Artificial Ecologies - Dynamic Models, Interactive Installations and Sustainable Design

PETER HASDELL
University of Manitoba

Outline

'Artificial Ecologies, Dynamic Models, Interactive Installations and Sustainable Design' has at its core a straightforward intent: to be able to explore notions of ecosystem through the construction and exploration of dynamic models. Coupled to this, my research and teaching has identified a need for alternative approaches to teaching sustainability[1] that can complement the existing modes. One approach is outlined here. Developed as a way to enhance critical thinking, play and invention, it expands on an idea developed and tested through studio teaching over a number of years. The approach, using the borrowed term Artificial Ecologies[2], develops studio-based projects using dynamic and interactive models, and draws from a diversity of sources including the Lucretius and Leonardo Da Vinci[3] and is situated conceptually "as a pocket of compromise"[4] in relation to the field of non-linear science. I argue for the use of the dynamic model not as an application of building technology but as a field of play, a pedagogical tool providing tacit hands-on experience and knowledge that can develop a culture of innovation in design education. In other words, a way of thinking and making that is more akin to the processes inherent within the concepts of an ecosystem and within sustainable design itself.

Sustainability recontextualizes architecture within a complex mesh of new relationships. This presently involves consideration of many aspects once understood to be outside the remit of conventional design: issues of embodied energy, carbon credits, energy consumption, energy cycles, performance criteria, quantification of thermal efficiency, ecological footprints, material toxicity and environmental impacts. These factors are significant and directly effect decisions across the spectrum of design. However, they result in an ever-increasing amount of technical knowledge, performance criteria and evaluation procedures for a large range of building components and systems that need to integrate into the design process. Whilst this leads to some significant architecture and projects of note, the effect of the additional requirements is not necessarily an encouragement to innovation and invention within the processes of design.

Figure 1. Singing Lemons Instrument: Light sensitive organic electronic music machine: Barbara Hurler, Manuel Kettel, Julian Krueger.

This directly impacts architecture education and the teaching of design. Existing approaches to teaching sustainability tend to be principle based or rule driven applications, usually taught as an offshoot of technical courses. As a result, the overlaying of sustainable technologies onto pre-existent design studio cultures and pedagogies is a somewhat technocratic solution, or at worst an accounting process. A top down approach that is necessarily analytic in its codification of parts that can be broken down, calculated, accounted and assembled, but which has shortcomings in terms of the open nature of design education. In order to comprehend Architecture not as a static entity but as a enmeshed within a set of dynamic relationships requires us to understand the built environment as a series of complex material and energy flows, lifecycles, external forces and climatic aspects. We need to understand of the dynamic relationships of material things (architecture) to inputs (energy, materials), outputs (waste) and their relationships to a larger idea of ecosystem. Moreover, we need to know how to intervene in this system. These processes need to be integral in the culture of the design education.

Ecosystems and Non Linear Dynamics

The notion of Artificial Ecologies suggests an apparently false dichotomy. On one level, this presupposes an idealized pre-human natural ecosystem in which all relationships are in continual and perpetual balance, separate from any human intervention in the world. Drawing a distinction between nature and culture, between the natural environment and the synthetic environment. This distinction predicates much of ecological and sustainable theory and thinking today. Presenting an idealized, if unreachable, point of balance to be sustained or maintained in both the global context (Kyoto, Agenda 21) and in local environments, climates, zones, regions, cities and buildings. Although sustainable design is undeniably effective, its growth and development generating large changes to the practice of architecture and the built environment, it maintains an idealist position that is fundamentally analytic and top-down in operation. The distinction between artifice and nature, whilst not precisely false is a factor that inhibits our ability to synthesize the two realms. A better point of departure is to state that all notions of ecology in the built environment are synthetic, and are fundamentally augmented environments that are already constructed, impacted and altered. This allows us to work on understanding and synthesizing the dynamic and complex nature of the ecosystem from the start.

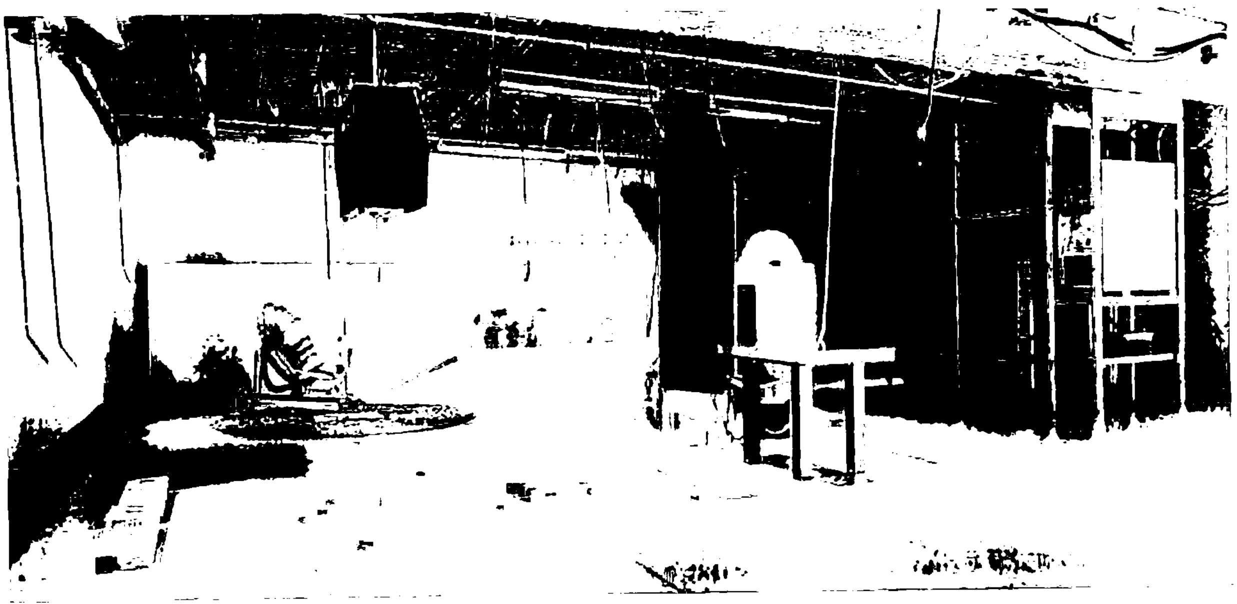

Figure 2. 'Interspace:' exhibition of A+URL work in the Kulturhus Stockholm: 2001.

To develop tools to connect existing ecosystems with the man made world as types of hybrid or artificial ecologies is a relevant issue today as increasingly more of the world is man made. Accelerated by the industrial revolution, population growth, and all environmental changes wrought, the natural world has transformed in a multiplicity of probably irreversible ways. For example, the sum of all earth-moving equipment used in making the built environment is now comparable or equivalent to natural forces of earthquakes, erosion and uplift.[5] Arguably, these changes have resulted in an environment in part natural and in part artificial, one that has altered to the point that the natural biotope no longer exists as an equilibrium or normative condition. As such, Artificial Ecologies may be what all models of ecology and sustainability in the built environment are tending towards; constructs that are biological in approach, dynamic in operation but at the same time mesh ecology with the man-made environment.

Arthur Iberall's[6] conceptual framework of homeokinetics assists the development of this idea. He proposes a model of society as a self-organizing ensemble of metabolic flows - of energy and material - and reservoirs of resources - knowledge, population, capacity and excess. Suggesting that we can understand the change over time in aspects of population, trade (convective flows), technological development and social strata, as a series of phase transitions related to the principles of thermodynamics. Society at any given point in time might be analogously gaseous, liquid, solid, or a mix of these in Iberall's schematic; for example fluid-like social formations of hunter-gatherers that eventually crystallize into stratified society or, undergo further phase changes. Manuel De Landa writes that: "...early societies may even have achieved a better consistency among their flows, a viscosity more in tune with their ecosystems than our own."[7] Whilst one might ague that the generality of Iberall's schema as outlined here is an over-simplification, it is useful inasmuch as it presents the structure of society as a complex set of transformations intrinsically related to change and defined by dynamics rather than static states. In essence, it highlights phase or state-change potentials over historical or evolutionary development that privilege step-by-step development. It emphasizes non-linear relations between entities, such that flows of a particular resource or aggregations of many smaller formations leads to certain types of societies developing and to specific chains of consequences or environmental impacts. We can find a related concept in the work of the biological systems theorist C H Waddington.[8] His concept of homeorhesis (similar flow) describes a system that returns to a trajectory after a disturbance, privileging the idea of continual flow, movement, exchange and change. Waddington employed this term in distinction to the term homeostasis that describes the equilibrium of a system that returns to a static condition or state. The power of Waddington's term lies in being able to understand and begin to describe a (biological) system whose constant and normal mode is change and flow itself. Meaning that the dynamic conditions of change necessarily become part of the way of thinking and working with such a system. We can draw from this in our understanding of ecosystems and sustainability.

An ecosystem is by definition a complex and dynamic structure. It is more than simply a dynamic system or a system defined by change alone, as it involves the interrelation and interdependence of a diversity of factors that manage to sustain or maintain its relations over time. Contingent on energy flow and food chains, it is also a metabolic system. Furthermore, it involves in a series of temporal relationships both the millions of constituent parts, and the overall structure of the ecosystem. Within the built environment, the seeds of an approach to ecosystem design are present in early ecological writing praxis and theory. Ian McHarg presciently and eloquently argued in *Design with Nature* over 30 years ago, that an understanding of ecology necessarily invokes a cycle of entropy and negentropy (order) in which energy is currency, circulating between inventories and reserves of matter, culture and gene pools.[9] The concept of energy flow as a necessary component of any evaluation of a sustainable environment is continued today in various ways whether through James Lovelock's Gaia concepts, the ecological footprint concepts of William Rees[10] or in Herbert Giradet and Richard Rogers'[11] concepts of a circular metabolism for cities (closed loop systems). The general argument made across the above-mentioned concepts is that any idea of sustainability requires a type of circular metabolism; using waste as food or energy, recycling material and products (a form of embodied energy), reconsidering lifecycles, reuse. Accordingly a sustainable ecosystem is one which has inbuilt mechanisms that self-regulate or manage its energy and material flows, its metabolic balances over time. The regulating mechanisms for such systems can be termed feedback loops. Feedback, for De Landa, is between:

> "...the two extremes of a complete fatalism, based on simple and linear causal relations, and a complete indeterminism... The most familiar examples of non-linear causality are 'feedback loops,' ... forms of circular causality [which] govern the dynamical behavior of a process."[12]

Feedback gives rise to what De Landa and others have termed 'emergent' or 'synergistic properties.' They are conditions that emerge because of the dynamic processes and complex interactions between entities and scales of operation in the ecosystem. For Iberall, these conditions give rise to critical points of change in the system that lead to large-scale changes of state or phase in a system. The presence of feedback mechanisms in an environment means that it operates as a circular metabolic system. Whereas the absence of these imply that a city for example operates on a linear consumption and waste cycle, it must be continually supplied with inputs of resources (energy, materials) to function and will produce waste as outputs. It is only in a metabolic, circular ecosystem that has inbuilt mechanisms of feedback and self-regulation that some notion of true sustainability can occur. Thus, for the built environment, being able to synthesize or design artificial ecologies would mean the designing in of feedback systems that can develop the self-regulation of the ecosystem as a whole. This requires the ability to understand the system as a whole and its impacts on its constituent parts and how the individual parts influence or affect the system itself. As De Landa, suggests:

> "...a top down analytical approach that begins with the whole and dissects it into its constituent parts (an ecosystem into species, a society into institutions), is bound to miss precisely those [synergistic] properties. In other words, analyzing a whole into parts and then attempting to model it by adding up the components will fail to capture any property that emerged from complex interactions."[13]

In effect, to understand an environment only as a cause and effect system (top down analysis) or as an indeterminate system (bottom up) does not permit the intervention of sustainable practice and is not in essence an ecosystem. This is key to the understanding of artificial ecologies and dynamic systems. It is only through working with both modes that an ecosystem could be synthesized. Further, De Landa writes of the need to create "new ways of modeling reality"[14] that combine both top down and bottom up approaches, combining analysis with synthesis. Not as closed and static models, but as open and dynamic models capable of producing emergent properties. To design with these therefore requires modes of working that sees ecologies not as principles and rule sets but as dynamic thinking, understanding the relationships between the artificial and the natural as metabolic processes involving parameters of non-linearity, feedback, flexibility, adaptability, and augmentation.

Figure 3. Glacier research: Staffan Engqvist, Milo Laven, Erik Tornkvist.

Tolerance: Play in the System

The pervasive aspect of computing has altered our mediation with the world. Likewise, the practice of architecture has transformed as the computer, plotter and CAD technician has superseded the scale-rule, the drawing table and draftsperson. Integration of the various formerly discrete processes has become more possible, and at the sophisticated level, the architect's representations increasingly become linked in the engineering, manufacturing and production realms. Similarly, design education is gearing itself up towards new modes of digital fabrication, mass customization, rapid prototyping and a whole manner of new tools and approaches that signal the integration of the digital and the manufacturing worlds. At the same time, there is an imperative to begin to critically rethink some of the design processes and modes of old. Schools are evolving to consider a wider definition of environment and the wider ramifications and impacts of design on the physical world: as resource management, consumption and waste, adaptability, material economies, reuse and recycling. Whilst these imperatives are enabling and useful developments, there is an opportunity to explore issues of responsive systems and ideas of ecosystems feedback through the emerging technologies of programmable media,[15] and interactive modeling. These technologies can effectively close the digital - physical loop.

In 2000, I established the postgraduate research laboratory and studio Architecture and Urban Research Laboratory.[16] The point of departure of A+URL was to understand architecture and the city as a dynamic system, and to research issues of the mediated city, urban scale metabolic systems and artificial ecologies. The yearlong program asked postgraduate participants in small groups to develop own research agendas within the framework established, around issues such as: Can there be symbiosis between artificial and natural systems? Can we imagine possible metabolic (non linear systems) that can work between natural and artificial environments? Inputs provided technology and design workshops and seminars that focused on emergent metabolic systems, spatial formations, and new organizational patterns. The program was structured in three related parts that utilized ideas of applied research as a mode of development, privileging process over product. This partially replaced the conventional studio structure of analysis, concept and synthesis, restructured as a hands-on laboratory. New modes of working were tested and developed through unconventional experimentation within this milieu. The core part of the work involved making physical and interactive electronic installations (with sensors) that link physical phenomena to virtual aspects, conceived as strange kinds of artificial ecologies, and tested in an exhibition. (fig. 2) These were later applied to design studio projects.

The first stage asked participants to investigate, model and derive hands-on principles and understanding from 'natural' ecosystems as a form of bio-mimesis. (figs. 3, 4, 5) Issues investigated included swarm behavior, phase transitions in ice, aurora

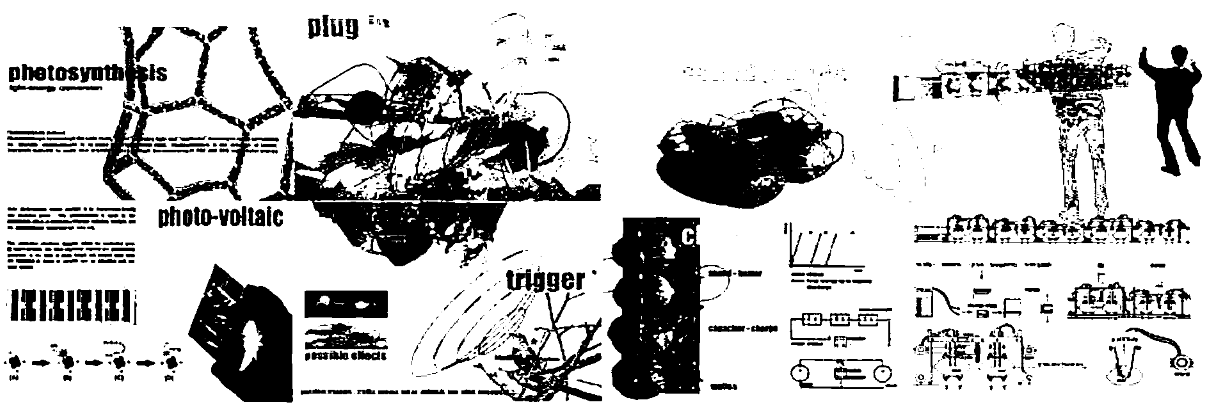

Figure 4. Singing Lemons and photosynthesis research: Barbara Hurler, Manuel Kettel, Julian Krueger.

borealis, static electricity, photosynthesis, glacier formation and bioluminescence. The intention of this stage was to enable participants to understand ecosystem as process, and to be able to extract, model and manipulate some of the aspects they uncovered in their research. One group investigating the northern lights made fog clouds and studied their dispersal in the environment. Another group interested in static electricity wired up a three level building to see what potential electricity they could get from this, later making a device to harvest static electricity from rainfall.

Secondly, the program asked participant to synthesize their principles into small-scale 'ecologies' or 'ecosystems', developing dynamic or interactive models, assemblages and systems that used feedback. Through a series of models or prototypes that evolved, made from fabricated parts, found objects, washing machines, plotter parts and fruit, the final dynamic models employed programmable technology of microprocessors,[17] coupled with sensors and servo motors as a means to generate inputs, outputs and feedback. Each dynamic model is therefore an elaborate and artificial environment that operates according to both internal and external inputs and the mediation of these. This embodies some aspects of ecosystems and the principles of ecology in its dynamic and cyclic system and uses the principles of transformation of energy as an integral part of the functioning of the model. This way of working allowed students to grasp some of the complexities of sustainability and ecological systems as hands on thinking.

Examples of projects include: The Fog Table (fig. 7) mimicked the Aurora Borealis' plasma clouds by moving a cloud of fog according to changes in a magnetic field. Such that the magnetic field of a cell phone or any electronic device had the effect of moving the fog cloud captured in a table. Singing Lemons (fig. 1) derived from the earlier investigation of photosynthesis, was a musical instrument that drew its energy from the galvanic potentials of

Figure 5. Glacier research and initial prototype testing: Staffan Engqvist, Milo Laven, Erik Tornkvist.

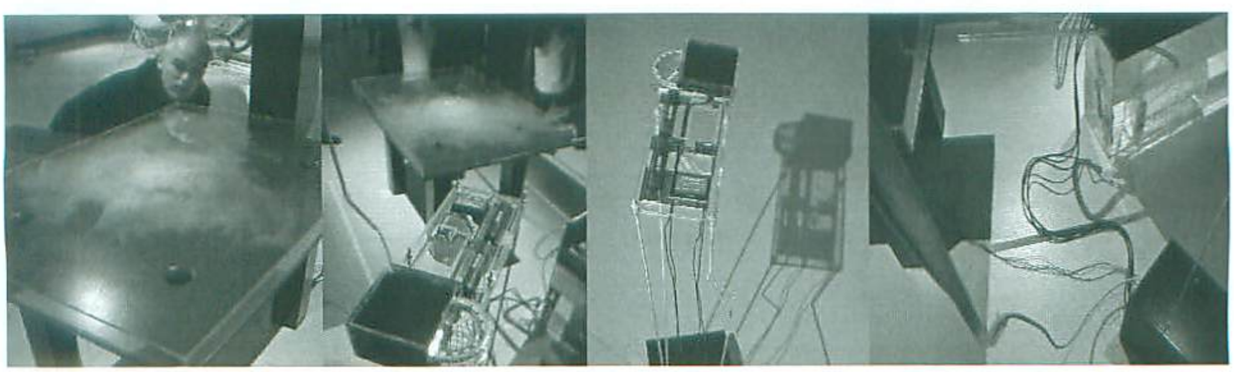

Figure 6 Fog Table: magnetic field sensitive fog table: Torbjörn Lundell, Magnus Schön, David Valldeby.

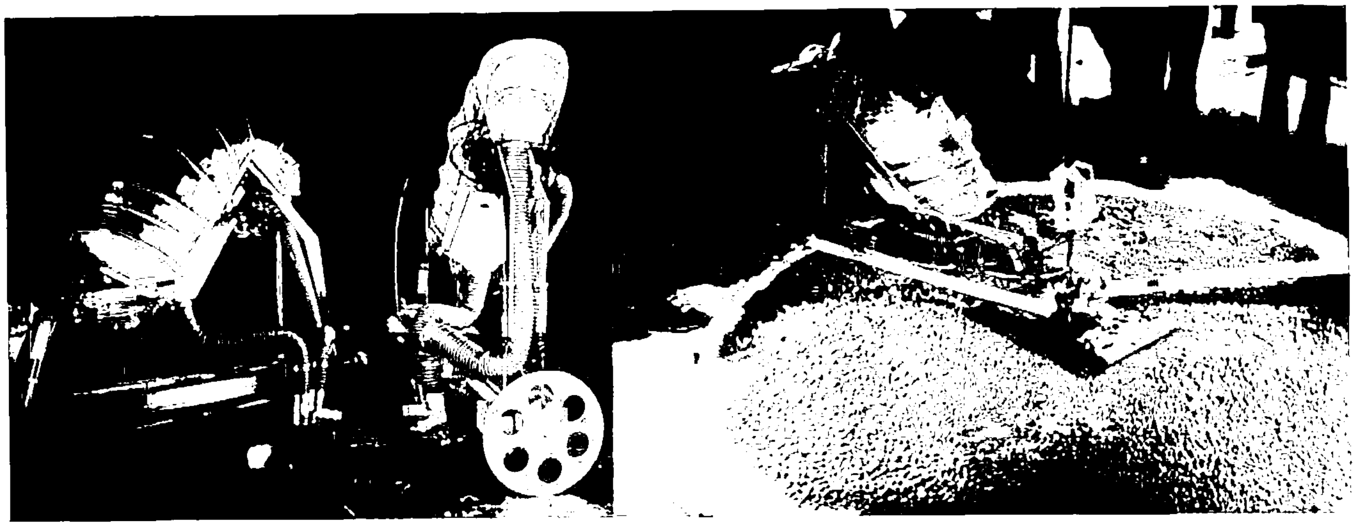

Figure 7 Terra-iser: landscape randomizing and sorting machine: Staffan Engqvist, Milo Laven, Erik Tornkvist.

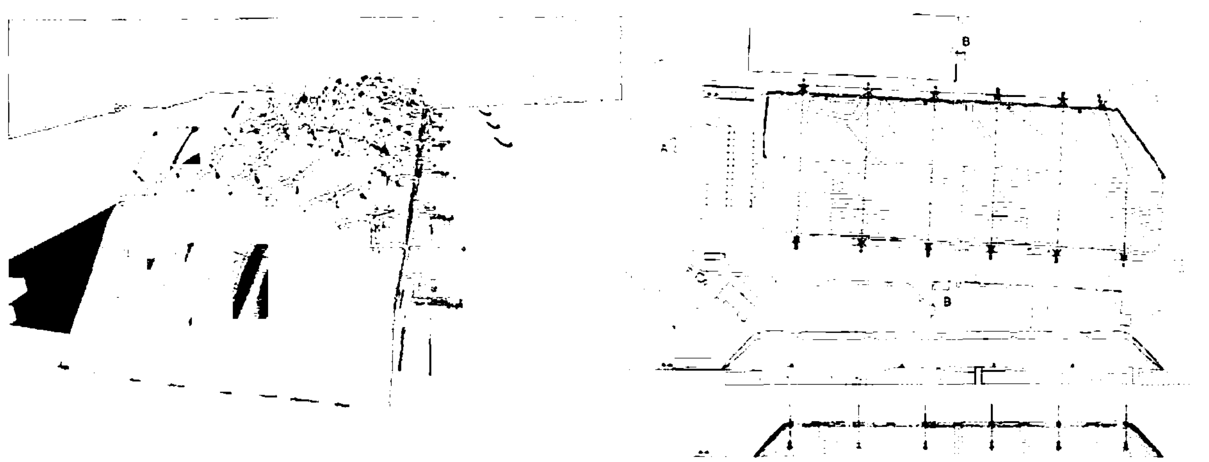

Figure 8. City Glacier Facility: ice storage facility and indoor ice rink: Staffan Engqvist.

the lemon itself that responded to people's movement and light. The Terra-iser (fig. 7) derived from the study of glaciers as landscape generators constructed an ever-changing landscape according to the movements of people around its orbit.

The third stage program asked individual participants to use ideas developed in earlier work in architectural, urban or landscape artificial ecology propositions for a part of the city termed Ekoparken (Eco Park) that attempts to maintain or keep the 'nature' and 'cultural' aspects of the area frozen. In many cases, the earlier dynamic model or ecosystem and dynamic model work informed proposals in ways that might not have been generated through conventional or top down sustainability approaches. Proposals included a proposal to divert carbon dioxide waste emissions from a municipal heating plant to a new garden,[18] a project directly informed by earlier experimentation and investigation of the fog table (which used carbon dioxide). A project for a summer cooling facility (fig. 8) and ice rink based on the city's existing snow collection (an annual snow mountain that by the end of the winter has become glacier like) developed from earlier the interest in glaciers and the constantly changing landscapes of the Terra-iser.

Conclusion

Significantly, the dynamic models developed embody a sense of play that remains open and active. Although technology driven and machine like, they are without utility value or useful function. The play in the machine here relates to the non-linear causality that De Landa mentions, potentially acting as a bridge between different environments, scales and entities. Play in the machine therefore avoids the technocratic mechanistic phylum of cause and effect (the functional machine, the factory robot, the tractor or the plough). It does this through becoming imbued with sensory capabilities and responses (sensors) and through processes of feedback it is enabled with characteristics (character) that are not only contingent on simple cause and effect (input and output) but take into account effects from wider environments. As a larger issue, the notion of tolerance in an ecosystem, is the play in the system, the degree to which it can adapt, and is a measure of robustness of a system.

Equally important is the tacit knowledge gained through making and testing. Implicit in this are the two abilities of top down analytic skills and the need to apply bottom up thinking processes to integrate numerous entities and the various components into a synthetic whole. Through making a range of prototypes, the construction of their final dynamic models the student's abilities to synthesize through making are tested. The dynamic or interactive model is useful in these terms because it is only relevant or has meaning as a construct that is active, operating as an object or installation that communicates with and senses the environment around it.

There are of course limitations that the digital world meets in modeling non-linear systems or dynamic systems in this way. Digital cause and effect is an undeniable parameter as behaviors, actions and interactivity in general, need to be programmed, sequenced and may in some way be predetermined by their intrinsic computer coding. The aspects of play in dynamic models however, bypasses the fundamental technological limitations and allows for the unexpected in the lemon powered musical instruments that operate on photosynthesis principles.

To paraphrase Robert Smithson,[19] it is the dream of architecture is to escape from entropy; architecture is contingent on the suppression of entropy, of providing order. Like Alchemy, Architecture has always mobilized and transformed material and matter, moving it from one place to another, changing its relationships to its originary place and context, taking base matter and changing its value to one of a usually higher order in which entropy is reduced. And like Alchemy, Architecture requires energy to effect these transformations, to resist the fall of all matter to their entropic states.

References

1 The word sustainability privileges both the notion of sustaining but also carries the connotation to sustain, or maintain as a equilibrium. Its use here is in the absence of a better term.

2 The concept of Artificial Ecologies borrows from the development of Artificial Life simulations, a related issue but beyond this paper.

3 Leonardo Da Vinci systematically studied dynamics, filling numerous notebooks with analytic sketches of dynamic phenomena. He studied flows in river systems, braiding of hair, the pattern of leaves around a flower and the forces of storms (deluge series). Significantly, his cross fertilization of ideas and concepts occurs across vastly different domains and scales: the turbulence of blood in the heart that causes the valve to flutter open and closed can be compared to the erosion study of water turbulence in the bank of the River Arno. They reveal his fascination with turbulence and the vortex as aspects of dynamic systems; the vortex becomes a ubiquitous sign of the life beneath the surface of 'nature'. We can learn many principles applicable to the study of ecosystems and sustainability from these studies: The drawing out of analytic principles derived from natural systems and the use of these in synthetic design is part of what we might term bio-mimetics today. The study of forces, entropy and energy relationships in complex circulation systems. The ideas of self-regulation that are principles of understanding an ecosystem. These principles when taken together construct a reservoir of knowledge of the design of dynamic systems and can frame a potential definition for ecosystems. Leonardo's work owes a debt to the Epicurian Philosophy of Lucretius whose De Rerum Natura outlines the first physics of natural systems.

4 Rene Thom, *Semiophysics: A Sketch, Aristotelian Physics and Catastrophe Theory:* (Redwood City, California: Addison Wesley Publishing, 1990): 157. This paraphrases Thom's description of the process of constructing a house.

5 According to the World Wildlife Foundation 2004 report, the resources used per capita doubled since 1960. During this time, average house size in North America has tripled whilst the average family size shrank to two thirds, with corresponding impacts on

resources, energy use etc. LEED as an entity cannot address all of the pressing aspects of the consumption society; one could have for example a gold LEED rated building that is in all other ways supporting and contributing to the waste of resources.

6 See Arthur Iberall, *Towards A General Science of Viable Systems:* (NY: McGraw-Hill Book Company, 1972).

7 Manuel De Landa, "Nonorganic Life," *in Zone 6: Incorporations*: Ed. Jonathan Crary and Sandford Kwinter (NY: Zone Books, 1992): 154. De Landa's book *A Thousand Years of Nonlinear History:* (NY: Swerve Editions, Zone Books, 1997) is based partly on the ideas of Iberall. It is significant to note that these phases are determined from the interaction of millions of small flows and the system state itself, in other words from the interactions of the micro and macroscopic.

8 See Waddington, C. H. ed., *Towards a Theoretical Biology vol. 1: Prolegomena* (1968), Edinburgh: Edinburgh University Press. This relates to the concepts of an epigenetic landscape.

9 Ian L McHarg, *Design with Nature*, (NY, Natural History Press: 1971): 197.

10 See Mathis Wakernagel and William Rees, *Our Ecological Footprint: Reducing Human Impact on the Earth,* (Gabriola Island, New Society: 1996).

11 See Richard Rogers and ed. Philip Gumuchdjian, *Cities For A Small Planet*, (London, Faber and Faber: 1997). See also Herbert Giradet, *The GAIA Atlas of Cities: New Directions for Sustainable Urban Living,* (London, GAIA Books, 1996).

12 See also Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, (NY, Bantam Books: 1984). And Gregoire Ntoolis and Ilya Prigogine, *Exploring Complexity*, (NY, W.H. Freeman: 1989).

13 Manuel de Landa, *A Thousand Years of Nonlinear History:* (NY: Swerve Editions, Zone Books, 1997) Introduction 17-18.

14 De landa Markets, "Antimarkets and Network Economics" in *Found Object*, Vol. 8, (NY, City University: Center for the Study of Culture, Technology and Work: 1996): 53.

15 See Neil Gershenfeld, Fab: The Coming Revolution on Your Desktop - From Personal Computers To Personal Fabrication, (NY, Basic Books: 2005) Fabrication Labs is an initiative from MIT that enables fabrication to a variety of global users. Neil Gershenfeld, its founder, writes of a 'just in time' model of teaching opposed to a just in case model, arguing for a mode appropriate for a rapid prototyping type education. Proactive not reactive, able to be generative or evolutionary in operation, relevant for the shift of fabrication from mass fabrication (industrial age) / mass customization (post industrial age) to personal fabrication / customization is an enabling revolution according to Gershenfeld and both allows and argues for the need for a hands-on literacy that develops fabricating literacy for today's contemporary world. This concept has been slow to develop in architectural schools. In part due to the prevalence of the more directly applicable computing skills, and the emergence of newer digital fabrication modalities. Some schools that have encouraged this are the Architectural Association, driven by its long association with cybernetics through theorists such as Gordon Pask, later developed through the work of John Frazer and the Design Research Laboratory. The Bartlett School in London where the author taught for 6 years has also enabled this type of exploration, as has the Royal College of Art in London.

16 Architecture and Urban Research Laboratory (http://www.arch.kth.se/a-url/description.htm) was co-established by the author with Ana Betancour in The Royal Institute of Technology (Kunliga Tekniska Högskolan), Stockholm, Sweden in 2000. For some examples of the work, refer to http://www.arch.kth.se/a-url/interspace.htm. Interspace exhibition of the work was held at the Kulturhus in Stockholm and a catalogue publication was made.

17 Basic Stamp II microprocessors, 'breadboard' circuits and interactive design was assisted in 3 one-day workshops by Jon Rogers. There was no shop for fabricating parts.

18 This project will be published in a forthcoming edition of Journal of Architecture Education.

19 Refer to Robert Smithson: The Collected Writings, 2nd Edition, edited by Jack Flam, The University of California Press, Berkeley and Los Angeles, California; University of California Press, LTD. London, England; 1996. Originally published: The Writings of Robert Smithson, edited by Nancy Holt, New York, New York University Press, 1979.