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Starting with Universe: Buckminster Fuller's Design Science Now

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ABSTRACT

Increasingly, decision makers seek to harness "big data" to guide choices in management and policy settings as well as in professions that manufacture, build, and innovate. Scholars examining this trend tend to diagnose it at once as techno positivist in its insistence on design yoked to quantifiable variables and computational modeling and, alternatively, as an imperative integral to realizing ecologically sustainable innovation. This article investigates this tension. It reflects on the role of futurists, designers, architects, urban planners, social scientists, and artists in interpreting and utilizing *comprehensiveness* as a design frame. Among nine experimental foresight workshops at the inaugural *Emerge* conference at Arizona State University, many focused on producing physical objects or media, one modeled and expanded upon a method pioneered by architect and polymath R. Buckminster Fuller. At a time when many of the capabilities to realize Fuller's specifications for big data have matured, I investigate whether comprehensive design as framed by Fuller's method shows promise as a trend enabling ecologically sustainable innovations. A historical look at Fuller's Design Science and the reflection on it in the *Emerge* workshop marks an opportunity to highlight and interpret the resurgence of comprehensive thinking in design while navigating the contradictions this orientation engenders.

1. Introduction

Global change induced by human activity is occurring at rates unprecedented in our history. Racing ahead too is our enhanced propensity to monitor, describe and contextualize this change by amassing eco-bio-social and geospatial data. Increasingly, decision makers seek to harness this "big data" to guide choices in management and policy settings as well as in professions that manufacture, build, and innovate with the hope of achieving a more complete view of problem spaces. At the same time, computational tools for systemic analysis of myriad natural, social and economic phenomena are shaping and redefining the way we view the scope and reach of problems, innovations and interventions. Global systemic interaction is now a dominant frame for decision making in important planning and policy concerns in defence, resource, economic and environmental management (Bloomfield, 1986; Godin, 2008; Hughes & Hughes, 2000; MacKenzie, 1990; Miller, 2004, 2005). Scholars argue that markets, science, technologies, and landscapes we have today are in conversation with increasingly holistic models of the problem frame.

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Evidence that innovators in multiple sectors are responsive to the notion of systemic interaction marks the ascendance of *comprehensiveness*. This frame is now a driver of design and planning, particularly as it relates to future studies. Recent work on futures and foresight methodology proposes tools for conducting meta analysis of alternate scenarios, as in "integral futures" and the companion concept of "integrative foresight". These methods emphasize inclusive participation in scenario building (Hideg, 2013; Ramos, 2010; Slaughter, 2008). Both are examples of efforts to take comprehensiveness into account methodologically. These novel methods for futuring project the complex and global decision frames that structure the problem spaces of today's designers and decision makers.

Scholars examining this trend diagnose it at once as techno positivist in its insistence on design yoked to quantifiable variables and computational modeling and, alternately, as an imperative integral to realizing ecologically sustainable innovation. Historians and cultural theorists have documented this wave of data-informed design as an expression of a modernist trend in "Total Design" wherein the innovator, whether she be an artist, designer, architect, or industrialist, exercises control over all environmental elements (Wigley, 1998). Others assert that artists and designers include scientific and social science data as inputs into increasingly techno positivist research processes in order to establish legitimacy and to secure resources for the humanities among the hard sciences and engineering disciplines (Dutta, 2013). At the same time, sustainability scientists concerned about industrial production as a negative driver of global change insist that taking stock of the effects of material production and manufacture on environments at the design stage is an urgent matter.

This article reflects on the role of futurists, designers, architects, urban planners, social scientists, and artists in interpreting and utilizing comprehensiveness as a design premise on the occasion of the inaugural *Emerge* conference at Arizona State University, entitled *Artists and Scientists Redesign the Future*. Among nine experimental foresight workshops, many focused on producing physical objects or media, one modeled and expanded upon a method pioneered by architect and polymath R. Buckminster Fuller, a figure among the first wave of 20th century thinkers to articulate a process that incorporated advances in strategic planning and computational modeling. The workshop involved experimental methods to heighten participants' awareness of global systems as nested in cosmic ones. Participants then interrogate the implications of these connections in relation to a given environmental design challenge through facilitated discussion. The workshop was conducted by members of the Worldviews Network, a collaboration of pioneering research and informal science education institutions committed to integrating visual systems and design thinking. The network is supported by a three-year environmental literacy grant from the National Oceanic and Atmospheric Administration's (NOAA) Office of Education.[1] A historical look at Fuller's Design Science and the reflection on it in the *Emerge* workshop marks an opportunity to highlight and interpret the resurgence of comprehensive thinking in design.

At a time when many of the capabilities to realize Fuller's specifications for big data have matured, I investigate whether comprehensive design as framed by Fuller's method shows promise as a trend for leading architects, urban planners, social scientists, and artists to produce ecologically sustainable innovations. I outline practical lessons that can be extrapolated from Fuller's "Design Science" for contemporary foresight practice. Fuller's legacy challenges contemporary futurists and designers to put theories about the benefits of reflexive design into practice while navigating the contradictions that this position engenders.

This article first relates the activities of the *Emerge* workshop, "Starting from Universe", illuminating its characteristic methodologies – the use of immersive data visualization and facilitated dialog – to inspire design that takes a comprehensive problem frame into account. I next place the workshop activities in historical context by introducing Buckminster Fuller's Design Science process as exemplary of the modernist sensibility in Total Design. I outline the grounds for a critique of Fuller's approach as techno positivism. In the discussion section, I suggest ways that parts of Fuller's process that have been overlooked by his critics might be reclaimed. The process has the potential to increase the reflexivity of innovators who not only marshal myriad data inputs, but also contend with social and cultural values in defining the goals of a given project. Finally, I distil practical lessons from Fuller's original process that could better inform contemporary design and futures practice.

2. Starting with Universe: the ASU *Emerge* workshop

The 2012 *Emerge* workshop began with fifteen attendees sitting cross-legged in a darkened twenty-five foot inflatable 'GeoDome' theater, viewing an immersive projection of a "cosmic zoom", the scene quickly moving out and away from the familiar "blue marble" of the Earth, through the solar system and the Milky Way to pause at the edge of a giant cluster of galaxies represented by the Sloan Digital Sky Survey containing more than 930,000 galaxies and more than 120,000 quasars out to the edge of what astronomers call the "observable universe".[2] This sense of universe is painstakingly crafted from 1s and 0s using a real time rendering data visualization software. It was in this atmosphere that this group of arts and theater faculty, graduate students, corporate and freelance designers, planetarium managers and visualizers began a two-day debate to determine what Fuller calls "the preferred state" of education for ecological design with the help of this curved scrim and immersive patterns of light and color (Fig. 1).

The 2012 *Emerge* workshop, *Starting from Universe: Design Science Now*, prototyped a new "Design Science" – drawing from a process articulated by Buckminster Fuller to link scientific data about the cosmos to ecological conditions on Earth

[1] See http://worldviews.net/.

[2] For detail about digital universe atlas, see (*Carter Emmart Demos a 3D Atlas of the Universe|Video on TED.com* n.d.).

Fig. 1. GeoDome theater used for projecting the cosmic zoom, *photo by David McConville*.

with a "comprehensive anticipatory" group dialog process that tackles ecological design problems. Organizers presented contextual information about an environmental literacy project called the Worldviews Network. This three-year project links a network of participating planetariums and GeoDomes across the United States and creates visualizations and programming to educate audiences about global change such as biodiversity loss, climate change, and ocean acidification, using the planetariums' immersive visualization technology as a teaching tool.

Though the programs cover myriad topics, each connects data about specific instances of environmental change with larger systems through immersive presentations of visualized scientific data. At the time of the ASU *Emerge* event, Worldviews organizers were beginning to pair data-laden planetarium presentations meant to educate public audiences about global change with facilitated community dialogs that explore the interconnections between the resilience of social-ecological systems across cosmic, global and bioregional scales. As designers of these informal science-learning programs, Worldviews project organizers were faced with the question of how a comprehensive, data-rich view on a regional ecology problem might open up new ways that communities could talk together about the future, define the scope and nature of regional issues, and also generate novel strategies for confronting these issues and involve influential stakeholders. The *Emerge* workshop was a vehicle for testing out how steps in Fuller's Design Science process might shape the planned community dialogs and motivate stakeholders to produce concrete and actionable solutions on the topic they treated.

On the first day, workshop organizers oriented participants to adopt a comprehensive mindset by using immersive visuals to show the position of planet Earth in larger cosmic systems. Sharing personal reflections and memories, the group debated whether and how these macro perspectives about the structure of outer space and the Earth's place in it relate to communities, ecologies, and their personal work.[3] Having traced connections between these artistic and scientific renderings of a universe map to everyday experiences, participants each articulated several design problems that emerged during his or her contemplation of those linkages (Fig. 2).

On the second day, participants then learned about Fuller's Design Science Process. It is a method by which individuals or small groups can design alternative future paths for themselves and society as a whole. By providing a larger vision of change in which smaller design projects and initiatives can be conceived, a Design Science plan can become the basis for developing specific artifacts, programs or policies.

Organizers then used a group facilitation technique called "thirty-five" to allow the group to prioritize one or two guiding questions to be worked on collectively from among the individual provocations that each member had generated. Participants wrote a single question they would like to put forward for further work on an index card. They then walked around and exchanged the cards with other group members without reading the questions. After a set amount of "shuffling" time, group members paired up. Each pair reviewed the responses on the two cards they held and assigned a score to each question, distributing seven points between the two responses to reflect the relative importance of the questions. Participants wrote the score for that round on the back of each card. Participants repeat the card trading process for a total of five separate rounds of scoring. At the end of fifth round, people take their seats holding one card and make a tally of the five

[3] A similar approach can be found in the premise around "big history" which seeks to tie the history of natural phenomena to the accounting and development of human events (Brown, 2007).

Fig. 2. Starting with Universe, *photo by Ned Gardiner*.

scores now written on that card. The facilitator then counts down from thirty-five; participants read the questions that received the highest scores.

The group identified four issues as most pressing to resolve in order to achieve a comprehensive stance in ecological design:

(1) Individuals do not experience a sense of agency or empowerment in connecting to global issues.
(2) Science and art are divided.
(3) There are not enough clear examples of project designs that address multiple interconnected issues within educational systems.
(4) An empirical argument alone is insufficient to convince most people that an equitable distribution of resources is the highest priority.

The group settled to work with these issues at four separate tables (Fig. 3). Through small group discussion, participants stepped through the first part of the Design Science process: defining the preferred state and describing the present state. In two additional rounds of discussion, the groups developed a definition of how educational systems should take up comprehensive pedagogical designs in a preferred state by first generating a set of general values shared by the group and

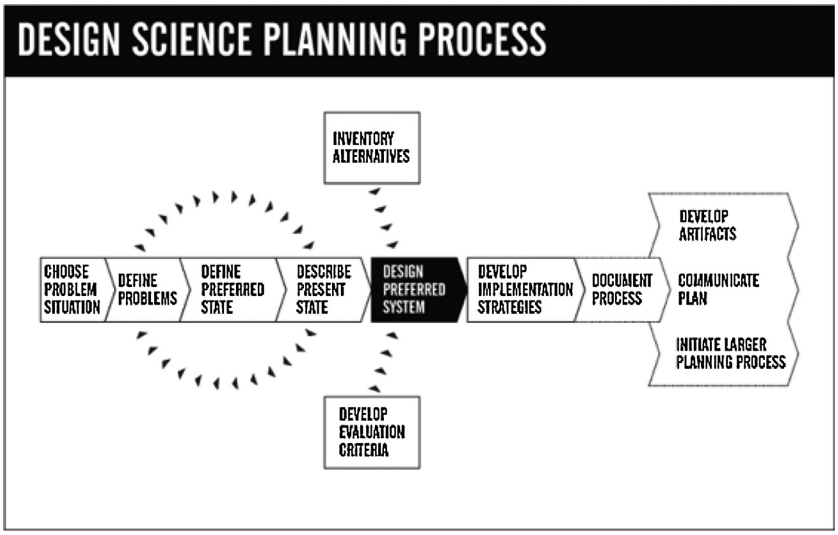

Fig. 3. The Design Science planning process.
Figure is reproduced from Brown et al. (1975).

then comparing them to a set of values that are known to be operative in the problem state. They were asked to distinguish between the general preferred values and problem state values. The workshop culminated with participants reporting on the sketch of a preferred state (Fig. 4).

3. Design science then: Buckminster Fuller's process

Increasingly, design professionals operate with a concern to illuminate and incorporate within the design itself the otherwise opaque parts of the production process. Broadly, this emphasis on what William McDonough (2002) calls "cradle to cradle" making encompasses the set of systemic concerns that must be accounted for across a spectrum of material production. Fuller's Design Science, conceptualized over a career that spans from the late twenties through the early eighties, defines this drive for holism as using the principles of science to the conscious design of our total environment with the goal of using finite resources to meet the needs of society without disturbing ecological balance.

The methods and processes that Fuller advances in a variety of texts and reports, not least in the two-volume opus on synergetics, the study of whole systems behavior, prepare the designer to train as a comprehensivist. The influence of these processes aimed at comprehensive design is little studied. Following the rise of the industrial revolution, the insistence on comprehensiveness rather than specialization in Fuller's work tracks a trend of utopic thinking that surged with it. Fuller and other contemporaries saw this as a needed antidote to the pressures inherent in industrial production that favored specialization in scientific and technical training and in the labor force.

The interaction of whole systems that Fuller articulated and used to guide his own work has a powerful influence on contemporary practice in science and engineering. The two key contributions I will outline here include the significance of examining aggregate, or "big", data and a directive to base design decisions on the contours and behavior of whole systems rather than component parts, or what Fuller terms "Starting with Universe". These two contributions evolved in tandem with enhanced technological capabilities leading to faster computation and new data models for naval aviation, weather, climate, and world dynamics models developed in the post WWII period. Systemic modeling has changed the scope and

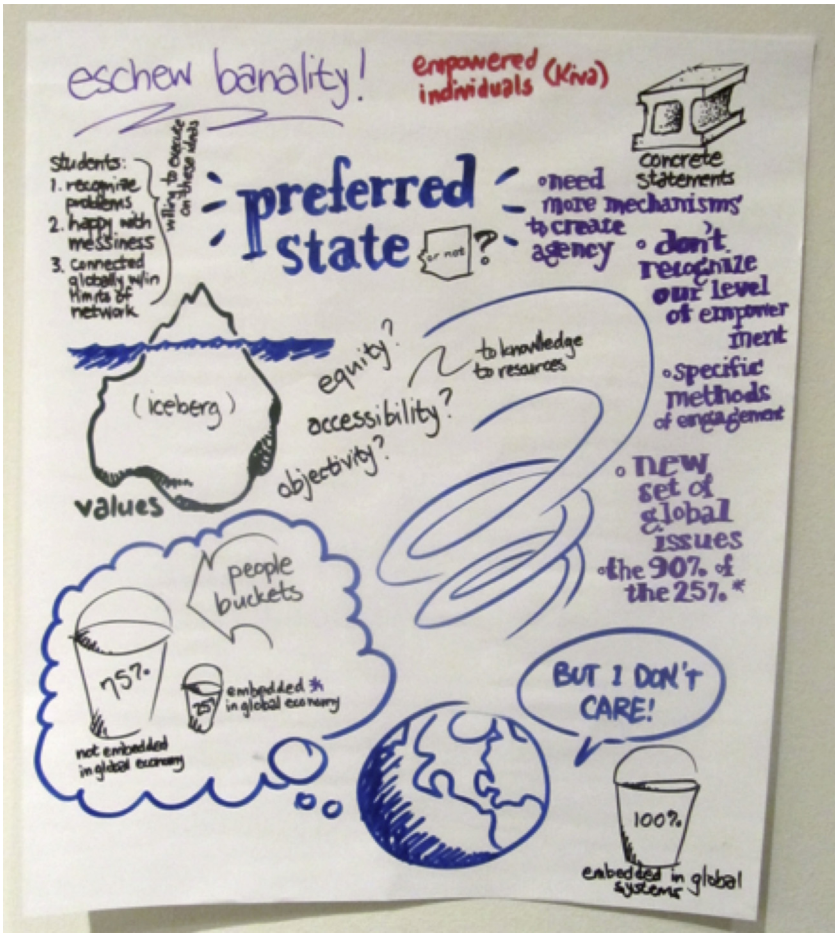

Fig. 4. Workshop notes toward identifying the preferred state, *photo by David McConville.*

mental models of those interested in environmental issues and constructed the modern world concept (Edwards, 2000). Notably, this stock taking of world trends involved data collection and aggregation on both ecological and human-produced phenomena. For Fuller, design processes that utilize global data and computational simulation as tools stand to change the shape of innovation because these can make visible large scale patterns that can bound the design process and align technological interventions more closely to these patterns. He wrote:

> Universe is, inferentially, the biggest system. By Starting with Universe, we automatically avoid leaving out any strategically critical variables. In the Universe, everything is always in motion and everything is always moving in the directions of least resistance. When we are dealing always in terms of a finite Universe or totality of behavior, we are able to work from the generalized whole to the particular or special-case manifestation of the generalized accounting. This is the basis of the grand philosophic accounting of quantum mechanics. (Fuller, 1975, p. 82)

He imagined Design Science as a part of the specifications for an activity that would be conducted inside a geodesic dome to be built for Expo 67 World's Fair in Montreal. Budgetary considerations eliminated the activity Fuller dubbed "World Game" that would instantiate a group process for public audiences meant to sharpen individual perception so as to take whole systems behavior into account. Undaunted, Fuller established the World Resource Institute at his home school, the University of Illinois Carbondale, and began syndicating the process around the world – traveling to over five hundred colleges and universities to conduct instances of the game (Gabel, 1987, p. 21). A play on the strategic war-gaming of the era conducted at think tanks like the Rand Corporation, Fuller's was a peace game that enrolled participants in a procedure for solving global resource problems.

Fuller believed Design Science might enable design teams to reflect critically on the path toward production and provide a mediating mechanism between data inputs and the values of the participants. Thus he lays out a process that begins by having the design team establish and quantify the resources needed to produce a "preferred state".

The Design Science planning process enables participants to develop:

- A set of perceptual tools for complex problem solving.
- A shared language for communicating a systems-based approach to solving problems.
- A deeper understanding of local issues and the connections between those issues.
- New strategies for deploying untapped resources. (Brown, Cook & Gabel, 1975)

Fuller's plan for a 'World Resources Inventory' exemplifies how such a data store forms the backbone of a new Design Science based on aggregates. According to Brown, Cook and Gabel (1975, p. 50), Fuller developed a capacity for thinking about the contribution of aggregate data to forecasting through a number of formative experiences:

> In 1936, Phelps-Dodge asked him to make a comprehensive study of the world's resources and trendings, in particular relating the role of copper to the rest of the world's resources. In 1938, Fuller served as consultant to *Fortune* magazine, producing a special 1940 anniversary issue which compared world resource reserves to United States resources. In the war years, 1942-44, Fuller was chief mechanical engineer for the Board of Economic Warfare and was involved in the Inter-agency Alternate World Resources Substitution Committee where he helped formulate a long-range economic plan for Brazil."

Fuller's World Resources Inventory enumerated the global data that would be needed to support comprehensive analysis of global problems, drawn from these forays and others. Grounding Design Science in the analysis of aggregates surfaces the conviction that analyzing phenomena at the systems level matters and can be more salient in the design than isolating component parts or near term conditions. The application of technology in the service of extended perception is integral to supporting the discovery of these systemic interactions.

3.1. Comprehensiveness as techno positivism

Critics of technological solutions and big data tend to label Fuller's efforts as techno positivist. The components of Fuller's vision do appear linear and heavily reliant on computer processed information: first data gathering, then data visualization for decision support, and last a choreographed social process that best facilitates "conscious" design. Fuller's designer is "preoccupied with anticipation of all men's needs by translation of the latest inventory of their potentials" (Fuller, 1963, p. 174). Design becomes the ultimate in technologically mediated resource management.

There has been significant attention to this critical view in both the history of science and the history of architecture as well as a growing literature on the history of cybernetics, and the interdisciplinary intersections of these (Dutta, 2013; Pickering, 2010; Wisnioski, 2012). Scholars of this trend look into structural reasons why big data and its use by futurists, artists, architects, designers and social scientists have gained steam. These scholars relate how the humanists and social scientists established disciplinary and institutional legitimacy and secured needed resources by prioritizing interdisciplinarity and harnessing scientific research and technological solutions in a characteristically uncritical manner. Fuller's work can be interpreted against the trend in "Total Design" as both an implosion and explosion of the purview of the designer and architect (Wigley, 1998). In the logic of Total Design, the innovator lays claim to all parts of an environment, drawing upon any and all data inputs and types of knowledge perceived as vital to aid the project, in effect, assuming total control.

3.2. Comprehensiveness as an imperative for sustainable innovation

On the other hand, sustainability scientists argue that a command of comprehensive data about social and environmental factors may speed the way to more ecologically sound innovation. Fuller posits that this focus on whole systems produces unique insights that leap over traditional methods of forecasting, defining synergy as "the behavior of a whole system unpredicted by the behavior of its components or any sub assembly of its components" (Fuller, 1975, p. 3). Principles in biomimicry, design aligned with systemic patterns found in nature, are instantiations of this tradition.

The discovery of the Buckminsterfullerene in materials engineering is a striking example of how Fuller's view of whole systems has anticipated both a set of structures identified in nature and also sparked a novel scientific methodology. In 1985, while condensing carbon vapor, chemists R. E. Smalley, R. F. Curl, J. R. Heath, and S. O'Brien at Rice University, and H. W. Kroto of the University of Sussex in England witnessed the spontaneous generation of hollow truncated icosahedron, similar in shape to soccer balls with structures like Fuller's architectural geodesic domes that became a sensation in the 1960s and 1970s. These molecules, composed of 60 carbon atoms, were the size of about one billionth of a meter (Frost, 2004). Subsequent experimentation with C_{60} pioneered a new method in nanomanufacturing known as "self-assembly", where engineers specify geometries that guide the subsequent spontaneous formation of molecular structures that conform to the determined shape. In this way, nanoscale molecules, called fullerenes, or buckyballs, represent 'building blocks' of a comprehensive enterprise of 'self-assembly at all scales' (Brown, 2008, p. 10). Creative director and urbanist, Bruce Mau, extends this interpretation by asserting that designers should make "designing things" (Brown, 2008; Mau and Institute Without Boundaries, 2004), meaning that the design specification itself should evolve in different ways and independently shape the behavior and composition of its environment. Data aggregation and the directive to begin design with whole systems rather than component parts, or what Fuller terms "Starting with Universe", are key markers of how a holistic approach has informed scientific inquiry and how the principles of construction at the systems level in anticipation of unique aggregate effects could function in the service of sustainable innovation.

4. Discussion

While Fuller's physical constructions make *material* his preference for technocracy that lead some scholars to date or dismiss the work, our workshop's enactment of the *procedural* Fuller reveals that Design Science is a systematic cultivation of methods by which the designer can change her perspective to move beyond immediate term variables. Like Harold Garfinkel's breaching experiments in ethnomethodology (Garfinkel, 1967, 2002) and interactionist Erving Goffman's idea of "breaking frame" (Goffman, 1974), Fuller was determined to change the perspective of those who participated not with the material, but instead through processes and methodologies. He wanted to move the minds of innovators beyond the perception that systemic interaction is somehow beyond apprehension (Fuller, 1963) to give experts, and as his scuttled plans for introducing "World Game" to audiences at Expo 67 suggest, the broader public, command over a vision that could change the way design is performed.

Unlike many of the other *Emerge* workshops, *Starting with Universe* asked group members to open up space for personal and collective reflection about their own assumptions and information gaps when they begin a creative or engineering work. Based on Fuller's original process, workshop activities employed methods that relied upon the aggregation and visualization of scientific and technical data, logical and evidence based argumentation, as well as the affective associations, social and political contexts elucidated through facilitated conversation. Several participants remarked at the conclusion of the session that they rarely take the time to question their frames of reference with a comprehensive lens in the ways that this workshop facilitated. Scientific and technical data informing esthetic and contemplative experiences in the immersive environment were complemented by the dialogic energy that informed a shared frame of reference with which to begin the design process.

5. Conclusion

The word comprehensive has three important connotations "comprising or including much; of large content or scope", "inclusive *of*; embracing", and "containing much in small compass, compendious" (Oxford English Dictionary, n.d.). These meanings correspond well to the delineations I have made here to characterize the ways in which Fuller's interpretation of comprehensiveness as a driver for design has made its mark on today's decision rubric in many areas of innovation. Fuller's use of the concept has influenced science, engineering, planning and design practices to place the focus on the quantification of wholes.

By resurrecting and enacting Design Science in 2012, workshop organizers investigated the utility of the Design Science process, among the least well studied aspects of Fuller's vision. In the collection of autobiographical essays *Ideas and Integrities*, Fuller (1963) sought to overcome a problem with design assumptions epitomized by the saying "a chain is only as strong as its weakest link" by embedding a process in the training of architects and designers that would make systemic interactions less mysterious and procedures for interrogating wholes more precise. One could argue now that processes entangled with globalization and economic development have absorbed these lessons. The supporting epistemologies and tools for systemic analysis that make up the comprehensive stance in turn shape and redefine the processes for economic growth and governance in ways that now heavily influence decision making in important sectors of energy, resource, and climate change (Miller, 2004, 2005). Others have argued for the creation of institutions and networks of national and transnational governance to work at comprehensive scales (Godin, 2009). For the participants at the *Emerge* workshop, Fuller's Design Science provided the motivation to guide our future-oriented inquiry into the analytic culture of "whole systems thinking".

While Fuller is, as critics have pointed out, technocratic and positivist in his affirmations of the utility of technology in orienting society toward efficient solutions, he contributes in surprising ways to our collective understanding of systemic interactions that bind up the world. Evaluated alone, the artifacts Fuller leaves us are monuments to technocracy that lead some to discount the work, but a look at the processes he prescribed reveals that there crucial gaps that remain unrealized in today's design and futures practice even as technological capabilities for resource quantification have surpassed that of the visionary.

Despite a contemporary trend in "green" production and consumption that is unfolding today, the kinds of monumental shifts Fuller believed could be driven by comprehensive anticipatory innovation have not materialized (Luke, 2010, p. 360). Though a number of science, engineering and industrial design programs convene interdisciplinary product design teams as a means to achieve socially appropriate and environmentally sustainable products, few undertake the design of whole systems to the extent that Fuller envisioned. A key reason may be that today's technologically advanced design and foresight practices largely omit a full realization of the kind of self-reflexive design process that is necessary to achieve a truly comprehensive view. The Integrated Innovation paradigm in industrial design is a promising exception, wherein interdisciplinary teams seek to create marketable products sensitive to social needs and to ameliorate negative impacts on the environment (Selin & Boradkar, 2010). It was this democratic self-reflexivity that the *Emerge* workshop sought to enact.

The *Emerge* workshop featured the conceptual phases of Design Science. Practitioners interested in deriving practical lessons from concrete projects aligned with a holistic conceit should consult project descriptions listed among the winners of an annual design challenge hosted by the Buckminster Fuller Institute. Launched in 2007, the Buckminster Fuller Challenge recognizes design projects that take a whole systems approach to intervene in complex and interrelated crises for wide-scale social and environmental impact.[4] Each year the Institute awards a $100,000 cash prize to support the ongoing development and implementation of a design solution that embodies a comprehensive anticipatory approach. Recent winners have included the project called *Living Breakwaters* that "combines coastal resiliency infrastructure with habitat enhancement techniques and community engagement, deploying a layered strategy that links in-water protective forms to on-shore interventions".[5] The scope and details of the winning projects underscore that Fuller's legacy challenges contemporary futurists and designers to put theories about the benefits of reflexivity into practice while navigating the contradictions that this position engenders.

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[4] See https://bfi.org/challenge.
[5] See https://bfi.org/ideaindex/projects/2014/living-breakwaters.

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