# SPHERES, DOMES, LIMITS, INTERFACES: The Transgressive Architecture of Biosphere 2

MEREDITH MILLER
University of Michigan

> If wilderness can stop being (just) out there and start being (also) in here, if it can start being as humane as it is natural, then perhaps we can get on with the unending task of struggling to live rightly in the world—not just in the garden, not just in the wilderness, but in the home that encompasses both.
> - William Cronon, "The Trouble with Wilderness"

Architecture's shifting alliances with technology and nature have sponsored a number of sub-disciplines. From Wright's Broadacre to Banham's "mechanical invasion," the thickening field of polemics has produced new crossbreeds of disciplinary terms. Landscape urbanism, "synthetic landscapes," manipulated environments, "corrupted biotopes," subnatures: each position accepts that the natural world is not "out there" but "in here." And not only is "it" in "here," within the domain of architecture's concerns, but given the more recent mandates on design's agency in a global ecological crisis, architecture is also out there. Central to these hybrid discourses, which share the rhetoric of blending, exchanging, growing, and emerging, is the question of limits.

Where do you locate the threshold between architecture as a set of built intentions and the ecological complex in which these intentions take form? What are the limits of design's capacity to access and inflect the networks that comprise this complex (or how far can this capacity reach before we lose track of its outcomes)? Do these pragmatic limits circumscribe firm disciplinary boundaries, and are these boundaries in need of defense or liberation?
In order to investigate such contested edges, this paper recuperates aspects of the ultimate ecological container, the Biosphere 2. An ambitious experimental project that ruffled the scientific community and engrossed the American public during the 1990s, the Biosphere 2 attempted the idealized union of nature and technology. The formative ideas on air and environment that extended from the decades leading up to its construction are mapped onto its architecture, as both a literal materialization and a symbolic form of environ-mental intervention. Constructed over six years in the Sonoran Desert in southern Arizona, the Biosphere 2 structure houses approximately 12,000 square meters of interior space, and 180,000 cubic meters of enclosed volume;[1] this megastructure established an expansive interiority within a remote location (at least the time of its completion in 1991), about 30 miles from the urban extents of Tucson. Contained within a vast space-frame envelope, a mini-wilderness would theoretically sustain eight human lives through a controlled balance of organic processes (and some mechanical assistance). Designed to seal off any material inputs, from water and air to food and other external aids, the glass-and-metal shell became the site of complex negotiations (Figure 1).

The ideal model of a "materially closed" but "energetically open" system[2] not only shaped the research agenda but also tested the limits of construction; the theoretical model could not be realized given the material tolerances of the physical assembly—an infrastructural deficit that required a constant revision of the terms through which the project defined its purpose. As the eventual transgressions of the seal will make evident later in this account, these events and their unexpected agents in turn recast the structure not as the fixed boundary of the world within, as intended, but as an ecological interface where social, informational, and atmospheric exchanges implicated larger territories.

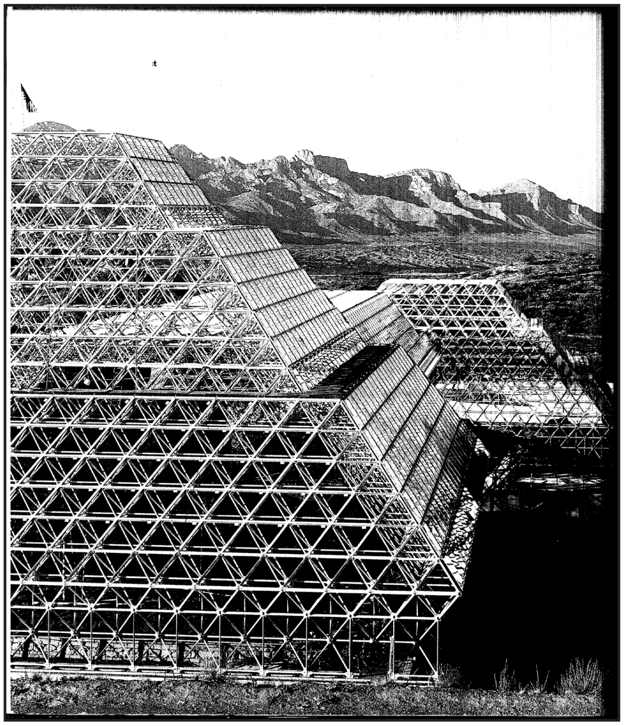

Figure 1: Biosphere 2, Oracle, AZ, 1991.

Focusing on the design of the Biosphere 2 structure and the fraught implementation of two experimental periods of closure (1991-1992; 1994), what follows is a fable of misaligned intentions[3]. The project's extraordinary efforts in recreating a *known nature* and controlling its processes points to an incredible faith in (so-called) nature's benevolence, a faith that obscures the other ways in which this nature-culture union might be allowed to materialize. Beyond the historical insights into previous environmental paradigms, I am interested the possible lessons for architecture in the context of this contemporary conundrum of expanded practices. Removing the totalizing ambitions and scientific imperatives of the Biosphere 2 enterprise, we can uncover an infrastructural architecture that provides a case study in cultivating *unknown natures*.

**-SPHERES**

The origins of Biosphere 2 can be located at a confluence of different forms of ecological awareness that emerged in the 20th century and produced a perceptual shift from the individual or subjective means of accessing experience to a connected and contingent notion of population and environment.

In the book *Terror from the Air,* Peter Sloterdijk states that the defining characteristic of modernity is the emergence of an atmos-pheric consciousness.[4] In his account, the dawn of the 20th century can be pinpointed to a precise time and place: April 22, 1915 at Ypres, in Northern France, during the first World War. On this day, a German regiment discharged several tons of chlorine gas to disable French troops. For Sloterdijk, this moment represents a fundamental shift in military strategy from targeting the body of the enemy to targeting the environment on which the enemy depends for survival.[5]

> "With the phenomenon of gas warfare, the fact of the living organism's immersion in a breathable milieu arrives at the level of formal representation, bringing the climatic and atmospheric conditions pertaining to human life to a new level of explication."[6]

Modernism brought about the ability to recognize this background of that which sustains us but which we take for granted. The new atmospheric consciousness signifies a type of knowledge that was not intellectualized but, rather, *embodied*; whether by military attack or the ambient threat of air pollution, the atmosphere becomes vitally evident through the subject's anxiety of its potential disappearance.

As an extension of this logic, the gas attacks also indicate that the explicated atmosphere is a medium for control; shapeless, transparent, dyanamic, air is still a material can be transformed through design. "Air-design is the technological response to the phenomenological insight that human being-in-the-world is always and without exception present as a modification of 'being-in-the-air.'"[7]

The vulnerability of our own atmospheric life-support exposed the vital linkages between the immediate realm of human experience—the air in which we breathe—and larger scales of ecological processes—the air of the global commons. New insights on the dispersed effects of urbanization led to new demands on the built environment (a familiar illustration is how Rachel Carson's *Silent Spring* shaped later planning ordinances); but rather than a circumstantial retrofit of a given reality, this "technological response" could also derive wholly new architectures. These overlapping spheres of existence ("in-the-air" and "in-the-world") form a context of contingent factors. The spatial products of the new atmospheric consciousness could act as mediating elements within this context where the Biosphere 2 positioned instead the apparatus of atmospheric control.

## DOMES

If atmospheric control became a measure against the threat of atmospheric change, a parallel perceptual shift led to an evaluation of material practices. After the "Christmas mission" of Apollo 8 in 1968, when photographs of the earth taken from lunar orbit were broadcast, the astonished global public saw, for the first time, a complete and self-contained planet. These images offered an understanding of the planet as a closed system, a vast interior where a fixed amount of living and non-living systems were held in a delicate balance.[8]

An influential prophet of this new sensibility, Buckminster Fuller developed a body of theories that shaped this systematic under-standing of the earth's finite resources, such as the "whole systems" design approach, the World Game, and "synergetics" (Figure 2). Fuller's supposedly anti-aesthetic design approach appealed to the "whole earth" generation, and his geodesic principles can be visually tracked through a particular strand of cultural activity, particularly in the south-western United States.

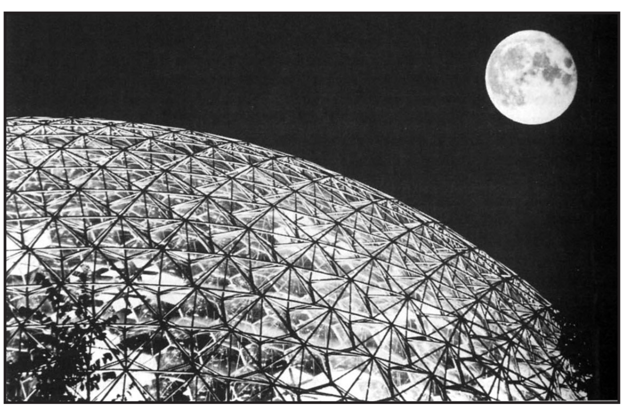

Figure 2: Geodesic Dome, Buckminster Fuller; EXPO '67, Montreal

Figure 3: Drop City, near Trinidad, Colorodo. Founded May 3, 1965

"Drop-out" culture and the discursive echoes of their polemic in architecture post-1960s is one crucial narrative of Felicity Scott's *Architecture or Techno-Utopia: Politics after Modernism*. Scott identifies these dispersed communities, such as "Drop-City" as forming a space of collective identification and cultural production (Figure 3). This mindset was encapsulated and spread through publications like the *Whole Earth Catalog*, first produced in 1968 and Steve Baer's *Dome Cookbook*, also of the same year. Dome-building, which began as a form of political refusal or an assertion of autonomy from complicit lifestyles, eventually arrived at pure signification.[9]

Not only does the Biosphere 2 deploy the external signs of geodesic efficiency that identify it with these counter-cultural movements, but the same cultural currents were at the very foundations of the project. Swept up in the "whole earth" momentum, the key founders of the Biosphere 2 participated in this "hippie exodus" and established a self-sufficient community called "Synergia Ranch" in New Mexico. Here the foundational ideas for the Biosphere were formulated, alongside the ranches collective experimentation in agriculture, explosives, and improvisational acting—placing the Biosphere in a decidedly social and political, rather than a strictly scientific, milieu. A few Synergia residents, including a metallurgist, an engineer and a Harvard Business graduate named John Polk Allen, founded an environmental think tank called the *Institute of Ecotechnics*.[10] A play on Lewis Mumford's biotechnics, ecotechnics involved the investigation of "the ecology of technics and the technics of ecology."[11] This ambition was symptomatic of an era shaped by the dual products of the burgeoning space age: an emerging ecological consciousness on the one hand and a technological confidence on the other.

The particular means of realization for this ambition, however, maintained the ethics of the commune and played to the perception of an ambient and impending environmental failure. Rejecting strategies of integration, the bio-dome established autonomy from collective infrastructures, support networks, urban systems or larger territories of ecological engagement.

The point here is that this ecological world-view provided more than an interpretive lens; building on insights from new sciences, especially biology, it engendered strategies of projection, which take form in very concrete architectural ways. However, the problem lies in how this world-view gets applied – just as the dome became a mere visual expression for a certain cultural register, analogous practices today rely on aesthetic associations with biology, ecosystems, genetics, etc. This is the *Architecture that looks like*. On the other hand, we get into more messy territory of *Architecture that behaves like*. With critical implications for how architects engage the world through design, these two modes of practice are increasingly difficult to disentangle, but especially when emulating processes that reach beyond architecture's disciplinary techniques. The Biosphere 2's objective to build an inhabitable scale model of the earth seems an absurd endeavor; but the Biosphere 2 not only developed out of the same late 20th century hotbed as practices from our own discipline (architecture collectives like Ant Farm clearly share the same DNA), but it could also be seen as a more earnest cousin to the techno-climatic productions of Diller+Scofidio's *Blur*, Philippe Rahm's convective interiors or RnSie's *Green Gorgon*. These are infrastructural in approach rather than totalizing simulations; they *provoke* atmospheres, each leveraging site and a technical reach beyond typical practices to enact a contemporary and contingent notion of environment. Still, the limits are blurry…

## INTERSECTION = BIOSPHERICS

At the margins of art and biology, a new field called "biospherics" formed as the study of closed ecological systems to project new models of inhabiting the earth. In the same year as the Apollo 8 mission, a University of Hawaii biologist, Clair Folsome, scooped up a flask full of Pacific ocean water and sealed it. Without any interaction or exposure to the exterior air, the microscopic world of sea life inside survived many cycles of photosynthetic and metabolic exchanges; biospherics[12] was born. Playing to modernism's alignments of spatial organization and social programming, the project designers' enthusiasm for biospherics invested the architecture of the Biosphere 2 with an unprecedented set of building criteria. The Biosphere 2 housed seven reconstructed biomes: desert, rainforest, savannah, marsh, ocean, farmland, and city, forming the "building blocks" of a closed food and oxygen machine.[13] The translation from Folsome's desktop micro-world to the three-acre enclosure represents the considerable scalar leap, pointing to a shared certainty in the science and its future applications.[14]

## MECHANICS OF CLOSURE

The primary objective of this enormous investment[15] was to construct a "materially closed" but "energetically open" complex that would emulate the Earth (Biosphere 1). The architectural envelope was detailed to be as airtight as possible, minimizing atmospheric exchange between interior and exterior; but the structural enclosure also had to be simultaneously as transparent as possible, maximizing the entrance of light to support the vegetation within (artificial lighting had been considered but rejected). Both performative requirements put opposing pressures on the design of the envelope (how it should behave); both the excessive escape of air or the failing rates of photosynthesis could throw off the chemical balance of oxygen and carbon dioxide, threatening the survival of the researchers inside. Essentially, the constructed boundary materialized the odd conflation of the objective data of the experiment with the humans' experience of the air quality. In this sense, the atmosphere is both information and material, and the respiration of the human test-subjects inside could, in a sense, serve as a form of embodied knowledge in dialogue with the architectural envelope.

The space-frame (structural skin) was developed and fabricated by Pearce Structural Engineers, led by Peter Pearce who in the late 1960s had worked with Buckminster Fuller on his book *Synergetics* (a fact promoted by the Biosphere 2 literature[16]). The powder-coated whiteness of the metal components projected an image of lab-like objectivity, certainly encouraging the associations with geodesics (what it should look like). Each frame component was pre-assembled in a factory, with careful attention to the glazing detail: to ensure that each connection received two layers of silicon sealant, grey-colored sealant was applied first on site to distinguish from the white of the second coat.[17] This verification system for double caulking is perhaps an expected solution springing from quality-assurance protocols, but charged with the extreme criteria of stabilizing an unseen but vital substance, the assembly not only performs to these criteria; it must represent its performativity (Figure 4).

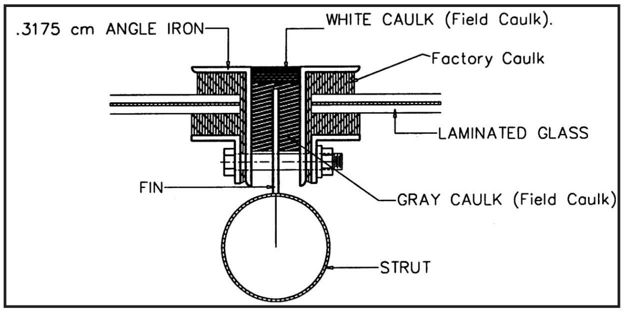


Figure 4: Section detail at typical mullion

## RHETORIC OF TOLERANCE

However, no matter how precisely machined the structural skin could be and how well maintained by the resident team of contractors who were perpetually on call to patch leaks, certain construction limitations made a 100% airtight skin physically unattainable. The considerable temperature shifts of the desert climate could cause significant movement in the assembly, a design problem that would typically be accommodated through a strategy of tolerances. But in this project where gaps and breaks were, precisely, the only construction techniques that were strictly out of the question, other strategies had to be innovated. To absorb the inevitable fluctuations in the volume of total air, two independent structures called "variable volume chambers",[18] were linked to the main structure. Acting as the lungs of the complex, these "inhaled" as higher temperatures expanded the volume of air and "exhaled" air back into the biomes by applying pressure through a flexible, mechanical membrane.

In the end, only two experimental periods of full closure with human inhabitants put this techno-biotic apparatus to the test, with both trials plagued by sudden drops in oxygen levels. Mission 1 completed the 2-year period, only after an emergency supply of oxygen was clandestinely pumped in. Mission 2 was terminated after 6 months. Reports published afterward excuse the unpredicted fluctuations of the atmospheric conditions by appealing to the limits of construction. In a 1999 report, the mechanical engineer argues for ratios over absolute numbers: "If the rate of leakage is small compared to the rates of gas exchange involved in the ecological processes, then the closed system will be a powerful instrument to study those processes."[19]

Tolerance as an architectural strategy becomes absorbed into the rhetoric of the experiment. In the same year, John Allen begins to define the Biosphere 2 as a "*relatively materially closed*" system.[20] Imperfection and contingency are introduced into the modernist belief in environmental technology. For this author, it's precisely these moments of vulner-

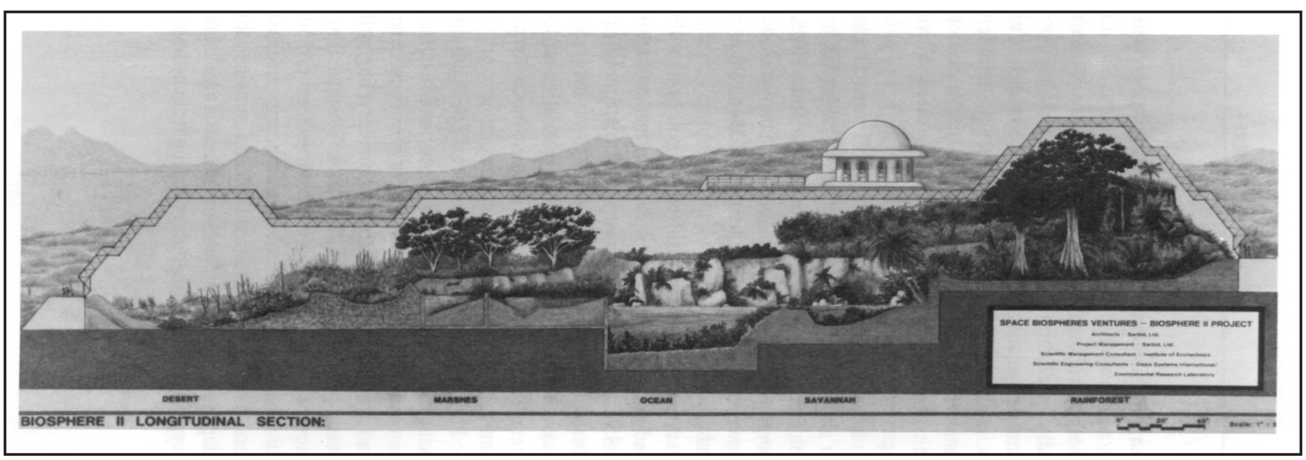


Figure 5: Schematic Section through biomes

ability that reveal traces of modernism's pragmatist technocracy and open up space for architecture to shift out of programs of conditioning to strategies of connecting, from ecological containers to environmental interfaces.

## SYNTHETIC LANDSCAPES

The Biosphere 2's lungs were relegated to the periphery of the site, just as the air handlers, water pumps, waste treatment, grow lamps, and mainframe occupied a basement level. Omitted from the building section, which depicts only the wilderness inside a stepped dome (Figure 5), this sub-grade zone was known as the "technosphere." Clearly, the translation between ecotechnics as a techno-utopian ideal and its materialization as a building required numerous design decisions along the way that adjusted the initial diagram. First, fabricating the right conditions for a 100% homeostasis meant "nature" could not be trusted on its own – the technosphere was essential as mechanics and surveillance of the experiment. But, secondly, rather than integrate the machinery into the garden, the image broadcast to a global audience was a design consideration; "the power of the technosphere was harnessed for the creation of natural splendor"[21] (Figure 6). While Fuller's protégé contributed the space-frame enclosure, the job of building out the wilderness biomes was awarded to a construction company that had built naturalistic sets for a Tokyo aquarium and Universal Film Studios. With foam rocks, mist nozzles, hidden access panels and imported coral reefs, the simulated nature assumed its form at a distance from the technological infrastructure.

Here, the connections to ongoing discussions in cross-disciplinary modes of architectural practice become vital. In an essay from 2003, Stan Allen and James Corner provide a useful basis for designing within and for the overlapping territories of urban and ecological processes.

> "The nature/culture and artificial/natural distinctions are no longer interesting. To say "all nature is constructed has no critical force; it is simply a given, a starting point for a more complex synthesis. Synthetic landscapes make use of the logics of natural systems and the dynamics of ecological feedback without the romantic attachment to a pastoral idea of nature." [22]

The Biosphere 2 can be understood as an accidental precursor to synthetic landscapes, although rather than finding ways to incorporate "feedback" with systems external to the dome, the experiment maintained that the ideal state is one of hermetic constancy, governed by a natural order. Referring to the projected lifespan of the structure, which was designed to last 100 years, John Allen writes "The key question then seemed not how long nature inside the Biosphere 2 would last—if it were truly self-sustaining it could go on indefinitely—but rather how long the materials out of which the Biosphere was constructed would last."[23]

Figure 6: Technosphere exposed during the construction of the rainforest biome.

In practice, however, the "unanticipated behaviors of the biotic life within the system" threatened this clean separation of an independent container and the self-organized ecosystem it contained. Rapid-growth vines flourished in the carbon dioxide rich environment; these spread close to the glass skin, choking out sunlight from other rainforest plant life. By the end of Mission 1, "an Arizona greenhouse ant whose common name is the 'crazy ant' (*Paratrechina longicornis*) flourished and proved to be prob-

Figure 7: Promotional image of the Mission 1 crew

lematic in maintaining a tightly sealed structure." These ants chewed through the white and the grey caulking, causing multiple leaks in the structure.[24]

**ACTORS AND NETWORKS**

If the non-human agents like the crazy ants challenged the projected distinction between the fixed architecture of the container and the organic processes of the contents, the human actors within this micro-society are also implicated in this network. As I described it before, the design of structure was saddled with materializing the union of nature and technology, but through its failures the physical infrastructures became conceptually detached from the more significant components of the experiment. Beyond the literal interaction with this crucial boundary by pruning weeds and caulking cracks, the researchers performed a similar dual role as the architecture: their vital systems were an integral part of the experiment's apparatus - just as their personas were the face of the experiment in the public media (Figure 7).

But what of the Biosphere's clearly defined limits when the system produces outputs: its human occupants? What becomes of the closed loop when its managers, armed with a new atmospheric consciousness, exit the sphere and look back on it with a critical distance?

The second mission replenished the ecosystem with a new crew of seven, and within a few months of closure *The New York Times* reported an early-morning incident on the Biosphere estate. Two original crewmembers stole into the grounds of the complex, forced open several airlock doors and—through a symbolic and literal attack on the hermetic boundary—broke the glass seal of the enclosure. The Times report described the charge: "The two, Abigail Alling and Mark Van Thillo, were arrested and charged with burglary, criminal trespass and criminal damage, felony counts." The comments in defense of their actions point to the crux of this plot twist. "Their lawyer, D. Jesse Smith of Tuscon, says...'*They made what they consider was a scientific judgment.*'"[25]

**CONCLUSION**

In both missions, hermetic closure was violated from the outside: first by pumping air in mechanically and second by the assault on the building envelope. In response to the criticism that the experimental set-up had been compromised and thus the science had been rendered invalid, William Dempster, the mechanical engineer, defended the work by claiming that Biosphere's biological systems were effectively isolated. "It's only a matter of degree," he said. "It's impossible to build anything that is perfect in this regard, and so there's always going to be some degree to which the perfection is not met."[26]

Here, as a way out of the dismal prospect of perfection as architectural endgame, I want to return to Sloterdijk's description of modernity through Bruno Latour's adaptation:

> "This is Sloterdijk's explicitness: You are on life support, it's fragile, it's technical, it's public, it's political, it could break down—it is breaking down—it's being fixed; you are not too confident of those who fix it. Our current condition merely relies on our more explicit understanding that this tentative technological system, this "life support," entails the whole planet—even its atmosphere."[27]

By situating humanity *within* "nature" Latour removes the distinctions of a scientifically defined world versus an experiential realm, doing away with the 19th-century separation of empirical knowledge and sensorial knowledge. But the urgency also suggests a bottom-up agency within this organization that leverages the anxiety into new techniques of creative production in service of the further activation of this sensorium.

Having survived the near crisis of disappearing oxygen in Mission 1, Alling and Von Thillo had *empirical and sensorial* proximity to the same dangers they perceived as threatening the second Mission's crew. Atmospheric explication compelled the two scientists to transgress the critical seal in order to transfer this embodied knowledge to those inside. Their attack was not violent rejection of the Biosphere as a utopian ideal; they were protesting the experiment as a black-box technology, a machine for atmospheric control. Moreover, this transgression cannot be separated from the networked ecology the Biosphere 2 had set into motion, even if not part of the original script.

> "Like the city, *these synthetic landscapes are active rather than passive; design has a transformative, activating agency*. Natural operations are used to produce artificial, ambient effects. Instead of nature as a scenic, benign force, we are proposing a new metabolism—the synthetic landscape as a bacterial machine. Here, innovative landscape—based urban practices draw from geography, politics, ecology, architecture, and engineering in working toward the *production of new urban natures*."

If we can accept (as the rogue bionauts did) that architecture is both form and per-formance, then the ability for architecture to participate in larger systems does not lie in hermetic, totalizing programs such as the Biosphere 2 (the single bubble, the introverted dome). Supplementing Allen and Corner's call for architecture to mobilize cross-disciplinary techniques, one lesson of the Biosphere 2 is that the limits of our architectural intentions inevitably become filters, interfaces, and sites for metabolic processing. Another may suggest that this type of architecture can be more than biotechnic hardware; as "synthetic" objects, they can simultaneously operate on cultural and sensorial registers.

Perhaps, then, the visionary reach of the Biosphere 2 relied on strategies of densification over dispersal. And if we understand this as an analogous challenge to the dispersed nature of the discipline: should architecture's disciplinary limits be clearly maintained so that the moments of transgression can be legible and productive? Specifying means over outcomes, can architecture put into play infrastructural relationships that accept the possibility for other agents and interactions to produce other (unknown) natures? The architectural outcome of this approach doesn't necessarily look like or act like. It simply gets started, leaving room for unanticipated spatial acts—whether a sudden change in air pressure, a creeping shadow of wayward vine, or a radical assertion of life.

## ENDNOTES

1 William F. Dempster, "Biosphere 2 Engineering Design," in *Biosphere 2: Research Past, Present and Future*, vol. 13 (Ecological Engineering:, 1999), 33.

2 John P. Allen, *Biosphere 2: the human experiment* (New York: Penguin Books, 1991), 27.

3 See Janette Kim and Erik Carver, "Crisis in Crisis: Biosphere 2's Contested Ecologies," Volume: 20 Storytelling (September 2009), for a wonderfully thorough account of the Biosphere 2 and a reading of the project as a frenzied deployment of resources, cultural and material, in response to newly perceived ecological crisis. Thanks to Janette, too, for sharing her cultural and material resources for the purposes of my research. I hope that by broadening the discussion to some theoretical underpinnings and approaching the bio-dome as a source for insights into current architectural practices, this paper offers a different narrative.

4 Peter Sloterdijk, *Terror from the air*, Semiotext(e) foreign agents series (Los Angeles : Cambridge, Mass.: Semiotext(e) ; Distributed by the MIT Press, 2009), 6. http://hdl.handle.net/2027/[u]:mdp.39015080821518.

5 Ibid., 10.

6 Ibid., 30.

7 Ibid., 35.

8 Christine, Macy and Sarah, Bonnemaison, "Closing the circle: the geodesic domes and a new ecological consciousness, 1967," in *Architecture and Nature: creating the American landscape* (London; New York: Routledge, 2003). Macy and Bonnemaison relate the historical significance of this moment to changes in architectural discourse, but Biosphere 2 founder John P. Allen also refers to this critical moment, citing an astronaut's account of beholding the earth from space "…national boundaries and human artifacts no longer seem real. Only the biosphere, whole and home of life." *Allen, Human Experiment*, 11.

9 Despite the technocratic origins and later developments in the use of geodesics. Felicity Scott, *Architecture or techno-utopia: politics after modernism* (Cambridge, Mass.: MIT Press, 2007), 155.

10 Alex Heard, "Lost in Space," *The New Republic* 204, no. 3 (January 21, 1991): 12.

11 John P. Allen, "Description, Purpose, and Conceptual Design," presented at the International Conference on Life Support and Biospherics, University of Alabama, Tuscalusa, AL 1002.

12 Allen, *Biosphere 2: the human experiment*, 13.
13 Allen, "Description, Purpose, and Conceptual Design."
14 Ibid. In this lecture, Allen states: "The purpose of the Biosphere 2 project is threefold: to elucidate the laws of biospherics; to create the corporate capacity to design, build, operate, and consult on the management of artificial biospheres; and to assist in the ecological improvement of the human impacts on Earth's biosphere."
15 An important point to add here is that the project was a private venture, banked on its commercial application for space industry and other environmental technologies, an irony that parallels the military adoption of Fuller's structural research. With an estimated cost between $40 and $100 million, mostly fronted by a Texas billionaire and oil-man, this scale model of the earth was seen as prototype for future versions with social benefits as well as economic returns.
16 Allen, *Biosphere 2: the human experiment*, 62.
17 Bernd Zabel et al., "Construction and engineering of a created environment: Overview of the Biosphere 2 closed system," in *Biosphere 2: Research Past, Present and Future*, vol. 13 (Ecological Engineering, 1999), 43-63.
18 Ibid., 52.
19 Dempster, "Biosphere 2 engineering design."
20 John P. Allen and Mark Nelson, "Overview and Design: Biospherics and Biosphere 2, mission one (1991-1993)," in *Biosphere 2: Research Past, Present and Future*, vol. 13 (Ecological Engineering, 1999), 15.
21 Allen, *Biosphere 2: the human experiment*, 61.
22 Stan Allen and James Corner, "Urban Natures," The State of Architecture at the Beginning of the 21st Century (New. York: The Monacelli Press, 2003), 17.
23 Allen, *Biosphere 2: the human experiment*, 63.
24 Zabel et al., "Construction and engineering of a created environment: Overview of the Biosphere 2 closed system," 51-53.
25 Drummond Ayres, "Ecological Experiment Becomes Battleground," *New York Times*, April 11, 1994.
26 "Air Is Pumped Into Biosphere 2," *New York Times*, December 20, 1991.
27 Bruno Latour, "Air," in *Sensorium: Embodied Experience, Technology, and Contemporary Art*, 1st ed. (The MIT Press, 2006), 106.

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Figure 1:Michael J Crosbie, "Desert Shield: Biosphere II, Oracle, Arizona: Sarbid Corporation, architect," *Architecture: the AIA Journal* 80, no. 5 (May 1991) 77.
Figure 2: Macy and Bonnemaison, "Closing the circle: the geodesic domes and a new ecological consciousness, 1967."
Figure 3: Felicity Scott, *Architecture or techno-utopia: politics after modernism* (Cambridge, Mass.: MIT Press, 2007), 155.
Figure 4: Bernd Zabel et al., "Construction and engineering of a created environment: Overview of the Biosphere 2 closed system," in *Biosphere 2: Research Past, Present and Future*, vol. 13 (Ecological Engineering, 1999), 51.
Figure 5: John Polk Allen and Mark Nelson, *Space biospheres* (Orbit Book Co., 1987) 57.
Figure 6: Allen, *Biosphere 2: the human experiment, 95*.
Figure 7: Allen, *Biosphere 2: the human experiment, 166*.