Affairs, Population Division, "World Urbanization Prospects" (United Nations, 2018), https://esa.un.org/unpd/wup/.
8. Jed Kolko, "Americans' Shift To The Suburbs Sped Up Last Year," *FiveThirtyEight* (blog), March 23, 2017, https://fivethirtyeight.com/features/americans-shift-to-the-suburbs-sped-up-last-year/.
9. Jed Kolko, "Neighborhood Data Show That U.S. Suburbanization Continues," March 25, 2016, http://jedkolko.com/2016/03/25/neighborhood-data-show-that-u-s-suburbanization-continues/.
10. Dunham-Jones, "Harvard Design Magazine."
11. J. Glass, "Facing the Future by Designing in Resilience: An Architectural Perspective," in *Hazards and the Built Environment : Attaining Built-in Resilience*, ed. Lee Bosher (London ; New York: London ; New York : Taylor & Francis, 2008).
12. Lee Bosher Dainty, Andrew, "Disaster Risk Reduction and 'Built-in' Resilience: Towards Overarching Principles for Construction Practice," *DISA Disasters* 35, no. 1 (2011): 1–18.
13. Michel Bruneau et al., "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities," *Earthquake Spectra* 19, no. 4 (November 1, 2003): 733–52, https://doi.org/10.1193/1.1623497.
14. Karen L O'Brien and Robin M Leichenko, "Double Exposure: Assessing the Impacts of Climate Change within the Context of Economic Globalization," *Global Environmental Change* 10, no. 3 (October 1, 2000): 221–32, https://doi.org/10.1016/S0959-3780(00)00021-2.
15. Laboy and Fannon, "Resilience Theory and Praxis."
16. Robert Phillips et al., "Do Resilient and Sustainable Design Strategies Conflict in Commercial Buildings? A Critical Analysis of Existing Resilient Building Frameworks and Their Sustainability Implications," *Energy and Buildings* 146 (July 1, 2017): 295–311, https://doi.org/10.1016/j.enbuild.2017.04.009.
17. NCARB, National Council of Architectural Registration Boards, and NCARB, "2018-2019 Model Rules of Conduct" (National Council of Architectural Registration Boards, July 2018), https://www.ncarb.org/; AIA, "Code of Ethics & Professional Conduct" (The American Institute of Architects, 2017), AIA.org.
18. Phillips et al., "Do Resilient and Sustainable Design Strategies Conflict in Commercial Buildings?"
19. Giancarlo de Carlo, "Architecture's Public," in *Architecture and Participation*, ed. Peter Blundell-Jones, Doina Petrescu, and Jeremy Till (Taylor & Francis, 2005), 9–22.
20. John Elkington, "Enter the Tripple Bottom Line," in *The Triple Bottom Line, Does It All Add up? Assessing the Sustainability of Business and CSR*, ed. Adrian Henriques and Julie Richardson (London; Earthscan, 2004).
21. "Neighborhood of Affordable Housing, Inc.," accessed July 24, 2018, http://noahcdc.org/.
22. "The National Flood Insurance Program," https://www.floodsmart.gov/, accessed July 24, 2018, https://www.floodsmart.gov/.
23. "About IBHS," Insurance Institute for Business & Home Safety, accessed July 24, 2018, https://disastersafety.org/about/.
24. "Developing Pre-Disaster Resilience Based on Public and Private Incentivization" (NIBS, October 29, 2015), http://www.nibs.org/resource/resmgr/MMC/MMC_ResilienceIncentivesWP.pdf.
25. "Metro Mayors Climate Preparedness Taskforce," MAPC, accessed July 24, 2018, https://www.mapc.org/our-work/expertise/climate/mmc/.

The Warming Hive: Building Community, One Inflation at a Time

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Figure 1: Premier installation of *The Warming Hive* during a gallery opening at The Open in Riverwest, Milwaukee on April 1, 2017. The Oven, which is located behind the *The Warming Hive*, provided thermal comfort inside the inflatable as well as hosted local Chef Peter Sandroni who cooked up a variety of dishes for the community event on a chilly afternoon. Photo courtesy of Davis Dolson.

Is it possible for an architectural space that can be used by anyone, to happen anywhere, anytime? This paper explores how pneumatic (a.k.a. inflatable) architecture can be deployed to address social resilience on a multiplicity of levels. Focusing on *The Warming Hive*—a recently completed pneumatic enclosure designed by architecture students at the University of Wisconsin-Milwaukee—this study challenges a common misconception that social resilience in architecture is limited to disaster relief. As evidenced by *The Warming Hive*, pneumatic architecture can generate new forms of social resilience, whereby communities are built though social engagement, one inflation at a time.

THE PREMISE

What role can architecture play in addressing social resilience? The social, political, environmental, and economic changes that each community deals with presents a constantly shifting set of programmatic demands and desires. In the construction (and reconstruction) of urban identity, architecture has agency through placemaking. Through the creation of public spaces, placemaking fosters community interaction and well-being. Yet, there are many financial and regulation-based obstacles to implementing change at the urban scale. In recent years, a trend towards tactical urbanism has emerged. Often ad hoc, do-it-yourself (DIY), or grassroots in nature, tactical strategies of placemaking are typically defined by temporary and low-cost transformations of the built environment. The intentions of both placemaking and tactical urbanism are to improve neighborhood conditions, with the objective to attract and engage participants. The latter model offers an expedient and flexible alternative to more permanent interventions—often serving as a test-case or prototype for subsequent changes to the built environment.

The perceived value of temporary transformations of the urban fabric is not only a contemporary phenomenon, but occupies a deep history in architectural discourse. From touring theatrical productions and circuses to festivals and world's fairs, temporary and mobile constructions have catered to the shifting demands of time, location, and

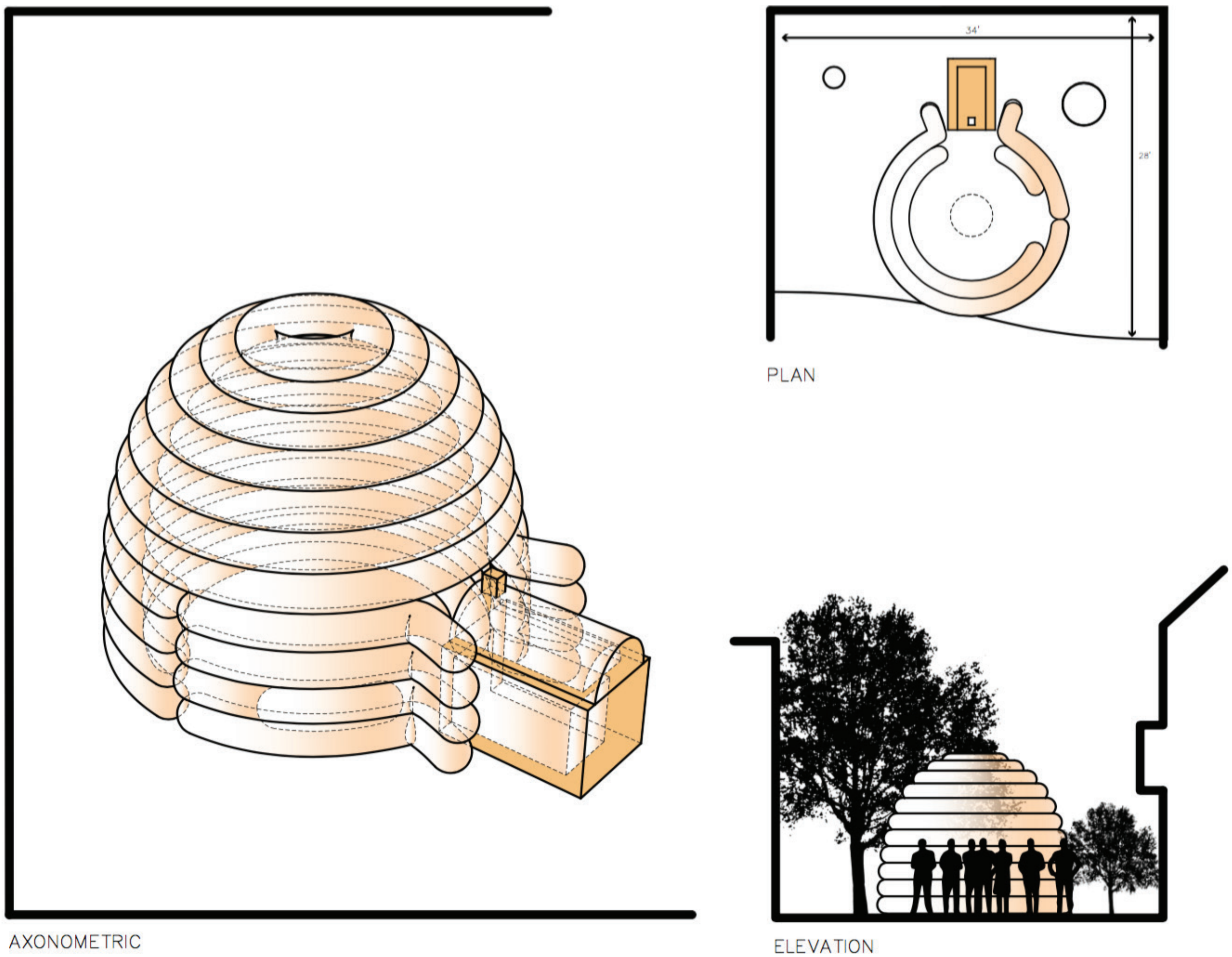

Figure 2: *The Warming Hive* was designed by the eleven undergraduate and graduate architecture students of ARCH 533: Pillow Talk "Blow Up!" at UWM-SARUP in Fall 2016, taught by Assistant Professor Whitney Moon, PhD, RA, in collaboration with local artists Nicholas Frank (Nicholas Frank Public Library), John Riepenhoff (The Oven & Green Gallery), & Katy Cowan (The Outlet). Drawings courtesy of Jordan Nelson.

audience. These ephemeral, event-based architectures employ spectacle as a means to both communicate and entertain. They also serve as opportunities for architecture to redefine itself through alternative modes of expression. That is, the transient nature of these event-based constructions presents a host of technical and social challenges through which architecture can transform itself. Demands for expediency, lightness, durability, affordability, and flexibility encourage creative problem solving. The experimental nature of these provisional architectures, whereby new materials and construction methods are often employed, encourages (if not necessitates) innovation.

According to the late British architect Cedric Price, "The value of permanence must be proven not merely assumed."[1] An advocate for temporary, lightweight, and flexible architecture, Price was also a leading figure in the research and development of pneumatic architecture in the 1960s and 70s. Dedicated to exploring the potential of structuring air as both a technical and social project, Price was drawn to pneumatics because they were an efficient, effective, and economical means by which to enclose and/or define space. Importantly, pneumatics also offered the opportunity to eschew architecture's conventional relationship with permanence. That is, the near-instantaneity of inflating a building also meant that it didn't need to be around for longer than its intended use. Responding to a cultural fascination with expendability (or a throw-away society) at the time, the perceived disposability of paper and plastic products urged architects like Price to consider alternative modes for constructing environments.

Price believed architecture had an expiration date. An advocate for impermanence, he was concerned with the possibilities that architecture produced, rather than an obsession with buildings proper. Because he was an advocate for the temporary and

Figure 3: Test inflation of *The Warming Hive* at Landmark Creations near Minneapolis, Minnesota on January 5, 2017. The pneumatic inflates in under three minutes, and is powered by two portable blowers (one inflates the enclosure, and the other inflates the interior bench). Weighing under 200 pounds, *The Warming Hive* packs up into a bag and can easily be transported by car to a selected site and installed by two people. Photos by author.

new technologies, Price was continually searching for ways to redesign the built environment as an adaptive and interactive infrastructure that could anticipate the changing needs of society. He was less interested in buildings—Price deemed them fixed, static, inflexible and obsolete—and more intent on structures that could anticipate future change and use.[2] This is why, starting in the early 1960s, he worked to bring attention to the potential of "air," which until then had been mostly invisible to architecture. The near instantaneity and perceived instability of air structures led Price to dedicate years of his practice to their development and regulation.[3] A champion of "anticipatory design,"[4] Price referred to air structures as "valuable distorters of time, place and frequency for social advantage."[5]

THE PROJECT

One of the most culturally, ethnically, and religiously diverse neighborhoods in Milwaukee, Riverwest is currently experiencing a renaissance. According to a local anthropologist, the art scene is playing a key role in this transformation:

> But in Riverwest, art rules. And the art forms are as diverse as the people. The issues that united the major Riverwest cultural groups back in the 1960s and 1970s—fair housing, cultural tolerance, peace, and social justice—continue to be championed in the neighborhood. Art is routinely used to advance social causes, and a sense of civic responsibility is often reflected in the art forms.[6]

For example, The Open, a Riverwest gallery founded in 2017 by a collection of local artists, promotes diversity in both the arts and its community. The gallery is a "project platform housing several programs": Nicholas Frank Public Library (NFPL), Microlights, The Oven, The Outlet, and Designers Talking Library.[7] Three of these artists (Nicholas Frank, John Riepenhoff, and Katy Cowan), and their respective curatorial platforms (NFPL, The Oven, and The Outlet), served as not only the hosts for *The Warming Hive* project, but likewise its clients and collaborators.

Figure 4: Installation of *The Warming Hive* at ACRE Residency in Steuben, Wisconsin on July 11, 2017. Milwaukee-based artist Sara Caron mixed up craft cocktails inside the inflatable for visiting artists as part of her Bermuda Triangle pop-up bar project. Earlier in the day, a few artists from Japan collaborated with John Riepenhoff to cook mochi in an outdoor oven (pictured far right),around which the pneumatic was installed. Photo by author.

In Fall 2016, working in close collaboration with these three artists, eleven undergraduate and graduate architecture students at University of Wisconsin-Milwaukee School of Architecture and Urban Planning (UWM-SARUP)—taught by Assistant Professor Whitney Moon—designed, prototyped, and fabricated *The Warming Hive*, an inflatable installation which premiered on April 1, 2017 at The Open. As part of an architectural seminar entitled Pillow Talk: "Blow Up!", the project was conceived as an opportunity for students to not only design and realize a pneumatic construction, but to engage directly with their community. By actualizing a temporary installation, which could then be deployed in different locations for a variety of year-round uses, students demonstrated the capacity for air-supported structures to generate social resilience by catering to a wide-array of site conditions and programmatic demands.

Because The Open is comprised of several curatorial platforms, the objective of this temporary architectural installation was to engage multiple programs simultaneously, while providing an outdoor gathering space for gallery visitors during events. At the request of Frank, Riepenhoff, and Cowan, students were directed to consider a range of installation proposals that could accommodate this request to define a social space for the gallery. *The Warming Hive*—one of three group proposals put forth by the students—not only responded to the clients' request, but also explored the capacity for the outdoor installation to operate year-round, particularly in winter months. By providing a gathering space that was hospitable in sub-freezing temperatures and snow, this temporary pneumatic shelter could be deployed on an as needed basis. In addition to being "plugged-in" to The Outlet—an electrical outlet curated by Cowan inside the gallery—*The Warming Hive* was designed to engage, both thermally and socially, The Oven—an outdoor brick oven run by Riepenhoff.

Because this winning proposal—selected by the artists/clients and visiting critics—directly engaged with a heat source, it needed to comply with life safety concerns and code regulations.

Figure 5: Four different inflations of *The Warming Hive* in 2017 demonstrating social resilience through community engagement. Capable of being deployed in both urban and rural settings, the pneumatic enclosure provides a gathering and recreation space for all ages, any time of day or night. Photos by author.

That is, the pneumatic structure needed to be both fireproof and durable. Due to these constraints, it was not an option to work with typical DIY inflatable materials like plastic sheeting, Mylar and nylon. Fabricated by Landmark Creations in Minnesota using flame retardant 8.5 oz. vinyl coated white nylon, this structure inflates in under three minutes, and is able to have a lifespan of 10+ years, rather than days, changing the typical perception of pneumatics structures as disposable, wasteful, and unreliable.

The Warming Hive realizes a collaborative student research and design project exploring pneumatic technology in relationship to mobility, sociability, environmental responsibility, and pedagogical advancement. Adaptable to a variety of site and seasonal conditions, this dome-like air-filled structure offers capabilities of implementation and transportation that cannot be matched by traditional construction: it is inflated in under three minutes, weighs under 200 pounds, and can be easily packed up and transported to various locations. Designed with built-in pneumatic seating and an insulated, fireproof and projection-friendly skin, *The Warming Hive* provides a comfortable year-round shelter for exhibition, cooking and gathering.

In addition to its mobility, flexibility, and near instantaneous deployment, *The Warming Hive* offers unlimited potential for generating social resilience in the built environment. Although initially designed for a specific site and use, *The Warming Hive* was conceived as a prototypical nomadic structure: it can be deployed for a variety of temporary and event-based uses, is affordable ($5,0000), and can easily be reproduced and/or modified. Powered by two portable blowers, the double-membrane structure (14ft high by 16.5ft diameter) can comfortably accommodate twenty or more people, facilitating social interaction and providing protection from the elements (sun, wind, rain, etc.). In addition to an inflated bench, the enclosure features an oculus at the top of the dome, which allows hot air to escape through stack ventilation, and provides a visual connection to the sky. Likewise, two entries—one with interchangeable pneumatic "doors" (utilizing zippers and Velcro)—allow for customization of layout, flexibility of use, and enhanced accessibility and visibility.

The Warming Hive has been deployed ten times at seven different locations throughout Wisconsin. In addition to hosting three separate art opening events at The Open, and being inflated multiple times at UWM-SARUP, the pneumatic enclosure has been invited to several venues including: an art auction at the Green Gallery in Milwaukee, an artist residency at ACRE in Steuben, the Makeshift Festival in Madison, and a community event at the John Michael Kohler Arts Center in Sheboygan. In all but one of these cases, the requests to utilize *The Warming Hive* have been pro-bono, meaning that the instructor and one or more students have assumed the responsibility to coordinate its installation, as well as donated their time and labor. It was important to both the artist collaborators (Frank, Riepenhoff & Cowan), as well as the instructor and seminar students, that the project be made available to the greater community on an as-needed basis.

Each inflation of *The Warming Hive* offers an opportunity to test its technical and social performance with respect to variable site and programmatic conditions. In addition to offering a structurally sound temporary space for numerous kinds of activities, the pneumatic installation continually offers delight to users of all ages. As a constructed prototype which continues to be tested in a variety of contexts, including utilization during all four seasons, *The Warming Hive* demonstrates the potential for pneumatic architecture to facilitate social resilience in the 21st century. To date, *The Warming Hive* continues to be inflated upon request.

Project: *The Warming Hive*
Size: 14ft high by 16.5ft diameter
Material: Flame retardant 8.5 oz. vinyl coated white nylon.
Fabricator: Landmark Creations, Burnsville, MN
Inflation Time: 2.5 minutes
Cost: $5,000
Instructor: Assistant Professor Whitney Moon, PhD, RA
Student Designers: Jordan Nelson (Project Lead), Trevor Georgeson, Jackson Leverenz, Sean Mroczkowski, Jordan Nelson, Ryan Neidinger, Brandon Sather, Thomas Sebastian, Sam Smith, Indhumathi Venkatachalam, Yangtian Yin, and John Young.
Clients/Collaborators: Nicholas Frank (Nicholas Frank Public Library), John Riepenhoff (The Oven & Green Gallery), & Katy Cowan (The Outlet).
Donors: Wendel Chamberlin (UWM-SARUP '76), Chipstone Foundation, Design Fugitives, and Pacific Construction Co.

ENDNOTES

1. See Cedric Price, *Archigram 3*, 1963. It should be noted that in 1966, Price and Newby approached the British Ministry of Technology with proposals to conduct research on the use of air structures in the construction industry. As a result, the British Ministry of Public Building and Works commissioned them to undertake a survey on pneumatics in 1968. Their extensive research on the topic was published as a report entitled *Air Structures: A Survey* in 1971 and it covered the history, principles and applications of air structures. Although the British Government did not sponsor further research on the topic, what was particularly remarkable about this endeavor was Price and Newby's commitment to both the technological and cultural dimensions of inflatables. According to Price and Newby, the publication "surveys the current research and development in this field and makes a number of proposals for future research." Cedric Price and Frank Newby, *Air Structures: A Survey* (London: Her Majesty's Stationery Office, 1971) iii.
2. In an issue of *Archigram* dedicated to self-sustained and portable environments, Price writes "the value of permanence must be proven not merely assumed." Cedric Price, "Insert 25", *Archigram 8 – Popular Pak*, 1968.
3. Notes by Cedric Price, for a keynote speech delivered on 01 June 1973 at the Air Structures in Education conference in Columbia, Maryland. See Samantha Hardingham, *Cedric Price Works, Volume 2: Articles and Talks* (London: Architectural Association / Montreal: Canadian Center for Architecture, 2017) 211.
4. "The first thing to bear in mind when contemplating Price's work is that his central field of enquiry was what he called 'anticipatory design', an approach which is concerned with the importance of defining a question rather than solving a problem—on the basis that architecture is too slow for problem-solving—and which produces architecture that is specifically designed to expect change." Hardingham, *Cedric Price Works, Volume 1: Projects* (London: Architectural Association / Montreal: Canadian Center for Architecture, 2017) 14.
5. Notes by Cedric Price, for a keynote speech delivered on 01 June 1973 at the Air Structures in Education conference in Columbia, Maryland. See Hardingham, *Cedric Price Works, Volume 2: Articles and Talks*, 211.
6. http://www.neighborhoodsinmilwaukee.org/Riverwest.pdf (Accessed August 10, 2018).
7. https://www.nicholasfrankpubliclibrary.org (Accessed August 10, 2018).

CHAPTER TWO
TECHNOLOGICAL RESILIENCE & DESIGN

BILLIE FAIRCLOTH
KieranTimberlake

Technological resilience should be straightforward. We know it when we experience it and should have no problem defining it: a technology—whether it is a gadget or gizmo—is resilient when it persists through failure. When this definition is applied to architecture, however, it becomes less helpful, either sparingly pragmatic or insufferably simplistic. It does not address what designers are more likely interested in, for failure is but one behavior amongst a range of possible architectural behaviors. We want to know how a technology persists or how behavior is imparted to a system. What types of behaviors might we employ, and which systems of architecture display them? And, who does a behavior benefit or empower?

Designers Parlac, Del Signore, and Gray elevate a mechanistic, more surficial definition of technological resilience for and in the case of architecture, landscape architecture and urban design by focusing on resilience, adaptation, adaptive technologies, and, by association, adaptive behaviors and architectures. Their projects propose that architecture and infrastructural systems may persist and be made more resilient when they directly engage environmental flows in actionable feedback loops. This type of resilience is as much technological as it is ecological, hydrological, or thermal.

Parlac's pedagogical project champions an aware or sentient architecture, suggesting that architecture can adapt to an ever-changing context. Del Signore and Gray advocate didactic "place-making interventions" to engage community stakeholders in a dialogue about the current and future performance of hydrological systems in a fraught urban-ecological context. At the center of each of these projects is technology with capacity to adapt, whether it is the materials and algorithms in Parlac's work, or micro processing and display systems infused with localized data in Del Signore and Gray's project. These technologies allow both projects to purposefully interact with people and with their surrounding environments in real-time or near real-time, albeit in different ways. For each, the modes of speculation, collaboration, and prototyping are essential to building a knowledge of adaptive, resilient systems: speculation implies the time-based, scenario-driven qualities of adaptation, collaboration implies the centrality of interdisciplinarity to adaptive technological systems, and prototyping tests the efficacy of a strategy for a given set of scenarios and technologies.

By situating technological resilience within the subject of adaptation, these designers yield a provocation, insisting that architecture is missing agency, or the power to cause or participate in change literally. In response, they invite us to join them in such speculation and consider the behaviors that architecture needs now.

Adaptive Architecture: Towards Resiliency in the Built Environment

VERA PARLAC
University of Calgary

This paper discusses possibilities afforded by an integrative approach in which overlapping of intelligence, material capabilities, and social and ecological issues inspires an entirely new approach to designing resilience through adaptability. The ability to regulate behavior and adapt to the demands of a situation has always been associated with living organisms. This capacity to adapt is what defines resilience in nature. A technologically augmented built environment can often adapt to changes in its environment, but this adaptivity is often prescribed. If resilience is the capacity to recover from a disturbance and a traumatic event, how is then resilience manifested within a technologically enhanced setting? How do we design resilience into our engineered ecologies? How is this manifested in the design context where boundary between self developing and externally designed is increasingly blurred?

INTRODUCTION

The term resilience suggests certain immunity to trauma, an ability to recover quickly from an unexpected traumatic event. Synonyms for resilience, if related to a person, are tough, strong or hardy, or, flexible, pliable, or supple if related to an object. What is generally expected from a resilient built environment is a quick return to its prior condition and unchanged appearance. The fact that we expect a static response (status quo) from anything or any environment under the strain speaks about our attitude towards change and our tolerance (or the lack of it) for the unexpected. Even though, to be resilient, a thing needs to appear unchanged, it is also possible that a resilient thing is always altered. I start from this condition of being altered and propose it as a more viable starting point for the discussion of resiliency. To be resilient, the built environment should continue to operate and perform even if altered and preferably continue to alter itself as it 'rebuilds'. It is the process of alteration, transformation and change that should be 'designed' and channeled. To explore resiliency we should focus on dynamics and change and not on stasis and permanency.

In nature, the capacity of organisms to adapt to changes in their environment defines their resilience. In the built environment, resilience is traditionally seen as a capacity to resist a potentially catastrophic event and is achieved through the use of specific materials, specific construction techniques, or by engineering our way into a comfortable environment – in other words by strength or by 'more'. This attitude is very well reflected in Frei Otto's observation that "Architecture is man's oldest skill in his struggle for survival in nature. It is therefore directed against nature."[1] But, what might make architecture truly resilient is its ability to productively participate within its larger ecology – to be given an opportunity to 'behave' according to a challenge it is facing. To achieve that, architecture and the built environment in general should be more tightly bound to the dynamics of local ecologies. Strong links to the undercurrents of the surroundings (near and far) could facilitate an active response to disruptions and could accommodate unexpected changes. In other words, adaptability and responsiveness could be key to resiliency in architecture.

Technological resilience in architecture could be achieved by incorporating directly into the built environment embedded and sensing technologies, data and energy harvesting, synthetic biology, robotics and/or material innovation. These technologies would make the built environment active and sensing – and not passive, as is presently the case. Such resiliency would consist of a capacity to anticipate and respond to changing environmental, programmatic or energy demands, and to actively engage the constructed fabric even in non-catastrophic events that might require some kind of adaptation.

Technologically augmented environments would interface with their larger contexts more productively because they are not inert, because they sense and communicate and more effectively extend into their surroundings. Technological resilience requires adaptability and responsiveness that in turn requires existence of (1) a boundary that could facilitate that response (as an interface) and (2) incorporation of technologies necessary to make otherwise inert environments active. Technological resilience would ideally result in the capacity of the built environment to retain its functions in spite of a strain (natural or man-made). Furthermore, when made of active and sensing material systems, environments can be closely linked to their local conditions and might be able to signal an unanticipated event long before it causes a problem.

In "The Thousand Dreams of Stelavista" James Graham Ballard describes "psychotropic" houses, constructed from a material he called plastex, that can bond with their inhabitants, sense their emotions and needs and adapt to them.[2] We don't have plastex but the latest advances in distributed computation, embedded computing, sensing technologies (including brain wave sensing), biosensors, material innovation and synthetic biology (all coupled with digital design) are enabling proposals for integrated strategies that facilitate further development of adaptation and resilience in the built environment.

EXPLORING RESILIENCY

As the natural and constructed worlds meet there is a need to control the boundary (interface) between them by preventing what we perceive to be undesirable effects. That very space is what generates some of the most interesting questions pertaining to the humanity's relationship to technology. Impermeability of a boundary that separates the constructed environments from the natural, and perception of what undesirable is, might need a second look.

This issue of the boundaries between the built and the natural were explored in student projects completed in a senior level research studio I taught at the University of Calgary. The studio explored in general the idea of responsiveness in architecture. It engaged questions of how a technologically augmented and resilient built environment can be designed and how it could participate in a larger ecology. We were interested in new forms of resiliency that are linked to their local ecologies (natural or constructed) and in articulation of innovative design approaches that integrate data, sensors, synthetic biology, or new materials. Students were encouraged to think in terms of flow and exchange of information, energy and matter rather than in terms of architectural form. The matter (material systems) was viewed as dynamic and active and a form understood as changing. Resulting projects demonstrated how technology could empower architecture to operate as an intelligent interface that connects spaces, users, performance criteria and environment in real time. The projects looked for more productive as well as creative ways to negotiate the boundary between the natural and the constructed by relying on some of the latest technological and scientific propositions. By focusing on technologically augmented environments that respond to spatial, programmatic or environmental pressures instead of an architectural object, the projects challenge conventional definitions of architecture. They underline a necessity to think of design space as dynamic and to incorporate change over time into the design proposals.

More specifically, the projects engaged the question of a permeable boundary (interface) by designing responsive spatial boundaries (see the Swarm Space project), programmatically or environmentally responsive modular systems (Augmentum and Remedia[c]tion), resilient dwellings (The Imminent Emergency Defense System), or explored the nature of a productive relationship with the larger ecology (Urban Reef, Charged Landscapes).

Swarm intelligence is at the core of the Swarm Space project (Figure 1) by Bin Tian. The project explores an application of a swarm intelligence algorithm as a way to negotiate between natural and artificial systems. It proposes a variable spatial boundary that responds to the idiosyncratic movement of people (collective or individual) and realigns the space to allow for adequate room size and the passage of people. The

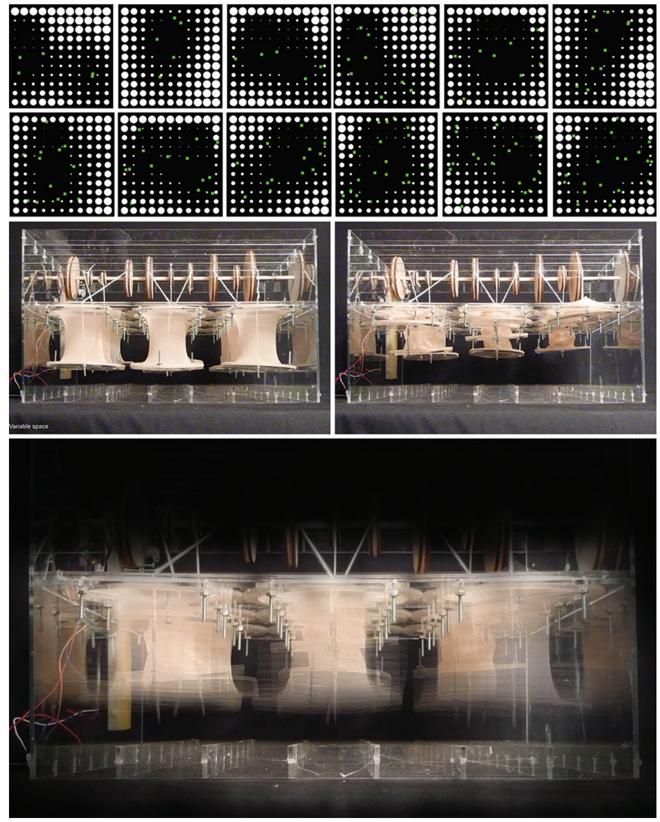

Figure 1: Swarm Space by Bin Tian.

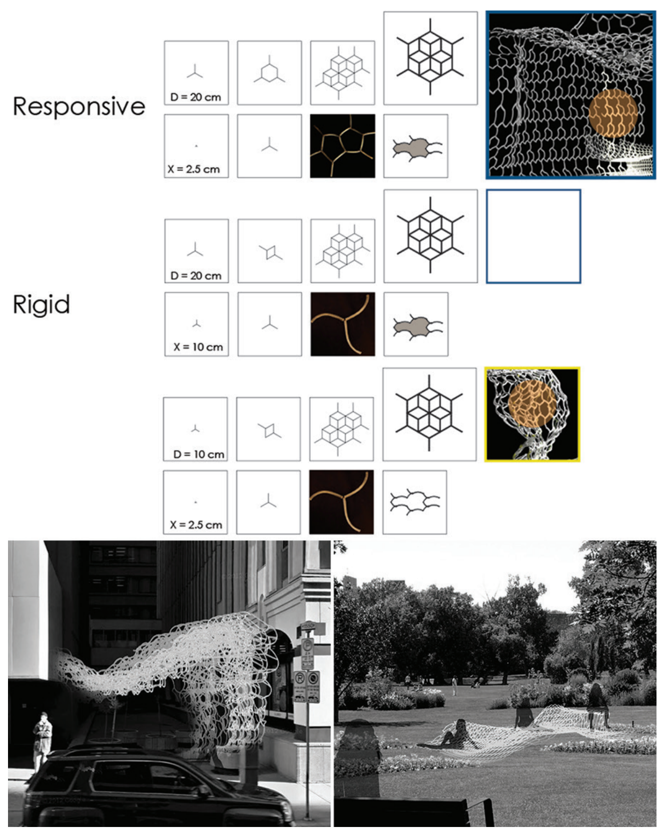

Figure 2: Augmentum by Faria Hamidzadeh.

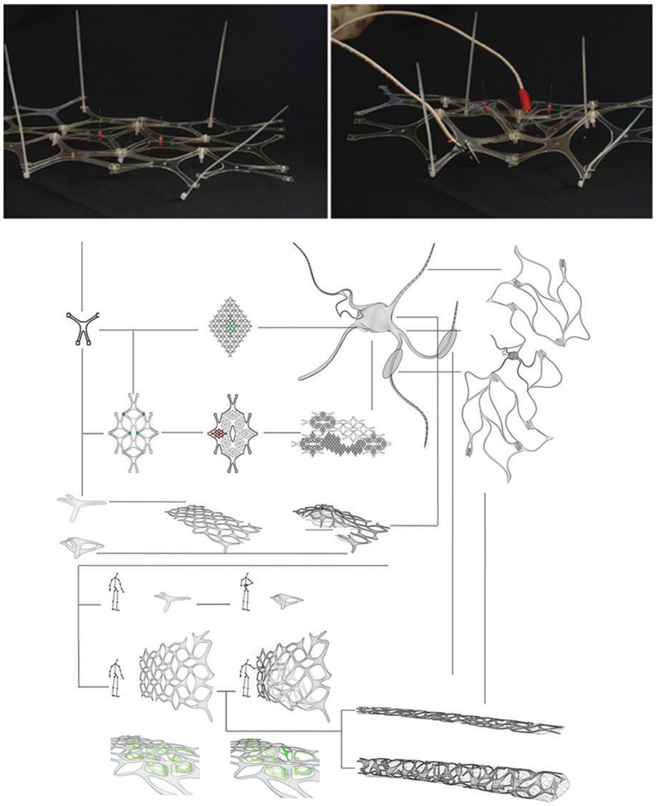

Figure 3: Remedia[c]tion by Matt Parker.

Figure 4: The Imminent Emergency Defense System by Kevin Spaans.

proposal offers a dynamic environment that addresses programmatic needs in real time. At the same time, the project explores the notion of a permeable boundary by offering a space divider whereby permeability is manifested in its changeability and capacity to offer varying degrees of passage (of people or light) or transformation (of space).

The projects Augmentum and Remedia[c]tion are based on self-similar modular and adaptive components. The Augmentum (Figure 2), by Faria Hamidzadeh, is an adaptive material system capable of adjusting to a wide variety of spatial conditions. It can be constructed within any public space and can serve as a transition between sheltered and open environments. It is easily erected out of a large number of self-similar components designed to enable the "growth" of the system, regardless of the spatial boundaries. By combining the components in a particular way, the system can vary from "soft" to "hard" to provide soft surface conditions as well as hard structural regions. The Augmentum can shift between parasitic and self-supporting structure and be constructed in a variety of urban void conditions. The cells of the structure have active or inactive infill. Active infill enables an energy-harvesting capacity that can power regions of the structure. Inactive cell infill provides a seating surface or shading. The project can be "grown" into a light sculpture, a landscape piece, an active façade, a shelter or a seat.

Remedia[c]tion (Figure 3) by Matt Parker, is a transportable aquatic disaster relief laboratory (and dwelling if needed) for a deep water oil spill remediation. It consists of a network of flexible pods that can be deployed to help stabilize and clean polluted marine ecosystems. The pods could be connected and reconnected to form variable configurations as needed. The project explores what it means for architecture to be fully integrated through a responsive system capable of sensing and productively adapting to environmental inputs and inhabitant occupation. The responsiveness of the system is reflected in its capacity to sense the level of pollution and to grow, cultivate, and release oil-degrading microbes as needed. Their production is located in the pod's "tentacles" and certain regions of its surface.

Both Augmentum and Remedia[c]tion explore the notion of an active material system as a way to interface with the surroundings and respond to their condition. The Augmentum supports spatial adaptability and energy requirements by exploring the idea of the 'growth' of the structure from self-similar components, while in the Remedia[c]tion the active material system is an operative boundary between the polluted natural environment and a constructed system that is actively participating in its remediation.

The Imminent Emergency Defense System (IEDS) project (Figure 4) by Kevin Spaans explores the idea of a disaster-resilient dwelling. It proposes a living pod that reverses inevitable destruction expected of traditionally built houses in regions prone to major meteorological catastrophes. The IEDS living pod consists of a system of exterior and interior panels that inflate to cushion and protect the pod exterior against flying debris and its interior during relocation. The panels are connected to a series of internal air pumps that respond to disturbances in the natural environment and are activated when necessary to provide the appropriate level of defense. While the exterior and interior inflate to accommodate the influences of high winds or vigorous movement, the interior also may be inflated or deflated to accommodate different spatial demands. The pods are conceived without rigid foundations. Therefore, they migrate and their relocation is shaped by the dynamic forces of the wind and the configuration of the landscape. On one hand these nomadic, technologically equipped pods resist damage and on the other their movement creates migrating urban landscapes responsive to the weather conditions and shaped by its land configuration. The lack of permanency of their location suggests that these pods would eventually be brought to a locality that is less affected by the meteorological catastrophes.

The Urban Reef and Charged Landscapes projects explore productive relationship of an architectural intervention with the larger ecology. The Urban Reef project (Figure 5) by Caitlyn Browning is conceived as remediation of a heavily polluted industrial area in Detroit. It relies on synthetically produced protocells that use pollutants to produce matter that provides a new ground and building material for the site. The project is supported by current research in synthetic biology and a capability to produce synthetic "organisms" that could be programmed to consume specific substances. The protocells are distributed throughout the polluted terrain by following the topography and the level of pollution. The density and the distribution of the growth are channeled through an infrastructure that supports its hardening and is integrated into the topography of the site. The emerging landscape is a product of all those forces as they work across the site. The infrastructure distribution is related to the projected program that evolves over a long period of time. Nothing in this project is entirely predictable. The design of this environment is driven by the processes that will generate new ground. The program and activities on the site change over time based on the site's terrain transformation. The proposed infrastructure mediates and forms the terrain so that at different phases of its formation it could support specific activities.

The Charged Landscapes project (Figure 6) by Jose Trinidad takes advantage of under-utilized sites that intersect with high-voltage transmission routes passing through the city of Calgary. The project charts the network of electromagnetic energy and attempts to overlay new "metabolic morphologies"[3] upon

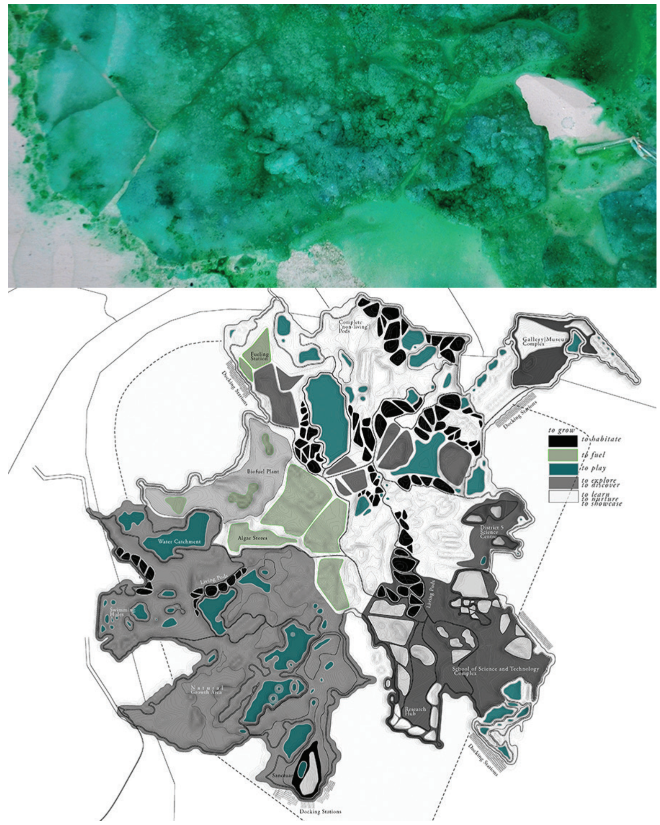

Figure 5: The Urban Reef by Caitlyn Browning.

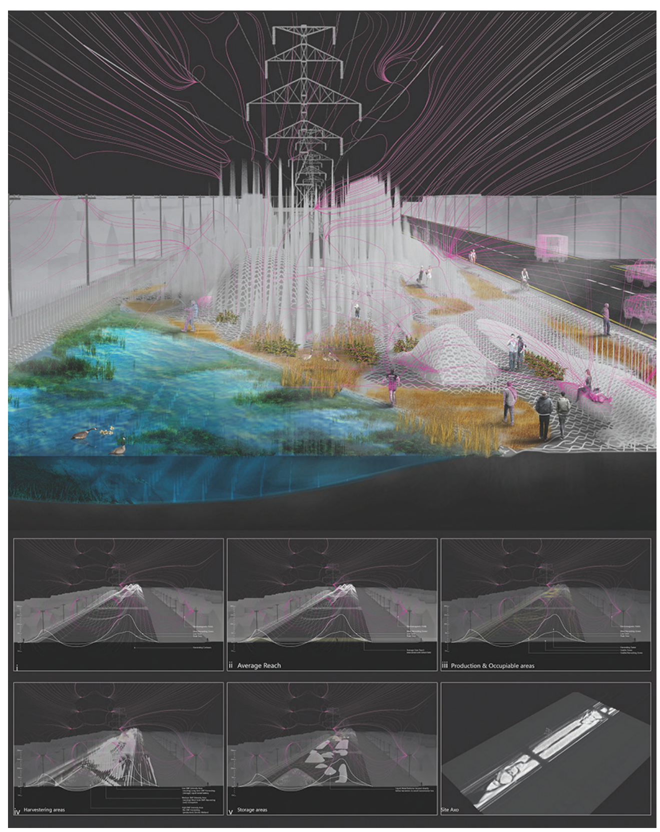

Figure 6: Charged Landscape by Jose Trinidad.

existing single-purpose energy infrastructures. Diagraming the form and flux of the electromagnetic boundaries around high voltage transmission lines reveals patterns of consumption, the potential of harvesting wasted residuals, and its hazards to health and the environment. Through this process, zones of energy production, storage, recycling, and human occupation are established. Together, these zones synthesize into productive, connective, and charged landscapes. The project attracts public interaction and participation by creating regions for human occupation that mediate the external environment by generating heat. Spaces delineated in this way are in constant flux; their sizes are determined by the interplay of released energy and air temperature. This is not a stable environment; to be in such a thermally modulated space one has to accept its fluctuating thresholds.

The Urban Reef and the Charged Landscape projects use different logics to construct drivers of the new environments. The Urban Reef uses bio-logic and strives to imprint that logic on the emerging new ground and unfolding of program over time, while the Charged Landscape uses energy distribution as an initial driver for patterns of energy harvesting and human occupation.

These projects tap into the idea of metabolism by exploring qualities that an artificial permeable boundary (supporting information of energy feedback loops) should have as an interface between the natural and the constructed. Michael Weinstock suggests that the notion of metabolism if linked to design could "relate pattern and process, form and behavior with spatial and cultural parameters"[4] and support a symbiotic relationship of architecture with the natural world. In his seminal book, Evolutionary Architecture, John Frazer argues for a new form of designed artifact, one that is interacting and evolving in harmony with natural forces, including those of society.[5]

The idea of coupling the responsive, sensing or 'bio' technologies with the notion of metabolism opens the possibility of an intelligent, environmentally sensitive built environment that is connected to broader metabolic networks. Buildings that could sense and interact with its environment can operate more synergistically within larger ecologies and therefore can move closer to more sustainable participation within the global environment. The responsive architectural systems could act as ecologies in themselves, allowing architecture as a discipline to recalibrate its role in the larger socio-economic context by becoming a more intelligent and operative participant – a participant imbued with foresight.

EXPANDING RESILIENCY

In these projects the deployed active and sensing matter and material systems would result in a kinetic effect, a change of their configuration, or a capacity to grow or be generated. Such general capacity for change suggests that regardless of technological or traditional practices towards resilience, what we need to do in these times of proliferating technologies and abundant disruptions is to be flexible and fluid with what arises. The forces that govern our ecologies, natural or engineered, are dynamic and changing. The technology alone will not save or emancipate humanity from the constraints of the turbulent environment, but it will enable us to extend more effectively into our environment and tap into constructive feedback loops of information or energy that would facilitate a more seamless transition between the constructed and the natural.

We extend ourselves into the environment with our technological artifacts. As we do that, the boundary between the internally developed and externally designed is constantly being contested. In this space, where the rules of the animate and inanimate, the living and synthetic overlap, 'designing' the resilience is a concept worth exploring. The prevailing mindset of the engineered might present a particular challenge in accepting the new forms of resiliency that tap into the indeterminate. For example, in engineering, specificity of a problem definition allows for an efficient solution. Operating in the space between the natural and the constructed might not always provide a context for a clear definition of the problem and a path to its solution. This space (in between) would require a transition, an interface, or a permeable boundary through which different logics could be brought into productive contact and generate new possibilities and realities. In other words, it requires fluid thresholds that can bridge the difference between the internal logic of the constructed and the logic of thermodynamic or indeterminate.

If we could through technological augmentation bring the constructed environment closer to the resiliency of natural ecologies we might be able to mediate consequences of sudden or persistent exigencies. In his text "Resilience and Stability of Ecological Systems" C.S. Holling talks about the change of a domain in ecological systems – a situation when permanent change takes hold within the system and influences the system towards a change. An example of this is an invasion and establishment of shrubs and trees in cattle grazing areas. When they gain sufficient density and cattle moves elsewhere the grassland will not reestablish itself. Only if trees and shrubs are removed grassland can return. An interesting point he makes is that in natural systems the question is not how stable they are but how likely they are to change domains and stay in the changed configuration.[6] As C.S. Holling suggests, natural systems that are constantly confronted with unpredictable internal and external changes are less concerned with constancy and more with persistence of the relationships.[7] On the other hand, engineered systems or devices that perform specific tasks under predicable external conditions have their performance goal immediately adjusted if the variation in performance is observed; they are concerned with constancy of performance. An equilibrium-centered view of such systems is static and doesn't support transient behavior of natural systems. Awareness of this distinction could be influential when designing within a dynamic design space in which the natural and constructed meet.

When designing active and adaptive artificial environments, whether they are intelligent facades or built environments that connect to natural ecologies, it would be useful to establish relationships that persist between the natural and constructed so that, when interfaced, they could behave similarly. In this context we might be less interested in stability of an engineered ecology and more in the zones of stability and establishing its gradient (or ability to perform under the constant change). Analogous to Holling's view, the boundaries or limits of such ecologies might facilitate change of the domain.[8] Designing such indeterminate systems would certainly require a change in design attitudes.

Furthermore, a built environment is deemed resilient if there is a coordinated effort, as in the case of a natural disaster that would alleviate the effects of a disaster and foster a fast return to the normalcy. Such a focus on the return to a pre-disaster condition of the environment (through fast rebuilding, for example) doesn't account for emergence of different conditions and configurations of that environment that might call for some built-in behaviours (of the built environment) that would allow its re-configuration.

Thinking in terms of exchange, dynamics, energy, and flow and not in terms of assembled elements affects the way we think about architecture. It fosters thinking in terms of thresholds and not of constructed impermeable boundaries. Thresholds support the notions of gradients and transitions. Thresholds, gradients and transitions are qualities of ecological resiliency. If we succeed in supporting these conditions through technological augmentation of the constructed environment we should be able to disperse technologies that could be activated locally and only when needed. For example, instead of heating or cooling an entire building, the heat or coolness effect could 'travel' with the occupant. Reyner Banham reminds us that two basic ways of controlling environment were by hiding under the tree/tent/roof (in other words, by building a shelter) or by mediating local environment by campfire. He points out that "a campfire has many unique qualities which architecture cannot hope to equal, above all, its freedom and variability."[9] It was his argument for the inclusion of environmental phenomena and their variability into a design process that began to orient architecture towards adaptive environments.

The examples where a boundary between external and internal condition, or the variability of a phenomena is used as a driver for design can be found in the work of Philippe Rahm and Sean Lally. For them, the essence of architecture is to create a gradient of temperature, humidity, air or sound that provides fluid, dissolved boundaries of comfortable or desired conditions (the atmospheres, as articulated by Rahm). Inhabitation of these spaces is driven by a desire or need for a particular sensorial experience or comfort. Architecture's agenda in these projects, similar to Reyner Banham's ideas, encompasses the domain of environment and not that of the object. If we could construct atmospheres by modulating flows of heat, coolness, air or noise, the boundary is then dissolved into phenomena that exert subtle influence and support organization of people and activity differently than physical boundaries would. Such design logic would begin to erode traditional notions of control and organization of space and 'contaminate' design with the notion of variability, leading to a richer interaction with the built environment. For example, if the infrastructure for space organization is not concerned with the traditional logic of the constructed but is informed by the logics of thermodynamic behaviours, that would lead to new notions of order and organization of space. Such an attitude, however, would increase organizational complexity, introduce emergence, resulting in the design of open systems.[10]

Rahm's architectural projects invite us to re-think the wall as an impermeable tectonic element that separates interior and exterior by introducing a concept of the wall as strata. For example, to insure good thermal performance of buildings we often add insulation. Rahm proposes that instead of adding thermal layers to the wall we should stratify (programmatic) spaces as different thermal zones, organizing a building program in terms of their thermal coefficients, thus triggering thermodynamics of the airflow by using thermal difference between the spaces. The space with the lowest coefficient would be at the center and those with the highest coefficient on the periphery; the thermal difference would trigger a constant flow of air, forming an internal climate of gradients. In this way, the boundaries between inside and outside would dissolve into different spatial and thermal thresholds. Such an approach requires a different logic for space organization based on thermal zones and air flows. The built environment can be organized by defining zones of transition, comfort, economy, transportation … and, by aligning itself with a larger environment, could result in stratification and re-layering of its regions and their appropriation through occupation and use as a strategy for bringing the constructed and natural together.

Recent research advances in the field of synthetic biology offer another promising direction for changing the way in which buildings participate in their environment. In synthetically produced biological materials, "intelligence" is embedded in the matter itself. In 1974 Waclaw Szybalski suggested that synthetic biology "would be a field with an unlimited expansion potential and hardly any limitations to building 'new better control circuits' or [...] finally other 'synthetic' organisms."[11] In an article published in 2010, Rachel Armstrong discusses a new class of materials, developed with technologies derived from synthetic biology, which are capable of 'decision making' by relying on the chemical computational power of their molecules.[12] They are 'programed/designed' to make decisions about their environment and respond to it in complex ways that involve a change in their form, function or appearance. Responsiveness of these materials lies in their capacity for chemical computation. Without the need to rely on traditional computing methods and actuation devices, these materials offer a very different way of imagining an operational capacity of matter.[13] Armstrong's Living Brick project puts these ideas to work by proposing a brick based on Microbial Fuel Cell (MFC). These metabolically active building blocks can harness the metabolic power of microbes and convert it into electricity.[14] Structures made of this material can become active contributors to their environment and even appropriated by living creatures or other substances or chemicals. As such, they can choreograph behaviors or transformations of their physical or chemical context.

CONCLUSION

As we move from an attitude of determinacy and constancy (in engineering systems) towards the one of indeterminacy and adaptability, we move closer towards resiliency. Furthermore, the disruption of resilient systems results in their transformation over time. Designing change over time in the built environment, however, is a challenging proposition that can change the conceptual basis of design. It means that instead of designing for a particular condition and under specific design programs or criteria, we would design for change and transformation, taking into account the time that is necessary for a particular change to happen (as in the Urban Reef project). In such a 'mutable' design process, the design elements might include designed disruptors that would act as catalysts (as in the Charged Landscapes of Swarm Spaces projects).

Natural systems are open systems in which invasion and reinvasion of disruptors is a pivotal factor; they are constantly in transient state.[15] If we need to interface with them through technology, these new synthetic systems should be sensitive and responsive to natural system and its fluctuations (as in the Swarm Spaces and Remedia[c]tion projects). Striving for consistency of performance might move the system away from resiliency. Instead, we should strive for designing our constructed environment as an open system and accept transformation over time as an integral part of the design process and its life.

To form an interface or a permeable boundary between the designed and its local ecology requires a redefinition of the design framework to include fluidity of processes. Ibanez and Katsikis call this expanded framework the Grounding Metabolism and base it on a concept of urban metabolism.[16] The porosity of boundaries and a blurred distinction between the natural and constructed (or the natural and social as Jason Moore would suggest) allows design to expand its territory.[17] It makes the struggle to engage with the larger context less challenging by undermining the distinctions. The shift from a binary relationship to the recognition of interdependencies enables designers to focus on the interactions between social and ecological processes, which in turn makes conditions produced by these interactions more visible. The dynamics of the interactions would move environmental factors from the insulated position of an add-on factor to an equal participant as "producer and product of the web of life,"[18] potentially shifting the design space towards awareness of a constant production of new conditions and a new ground.[19] As Ibanez and Karsikis suggest, the temptation to engage larger territories comes from increasingly complex urban environments and also from the need to understand that complexity and its interdependencies and influences on the social and ecological networks across the planet.[20]

If we were to accept change as a fundamental contextual condition, architecture could then begin to truly mediate between the built environment, the people who occupy it and the larger context. As Ed van Hinte notes, "instead of being merely the producer of a unique three-dimensional product, architects should see themselves as programmers of a process of spatial change."[21] The principal task for architects is to create "a field of change and modification" that would generate possibilities instead of fixed conditions.[22]

To be resilient architecture has to form dynamic relationships to the external environment. It should interact with various conditions regardless of their nature (favorable, benign or polluting). In such a context, architecture is no longer a controlling agent sealing off its occupants from the surroundings but an agent of dynamic exchange between the interior and exterior. A porous relationship between the interior and exterior is what could promote that dynamic relationship. We should suspend a challenge of seeking a non-permeable and clearly defined boundary between inside and outside, the constructed and the natural, and instead design open systems that foster a constant flow of information, matter and energy.

ENDNOTES

1. Frei Otto, *Pneu and Bone*, (Stuttgart: Institute for Light Structures, 1995), 8.
2. James Graham Ballard, "The Thousand Dreams of Stellavista" in *Vermilion Sands*, (London: Vintage, 2001), 185-208.
3. Michael Weinstock, "Metabolism and Morphology," *Architectural Design*, March/April (2008): 26–33.
4. Ibid.
5. Frazer, John, *An Evolutionary Architecture* (London: Architectural Association, 1995).
6. C.S. Hoiling, "Resilience And Stability Of Ecological Systems," *Annual Review of Ecology and Systematics* 4, (1973): 1-23.
7. Ibid.
8. Ibid., 10.
9. Reyner Banham, "A Home is not a House," *Art in America* 2, April (1965): 75.
10. Alan Pavé, "Biological and Ecological Systems Hierarchical Organization", in *Hierarchy in Natural and Social Sciences*, ed. Denise Pumain, (New York: Springer-Verlag, 2006), 39-70.
11. Szybalski, Wacław, "In Vivo and in Vitro Initiation of Transcription" in *Control of Gene Expression*, ed. Alexander Kohn and Adam Shatkay, (New York: Plenum Press, 1974): 23.
12. Armstrong, Rachel, "Systems Architecture: A New Model for Sustainability and the Built Environment using Nanotechnology, Biotechnology, Information Technology, and Cognitive Science with Living Technology", in *Artificial Life* 16, no.1 (2010): 73-87.
13. Ibid.
14. Tafline Laylin, "'Living Bricks'" could turn sunlight and waste water into energy-generating bioreactor walls," *Inhabitat*, https://inhabitat.com/living-bricks-could-turn-sunlight-and-waste-water-into-energy-generating-bioreactor-walls/.
15. C.S.Holling, *Resilience And Stability Of Ecological Systems*, 1-23.
16. Daniel Ibañez and Nikos Katsikis, "Grounding Metabolism," *New Geographies* 06 (2014): 3.
17. Jason W. Moore, "Towards a Singular Metabolism," *New Geographies* 06 (2014): 10-19.
18. Ibid., 12.
19. Ibid., 14.
20. Ibañez and Katsikis, *Grounding Metabolism*, 3.
21. Ed van Hinte, Marc Neelen, Jacques Vink, and Piet Vollaard, *Smart Architecture* (Amsterdam: 010 Publishers, 2003), 132.
22. Ibid., 132.

DATAField
Strategies for Technological RESILIENCE through URBAN PROTOTYPING

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The leveraging of digital technologies at the intersection of architecture and urbanism allows for imagining scenarios for the future of cities. In line with recent cross-disciplinary research, this paper aims at investigating how large-scale prototyping applied to urban space can generate impact and provide a working model for Resilient Strategies.

DATAField, a placemaking intervention developed in New Orleans, investigates how the synthetic integration of 'the making' of place, the importance of citizens' engagement and the incorporation of digital technologies can provide an operative framework for large scale urban prototyping. Introducing models for urban hydrology management, citizen-engaged science, visualization strategies of underlying infrastructural systems and resultant urban prototyping related to resiliency, DATAField demonstrates how digital technologies implemented through systemic approaches can be a powerful tool to design in soft-land and to strengthen citizens' awareness of 'how we can live with water' in vulnerable ecosystems.

INTRODUCTION

> If we can use information to make cities more mobile, accessible, sustainable, and resilient, then we must use the existing information to help shape the built environment, as well as direct the information of the future by determining what data should start being collected now.
> —Aaron Betsky[1]

The exponential growth of cities globally in conjunction with expanding social and ecological challenges and the increasing impact of digital technologies demands a renewed understanding of public space as a means to catalyze 'the making' of place in close relationship to the contextual urban conditions. The engagement of built space, cities and people not just as isolated entities but as parts of an extended network that encompasses the production of information, cultural and social infrastructures can be strengthened through inter-scalar placemaking strategies to foster resilience.

Many urban environments currently face the challenges of securing and maintaining natural and manmade systems and resources implemented to reduce the physical vulnerability of cities. Climate change and coastal erosion, subsidence, social transformation and absence of equity and equal opportunities generate weakened metropolitan scenarios while drawing attention to important regional and local issues such as water management related to long-term sustainability at the city scale. Megacities like Mexico City suffer from severe destabilization of water resources and subsequent subsidence due to extreme population growth and the overexploitation of aquifers. The city of New York after Hurricane Sandy faces the challenge to accommodate rapid population growth, aging infrastructure and the dangers of rising flood plains and adequate preparation of its coastal areas. New Orleans in the Mississippi Delta is especially strongly affected by its peculiar geographic location. Situated mostly below sea level, its infrastructural systems designed for protection and control over natural forces constantly struggle to accommodate existing contextual complexities. In order to direct attention towards long-term sustainability as well as underlying contextual challenges the connections between the physical, built urban eco- and infrastructural systems and the immediate user become increasingly relevant.

In New Orleans existing ecological, social and technological systems related to water management often remain buried and illegible, partially due to their physical disconnection and the neglect of the immediate site context as a valuable source of information. Pumping stations, crucial nodes within the infrastructural framework of New Orleans that have protected the virtually submerged city from the imminent danger of flooding for more than a century remain anonymous, their essence and effectiveness disguised behind thick walls. In an effort to educate citizens about the risks of living in the Mississippi Delta in a city below sea level, communities will benefit from legible, integrated water management systems to collectively formulate a viable urban identity.

In his definitions of 'Non-Place' Marc Auge draws a 'parallel between the place as an assembly of elements coexisting in a certain order and [the] space as an animation by the motion of a moving body.' Similarly in 'Phenomenology of Perception' Merleau-Ponty delineates an important distinction between 'geometric' and 'anthropological space' to define 'existential' space as an important experience of hierarchies and relations.

Smart technologies already inhabit major parts of society, directing information and forming ubiquitous network infrastructures. Rather than burdened by 'simplistic functionalism', interactive multi-layered design strategies can 'affect how each of us inhabits the physical world.' Current surveys advocate that the "phenomenology of engagement" is at the root of interactivity, this results in a shift of design values from, "objects to experiences, from performances to appropriateness, from procedure to situation, and from behavior to intent."

Urban place-making that utilizes built space to abstract and visualize data and infrastructure networks should allow for human interaction and interpretation as they offer the opportunity to create context-conscious spatial connections within participatory environments amongst an engaged citizenry. The goal lies in the actuation of social structures in order for occupants to gain knowledge about the conditions of their context. In conjunction, how can we successfully develop multi-scalar strategies aimed at generating resilience through large scale prototyping and data collection and connect responsive systems with smart citizen participation to create a method for engaging users through interaction?

Resilience is now largely accepted as a concept that refers to the capacity of a system to maintain its function and withstand a disturbance, recover from it, and reorganize itself in response to it. Recent literature focuses attention on urban competence as community-scale resilience, acting as a response to the belief that resilience is largely dependent on local action and on solutions dependent on micro-scale conditions. At the same time, the concept of resilience has always been closely related to the general systems theory as adaptive capacity to a positive trajectory that occurs when communal abilities such as information and communication, economic development, social capital, and community competence are achieved.

As multiple definitions of resilience have been developed, a particular focus is placed on how large scale urban prototypes connected to place making, citizens' participation and technologically responsive processes can offer an integrated physical and virtual platforms for increased resiliency in communities through participation, awareness and communication while simultaneously creating a physical place. As working models, these kinds of prototypes can teach, learn and evolve while educating resilient communities. A vital community structure can be measured by the ability to provide habitable urban landscapes that embrace processes which can take on an agency of communication and connectivity. Design at every scale has to embrace an unpredictable and fluid context. Policy and governance have to adapt in equal measure to environmental, economic and social needs of a community, with the community genuinely being able to participate in this process.

LARGE-SCALE URBAN PROTOTYPING AS A STRATEGY FOR RESILIENCE

A Prototype is defined as an "early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from." The act of prototyping entails a process of testing a set of parameters through a synthetic whole that becomes a vehicle for further evaluation and exploration in the real world. It provides the capacity of developing a 'working system', a 'functional whole' for possible future formalization of an idea. Prototyping is a process that brings to reality a set of ideas or elements into a evolving working system. A prototype is a model that while being provisional in nature, as in-existence in the present moment, it has the embedded possibility of mutating, transforming and evolving into other forms. It is interim, partially temporary therefore highly responsive to change. As Diego Rodriguez states: "Similar to the scientific method, productive prototyping is about asking a single question at a time, and then constructing a model in the world which brings back evidence to answer your question. The goal of a prototype is not to be right, but to get an answer. That answer is what allows you to move forward with wisdom."

While the process of prototyping can be applied to any field, the focus in this paper is placed on how the act of prototyping can be related to the urban scale to give responses to specific issues or test solutions in the real world. To establish the operating framework within which the case study is analyzed, the paper focuses on a particular question: How can large-scale prototyping applied to the urban space provide a working model for resilient strategies? To introduce the argument, two main themes need to be explored: how time influences the act of prototyping and how scale and scalability are important factors during the testing process.

In this context the term 'rapid prototyping' refers to methods that produce prototypes fast enough to leave a substantial amount of time for actual changes of the product, providing enough time for several iterations in the design life cycle during which the prototype can be refined based upon earlier evaluation steps. In the last years, especially in the field of design thinking, rapid prototyping has become a form to quickly test ideas and move to the next phase by learning from the previous one. A prototype that usually tests one dimension of the particular issue is often called a 'low-fidelity prototype' as it has limited functionality, features and interaction, mostly used to depict concepts.In contrast, if we start talking about the importance of increasing scale as an crucial factor in prototyping at the urban scale, we have to refer to a type of prototype that it is closer to the one defined as 'high-fidelity prototype', typically fully functional, interactive and taking into consideration the users' experience at full scale.

Urban prototypes are fully-built physical working models that respond to a set of issues relevant at the urban scale while providing a platform for the evaluation of possible long-term solutions. In this framework, why is the notion of large scale and inter-scalarity so relevant? Why is scale strongly connected to impact, especially in defining resilient strategies?

Prototyping at large scale allows for a set of integrated factors to come into play when we evaluate the synthetic working model and its potential impact for resiliency. In particular:

1. Large scale urban prototyping facilitates placemaking.

2. Large scale urban prototyping triggers citizens' response and engagement in catalyzing urban interaction.

3. Large scale urban prototyping facilitates technologically mediated processes that relate to larger urban systems.

In the context of this paper the three categories above are particularly relevant as a means of supporting the idea that large scale urban prototypes can offer coordinated strategies for resiliency while educating and bringing awareness to communities that are at-risk.

LARGE SCALE URBAN PROTOTYPING FACILITATES PLACEMAKING

'PPS-Project for Public Spaces' states: "As both an overarching idea and a hands-on approach for improving a neighborhood, city, or region, Placemaking inspires people to collectively reimagine and reinvent public spaces as the heart of every community. Strengthening the connection between people and the places they share, Placemaking refers to a collaborative process by which we can shape our public realm in order to maximize shared value. More than just promoting better urban design, Placemaking facilitates creative patterns of use, paying particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution".

The development of place is connected to essential elements that bring together physical, relational and symbolic/cultural space as a process that acknowledges the construction of the physical environment. Urban prototyping can support the making of place both as short and long-term public space while fostering placemaking. Again, according to 'PPS-Project for Public Spaces', "a community's connection to place is at the very heart of resilience. In fact, resilience on its own has limited value if residents feel little attachment to, or investment in, a place. Placemaking is the process of building and nurturing this relationship between people and their environment. Through a broad focus on creating quality places, Placemaking builds the shared value, community capacity, and cross-sector collaboration that is the bedrock of resilient cities and thriving communities. As Jane Jacobs observed "Dull, inert cities, it is true, do contain the seeds of their own destruction and little else, (…) lively, diverse, intense cities contain the seeds of their own regeneration, with energy enough to carry over for problems and needs outside themselves." Indeed, what is often missed in top-down planning and policy—or upstaged by the loud voices and competing interests that generally dominate the discussion—is a community's own capacity to evolve and self-govern.

LARGE SCALE URBAN PROTOTYPING TRIGGERS CITIZENS' RESPONSE AND ENGAGEMENT

Due to their public and temporal nature, prototypes are meant to test out new ideas while the space generates visibility and dialog. Within this context, prototypes can be developed and displayed to solicit feedback from residents, city officials and stakeholders. They generate a platform for citizens' to respond and participate while sharing awareness. The prototype itself provides a physical node to meet, share and communicate; a place where public interactions can be intensified to foster exchange.

Public participation is expected to increase legitimacy, quality, acceptance, and efficacy of decisions and to foster empowerment of citizens. Thus, citizen participation is even appraised as a key element towards sustainability and resilience on the local level.

LARGE SCALE URBAN PROTOTYPING FACILITATES TECHNOLOGICALLY MEDIATED COMMUNICATION PROCESSES THAT RELATE TO LARGER URBAN SYSTEMS

The embedment of technologically mediated systems within the urban prototype facilitates the inherent nature of the continuous working model. Technology implemented through systemic approaches can be a powerful tool to design in vulnerable ecosystems and support resiliency: from data harnessing, sensing technologies and citizens' tech engagement resilient communities can be fostered.

The framework provided above will be tested through a large scale urban prototype: DataField, a project developed in New Orleans that operates as a place maker combining citizens' engagement and mediated technologies to catalyze urban responses both from citizens and larger infrastructural systems to support resiliency. A set of sub-strategies, such data tracking, sensing technologies and citizens' participation arecombined to foster the civic awareness. The project is a prototype that acts both at the micro and macro scale creating a localized node while impacting the expanded urban context.

Figure 1: DATAField- View from Broad Streeet, New Orleans.

DATAField: Urban Prototyping through Resiliency

In New Orleans, a city that continuously faces the challenges of living with water and unstable conditions of soft-land, the DataField project aims at synthesizing strategies for resiliency through the development of a large scale inhabitable urban prototype (Fig.1).

Prototyping additionally can be defined as a 'concrete representation of part or all of an interactive system', with prototypes viewed as both physical artifacts or as important components of the design process. As artifacts, prototypes can facilitate the manifestation and exploration of a design space and uncover relevant information about users, enabling communication and helping users interact with each other.

McCullough states that we must move our design focus from "things to experiences." Since its establishment on soft ground situated mostly below sea level, New Orleans has found itself inconstant battle with its chosen location. New Orleans' unfathomable proximity to water and natural systems as well as its vulnerable, dated, man-made water management infrastructure reminds us of the many threats as well as the opportunities that lie within this negotiated existence Its subtle topography, much unnoticed until the devastating effects of Hurricane Katrina, has provoked both ingenuity and hazardous decision making, leading to the implementation of successful protective measures as well as to failing strategies for resilience. New Orleans's interior drainage system, divided into several drainage sub-basins following topographic lines, mainly relies on storm sewers, outfall canals and pump stations, designed to work together to gather runoff released into nearby bodies of water. Its siting on soft ground, together with negligence in recognizing the dangers of draining and building on swamp land led to the consequential failure of several flood protection systems, due to long-term subsidence of the ground and the lack of attention towards its weak geological configuration. The recently introduced New Orleans Water Plan proposes a new investment model for public works where streets, canals, pump stations and storm water systems make use of undervalued and illegible water management assets and principals for urban design as well as provide a better understanding of the opportunities managing fragile soil conditions.

Building on the rich history of the city's water management infrastructure, the DATAField project draws its inspiration from the desire to establish a connection between the city's life-defining topography and its intricate system of pumping stations essential to the continued existence of the city within its current footprint (Fig.2). Using parametric modeling software as a means of generating the geometry, a network of macro and micro points is established based on the relationships between pumping stations and their respective capacities(Fig.3).

Designed as an exchange for citizens in accordance with Gordon Pask's Conversation Theory about interpretation and behavior, DataField aims at providing the user with a dynamic multi-loop method for experiencing spatial conditions. Within the project the occupant is invited to take on a primary role in configuring 'the space s/he inhabits, a bottom-up

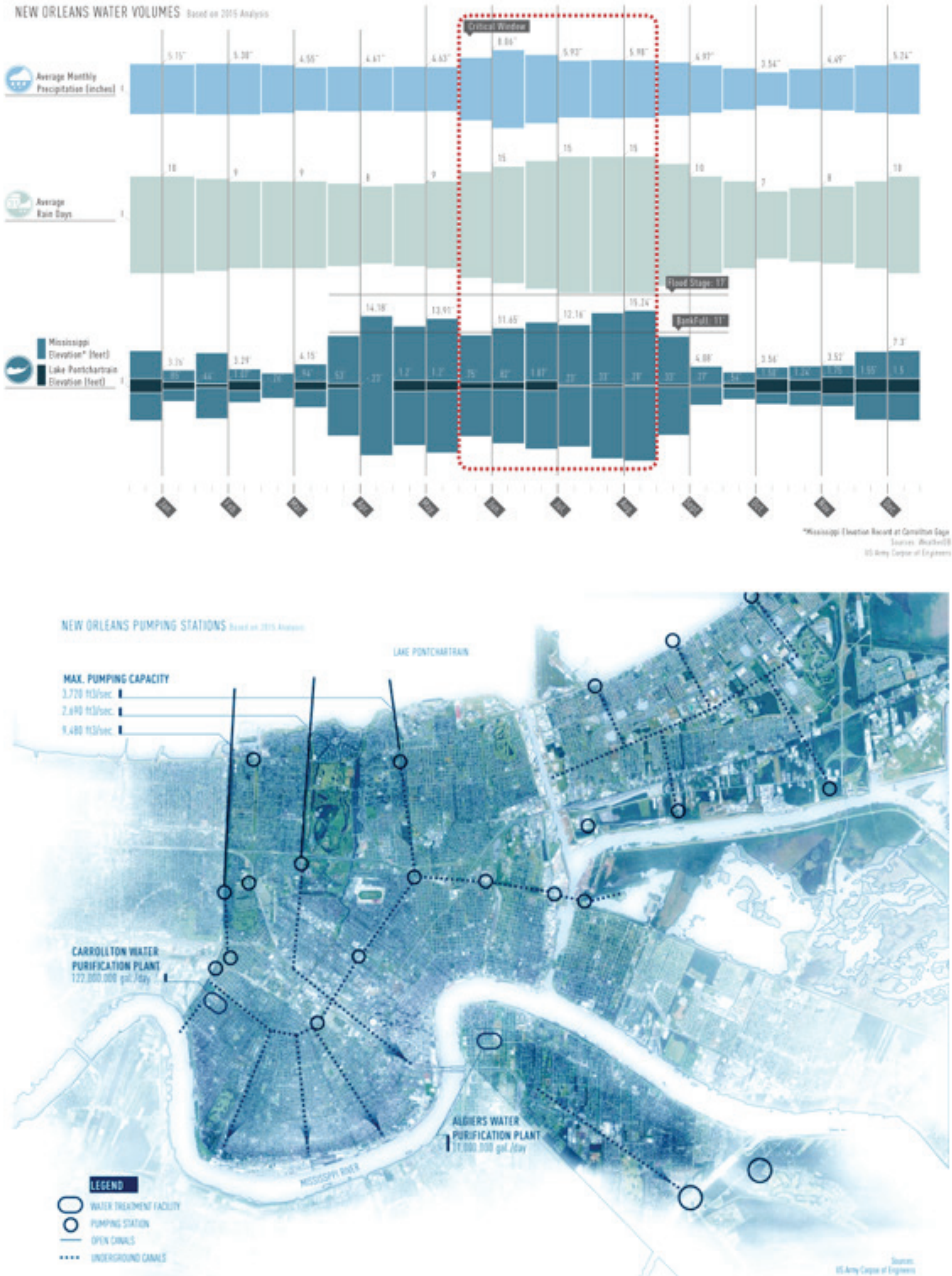

Figure 2: New Orleans Water Volumes and Pumping Stations.

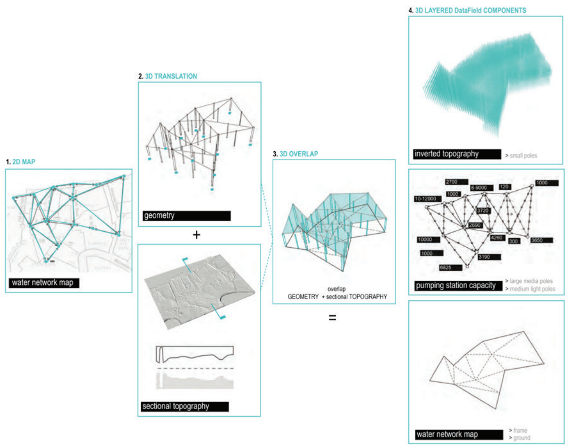

Figure 3: Generative Process (3D Water Network Map).

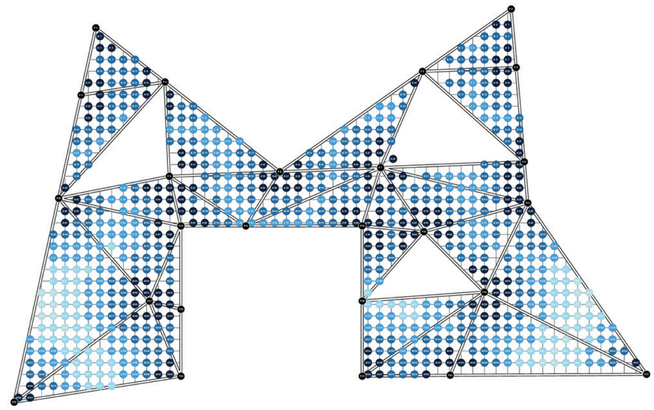

Figure 4: Components: Poles/ Gradient Map.

approach which results in a more productive relationship to our spaces and to each other. It is about designing tools that people themselves may use to construct their environments and thus to build their own sense of agency.

It is about developing ways to make people themselves more engaged with, and ultimately responsible for, the spaces that they inhabit. It is about investing the production of architecture with the poetries of its inhabitants.'

DataField consists of a dense field of data poles overlaid over an abstracted map of the existing New Orleans drainage network. Two different categories of poles are placed to index varying data streams in relation to water management activities (Fig.4).

The larger macro poles, steel poles with translucent plastic overlays are placed in a way that they directly relate to pumping station locations providing general user and systems capacity information. A field of medium poles record and display frequency and intensity of pumping activity at several New Orleans pumping stations, referencing real-life data. The experience is completed by densifying the field through the addition of micro poles, which physically allude to the configuration of the water network and spatially frame the pedestrian pathway leading through the space (Fig.5,6).

Overall the project focuses on the alteration of spatial conditions in favor of a successful place making strategy at different scales. The macro and medium poles respond to real time high- and low-end data transmission and processing (water moved by pumping stations at peak times) and incorporate vertical linear LED fixtures programmed through custom software connected to a light system manager registering the overall water fluctuation in the city and visibly translating it through light intensity. The installation organizes different invisible water-related data streams, specifically in relation to time and water flow quantities, aiming to apply integrated sensing technology and light responsive systems; as soon as the water flow at a pumping station fluctuates, an immediate response is displayed through a change in color and light intensity in the LED poles. The system can also be used to display past peak events, raising awareness about annual reoccurrences and their related outcomes (Fig.7).

Simultaneously real time messages sent from APPs via smart devices communicate awareness and concern about infrastructural challenges around DataField at the local scale. Citizens have the opportunity to connect with each other at crucial times, exchanging information and drawing attention to extreme local conditions at the micro scale. These challenges can include issues related to water conservation, management and quality, threatening local flooding events and status and maintenance of local frameworks and if addressed appropriately can trigger new ways of urban solution finding. Recent unexpected flooding events in and around New Orleans revealed a lack in ability to effectively

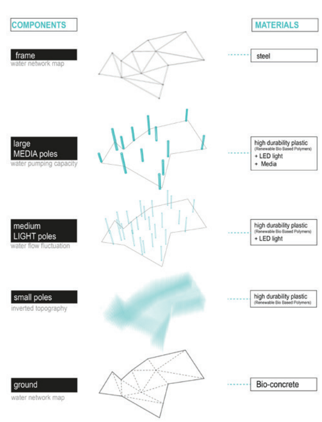

Figure 5: DATAField - Spatial components and material strategies.

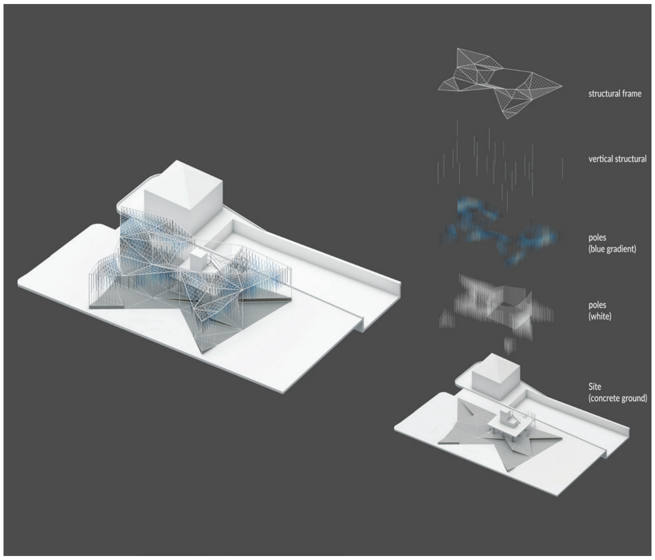

Figure 6: Axon- Spatial components.

disseminate information amongst residents and missed opportunities regarding the prevention of harmful decision-making. Enhancing communication processes that connect the local with the urban scale would allow for people-based action that could lead to the achieving of larger goals.

Research in the field of cognitive science suggests that the making of concrete physical artifacts, prototyping, can be a useful cognitive strategy to debate a design approach and its possible solutions. Meaningful cognitive experiences often extend beyond the individual and engage the environment and also other people.[32] With DataField, through its approach to prototyping, the goal is to identify underlying deficiencies in communication systems and for citizens to become the primary actors in the construction of a public experience of space that disseminates information. The users have the opportunity to individually and collectively interpret DataField's physical space and alter their relationships with the surrounding environment (Fig.8).

Within the structure, topologically, a folded pervious concrete surface, in conjunction with the color-coded micro pole canopy above, formulate a spatial reading of the city's topography, initiating conversation, discussion and experimenting. Participants can experience the place, becoming active participants, with "...the individual himself is present, participating...most definitely participating.'[33] (Jan Gehl) Linking the data pole to a sectional representation of the topography establishes a visible network of nodes visualizing the underlying water management system and creating a three-dimensional map of the city.

The basic principles of 'urban interaction' provide citizens here with ways to make their urban experiences more productive and efficient in the long term. Smart

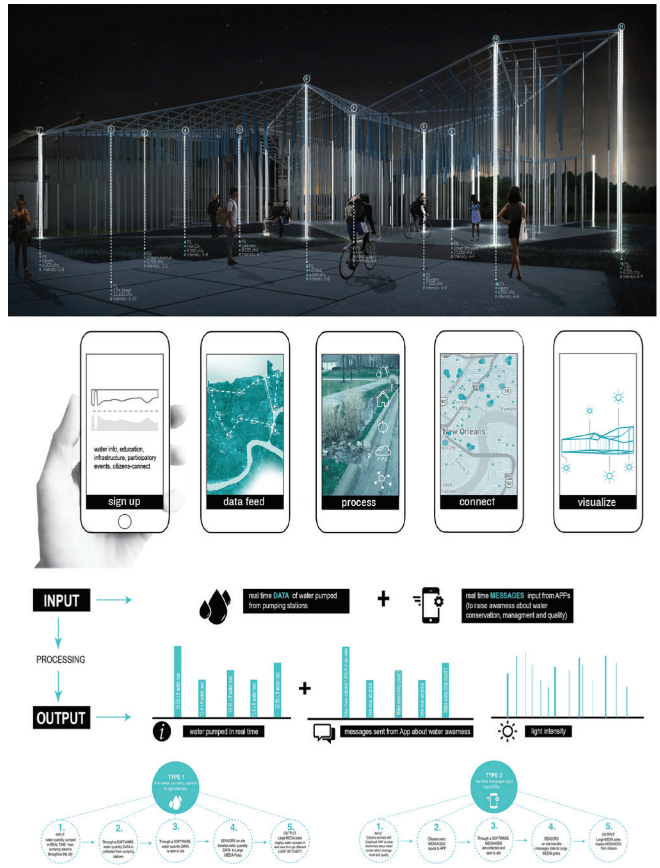

Figure 7: Media Concept and Narrative (Input - Processing - Output).

communications strategies triggered by remote sensing and the visualization of underlying, hidden data streams, enable active citizen participation. At the same time they also stipulate interfaces that help citizens understand the layers in the networked city, and let them organize themselves around these to share awareness and control outcomes in conjunctions with other stakeholders.[34] Large-scale urban prototyping in this scenario interrupt, evaluate and equalize. Prototyping for resilience requires proactive planning and a fact-based approach that communicates adaptive and ecologically-responsive design strategies as a response to multi-faceted and uncertain futures.

CONCLUSIONS

DataField demonstrates as a series of strategies for resilience could be implemented through a large scale urban prototype that acts as a testing and working model. As the project has already been tested as small scale prototype during the Luna Fete event in New Orleans in December 2017 (Fig.9) and currently in the pre-prototyping phase (Fig.10), the project is already generating impact and engaging a series of institutions, organizations and city officials in the feedback loop process. Architecture and its symbiotic relationship with the urban scale has the opportunity to

Figure 8: DATAField, View from Lafitte Corridor, New Orleans.

trigger immediate responses in observers and participants through indexing data streams in relation to the fluidity of water systems. The notation of these events in conjunction with the generation of successful public spaces enables a community-engaged environment, providing value to citizens through informingabout macro and micro issues relevant to real life data and existing infrastructures. At a time when city-wide planning strategies are failing due to a lack of governance and the widespread bankruptcy of communities, bottom-up models present themselves as an alternative approach to balancing public-private partnerships governed by corporate bodies.[35] DATAField, through the embodiment of bottom-up approaches has the ambition of generating impact and large-scale transformation, eventually acting as mediator of top-down actions (Fig.11).

The emerging scenarios, especially at the community level, that this project will bring to the city of New Orleans is yet to be defined and will be completely rooted in the continuous cycle of mutual stewardship between communities and place. As stated in the 'Places in Making: How peacemaking builds places and communities' by DUSP at MIT:" In most successful cases, the "completion" of the project is far from the end of the placemaking effort. Success at identifying these ongoing "making " activities and engagement in the civic processes that support them, creates the mutual relationship between community and place[36] that lifts these placemaking projects above a simple sum of the parts (…) The virtuous cycle model can benefit the larger placemaking field. Each new step in each new project represents a learning opportunity not just for the project, but for the larger community of placemakers. The field has everything to gain from an open-source model, wherein information about tactics, obstacles, successes, and failures becomes a constantly-updating resource base for the placemaking community. This continuous feedback loop is what will reinforce communities as they will learn to be more resilient and engaged in the process of 'making' places.

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Keywords: urban prototyping, water infrastructure, resiliency, place-making, sensing- actuating technologies.

ENDNOTES

1. 100 Resilient Cities – City Strategies. Available at: http:/www.100resilientcities.org/strategies/mexico-city/ (Accessed: 31 August 2017).
2. Marc Auge, *Non-places: Introduction to an anthropology of supermodernity* (London-New York, Verso, 1995).
3. Maurice Merleau-Ponty, *Phenomenology of Perception* (Routledge, 2012).
4. Mike McCullough, *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing* (Cambridge, MA, The MIT Press, 2004), 172.
5. Mike McCullough, *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing* (Cambridge, MA, The MIT Press, 2004), 50.
6. Lee Howell and WEF (World Economic Forum), Global Risks 2013 (Geneva,WEF, 2013).
7. Gonzalo Lizarralde, Arturo Valladares, Andres Olivera, Lisa Bornstein, Kevin Gould, and Jennifer Duyne Barenstein, A systems approach to resilience in the built environment: the case of Cuba, *Disasters*, n. 39, Issue s1, 2015, 76-95.
8. D. E. Alexander, Resilience and disaster risk reduction: an etymological journey, *Natural Hazards and Earth System Sciences Discussions*, n.1, 2013,1257–1284.

Figure 9: DATAField small scale prototype exhibited at the Luna Fete event in New Orleans in December 2017.

Figure 10: DATAField, View from Lafitte Corridor, New Orleans.

9. Norris, F.H. et al, Community resilience as a metaphor, theory, set of capaci ties, and strategy for disaster readiness, *American Journal of Community Psychology*, 41(1), 2008, 127–150.

10. Amy Hackney Blackwell and Elizabeth Manar, Prototype, *UXL Encyclopedia of Science*, 3rd ed., 2015.

11. “You can prototype anything” Available at: http://zine.ideo.com/downloads/Zine-IDEO-no1-YouCanPrototypeAnything.pdf (Accessed: 31 August 2017).

12. Deborah Hix and H. Rex Hartson, *Developing User Interfaces*, chapter 9, -Rapid Prototyping of Interaction Design, 249–281. Wiley Professional Computing, New York, NY, USA, and others, 1993.

13. Robert A. Virzi, Jeffrey L. Sokolov, and Demetrios Karis. Usability Problem Identification Using Both Low- and High-Fidelity Prototypes. In *Proceedings of the Conference on Human Factors in Computing Systems* (CHI 96), 236–243, New York, NY, USA, 1996. ACM Press.

14. Jim Rudd, Ken Stern, and Scott Isensee. Low vs. High-Fidelity Prototyping Debate. *Interactions*, 3(1):76–85, January 1996.

15. Marcella Del Signore and Mona El Khafif, Allographic Urbanism: from Guerrilla to Open Source, *ACSA 102 Annual Meeting Conference Proceedings*, Miami, 2013.

16. What is Placemaking? Available at: https://www.pps.org/reference/what_is_placemaking/ (Accessed: 31 August 2017).

17. How Placemaking Drives Resilient Cities Available at: https://www.pps.org/reference/placemaking-drives-resilient-cities/ (Accessed: 31 August 2017).

18. How Placemaking Drives Resilient Cities Available at: https://www.pps.org/reference/placemaking-drives-resilient-cities/ (Accessed: 31 August 2017).

19. Marcella Del Signore and Mona El Khafif, Allographic Urbanism: from Guerrilla to Open Source, *ACSA 102 Annual Meeting Conference Proceedings*, Miami, 2013.

20. Brandt, U.S.; Svendsen, G.T. Is local participation always optimal for sustain able action? The costs of consensus-building in Local Agenda 21. *J. Environ. Manag.* 2013, 129, 266–273.

21. Boonstra, B.; Boelens, L., Self-organization in urban development: Towards a new perspective on spatial planning, Urban Res. Pract. 2011, 4, 99–122.

22. Bell, S.; Morse, S. Breaking through the Glass Ceiling: Who really cares about sustainability indicators *Local Environ.* 2001, 6, 291–309

23. Nazem Tahvilzadeh, Understanding participatory govern.ance arrangements in urban politics: Idealist and cynical perspectives on the politics of citizen dialogues in Göteborg, Sweden. *Urban Res. Pract.* 2015, 8, 238–254.

24. Michael Beaudouin-Lafon and Wendy Mackay, *Prototyping Tools and Techniques, The human-computer interaction handbook* (NJ, USA, L. Erlbaum Associates Inc. Hillsdale, 2003), 1006-1031.

25. Michael Beaudouin-Lafon and Wendy Mackay, *Prototyping Tools and Techniques, The human-computer interaction handbook* (NJ, USA, L. Erlbaum Associates Inc. Hillsdale, 2003), 1006-1031.

26. Mike McCullough, *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing* (Cambridge, MA, The MIT Press, 2004), 172.

27. The New Orleans Hurricane Protection System: What Went Wrong and Why, A Report by the American Society of Civil Engineers Hurricane Katrina External Review Panel, Published by American Society of Civil Engineers, 2007.

28. Gordon Pask, Cybernetics (Entry in *Encyclopaedia Britannica*,1972).

29. Usman Haque, Architecture, Interaction, Systems, AU: Arquitetura & Urbanismo, AU 149 August 2006, Brazil.

30. Marcella Del Signore and Mona El Khafif, Allographic Urbanism: from Guerrilla to Open Source, *ACSA 102 Annual Meeting Conference Proceedings*, Miami, 2013.

31. Places in Making: How peacemaking builds places and communities. Available at: https://dusp.mit.edu/sites/dusp.mit.edu/files/attachments/project/mit-dusp-places-in-the-making.pdf (Accessed: 31 August 2017).

32. Places in Making: How peacemaking builds places and communities. Available at: https://dusp.mit.edu/sites/dusp.mit.edu/files/attachments/project/mit-dusp-places-in-the-making.pdf (Accessed: 31 August 2017).

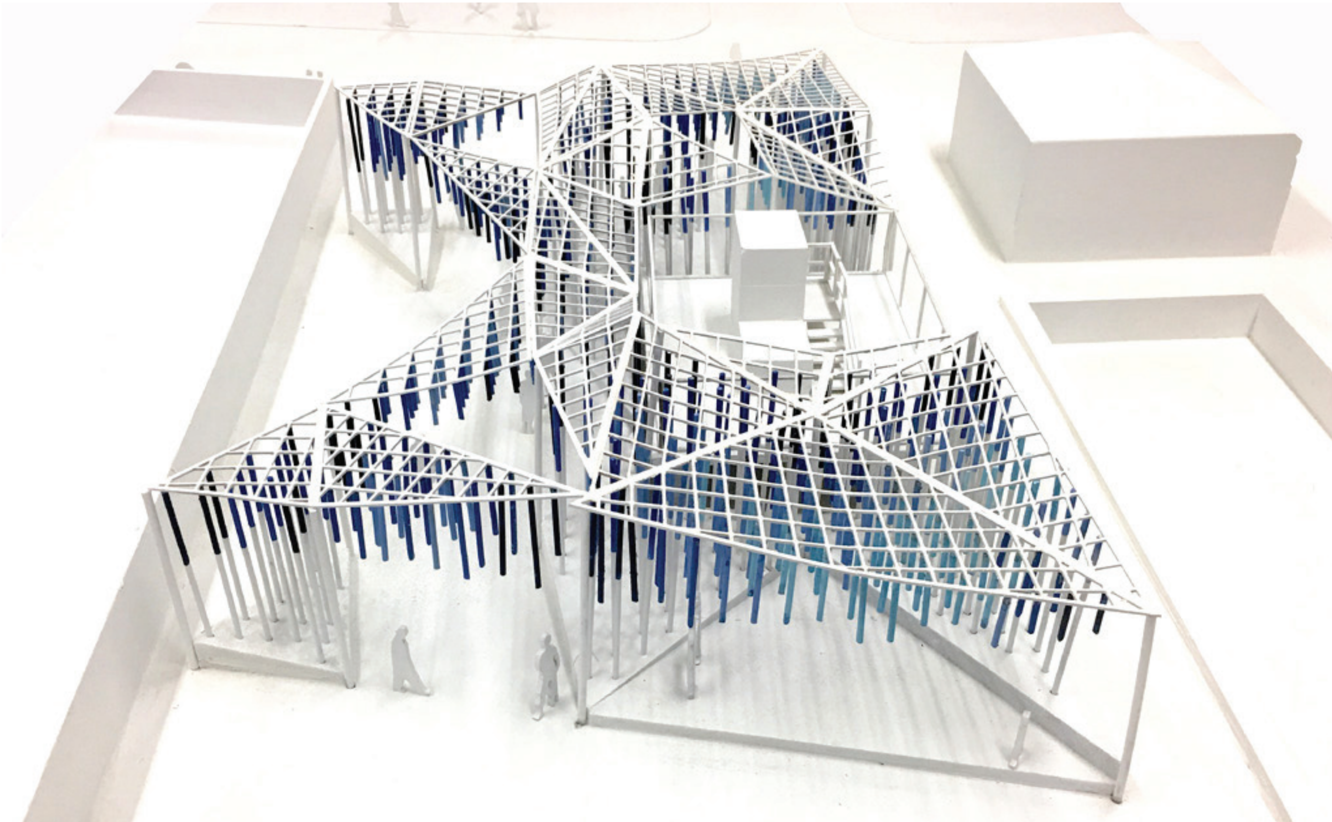

Figure 11: Arial View, Model- Field of Poles.

CHAPTER THREE
RESILIENCE, PERFORMANCE, PROTOTYPING, FABRICATION

SHAWNA MEYER
Kennedy & Violich Architecture, Ltd.

How can NATURE inform design to produce resilient structures that please the senses and engage the environment? Noted architect, Shawna Meyer, AIA, Kennedy & Violich, facilitated an interactive discussion of two projects presented by two architects, Julie Larsen (Syracuse University) and Sandy Stannard (California Polytechnic State University, San Luis Obispo). Focusing on questions of process, partnerships, and material logics through the lens of ecology, Julie and Sandra imparted their unique project experiences to an audience of teachers, thinkers, makers, and practitioners.

These projects address ecological design and resilience through infrastructure, materials, fabrication, building performance, aesthetics, and parametric tools. The Rhizolith Island (Columbia, South America) is a hybrid research/applied research project developed by a team of architects, engineers, a concrete manufacturer, government and NGOs, and works to combine innovative design strategies with advanced R&D concrete mixes and fabrication techniques. The second research project presents student research using parametric design tools, multi-modal methods, and performative material systems as part of a larger design dialogue and process. The projects are exemplary for their approach on "performance"– each process explores the limits of integrated design, and identifies an environmental necessity (need for water, need for cleaner air…) that informs projects' proposals.

The discussion is focused on methods and processes available for both researchers [students and academics] and practitioners. What are the available tools, how does this tool-kit affect the outcome? How do architects generate new tools to influence new outcomes? As practitioners, how do we generate a performance and resiliency as an inherent characteristic of architecture's DNA?

Rhizolith Island
Prototyping a Resilient Coastal Infrastructure

JULIE LARSEN
Syracuse University

ROGER HUBELI
Syracuse University

Rhizolith Island is a proof of concept design project that investigates floating, high performance concrete structures as a new, resilient coastal infrastructure that revitalizes depleting mangrove forests along vulnerable shorelines with continual flooding. The project is a collaboration between the authors, CEMEX Global R&D in Biel, Switzerland, JJSmithGroup Coastal Engineering, governmental agencies of Cartagena, Colombia, and local NGOs. The project uses new high performance and lightweight concrete technology to strengthen ecological performance of coastal infrastructure and reinforces appreciation for the ecologies that surround and protect communities. As a new, protective infrastructural type, the island is a resilient barrier that protects and enables new mangroves to grow and thrive while creating a public edge for visitors to engage with along the shore.

INTRODUCTION

Due to the devastating depletion of mangrove forests that naturally control sediment and shorelines from erosion, the project aims to repopulate mangrove forests along vulnerable shorelines in Cartagena, Colombia. A first prototype for Rhizolith Island was supported by the Cartagena Port Authority and the Naval Academy of Cartagena and was exhibited in the context of a concrete expo, 'RC 2016 Reunion del Concreto', in the old harbor of Cartagena, Colombia (Fig. 1). Based on the success of this prototype, the National Park Los Corales del Rosario and San Bernardo and the Cartagena Port Authority decided to support the further development of the Rhizolith Island as a proof of concept project to be implemented on Isla Grande off the coast of Cartagena. The city is interested in the project because they are looking for new ways to combat mangrove loss and subsequent flooding with soft and resilient infrastructural approaches that go beyond typical single purpose shoreline protection. Their interest is in providing solutions that respond to different site conditions while maintaining an aesthetically enriching public shoreline.

Mangroves, typically are highly productive forests built by a small group of trees and shrubs that have adapted to survive in the harsh interface between land and sea; often in places where rainforests meet oceans.[1] Mangroves play a crucial role in reducing vulnerability to natural hazards and increasing resilience to climate change, by acting as a form of natural coastal defense. Mangrove forests work as a defense mechanism because they play a central role in transferring organic matter and energy from the land to marine ecosystems. This matter and energy comes from detritus from fallen leaves and branches, and forms the base of important marine food chains.[2] However, mangroves are disappearing three to five times faster than overall global forest losses.[3] Human pressure on coastal ecosystems is often high, with land competition for aquaculture, agriculture, infrastructure and tourism. The conversion of mangrove areas to other uses over the past decades has been alarming with around some 15.2 million hectares of mangroves estimated to exist worldwide as of 2005, down from 18.8 million hectares in 1980.[4]

And although mangroves have the capability to 'keep up' with some sea level rise through accumulation of sediment and organic matter in the soil, any effort to grow further back from the sea is thwarted by urbanization.[5] So, mangrove forests are literally being pinched in both directions from rising sea levels on one side and agriculture and hard urban edges on the other. Due to this setback of growth, Rhizolith Islands aims to repopulate mangrove forests along vulnerable shorelines with aggregated, prefabricated concrete elements. The design of the Rhizolith Island is following the argument that "nature increasingly appears as a fragile entity that is itself in need of infrastructural support,"[6] serving as a response to the threats to the Colombian coastal region and providing the necessary infrastructural support to improve the shorelines and mangrove population.

BACKGROUND

As climate change becomes the norm, heavy storm surges and flooding require cities to take a different approach to nature. Continual urban growth, agriculture, and storm surges, in many countries around the world, contribute to devastating amounts of vegetation and habitat loss. And when "clearing mangroves" for new urban developments, this also "endangers humans because mangroves protect and stabilize coastal areas, and when they are removed, tidal waves can do greater damage."[7] Continual storm surges accelerate the depletion of mangroves along shorelines, which in turn makes urban areas even more vulnerable to flooding. In an effort to reverse this development, the project aims to achieve a soft, urban infrastructure that provides a floating protective barrier for new mangroves and marine life to grow and thrive in areas where more normative restoration does not work. This floating barrier is only achieved with a new composite of high strength and lightweight concrete mixes, to help redefine ecological performance for new coastal infrastructure.

Figure 1: Rhizolith Island first prototype, exhibited in Cartagena, Colombia (Source: Author).

The Naval Academy has investigated ways to combat inevitable annual storm surges and floods with breakwater armor systems, such as Xblocs and Tetrapod structures, most of which create a permanent, hard-infrastructural barrier between water and land. The city, however, would like to avoid hard breakwater applications due to their inability to be responsive to different site conditions, typically serving a singular use, and aesthetically diminishing the quality of the shoreline; all issues to overcome in many tourist destinations. Therefore, as a floating breakwater, rather than a hard edge, Rhizolith aims to create a resilient, soft infrastructure with three goals: protect and grow new mangroves, create well-crafted objects that ecologically perform, and design elements that can aggregate into different configurations to work in many different site conditions. To achieve this, the island is conceived as infrastructural elements through materiality and form, following D'Hooghe's argument that "any design of a contemporary infrastructure object should begin and end with an acknowledgement of the object crafted."[8] Unlike typical applications of infrastructure where the "material presence…is subservient to its bigger purpose,"[9] the project flipped the approach to rethink the performance and form of the breakwater elements to address protection of mangroves in high waters but to also address the public quality of the design. A key component to making the project viable for the City of Cartagena was to not only engineer a solution for littoral environments but design the forms to ensure high quality public and recreational spaces that people can engage with along the shoreline.

PRECEDENTS

The precedents for the project range from conceptual and formal references, to very specific applications of living shorelines and breakwaters in coastal regions. Existing floating ecological systems of naturally forming pumice islands, similar in material quality to porous concrete, are found in the vicinity of volcanic activity close to shorelines. Such is the case as the floating islands inhabited by the Uru People on lake Titicaca in Peru and Bolivia. Other types of precedents are Mangrove reforestation efforts such as the Mangrove Action Project which provides a holistic approach to mangrove reforestation by including research, education, community engagement and outreach.[10] But many of the current mangrove reforestation efforts focus more on reforesting natural environments with new mangroves without the challenge of working in littoral environments, relatively deep waters with strong waves, and don't need to mitigate between nature and the urban environment. The following precedents were instrumental to the development of the project.

Living Shoreline Breakwaters - There are many living breakwater strategies that served as a catalyst for Rhizolith Island; many of which stem from the Rebuild by Design competition. No longer are we seeing levee walls as a desirable solution because of its hard edge as well as its lack of any spatial quality and thoughtfulness to the public aspects of waterfronts in urbanized areas. Kate Orff's Living

Breakwater, a project conceived for the Rebuild by Design competition, looks at how to embed new habitats within a soft breakwater and still provide public access.[11] To keep water out and reduce flooding, most design strategies, like Orff's, use marshlands, beaches, wetlands and mangroves. There are a number of variables that must work in order to contribute to the success of a living shoreline. Limitations include "wave climate, regulatory policies, and property ownership."[12] And in order to "create an enduring living shoreline, the wave environment it is exposed to must generally stay below three feet (one meter) in height, a three-second wave period and blows less than a three mile stretch of open water."[13] These projects were closer in conception to the goals of the project but elements were never used in deep water conditions that had to simultaneously grow mangroves while protecting the shoreline. The Buras Boat Harbor by JJSmith Group Coastal Engineering uses a series of elements to create a living breakwater condition along the shoreline. The 'On the Water | Palisade Bay' coastal research project, by Guy Nordenson, Catherine Seavitt Studio and ARO, deals with similar oceanic forces acting on a soft infrastructure in the New York-New Jersey upper bay. Both projects look at wave and erosion patterns to design and situate soft edged infrastructural elements that help mitigate floods and allow for the reestablishment of marine habitat. These projects were highly influential in their coastal approach to the project and the amount of surface area needed to protect the shoreline but were not designed to grow mangroves, only marine vegetation.

Mangrove Restoration Solution - The Reef Ball Mangrove Solutions Organization deploys mangrove restoration strategies but typically in non-urbanized sites and in much shallower waters. The organization combines their 'reef ball' technology with split encasement tubes to stabilize the seedlings and ensure the fastest, healthiest, and most protected growth of the mangrove tree.[14] While this precedent helped in the design and development of the conceptual framework of Rhizolith Island, more specific engineering projects will be used to develop more detailed and technical modeling to design a resilient coastal strategy that provides an adequate ecosystem for natural habitats and mangroves to return while still withstanding heavy storms and sedimentation that isn't rich in nutrients for mangroves.

DESIGN STRATEGY: FOR VERSUS AGAINST NATURE

Before the environmental crisis, "nature served as the support for infrastructure", such as the Hoover Dam or Niagara Falls, "exploited the productive power of nature to the benefit of mankind."[15] Coastal infrastructural strategies, such as levee walls and fixed wave breakers, are 'single-purpose' systems, also meant to benefit mankind, and are traditionally used in threatened, urbanized areas prone to flooding. These systems are less resilient because they are short-term strategies that are known to increase long-term flood risk. They are built to protect a particular area but are designed as barriers to resist water and overcome nature as an obstacle. But as extreme climatic change becomes the norm, design of coastal infrastructure must flip and support nature, rather than exploit or resist it, which compounds the original problems.

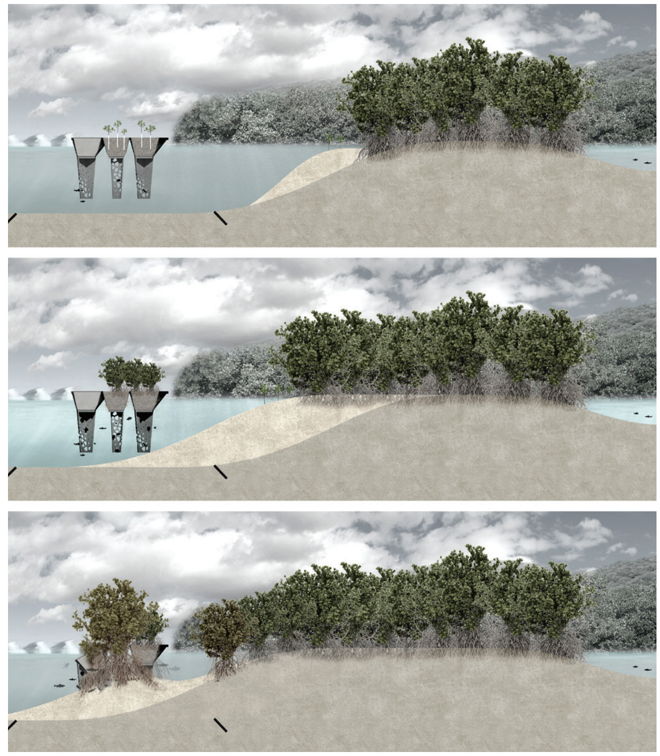

Figure 2: Three phases of Rhizolith Island, 1. planting mangroves, 2. Growing mangroves to maturity and 3. Concrete breaks and mangroves return as the dominant flood protection mechanism (Source: Author).

The conceptual design strategy of the island stems from a provocation by Lebbeus Woods, after the 2012 Tsunami, on the role of design in catastrophic events, "Can architects somehow design for earthquakes and tsunami, or only against them?"[16] In response to this question, if we aim for the latter – against – we must assume that in order to be against something, we must be in opposition to it or resistant to its effects. This sets up a clear boundary between what needs to be 'protected' (vulnerable forest, ecosystems, urban development) and what those bodies need to be protected from (recurring natural disasters, sea level rise). But if we assume the former – for – there is a potential for reciprocity between systems, rather than exploitation of one over the other.

New infrastructural boundaries along cities require a different perspective to nature – solutions that work for nature, rather than against it. Infrastructure that is not a linear, single purpose protection measure, such as dams and seawalls but a breakwater that becomes a field condition, creates more varied interaction with the environment and

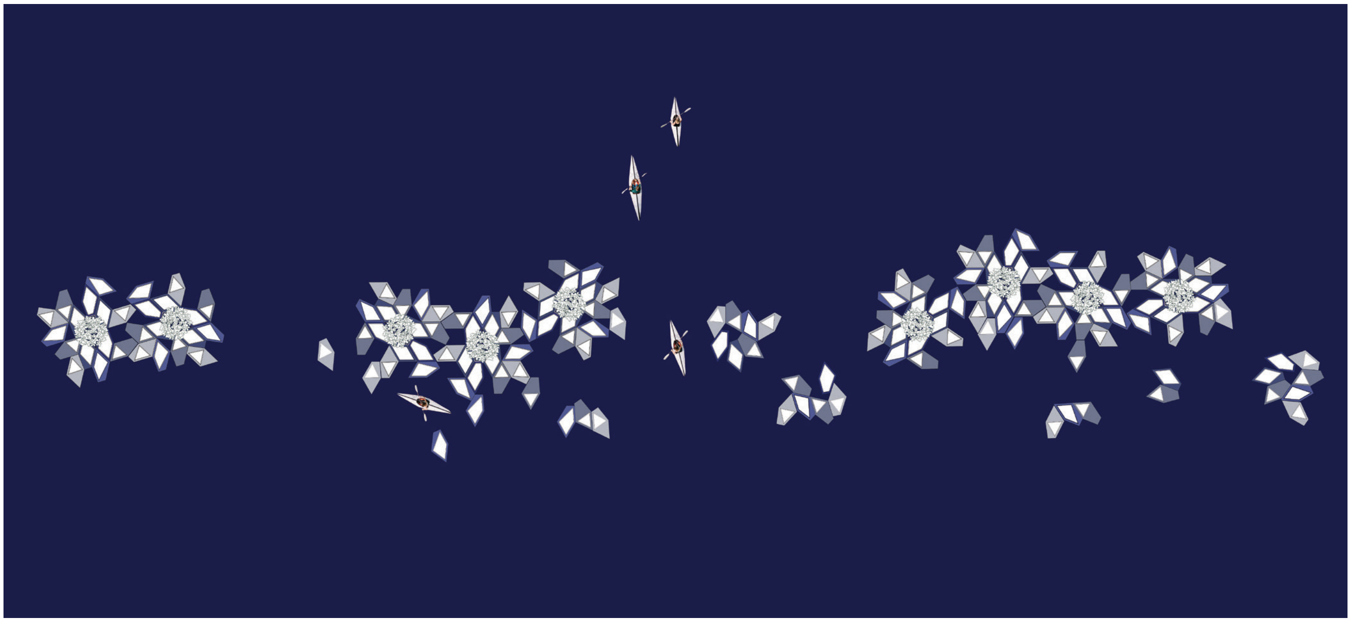

Figure 3: Aggregation of elements into larger field condition (Source: Author).

more opportunities for visitors. Following Lebbeus Woods' suggestion to "design for rather than against nature," Rhizolith Island is the design of a soft, resilient breakwater made with floating concrete elements that work 'for' nature by floating above the water; enough to break waves, without having to resist them to protect the shoreline. Especially since mangrove forests are the "ultimate illustration of why humans need nature with their ability to prevent erosion and mitigate natural hazards, a natural coastal defense whose importance will only grow as sea level rise becomes a reality around the world."[17] As a temporal structure, the design strategy recognizes that man-made structures cannot provide as resilient or as ecologically complex of flood protection as mangroves. Similar to mangroves with "above-ground roots that slow down water flows, encourage deposition of sediments and reduce erosion,"[18] the proposal aims to achieve floating elements that temporarily and artificially mimic the above-ground roots of the mangroves to provide a protective barrier for water to slowly pass under and around the elements. The design of the elements then provide protection for the roots of the mangroves to grow and allow nature to envelope and take over the structure over time as the preferred flood prevention (Fig. 2).

PILOT PROJECT

The team's pilot site for the proof of concept will be the Laguna Encantada in Isla Grande, off the shore of Cartagena. The edge of the lagoon has always been heavily forested with mangroves that bleeds into the Caribbean Sea. The lack of mangroves to protect the lagoon has greatly diminished the quality of marine life, the natural ecosystem, and mangroves surrounding the lagoon. As is the case with the mangroves abutting the lagoon, many "mangroves are particularly threatened in tropical coastal areas…the breeding grounds for many species of fish that grew up among the mangrove roots [are] destroyed"[19] as seen in 2016 when Isla Grande lost many mangroves buffering the lagoon and leaving two unprotected gaps to the lagoon that continue to threaten the ecosystem.

Without a floating, protective surface to keep mangroves above water, the coastal site of Isla Grande, with its exposure to the open sea, would otherwise be too challenging for mangroves to survive everyday wave occurrence, let alone harsh storm surges, as they grow. And due to the island being frequented by tourists, the Colombian Naval Academy is interested in providing a soft infrastructure strategy that not only protects the lagoon and provides shelter for mangroves, but also becomes a water feature for tourists and an opportunity to create awareness for visitors of the unique ecosystem they are inhabiting and enjoying. The project goals are to rejuvenate lost mangroves and design the concrete elements to intentionally break so the site reverts back to a more 'natural' state where mangroves, once again, control flooding. At the pilot site the intent is to test the elements at a larger scale to protect approximately 50 meters of coastline.

DESIGN STRATEGY

To derive a formal, material and performative logic through the use of concrete, the project began with the concept of 'Rhizolith'. According to the British Encyclopedia, 'rhizolith' derives from "fossilized root systems that were once encased in mineral matter and formed through a process of chemical weathering and cementation."[20] Rhizolith Island is conceptually aimed to begin as an artificial rhizolith that slowly returns to a natural, fossilized form of rhizolith over time. The design of the breakwater prototype, as an 'artificial

Figure 4: Single Rhizolith Island element, 10-20 of these elements make up one island (Source: Author).

root system,’ is comprised of ‘root-like’ concrete modules that work like an artificial rhizolith. It begins as a completely artificial, concrete structure but eventually ‘fossilizes’ and is taken over by the mangroves; thus, bringing the ‘rhizolith’ back to a natural state.

The approach of Rhizolith Island is that the structures float above water to protect mangrove seedlings in littoral environments with much more water depth and waves than in typical reforestation projects commonly located in shallower water. The islands create a floating protective breakwater that always remains above water in order for new mangroves to grow, responding to rising sea levels and ensuring mangrove seedlings stay above water while roots grow naturally down to the seabed. This is critical because without a way to keep mangroves above water, the site would be too challenging for mangroves to survive changing sea levels, harsh storm surges, or recurring waves, as they grow.For the islands to be effective as a resilient breakwater, in deeper littoral environments with rising sea level change and high waves, the design approach as a coastal infrastructure is to be a field condition of floating elements hovering over the water, which means the overall field absorbs and moves with the water, rather than creating a hard edge that resists it (Fig. 3).

The island modules work as protective barriers for planted mangrove seedlings to grow in harsh storm surges and waves that would otherwise wash them away if not protected. The concrete modules are made with a specific designed combination of concrete mixes to encase planted mangroves, while concrete fins below water create new habitats. The individual concrete modules aggregate into island clusters

Figure 5: Rhizolith Island Urban Speculation, shoreline of Cartagena, Colombia (Source: Author).

that can then aggregate into even larger, buoyant fields that act as a soft breakwater. The field aggregations also have the potential to become a larger, public infrastructure for urban growth. When the islands aggregate to a field, variation in the pattern creates gaps for boats and kayaks to pass through the islands, as well as for marine enthusiasts to enjoy the living breakwater as a place for recreation; added value to the growth of the urban spaces the breakwater intends to protect. Over time, the concrete elements survive long enough to protect the mangroves as they mature but are designed to fail so mangrove roots can easily moor into the seabed. As the roots break the elements, they sink to the seabed. Since concrete is rich in calcium, due to the limestone content of the cement, the elements will also help to support the growth of coral reefs that adjoin the lagoon.

FABRICATION

To ensure that the individual concrete elements are able to float and remain stable, they are made with a specific designed combination of high strength concrete technologies on the exterior of the element and lightweight and porous concrete on the inside of the element to create buoyancy as well as encase planted mangrove seedlings. The concrete fins, attached to underside of the structure, sit below water to create new habitats for local ecologies to develop around the elements as mangrove roots grow and moor into the seabed.

The individual elements of the breakwater are constructed of two individual pieces; a head and a fin, made with two different proprietary concrete mixes; one for strength, the other for lightness (Fig. 4). The fin of the element is made of high performance concrete that is needed for it to be strong and moor into the seabed over time and stabilize the structure. It formally has lightness due to the many voids in the surface of the fin to encourage flora, fauna, debris, and leaf litter to entangle itself into the structure. It's weight and strength stabilizes the elements in the water and provides a basis for the development of a marine habitat. The head of the element is made from a concrete mixture that is lighter than water and guarantees the island floats even if there are holes in the shell. In comparison to typical concrete, the concrete modules are half the weight so they can more easily be assembled off-site, shipped and placed into position. In the center of the element, a hole is created and filled with a porous concrete cylinder that encases the mangrove seedling.

Rhizolith Island is comprised to float, but more importantly, the lightweight and porous concrete is a weaker mixture that permits the roots of the mangroves to break the concrete and grow through it – leading to the eventual 'failure' of the concrete. Over time, the concrete elements survive long enough to protect the mangroves as they mature but are designed to fail, break, and sink so mangrove roots can easily grow and moor into the seabed. By the time the concrete fails and breaks, it is already trapped in the roots of the mangrove and other naturally formed debris and leaf litter that will accumulate within the shell of the fin and head of the module. The timing of the concrete elements breaking for the mangroves to take over is a new approach to the design of soft infrastructure because concrete rarely wants to intentionally fail. But in this case, CEMEX Global R&D is designing the mix in relationship to the force of the mangrove roots to have enough strength to protect the mangroves as they become mature but weak enough to break once the mangroves are fully grown. After several years, shorelines are eventually revitalized and revert back to a natural flood protection, where mangroves are the dominate flood mitigator (Fig. 5).

PROJECT DEVELOPMENT

While the first prototype that was exhibited and tested in the harbor of Cartagena was able to prove that the concrete technology and the method of construction can be successfully implemented for this application, currently, testing is being done to study the relationship between the concrete and the growth of the mangroves. According to the coastal engineers, the controllability of the height above water is the next phase of the project to ensure that elements can attenuate waves with approximately .4 - .6 meters raised above water. We are also working with a local NGO to test the rate of growth of individual mangroves in the porous concrete elements that will be part of the individual elements and serve as an incubator for the mangroves.

A series of tests were made of mangroves in the early stage of growth and development in the porous concrete. A local NGO in Cartagena is growing mangroves in concrete elements to test their ability to withstand the unique environment of the concrete with the first results being promising. Next, the elements will be brought to the open waters to see the rate of growth, expansion, and mooring capability of the mangroves in the concrete elements on site. If this is successful, the plan is implementing additional elements to test their ability to grow.

CONCLUSION

The impact of Rhizolith Islands starts with Isla Grande but the aim of the project is to far exceed the coastline of Colombia. Cities throughout the world are learning to accept that coastal erosion, mangrove depletion, and flooding are due to global warming, industrialization and, urban development. The loss of mangrove forests contributes to increased flooding and loss of valuable habitat. Since catastrophes do not represent decimations or extinctions of many species, but rather provide the crucial impetus for new developments,[21] there is potential for ongoing wave action or storm surges to spur new solutions to protect shorelines. Rhizolith Islands showcases an infrastructural strategy that ensures the longevity, protection, and possibility to include mangrove forest into the urban development of coastal cities while still maintaining a public interface with visitors and locals. To solve the larger issue of mangrove depletion, this will still require that urban development in the future not encroach on coastlines to ensure that mangroves remain the prominent flood mitigator.

Natural occurrences will continue, from storms to mangrove deforestation, but design can inevitability be the impetus for productive change. Rather than designing an infrastructure that is singular in its purpose and resists natural occurrences, Rhizolith Islands is resilient and multifaceted in its approach and designed for nature. This strategy ensures the longevity needed to protect the natural surroundings of Isla Grande and potentially other sites. There is an opportunity to design for nature and accept that human intervention can play an important role in supporting nature but without the need to control it. To design for failure understands that nature will endure and be the impetus for productive change is already within the natural environment itself.

ENDNOTES

1. Spalding, Mark D., Mami Kainuma, and Lorna Collins. *World atlas of mangroves*. London: Earthscan, 2010, 107-109.
2. LeGuen, Roger, "Blue Planet: Mangrove forests," WWF, Accessed July 12, 2017. http://wwf.panda.org/about_our_earth/blue_planet/coasts/mangroves/.
3. "UNESCO calls for better protection of mangrove ecosystems," United Nations, July 26, 2016. Accessed July 13, 2017, http://www.un.org/sustainabledevelopment/blog/2016/07/on-first-international-day-unesco-calls-for-protection-of-mangrove-ecosystems/.
4. "The world's mangroves 1980-2005 Report 2007," FAO Forestry Paper 153, Food and Agriculture Organization of the United Nations Rome, 2007, 9-13.
5. Spalding, *World atlas of mangroves*, 107-109.
6. Picon, Antoine. Nature, Infrastructure and Cities, In P. Scott Cohen & E. Naginski (eds.), *The return of nature: sustaining architecture in the face of sustainability*, New York: Routledge, 2014, 173.
7. Gleich, Michael, Dirk Maxeiner, Michael Miersch, and Fabian Nicolay, *Life counts: cataloguing life on earth,* New York: Atlantic Monthly Press, 2002, 150.
8. D'Hooghe, Alexander, "The Objectification of Infrastructure: The Cultural Project of Suburban Infrastructure Design," In *Infrastructure as architecture: Designing composite networks*, by Katrina Stoll and Scott Lloyd, Berlin: Jovis, 2010, 78.
9. ibid.
10. "About Us," Mangrove Action Project, 2013, Accessed July 12, 2017, http://mangroveactionproject.org/about-us/.
11. Orff, K., Nordenson, G., C. Seavitt Nordenson, Adam Yarinsky, "Living Breakwaters Rebuild By Design Competition," *Scape Studio*, 2014, Accessed July 12, 2017, http://www.scapestudio.com/projects/living-breakwaters-competition/.
12. Cox, Jack, "Living Shorelines: A Hard Look at the Softer Future of Marina Design," *Marina Dock Age*, July 2016, 19.
13. ibid.
14. "Explore Mangrove Solutions," *Mangrove Solutions*, accessed July 13, 2017, http://www.mangrovesolutions.com/index.html.
15. Picon, Nature, *Infrastructure and Cities*, 172.
16. "Lebbeus Woods, "Questioning Catastrophe," *Lebbeus Woods Blog*, January 23, 2012, accessed August 2013, http://Lebbeuswoods.Wordpress.Com/2012/01/23/Questioning-Catastrophe/.
17. Spalding, *World atlas of mangroves*, 107-109.
18. Spalding, Mark, *Mangroves for coastal defence guidelines for coastal managers & policy makers*, Wageningen: Wetlands Internat., 2014, 22.
19. Gleich, *Life counts: cataloguing life on earth*, 150.
20. "Meaning of Rhizolith," Encyclo.co.uk, accessed February 28, 2017, http://www.encyclo.co.uk/meaning-of-Rhizolith.
21. Reichholf, J. H.,Progress through Catastrophes: How Extinctions Further Evolution, in Spalding, M. (ed.) *Life Counts: Cataloguing Life on Earth*, New York: Atlantic Monthly 2002, Press,133.

When Performance Informs Design

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> This shifts the complexity of architecture from its frequently belabored preoccupation with the visual composition of a shape alone, to the actual behaviors and outcomes of a particular architectural formation. Both are as interesting and compelling as ever, especially when developed together. Therefore, an architect's consideration of formation might begin finally to reflect the degree to which its performance engenders complex adaptive effects of its formation.
>
> —Kiel Moe; *Convergence: An Architectural Agenda for Energy*

It is clear that building energy performance plays an essential role in architecture and in architectural practice, not only for reasons of occupant comfort and energy efficiency but also for minimal code compliance. While achieving energy compliance is essential and even laudable, our current definition of "building performance" is somewhat limited.[1] Energy performance analyses are often performed solely for code compliance with a minimal feedback loop during the design process. In the instances when analyses are completed as part of design, a growing array of simulation tools allow designers to make more informed decisions during the design process. There is tremendous potential in this trajectory.

The use of parametric and other performance analysis tools to help design professionals simultaneously achieve superior performance as well as delightful aesthetics represents an emerging chapter in the design professions. This paper will highlight a handful of sample undergraduate thesis and design/build projects which focused on the investigation of performative material systems as part of a larger design challenge. In each of these examples, "performance" went beyond the prosaic. Instead, these projects identified a particular environmental necessity based on the project situation (the need for water, the need for cleaner air; and so on). Inspired by natural systems or by emerging materials engineering, the students used multi-modal methods to explore their design ideas (parametric digital models; physical models at multiple scales; simple as well as complex math; and so on), ultimately resulting in an enhanced performative system that in turn influenced overall building form. In each case, it was performance that informed design, while simultaneously striving to appeal to the senses through an exploration of beauty.

THE SITUATION

Historically, there is no question that the essential relationship between vernacular architecture and building performance was necessary for survival, particularly in more extreme environments. One needs only to study traditional building methodologies around the world to appreciate the practical yet profound manipulation of building form and available materials designed to work symbiotically with local climate.

With the coincident rise of modernism and the technologies that supported multi-story buildings (elevators, mechanical comfort systems, electric lighting), building design in general failed to incorporate aspects of the essential collective wisdom inherent in vernacular design, particularly lessons related to building performance (in particular, thermal and luminous comfort). One distinct example of this shift is revealed through an investigation of Le Corbusier's Cité de Refuge. In the 1933 construction of the project, the multiple story building included a single-glazed southern facing façade designed with a purist aesthetic. The result was intense overheating and occupant discomfort that ultimately required a 1952 addition of an external shading device (brise soleil) and operable windows.[2] While scholars speculate whether the inspiration for Le Corbusier's brise soleil may have come from vernacular Brasilian architecture (an argument beyond the scope of this paper), the original as-built Cité de Refuge highlights the preferencing of design aesthetics over thermal performance. This might lead us to consider a generalized question in the area of architectural design thinking: does form and aesthetic decision-making take precedence over performance considerations, or is it possible that performance might inform design? And if performance can inform design, can it be achieved in a manner that is also delightful to the human user?

This is a question explored by a handful of undergraduate architecture thesis projects and one design|build example at the California Polytechnic State University. First, the method of how performance might inform or inspire design decision-making requires clarification. In this case, the method is different than the industry term of "performance based design ["PBD," which is the iterative process of testing design performance (even though each of the examples illustrated here also included iterative whole building energy analyses as part of the design process; this part of the design process will not be presented in detail here)].

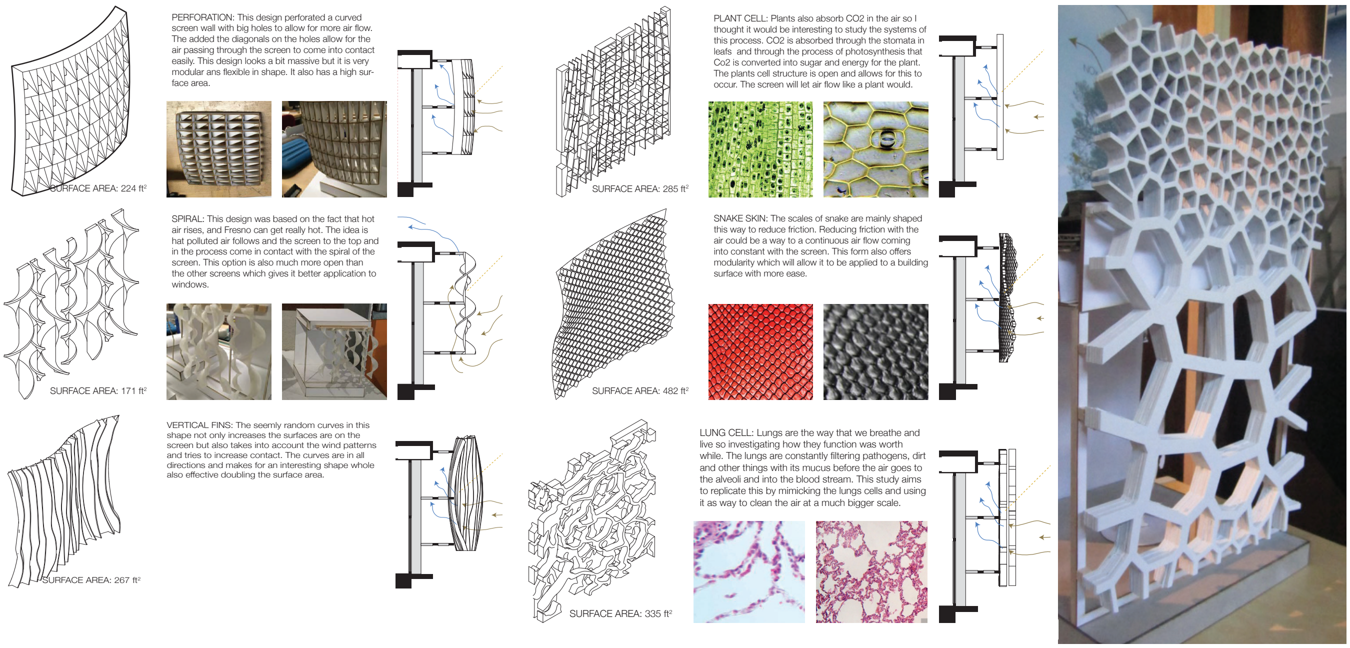

Figure 1: Air Pollution Mitigation Skin Studies (Andrew Valles, Cal Poly).

In the cases presented in this paper, performance led the design process. The first step in this process was identifying the primary issue or issues at the core of the project situation; the examples here revolved around particular environmental challenges. In each case, the environmental issues represented a challenge that could benefit from mitigation or maximization. In this way, the method these students used is more akin to what Ken Yeang identifies as an "ecological approach:"

> There are fundamental differences between an engineering approach to green or ecodesign and the ecological approach. In the engineering approach, the designer begins with the end, a picture of the desired outcome governed by the process of efficiency, and ends with the goal of production. In contrast, the ecological design approach begins with environmental discernment (ie, seeing what there is) and is governed by the process of achieving environmental harmony.[3]

The students then employed their investigative and design sensibilities through the use of a multiplicity of tools, from the digital to the analog. This multi-modal workflow allowed students to explore their chosen environmental issue(s); these explorations in turn informed micro as well as macro design decision-making. The use of parametric tools in particular fueled this method. These tools can help designers simultaneously achieve superior performance as well as delightful aesthetics.

While providing the initial inspiration for decision-making, performance was not the only goal of these projects. Creating simultaneously functional as well as beautiful responses remained at the core of each proposal, responding to the charge of Sim van der Ryn (among others):

> Where has beauty gone? Since our emergence as a species, humans have been making places and space. We've been designing them for the last thirty thousand years. All that practice has made us better at producing more material things, and doing it faster and cheaper. Our advancements in science and technology have provided the knowledge and tools that have allowed us to shape the material world in utterly fantastic ways. But we have lost our ability to create places of beauty, comfort, and durability that fit both the natural world and our own human nature.[4]

With these goals in mind, each student example will be presented in turn.

ISSUE: AIR QUALITY

Andrew chose a project site in Fresno, California, a city that has among the worst air quality in the nation. For Andrew, the question in this case revolved around how an architectural intervention might begin to mitigate poor air quality. The bottom line was a design that did not add to the problem. Then began an investigation into the potential for the building to demonstrate an alternative way forward (an active rather than passive approach).

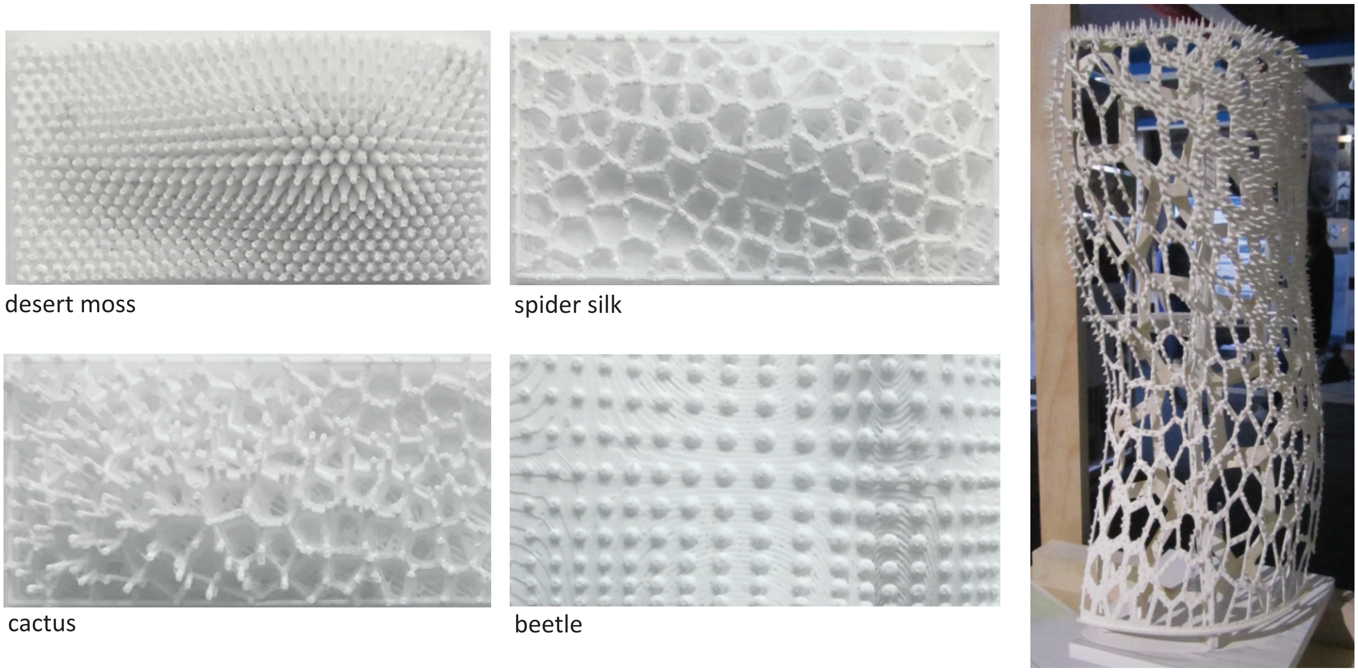

Figure 2: Water Collection Skin Studies (Shereen Ghishan, Cal Poly).

Andrew began studying the potential for the building skin to act as a purifying device. He researched the experimental use of titanium dioxide as a coating (a product called ProSolve 370e), which, in the presence of ambient daylight, reduces pollutants to harmless amounts of carbon dioxideand water.[5] He quickly realized that maximizing the surface area of the exterior building skin was critical for his design response. He looked to nature for sources of inspiration for the design of that skin, keeping in mind that he also needed to simultaneously maintain ventilation and views.

Andrew's investigations led him to study plant cells, snake skin and lung cells, along with pure geometric formations (perforations, spirals). While the snake skin provided him the most surface area, it provided no opportunity for light and air. Instead, he ultimately chose a combination of his test systems, somewhere between the lung and plant cell inspirations. Throughout his design process, he worked back and forth from digital to physical, using Rhino and Grasshopper to parametrically analyze the optimum surface area while also maintaining critical openings and of course continually seeking beauty.

ISSUE: WATER

As a native of Jordan, Shereen was intimately aware of the issue of water scarcity. She chose to investigate how the exterior skin of her design project could act as a water collector for atmospheric water. Like Andrew, Shereen drew inspiration from nature for her design investigations. Spider webs, cacti, beetles, mosses: all collect water in resourceful and inspiring ways. Her studies revealed the following collection methods: the desert moss uses leaf tip "awns;" the cactus utilizes cone shaped spines; the spider silk employs hydrophilic nanofibrils; and the beetle capitalizes on hydrophilic bumps. Through translating then modeling each of these systems discreetly at human and building scales, Shereen 3D modeled, printed and calculated the surface area for each study. She then hybridized the desert moss and beetle inspired studies to create a skin designed to capture and collect atmospheric water.

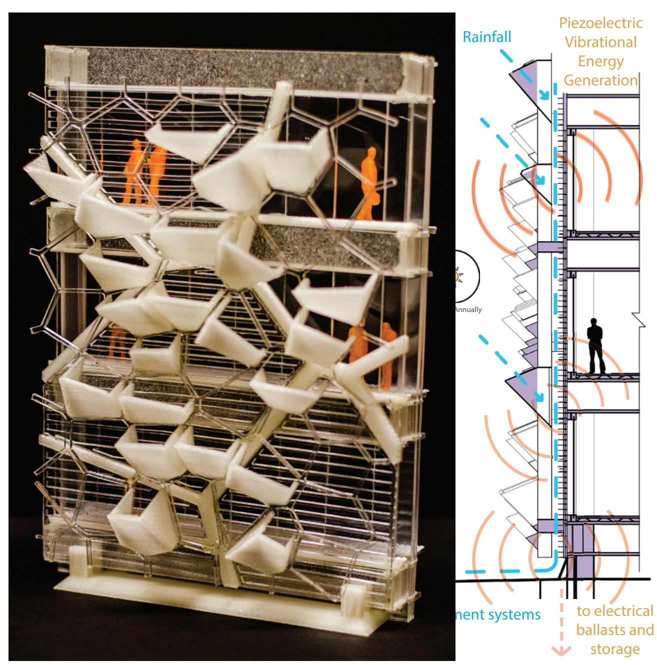

Figure 3: Piezoelectric Power Skin Studies (Eric Burford, Cal Poly).

ISSUE: CLEAN POWER

Eric chose a project site in Guangzhou, China, which has a serious air pollution problem. His site demanded a high-rise response and yet (similar to Andrew) he did not want the project to compound to the city's air pollution challenges. Rather, Eric aimed his response at the source of the air pollution: power production, which is predominantly coal-based in Guangzhou. Eric aimed to provide an emblematic solution through an alternative form of power generation. After completing an intensive analysis of this very wet climate (66 in/year of rainfall) and the electric potential embodied in that falling water, Eric chose to employ the use of piezoelectric technology to generate power for the project. He intended for the building to generate electricity from the vibrational energy of raindrops striking an array of piezoelectric films integrated into the building's skin. He calculated that this technology would generate about one third of the energy of his 50 story project. He further proposed that the water would then be re-purposed for use on site.

In addition to the use of Rhino for general design studies; hand calculations to confirm overall capacity; and 3D printing as well as other physical models for proof of concept, some of the more unusual tools that Eric used to develop his design solution included:

- APC Piezo Calculator: to calculate the piezoelectric potential of the individual pieces.[6]
- WUFI for studying the maximization of a drop of rainwater.[7]
- Autodesk's Flow Design to create a surface that would funnel rain at an appropriate angle without crowding any neighboring collectors.
- Grasshopper for structural iterations, balancing the necessities of securing the piezoelectric screen, carrying necessary building loads and eliciting delight.

By employing a multiplicity of tools, both analog and digital, Eric was able to transcend the hypothetical, producing a robust design proposal demonstrating how harnessing the energy potential of a raindrop can inform a full-scale building design while simultaneously appealing to the senses.

ISSUE: THERMAL CONTROL AND COMFORT

We also used similar methodologies in our work on Cal Poly's Solar Decathlon 2015 project, INhouse.[8] Without exhaustively describing the entire project, this paper will highlight a handful of design responses relating to thermal control and thermal comfort.

Understanding the intense climate of the Irvine competition site, we knew that shading was an essential climatic design response, including shading the building skin. While cladding and skin design are part of any architectural project, deploying the skin in a deliberate, tuned, responsive manner

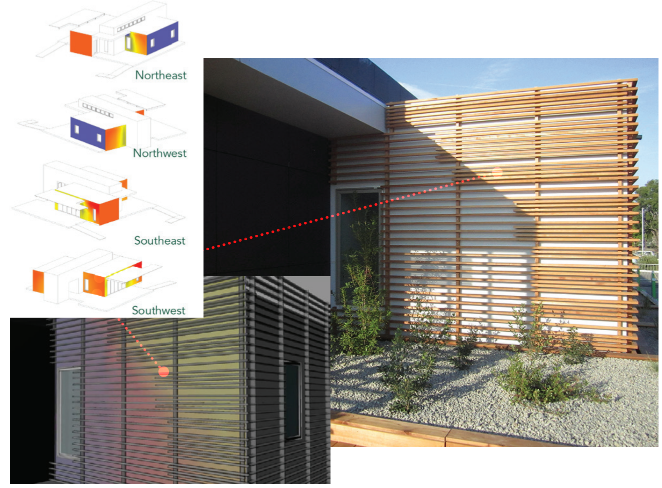

Figure 4: INhouse Redwood Screen Design (Thomas Kelsey/U.S. Department of Energy Solar Decathlon, Solar Cal Poly).

(that could also serve as an educational vehicle) was our goal. We created a composite map of incident solar radiation on each of the building's faces. With this information, we then "tuned" the redwood screen that was part of the skin design to precisely shade the envelope during the most extreme conditions. Such tuning also ensured the maximized use of the redwood; in this case the screen was not only aesthetic but also performative. In addition, the screen also represented a "heat map" of the environmental forces acting on the building skin. Thus, the climate data directly informed our design response: performance informing design.

An additional issue to meet our climatic responsive design goals for INhouse was providing adequate thermal mass to dampen internal diurnal temperature swings. Thermal mass is generally heavy; we needed to be weight conscious in the transportation of the project to and from the competition site. For this project, we chose to work with phase change material (PCM), some invisible inside a "phase change duct" running through the core of the house and some visible in an artistic screen. As an interactive piece, the visible PCM was designed as a decorative screen in order to make visible the performance of the building: the PCM tiles "freeze" and "melt" at roughly 70ºF, making visible the heat exchange capabilities of the bio-based oil inside the tiles.

MAKING AN ECOLOGICAL U-TURN

(inspired by environmentalist David Brower)

The aim of these examples is to demonstrate a methodology: identifying an ecological issue and then using contemporary tools (particularly parametric analyses) to help us discover responsive design solutions. In this way, perhaps we can learn how performance can inform design in a way that is not just solving a problem but that also strives to appeal to the senses through an exploration of beauty.

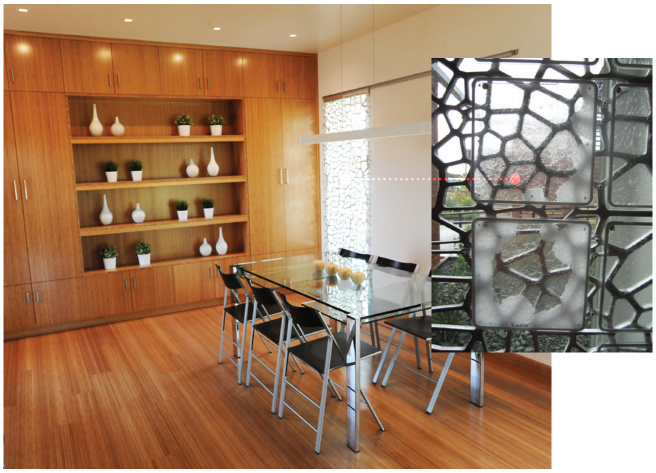

Figure 5: INhouse PCM Screen Design (Thomas Kelsey/U.S. Department of Energy Solar Decathlon, Solar Cal Poly).

The examples described here are relatively modest in scope and are predominantly speculative (with the exception of the design|build example). However, the method of "performance informing design" is repeatable and scalable. In an unselfconscious way, a version of this method is visible in many examples of vernacular architecture. In contemporary architectural practice, design firms dedicated to investigating ecologically responsive design solutions inspire us with performative design approaches. In the examples illustrated here, from larger issues (such as the air, water, and power examples), ecologically-minded performative design thinking can be at the scale of a building or a building skin. As demonstrated with the INhouse example, the method can be employed in a more discreet manner, focusing on particular design components (such as the thermally responsive PCM screen) within the scope of a larger project.

As thoughtful, educated designers, we are the stewards not only of creating meaningful spaces for people but also for respecting the environmental setting of these places. We have the opportunity to employ contemporary design tools and methods to fully explore the potential for performative interdependent relationships between a given situation and its inhabitants. Using this methodology, we might reach the goal of achieving a fitting co-existence, a symbiotic relationship that does not impoverish and perhaps even enhances the planet as well as our human experience.

> While the human animal is the most polluting one in nature, it is also the only species that has the capability to plan and manage its own future. It is this capability….. that must be effectively exercised now. [9]

ENDNOTES

1. For the duration of this paper, the term "building performance" will be used, with the intended focus on building energy performance.

2. Diaz, L.M. and Southall, L*e Corbusier's Cité de Refuge: Historical and Technological Performance of the Air Exacte* (LC 2015 – Le Corbusier, 50 Years Later, Valencia), p. 2.

3. Yeang, Ken, EcoDesign: *A Manual for Ecological Design* (London: John Wiley + Sons, 2006), p. 24.

4. Van der Ryn, Sim, *Design for Life* (Layton, Utah: Gibbs Smith, 2005), p. 7.

5. http://www.prosolve370e.com/, accessed 7/13/18.

6. https://www.americanpiezo.com/knowledge-center/apc-piezo-calc.html.

7. https://web.ornl.gov/sci/buildings/tools/wufi/.

8. Additional information about INhouse can be found at these two sites: http://www.calpolysolardecathlon.org/; https://www.solardecathlon.gov/2015/index.html.

9. Yeang, Ken, EcoDesign: *A Manual for Ecological Design* (London: John Wiley + Sons, 2006), p. 18.