Systems of Valuation

by

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Abstract

The 1972 publication of *The Limits to Growth* marked a watershed moment in ongoing environmental debates among politicians, economists, scientists, and the public in the postwar period. Sponsored by the Club of Rome, an influential think-tank established in 1968, the report was published against the backdrop of the progressive activism of the 1960s, and prefigured the neo-conservative politics of the 1980s. It represented a decisive moment in that it appeared to reconcile critiques of consumerism and capitalism by linking the limits of global consumption to a finite totality of resources on the planet.

As a pre-history to current systems of valuation, this thesis looks at some of the intellectual tendencies that undergirded mindsets such as those manifest in the report. More importantly, it follows the intricate logics and narratives buried within the enigmatic web of geometric symbols and snaking lines that suffuse the writings of systems thinkers, tracing a genealogy of this mode of thought that begins with semiotic language of ecologists Eugene and Howard T. Odum, and of Jay Wright Forrester and the Systems Dynamics Group at MIT, to its manifold ends. These actors will ground the implications of systems theory-in-practice, its implications, and its biases. In doing so, the thesis reconstructs how "environment" was first defined and captured by systems thinking. Navigating through a series of international conferences in which these principles were substantiated, the thesis looks at the ramifications of systems thinking in the present.

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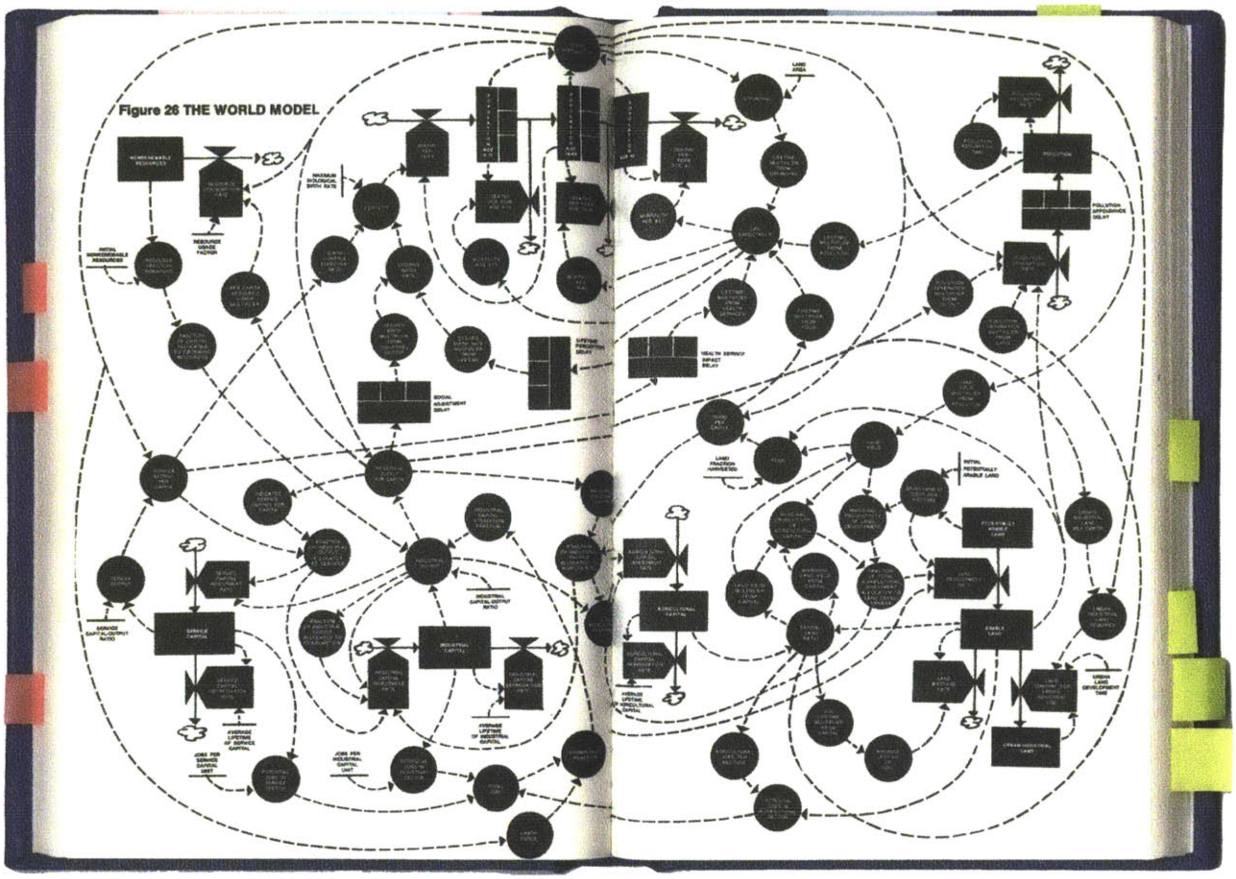


World Model represented by a flow diagram in System Dynamics notation developed for the Club of Rome, "Project on the Predicament of Mankind."Donella Meadows, et. al., *The Limits to Growth*, Universe Books, NY, 1972.

0. Introduction

The 1972 publication of *The Limits to Growth* marked a watershed moment in ongoing environmental debates among politicians, economists, scientists, and the public in the postwar period. Sponsored by the Club of Rome, an influential think-tank established in 1968, the report was published against the backdrop of the progressive activism of the 1960s, and prefigured the neo-conservative politics of the 1980s. The Club's co-founder, industrialist Aurelio Peccei, posed the problem the Club set out to solve: "We can perceive the individual symptoms of the profound malaise of society, yet we are unable to understand the significance and interrelationship of its myriad components, or diagnose its basic causes, and hence are at a loss to devise appropriate responses."[1] Working with the Systems Dynamics Group, directed by Jay Wright Forrester at MIT, the Club set forth to model the relationships between various components: a statistically "general" population, a set of pollutants, and a set of resources. The final report linked the limits of global consumption to a finite totality of resources on the planet. In doing so, it absorbed the critiques produced by counter-culture movements formed in the wake of Rachel Carson's *Silent Spring*, published in 1962,[2] into mainstream political and economic thinking. *The Limits to Growth* concluded:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial activity.[3]

1 Aurelio Peccei, "The Predicament of Mankind," MC439, Box 128, Institute Archives and Special Collections, MIT Libraries, Cambridge, Massachusetts [hereafter MC439].

2 Carson revealed the long-term and contingent effects of the pesticide DDT that was freely administered during World War II to eliminate malaria. Rachel Carson, *Silent Spring* (Boston: Houghton Mifflin, 1962).

3 Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William Behrens III, *The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind* (New York: Universe Books, 1972), 23. The Meadows' were graduate students in the System Dynamics Group. This report was followed by "Mankind at the Turning Point" two years later, written by Donella Meadows. By this point, the Meadows team separated from the Systems Dynamics Group and moved to Dartmouth College.

The report received much approbation and criticism and more importantly, fueled ongoing deliberations as to the role of the state in regulating the ownership and allocation of resources, and the new subject of the "environment." In stressing the delay between a cause and an effect, the authors of the report asserted a pragmatic argument: the world population must act now in order to prevent their prediction of the future. Accordingly, the Club also stressed that these issues could not be solved by individuals or nations alone, and would require a larger governing body—a multi-national one—to provide the assets and resources for research for the better management of all the world's "components."

To some, the shifting disciplinary, epistemological, and cultural complexities of the 1970s, generated anxiety about a collapsing world system. The social and Civil Rights movements, the consistent protests against the Vietnam War of the late 1960s, and the oil embargo, amidst ongoing stagflation only strengthened the numerous technocratic predictions of the world's end. The solution afforded to mitigate these issues, however, was the post-war stronghold of systems analysis, which drew on the broad discourse of cybernetics and systems, and was built on the premise of a rational, objective study of the myriad components and interests within a problem. In other words, this mode of thinking promised a rational means of for decision-making, and was extended to policy analysis and design of ongoing issues—from its application to solving urban housing issues, the consequences of radiation, or towards postulating the scale of world interaction and resource distribution.

As a pre-history to current systems of valuation, this thesis reconstructs how the "environment" was first captured by systems thinking, specifically through the post-war integrative science of ecology that attempted to make visible the "invisible wires of nature."[4] Through the work of several actors, this thesis investigates the intellectual tendencies that undergirded the absorption of counter-cultural arguments into

4 Howard T. Odum, *Environment, Power, and Society* (New York: Wiley-Interscience, 1971). The term "ecology" is typically related to Ernst Haeckel's coining of the term oekology in 1866 to describe the relations between plants, animals, and their habitats; in1864, George Perkins Marsh published a five hundred and sixty page tome, *Man and Nature; or, Physical Geography as Modified by Human Action*. Marsh defined ecology as such: "all nature is linked together by invisible bonds, and every organic creature ... is necessary to the well-being of some other." While certainly a continuation of this definition, ecology in the post-war period was specifically an operative and instrumental science.

mainstream forms of economic thinking. More importantly, I follow the intricate logics and narratives buried within the enigmatic web of geometric symbols and snaking lines that suffuse the writing of systems thinkers, tracing a genealogy of this mode of thought from its initial semiotic language to its manifold ends. Three actors within energetics, ecology, and systems thinking in post-war United States, Eugene and Howard T. Odum, and Jay Wright Forrester and the Systems Dynamics Group at MIT, will help ground the implications of systems theory-in-practice, its social implications, economic biases, and exchange values.

The infusion of systems thinking into post-war social science and research was dependent on numerous factors—federal and private sponsorship, the anxieties of democracy, desire for continued scientific and technical progress, and concerns for national security, to name a few. Debates on the definition of the "individual," as the definition of individual sovereignty shifted from individual as citizen, to individual as consumer, also influenced the ways in which the state viewed its subjects.[5]

Recently, there has been much interest in the intellectual influence of systems thinking in the early decades of the cold war.[6] As historian Jennifer Light writes, "taken together, studies of the military, business, government, and academia between the late 1950s and the late 1970s portray the prior as one when systems analysis, operations research, cybernetics, information theory, and related fields came to shape—and in many cases to dominate—myriad professional pursuits."[7] I was involved in one such project as a research assistant

5 Historian Eric Hobsbawm wrote, "The consumer takes the place of the citizen," tracing a transition in the definition of sovereignty, where "participation in the market replaces participation in politics." Cited in S.M. Amadae, *Rationalizing Capitalist Democracy: The Cold War Origins of Rational Choice Liberalism* (Chicago, IL: Chicago, 2003), 4.

6 Please see Paul Edwards, *The Closed World: Computers And the Politics Of Discourse In Cold War America*, (Cambridge, MA: MIT Press, 1997), Paul Edwards, *A Vast Machine: Computer Models, Climate Data, And The Politics Of Global Warming* (Cambridge, MA: MIT Press, 2010); N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies In Cybernetics, Literature, And Informatics*, (Chicago, Ill: University of Chicago Press, 1999); Agatha C. Hughes and Thomas Parke Hughes, *Systems, Experts, and Computers: the Systems Approach in Management and Engineering, World War II and After*, (Cambridge, MA: MIT Press, 2000); Jennifer S. Light, *From Warfare To Welfare: Defense Intellectuals And Urban Problems In Cold War America*, (Baltimore, MD: Johns Hopkins, 2003); Robert Henry Lilienfeld, *The Rise Of Systems Theory: An Ideological Analysis*, Ph.D. Dissertation, New School for Social Research, (New York, NY:1975); Reinhold Martin, *The Organizational Complex Architecture, Media, And Corporate Space*, (Cambridge, MA: 2003); Philip Mirowski, *Machine Dreams: Economics Becomes A Cyborg Science*. (Cambridge; New York: Cambridge University Press, 2002); and Peter J. Taylor and Ann S. Blum. "Ecosystems As Circuits: Diagrams And The Limits Of Physical Analogies." *Biology and Philosophy* 6 (1991): 275-94.

7 Jennifer S. Light, "Taking Games Seriously," *Technology and Culture* 49 (2008): 347-375.

for the forthcoming *A Second Modernism: MIT, Architecture, and the Techno-Social Moment.*[8] The heavily intertwined histories illustrate the ways in which architecture fell victim to the post-war research-industrial-academic complex[9] in adopting the methods and tools of operations research, systems theory, and developing computer technologies.

The Diagram, Static to Dynamic

Central to the creation of the discourse of systems analysis was the block diagram, a symbol adopted from early communication engineering and management. Throughout the work of Forrester and the Odum brothers, these diagrams are presented as scientific representations, explained with the sense of transparency and authority that lay in modes of scientific production in the immediate years following World War II. The diagrams use and manipulate existing electrical symbols, invoking an analogy of a pictographic script, such as hieroglyphics, for the imbrication of the language with the model. While the diagrams are first intricately tied to the scale of the author as means to represent mathematical equations; they become increasingly abstract as the author develops the code and rules of his own communicative system. The data gathered to generate these diagrams is itself powerless; it is designed as it is represented in pictorial form. As its language is abstracted from its direct purposes of observation and quantification, it tends towards universality, providing the impetus for a blanket application of its form upon any phenomena.[10] As social scientists gained political and professional power, their means of representation gained popularity, and vice versa, allowing for a visual argument to the claim of an evermore objective, apolitical, and value-free science.

8 *A Second Modernism: MIT, Architecture, and the Techno-Social Moment* is edited by Arindam Dutta and four students within the History, Theory, and Criticism program, Stephanie Tuerk, Michael Kubo, Jennifer Y. Chuong. It is forthcoming from MIT Press, Summer 2013. I am indebted to this experience and its twenty authors for providing a ground and innumerable illuminating arguments (and a wealth of footnotes).

9 Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford.* New York: Columbia University Press, 1993.

10 Geof Bowker, "How to be Universal: Some Cybernetic Strategies, 1943-70," *Social Studies of Science* 23 (1993): 107-27.

The thesis begins by situating systems thinking in its post-war context of a symbolic language and continues by tracing a genealogy of the notational, graphic representation in communication theory to its extension in the social sciences. Developed in the depths of defense laboratories during the Second World War, a regulating, goal-oriented mechanism used in weaponry systems and self-directed missiles re-introduced the notion of "feedback" to scientists. As research on feedback mechanisms prospered, its principles splintered into a number of applications, from behavioral science to the description of highly contentious political scenarios. The image and ideas of computer structures disseminated quickly as researchers and scientists found their vocations in a re-structured post-war society. Subsequently, what had once been defined as the individual's elastic milieu, was transformed into a "calculated and calculating" "environment."[11] Focusing on the many iterations of the post-war definition of the "environment," the chapter shows how these images, as superficial captures, were adopted towards the mapping of social, political, and economic systems, and the logics and narratives buried within.

Chapter Two focuses on "systems ecology," the extension of systems thinking to natural resources, as defined and practiced by ecologists Howard T. Odum and Eugene P. Odum. Systems ecology pushed for a rigorous accounting and management for the redistribution of resources under the imperative of an exigent global crisis. In highlighting specific examples from within Odum's vast repertoire, this chapter illustrates the ways in which systems ecology adopted and expanded upon counter-cultural arguments. In representing the entwined ideas of the "invisible wires of nature," the Odum brothers came to see the world as such, an "electronic technician's nightmare."[12] Although considered a "soft" science, it was touted to provide the necessary value-free, apolitical judgment so revered in the post-war period. As all processes and materials could be reduced to their equivalent in power, or energetic expenditure, systems ecologists came to see political parties, policies, and social systems as comprehensible and comparable through the measurement of the flow

11 Michel Foucault, Michel Senellart, François Ewald, and Alessandro Fontana, *Security, Territory, Population: Lectures at the College de France, 1977-1978* (New York: Picador/Palgrave Macmillan, 2009), 71.

12 Howard T. Odum, *Environment, Power, and Society* (New York: Wiley-Interscience, 1971), 267.

of energy. Population, materials, and economies collapsed into a single "flow" of inputs and outputs, the Odum brothers could imagine the three as a set of intertwined natural processes subject to management.[13]

I focus particularly on the implications of this view through a close analysis of Howard T. Odum's *Environment, Power, and Society,* written in 1968 and published in 1971, as it marks a culminating and comprehensive moment within Odum's prolific writings. *Environment, Power, and Society* is a peculiar source, as it was intended to be a textbook for undergraduate students in human ecology, yet extends systems thinking to its fanatical, yet perhaps logical, ends. A chapter entitled the "Energetic Basis for Religion" collapses energetics with a belief system to make the individual commensurate with its energetic environment, and presented "Ten Commandments" to its audience. "System survival makes right and the energy commandments guide the system to survival," Odum wrote.[14]

By the early 1970s, and certainly by the time *The Limits to Growth* was published in 1972, belief in systems thinking had grown to encompass the entirety of interactions of the world. The thesis concludes with an examination of the implications of systems in *The Limits to Growth*, and the substantiation of its argument through a series of international conferences. Within these conferences, the processes of decision-making towards informing policy shift from their use by experts to predict and rationalize the actions of individuals as principal-agents, to that of nations, acting in economic, national, and political best-interest. The popular perception that these conferences finally brought forth the "environment" as a true, moral object of concern are falsified. Understood within the constraints of game theory, the paradox of the structure necessarily imposed competition—while it may be collectively rational to cooperate in regards to common resources, it was individually rational to act in self-interest—thereby collectively undermining the common resource. With the creation of a set of commitments of "common but differentiated responsibilities," also came an array of market-based mechanisms to ease implementation, re-introducing industry to the "state-sustainability" complex.[15]

13 Foucault, 71.

14 Odum, 253.

15 Odum, 253. To conclude, each of the three actors continued to teach systems thinking within their respective fields and universities. Forrester embarked on a number of projects, from observation and optimization of organizations in

Industrial Dynamics, to testing policy in *Urban Dynamics*, and *World Dynamics.* that solidified his status within MIT. He also operates a business consultancy, and designed a System Dynamics curriculum for elementary schools. Forrester's System Dynamics, although transformed, is currently a required and popular course among students at the MIT Sloan School of Management. Odum, too, continued to teach, research, and write. *Environment, Power, and Society* was republished several times, each edited, yet promulgating energetic thinking—named emergy—throughout. These three actors are representative of just a few figures that were involved in such research—each maintained a research group or center, and their students went on to occupy influential positions at various universities, financial institutions, and federal agencies—introducing systems thinking to new frontiers.

1. Defining the "Environment"

Though ubiquitous today, the term "environment" originally defined a very minute area of study. It referred particularly to the feedback mechanisms and symbol-communication studies found in the depths of defense research laboratories during the Second World War, and to the space of a "task," defined by the transaction between a human and a machine. By the 1960s, the term "environment" defined a broader scope; within architectural and urban studies, it was the "built environment"; it marked a relationship to the burgeoning social sciences, as well as permeability between disciplinary frameworks;[16] within the sciences, it marked another space of exploration, a dynamic repository for the unintended consequences of industrial production; within computational developments it referred to a specific structure, defined by the engineer, in which an expression gained meaning.[17] The post-war launch of engineering systems—between the triad of analog and digital computers, integrated electronics, and operations research—quickly extended to the question of social systems. Could the same models used to construct and simulate computer and physical systems be suitable for mapping the dynamic relations of social, political, or economic systems? By 1973, this question extended even further. Jay Wright Forrester, Professor and founder of Systems Dynamics Group at MIT, asked "Why, then, do we not use the same approach of making models of social systems and conducting laboratory experiments on those models before we try new laws and government programs in real life?"[18]

By the 1970s, the "environments" that were modeled had increased exponentially in scale, from the scale of the mechanism, to the interpersonal task, to a group political exercise; simultaneously models came to be used to simulate organizations, belief systems, cities, and finally, the absolute totality of the world. The

16 Mary Louis Lobsinger, "Two Cambridges: Models, Methods, Systems, and Expertise," ed. Arindam Dutta, A *Second Modernism: MIT, Architecture, and the 'Techno-Social' Moment,* (Cambridge, MA: MIT Press, forthcoming 2013), 652-3.

17 Eric Grimson, Peter Szolovits, and Trevor Darrell, *6.001 Structure and Interpretation of Computer Programs,* Spring 2005. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed 1 May, 2013). License: Creative Commons BY-NC-SA.

18 Jay W. Forrester, "Counterintuitive Behavior of Social Systems," *Technology Review, Vol. 73, No. 3, Jan. 1971, 52-68.*

authors of these models argued that seeing the breadth of relationships and possible effects of changes would lend a much needed projective vision to the hordes of planners and experts trusted to make large-scale, and long-term decisions. The authors of such totalizing visions were perpetuated by certain institutional and extra-institutional contexts that allowed them the space, the audience, and the support to proselytize grand simulated visions. This chapter thus attempts to map the context that birthed this post-war systems thinking and the resultant expansive scale of its models, leading up to the MIT System Dynamics Group's World3 Model, to be used and published in *The Limits to Growth* in 1972.

Institutional Contexts

To paint a broad picture, the post-war period in the US is marked by intricate changes in the organization of research and the production of knowledge. As World War II drew to a close, and the dark cloud of the atomic bomb rested heavily over scientific research, a major concern among the government, scientists, and engineers remained the suspension or extension of the heavily funded research that occurred during the war.[19] World War II brought the national government into a much more active position in both domestic and international affairs. In both determining problems, as well finding solutions, the government required a large and very specific knowledge base to increase technical analysis and policy research. How it came to collect, refine, analyze this knowledge, and furthermore reflect upon the knowledge amidst the numerous diverging interests came to define the larger activity for social scientists, framing a new importance on the specialized knowledge of the expert.[20] As one scholar writes, "the distance between knowledge and power was being bridged routinely ... as experts were drawn into roles as administrators and policy planners, knowledge began to look like ... another instrument of political power."[21]

19 MIT in particular, as a technical and engineering institute was transformed by the war research. In 1946, the government signed a contract with MIT to continue research for the Army Signal Corps, the Office of Naval Research, and the Air Material Command, which funded the Research Laboratory for Electronics, the Radiation Laboratory, and the Joint Services Electronic Program.

20 David P. Haney, *The Americanization of Social Science: Intellectuals and Public Responsibility in the Postwar United States, (Philadelphia: Temple University Press, 2008), 26.*

21 James A. Smith, *The Idea Brokers* (New York: The Press, 1991), 94, as cited in Andrew Rich, *Think Thanks, Public Policy, and the Politics of Expertise,* (Cambridge, UK: Cambridge University, 2004), 42.

Federally sponsored university-based research programs proliferated; and MIT, among other institutions such as CalTech, and Harvard, developed much of their post-war character and organization based on these unprecedented relationships. In 1962, physicist Alvin Weinberg, then director of the Oak Ridge National Laboratory remarked that it was difficult to distinguish whether MIT was a "university with many government research laboratories appended to it or a cluster of government research laboratories with a very good educational institution attached to it."[22] This model attempted to differentiate, and separate basic and applied research, as well as academic and industrial science. This context is important to note as a preface, as it fostered a system of knowledge production that birthed and supported the actors discussed here.[23]

Contextualizing the work of systems thinkers, then, requires this discussion of how the work was supported financially, how it was popularized, and how it captured an audience—willingly, or not. In the following section, I situate several actors within their entangled social and financial networks, or within the "equipment, expertise, and funding," that facilitated their work[24]—focusing on social scientist Herbert Simon as he moved from the University of Chicago, the Cowles Commission, to the newly funded Carnegie Institute of Technology's School of Industrial Administration; Jay Wright Forrester and Norbert Wiener within MIT, the epitome of the post-war techno-social center; and the RAND Corporation, briefly, to highlight the adoption and transformation of systems analysis towards social theory and decision-making. The work in these three sites was situated within the contentious social sciences—which wavered back and forth between claims to scientific, specialized expertise, and an interdisciplinary elasticity as it worked to position itself within post-war research funding structures.

Within each of these contexts, academic research was pushed to parallel the ostensibly objective methodologies of science. Yet the changing exterior environment of each of the institutions necessitated

22 Cited in Stuart A. Leslie, *The Cold War and the American Science: The Military-Industrial-Academic Complex,* 14. By the end of World War II, MIT held 75 separate contracts worth $117 million, Caltech $83 million, Harvard $31 million.

23 Thus, during World War II, social scientists served in a number of departments, including the Office of Price Administration, the War Production Board, the Division of Statistical Standards, and perhaps most of all in the Research and Analysis Branch of the Office of Strategic Services.

24 Lobsinger, 660.

certain relationships, ones that were commonly felt between the three, that tied research to its external sponsors—whether that be government, a philanthropic foundation, or industry. Research and knowledge production was defined and legitimized by the mutual alignment between the three parts—the researcher, the research, and the sponsor.[25]

During the war, MIT was entrenched in defense research, and home to many of the future Macy Conference participants, including psychologists Warren McCulloch and Walter Pitts, and mathematicians Claude Shannon and Norbert Wiener. Each had been involved in one of the defense labs—either in the Servomechanism Lab directed by Gordon Brown, or the Radiation Lab. Forrester, too, spent his time in the Servomechanism Lab developing anti-aircraft mechanisms. Some moved to the Research and Development Corporation (RAND) was founded in Santa Monica, California as an extension of Air Force research in 1946;[26] Herbert Simon spent the summer of 1952 at RAND and began his collaborations with Albert Newell.[27] Others remained at MIT and continued their research. In 1951, MIT found the Lincoln Lab to develop the Semi-Automated Ground Environment (SAGE), an air defense system, with the MIT Research & Engineering Corporation, MITRE, founded to run the project. Forrester remained involved with SAGE until 1956, when

25 Herbert Simon's articulation of this alignment is conditioned by economic ideals, as we shall see. Michael J. Lacey and Mary O. Furner, *The State and Social Investigation in Britain and the United States*, (Washington. D.C: Woodrow Wilson Center Press, 1993), 1-59.

26 In 1946, "Project RAND" launched as an autonomous group within Douglas Aircraft. It was to function somewhat independently of both Douglas and the Air Force, yet was dedicated entirely to researching their concerns. It's charter stated: "Project RAND is a continuing program of scientific study and research on the broad subject of air warfare with the object of recommending to the Air Force preferred methods, techniques, and instrumentalities for this purpose." By 1948, RAND had 255 employees and an operating budget of $3.5 million. By 1949, the RAND population consisted of 78% engineers, mathematicians, and computer scientists, while political scientists and economists constituted only 5%. By the end of the 1950s, however, this ratio was reversed—economists greatly outnumbered all others. The goals shifted from hands-on technical work to the more dignified "high-powered brain trust," whose central work lay in speculation of the unthinkable—nuclear war. Abstract studies of strategy, values, tactics, logistics for renewed warfare came to signify RAND's unique area of expertise. For RAND's early studies see Amadae, "RAND 1948-57: Systems Analysis," in *Rationalizing Capitalist Democracy*, 39-47.

27 RAND claimed it focused on "the far more complex problem of choice among future alternative systems, where the degrees of freedom and the uncertainties are large, and where the difficulty lies as much in deciding what ought to be done as in how to do it." Claiming its cause as beyond simple "efficiency" calculations, to determining "what ought to be done… [the] good objectives and criteria." In fact, they were in charge of determining, or finding, "what indeed is the problem." RAND Pamphlet, Cited in Michael Kubo. *Constructing the Cold War Environment: The Architecture of the RAND Corporation, 1950-2005*. Cambridge, MA: M.Arch Thesis, Harvard University, 2006.

he received an offer for an academic position in the newly found Alfred P. Sloan School of Management at MIT. This was the first school of management within a technical institution, and Forrester saw this moment as an opportunity to leave the physical computing domain to that of management. Most advances in computing had been made, he argued; the logical step would be better understand the social systems and management.

The claims towards scientific expertise increased severely as social scientists—anyone working within economics, psychology, political science—attempted to fit themselves into postwar structures of institutional finding. Alongside defense commissions, social scientists were asked to help find solutions to solving conflicts at a variety of scales. They faced much resistance initially, and while they pointed to their similarity with the natural sciences, the natural sciences claimed the opposite—social scientists could not exercise the same objectivity and scientific methodologies as the natural sciences, they did not have a body of accepted methodologies, nor the institutional support. In return, social scientists claimed an approach of a generic, universalist science, one that could follow scientific methods of testability and quantification, and escape subjectivity and metaphysics, as these notions lacked scientific content.[28] This act towards professionalization, and subsequent push to establish social scientists as specialists within a certain field of knowledge, sought to separate the profession from "ideologically motivated social reformers" of the early 20th century. In doing so, social science attempted to move towards objectivity and scientific methods; they argued that their work was, in fact, observable and measurable. It is through these practices that social scientists attempted to claim their authority.[29]

This debate encountered its biggest clash as the social sciences attempted to find their position within post-war funding, specifically in gaining admissions to what would become known as the National Science Foundation. The Social Science Research Council, founded in 1923 with support of philanthropic foundations, commissioned Harvard sociologist Talcott Parsons to produce a report that would convince the NSF of their

28 Roger Backhouse and Philippe Fontaine, *The History of the Social Sciences Since 1945* (Cambridge: Cambridge University Press, 2010), 198-9.

29 In the US, social science as a "professional" category emerged in the late 19th century; the American Social Science Association was founded upon the conclusion of the Civil War in 1865. David Haney, "The Postwar Campaign for Social Legitimacy," in *The Americanization of Social Science*, 25. The postwar to which Haney refers is the post-Civil War.

scientific legitimacy. The report, *Social Science: A Basic National Resource*, failed to convince and the social sciences were not admitted to the NSF until 1959.

Philanthropic foundations, too, were imbricated within this knot of funding; arguing that they were most poised to provide support for nonpartisan research and objective knowledge production. According to a 1949 *Gaither Report of the Study for the Ford Foundation on Policy and Program*, in a section explaining why, "by its nature," a foundation is well-equipped to fund research, the Ford Foundation explained that as it "ha[d] no stockholders and no constituents…[and] represent[ed] no private, political, or religious interests," it was at the apex of objectivity and most suited to fund unadulterated research.[30] This is decidedly a false claim. The Ford Foundation, as just one example, was certainly driven by the interests of its directors—it funded both the MIT Systems Dynamics Group, as well as the formation of the Carnegie Institute of Technology School of Industrial Administration—where social scientist Herbert Simon, along with G.L. Bach and William W. Cooper would situate studies in economics and behavioral sciences.

In this light, it is helpful to look, too, to the Macy Foundation. The Josiah Macy Jr. Foundation funded the famous conferences on the social science of cybernetics, to which I will return shortly. In a 1950 review of its activities, the Foundation's President wrote that it was both the "duty and opportunity" of the Foundation to sponsor research, to launch a "coordinated attack by all the social sciences, including psychiatry, upon the urgent problems which threaten social stability and world peace."[31]

Established in 1930, the Macy Foundation was just one of a number of private philanthropic foundations; it positioned itself in the same lineage as the Rockefeller, Mellon, and other family foundations formed in the late 19th century. As the youngest foundation, it sought to find for itself a particular niche to which to provide support; its first President, Viennese physician Ludwig Kast, determined this to be aspects of health, focused on the "architecture of ideas," rather than buildings or laboratories. Several of the Macy

30 Gaither Committee, *Study for the Ford Foundation on Policy and Program*, 1949, 23.

31 Josiah Macy Jr.Foundation, *Twentieth Anniversary Review of the Josiah Macy, Jr. Foundation, 1930-1950*, (New York: 1950), 96.

Conference participants, including Foundation medical director Frank Fremont-Smith and anthropologist Margaret Mead helped found the World Federation for Mental Health in 1948.[32] The Federation adopted as its motto a phrase from the UNESCO constitution, "Since wars begin in the minds of men, it is in the minds of men that the defense of peace must be constructed."[33] The Foundation's President, William Rappleye, wrote in the 1955 report that social conflicts were symptoms of deeper underlying mental causes—not social or economics; research was to provide accessibility to science through psychology and anthropological methods.

As the method of systems analysis was deemed useful, research on decision-making prospered—from the Rand Corporation, to MIT and Carnegie Mellon, schools of business and public administration invested in its development. Systems emerged in trademarked form—as systems analysis—a method for making decision-making an objective process in writing and testing policy by the assessment of cost against risk in a number of pre-determined outcomes. It was this mode of analysis that was adopted by President Johnson to assess policy changes for his Great Society programs; it was a slight variation that was named the Program-Policy-Budget System, and made mandatory in all federal agencies..

Combined, the representational practices of cybernetics and systems, offered "kind of conceptual wonderland full of magnificently intricate and promising devices" for decision-making.[34] The systems process, both in analog methods, and through simulation became an accepted method to test and justify political decisions and policies. Social scientists, economists, and politicians, its users, promised that the representation of the structure of one's belief system would allow for retrofitted understanding of how or why decision-makers made these decisions, thereby explaining how certain policies emerged, as well as assist in the prediction of future events. Prediction using the systems approach undergirded ultimately subjective choices with ostensibly objective data; it assured the user that the decision would be the most desired

32 Fremont-Smith served as its second president, and Margaret Mead, its fifth, from 1956-7.

33 Cited in Jean Pierre Dupuy, *On the Origins of Cognitive Science: The Mechanization of the Mind* (Cambridge, MA: MIT Press, 2009).

34 William J. Gore and Fred S. Silander, "A Bibliographic Essay on Decision Making," *Administrative Science Quarterly* 4, 1959, 97-121. Cited in Deborah Lines Andersen and David F. Andersen, *Theories of Decision-Making: An Annotated Bibliography*. Working Paper 943-77, Alfred P. Sloan School of Management, June 1977.

outcome within a landscape of social and political risk. By 1969, organizational theorist and social scientist Herbert Simon re-assembled these disparate parts—symbolic language, computer systems, and decisions—into a "science of the artificial."

A Science of the Artificial

The relationship between human and machine was articulated by social scientist Herbert Simon in his 1969 book, The Sciences of the Artificial—as a science of the artifact, of the man-made,[35] for "they [artifacts] are what they are in order to satisfy our desire[s]...As our aims change, so too do our artifacts."[36] Acknowledging the world as an artificial construction, Simon remarked: "Almost every element in our environment shows evidence of human artifice. The temperature in which we spend most of our hours is kept artificially at 20 degrees Celsius; the humidity is added to or taken from the air we breathe; and the impurities we inhale are largely produced (and filtered) by man."[37] Simon's concept of a science of the artificial is a helpful heuristic for understanding the broader application of the transfer of research into physical systems of computers, and technological processes to the social sphere.

For Simon, the social sciences, especially economics and psychology, represented the "interface" between the objects and phenomena that embody both a natural law and human purpose, and he posited that it was at these moments that an "artificial" science could be conceived. The "environment," in this case, was a measure as to how well, if at all, an artifact fulfills its purpose. Divided into "interior," or "the substance and organization of the artifact itself," and "exterior," or "the surroundings in which it operates," successful performance was based on the artifact achieving an "appropriate" fit. From this definition, we can deduce further that no artifact could be valued simply for its intrinsic properties, or its beauty, but solely valued

35 Simon writes in a footnote in that he defines "man" as an androgynous noun, "encompassing both sexes, and "he," "his," and "him" as androgynous pronouns including women and men equally in their scope." See Herbert Simon, *The Sciences of the Artificial* (Cambridge, MA: MIT Press, 1984), 2nd edition, 2, fn. 1.

36 Simon, 3.

37 Simon, 2.

based on its achieving this near-perfect transcendence between two "environments." The same year, in 1969, speaking as chair of President Nixon's Presidential Science Advisory Council, he already argued that the term "environment" had been "stretched to envelop almost every social problem."[38]

Furthermore, Simon would argue that we only need minimal knowledge of the "inner" environment—the substance of the artifact—for "airplanes and birds, dolphins and tunafish" all attempt to accomplish the same goals, although they have different makeups. Changing an outer environment would provide ample information as to how the inner would adapt. "Analogous to the role played by natural selection in evolutionary biology is the role played by rationality in the sciences of human behavior."[39] From this followed that one can predict the behavior of an individual or organization based on its goals and outer environment. All this discussion was to make the case for simulation, a new method for understanding the nature of the artificial, in which observation, or "truth-to-nature"[40] occurs within the frame of the interface. The computer could be used to extrapolate grand phenomena from existing basic understandings of the phenomena's parts.[41]

The precursor to a "science of the artificial" was "cybernetics," a name that derives from the Greek "kybernetes," and Latin "governor" to describe the activity of a system as "steering" towards a pre-determined goal.[42] These regulating, goal-oriented mechanisms, described as closed causal loops, were used to design weapons systems and self-directed missiles. Mediating information between "a weapon" and its "environment," the mechanism was designed to correct its errors and re-align towards a target. This method of mediating information, in

38 Herbert Simon, "Item for the Agenda of a Council on Environmental Quality," for Presidential Science Advisory Committee. March 12, 1969. Herbert Simon Papers, Carnegie Mellon Institute Archives. Accessed 22 April 2013, http://doi.library.cmu.edu/10.1184/pmc/simon/box00051/fld03844/bdl0015/doc0002 .

39 Simon, 8.

40 See Lorraine Daston and Peter Galison, *Objectivity* (New York, NY: Zone Books, 2010).

41 Simon's example of the articulation of this parts to whole relationship is that knowledge of gas particles could then be extrapolated to form a theory of weather and weather prediction.

42 Cybernetics is defined as the "field of study concerned with communication and control systems in living organisms and machines, "cybernetics, n.". OED Online. March 2013. Oxford University Press. http://www.oed.com/view/Entry/46486?redirectedFrom=cybernetics (accessed May 23, 2013).

which information returns to the system is called "feedback;" the system manages to realign based on a measurement of error between its position, or a "state" and the goal.

Cyberneticians typically used a couple of examples to demonstrate this definition—the first is a ship adjusting its rudder to reach a port, the second is the airplane, the third is the thermostat, which adjusts according to the temperature of the room air. As Heinz von Foerster, a "second-order" cybernetician would say in 1995, "[c]ybernetics introduce[d] for the first time—and not only by saying it, but methodologically—the notion of circularity, circular causal systems."[43] This abstract concept of closed loops, wrote Otto Mayr, provided "the common basis for all the regulating mechanisms discussed in this study [the study traces the history of feedback mechanisms to ancient Greek and Islamic engineers], is an achievement of the 20th century," and is prevalent in later discourses on the environment as a closed system.[44] Research on feedback mechanisms continued after the war as communication engineers, biologists, physiologists, neuroscientists, and even anthropologists, adopted its concepts and its forms of graphic representation. The field splintered into a number of diverse applications united under the general headings of cybernetics and systems, understood as two new theories of the scientific method.[45]

The group of scientists, engineers, and mathematicians that would form the core of "cyberneticians," first met over a two-day period in May 1942 at the Beekman Hotel in New York City under the patronage of the Josiah Macy Jr. Foundation.[46] "Interrupted" by the war, the same group would meet again at Princeton University

43 Heinz von Foerster, interview by Stefano Franchi, Güven Güzeldere, and Eric Minch, SEHR Vol.4, Issue 2: *Constructions of the Mind,* June 26, 1995, http://www.stanford.edu/group/SHR/4-2/text/interviewvonf.html; Cited in Hugh Dubberly and Paul Pangaro, "Introduction to Cybernetics and the Design of Systems," Accessed 22 April 2013, http://www.pangaro.com/design-is/Cybernetics-minimized-v8b.pdf.

44 Otto Mayr, *The Origins of Feedback Control* (Cambridge: MIT Press, 1970), 129, as cited in Caroline Jones, "Artist/System" in *A Second Modernism: MIT, Architecture, and the Techno-Social Moment,* (Cambridge, MA: MIT Press, 2013), fn. 66.

45 Pamela M. Lee, *Chronophobia: On Time in the Art of the 1960's.* (Cambridge, MA: MIT Press, 2004), 237.

46 The Josiah Macy Jr. Foundation, was established in 1930 to assist in medicine and health services. The Foundation activities were always focused on a grant program and a conference program, with emphasis on multi-discipline approaches to scientific problems and "improved channels of communication between the professions in order to develop the 'architecture of ideas.'" This quote originates from Mrs. Kate Macy Ladd's initial letter from 1930, urging the Foundation to fund ideas over buildings and laboratories, setting forth an ideological, not social initiative from its

on January 6-7, 1945. MIT mathematician Norbert Wiener, a central participant, christened the group the "Teleological Society," and proposed a journal and research center to be established at MIT. While this did not occur, with some convincing, two of the group members renewed the interest of the Macy Foundation;[47] this meeting would thus mark the beginning of a series of colloquia between Cambridge, MA, New York City, and Princeton, NJ, described by Wiener as "the birthplace of the new science of cybernetics, or the theory of communication and control in the machine and the living organism."[48]

The formation of cybernetics has an intricate history which cannot be traced fully here.[49] Most important to note is historian Paul Edwards' discussion of cybernetics as a "discourse formation," that is, a discipline that was distinctively constructed between a concatenation of meetings, conversations, and construction of diverse artifacts for laboratory experiments.[50] Between supper clubs at Harvard, meetings of

creation. Kate Macy Ladd, established the foundation in 1930 with funds derived mostly from the family's enterprises in oil and shopping, partly in collaboration with the Rockefellers. Cited in President Willard C. Rappleye's foreword to the *Twentieth Anniversary Review of the Foundation, 1950.*

47 Participants McCulloch and Rosenblueth conspired with the foundation's medical director, Frank Fremont-Smith, to sponsor a series of meetings to spread the gospel of cybernetics. McCulloch serves as chairman continuously, demonstrating his desire to bolster cybernetics. Lily E. Kay, "From Logical Neurons to Poetic Embodiments of Mind: Warren S. McCulloch's Project in Neuroscience," *Science in Context. 14.4 (2001): 591-614.*

48 Norbert Wiener, *I Am a Mathematician*, (Cambridge, MA: MIT Press, 1981), 269. The first meeting of the official Macy Conferences was also at the Beekman Hotel in NYC from March 8-9, 1946, entitled "Feedback Mechanisms and Circular Causal Systems in Biology and the Social Sciences." Present at this meeting were physiologists Arturo Rosenblueth and Warren McCulloch, medical director, and later director of the Macy Foundation Frank Fremont-Smith, Lawrence Frank, a former administrator for the foundation, psychoanalyst Lawrence Kubie, and anthropologists Gregory Bateson and Margaret Mead. As several historians have noted the last meeting was entirely distinct from the first—new participants, and new conversations. It was held at a small in in Princeton NJ in 1953.

49 For broader and more accurate discussions, please see Steve J. Heims, *Constructing A Social Science For Postwar America: The Cybernetics Group, 1946-1953* (Cambridge, MA: MIT Press, 1993); N. Katherine Hayles, *How We Became Posthuman Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago, Ill.: University of Chicago Press, 1999); and Jean Pierre Dupuy, *On The Origins Of Cognitive Science: The Mechanization Of The Mind* (Cambridge, MA: MIT Press, 2009). See especially Heims' Chapter 3, "The Limits of Interdisciplinarity." Heims uses the transcripts of the Macy Conferences, as well as personal interviews with the living participants to construct the first history. Dupuy follows Heims' account, positioning cybernetics as the precursor to present day cognitive science. Dupuy takes Warren S. McCulloch as his protagonist, who by the 1960s was honored as the "High Priest of Cybernetics, Bionics, or Self-Organizing Systems, whatever you call it." (Lt. Col. Callahan Jr., cited in Kay, 77.

50 Edwards' "discourse analysis" is the "entire field of signifying or meaningful practices; those social interactions—material, institutional, and linguistic—through which reality is interpreted and constructed for us and with which human knowledge is produced and reproduced." A discourse, for Edwards, is a "self-elaborating 'heterogeneous ensemble' that combines techniques and technologies, metaphors, language, practices, and fragments of other discourses around a support or supports." Paul Edwards, *Closed World*, 30-37.

the "Inter-scientific Discussion Group" of the Institute for the Unity of Science—the American transplant of the logical positivists of the Vienna Circle,[51] the "Cybernetics and Communications" study group in the Electrical Engineering Department at MIT,[52] to the ten Macy Conferences held between 1946-1953, it was clearly a large group of individuals that contributed to its formation.[53] The Macy Conferences were unique in that they were not only crossing fields of the social sciences, but invited mathematicians, physicists, biologists, and physiologists into their discussions—the cybernetics/systems dichotomy was always already an entangled web of conversations and close collaborations.[54] What held together such a diverse contingent of people and interests? Historian Slava Gerovitch succinctly summarizes:

> What held it together was a set of interdisciplinary ambitions and connections: the same mathematical theory described feedback in control engineering and noise reduction in communication engineering; information theory was linked to thermodynamics, as information was equated with "negative entropy"; information was interpreted as a measure of order, organization, and certainty, while entropy was associated with chaos, noise, and uncertainty; brain neurons were modeled as logical elements; and thinking was likened to computation.[55]

I will attempt a rough, but hopefully helpful distinction between these two strands of cybernetics/systems. The difference between cybernetics and systems is described as the difference between the how—how something functions—and the what, its constitution.[56] Cyberneticians strove to describe how systems

51 The weeklong Fifth International Congress for the Unity of Science began at Harvard on September 3, 1939, just two days after the start of World War II in Europe.

52 Peter Galison, "The Americanization of Unity." *DÆdalus* 127.1 (1998), 54. See also John Guttag, *The Electron and the Bit: Electrical Engineering and Computer Science at the Massachusetts Institute of Technology,* 1902-2002. (Cambridge, MA: MIT, Electrical Engineering and Computer Science Dept, 2005).

53 Some of the most well-known participants include Norbert Wiener and John von Neumann, mathematicians, anthropologists Gregory Bateson and Margaret Mead, neurophysiologist Warren McCulloch, psychologist Conrad Lorenz, and physicist Heinz von Foerster. The Macy Conferences ended in 1953, but two other ongoing conferences on "Problems of Consciousness" (1950-4) and "Neuropharmacology (1954-9) overlapped and transmitted information between shared attendants. Anthropologist Margaret Mead continued to attend, as did sociologist Talcott Parsons.

54 In his brief, yet illuminating essay, "The Cybernetics Scare and the Origins of the Internet," historian Slava Gerovitch collects the analogies used to describe the human and machine: "the body as feedback-operated servomechanism, life as an entropy-reducing device, man as an information source, human communication as transmission of encoded messages, the human brain as a logical network, and the human mind as computer," Slava Gerovitch, "The Cybernetics Scare and the Origins of the Internet," *Baltic Worlds,* Vol. II:1, (2009), 32-38.

55 Gerovitch, 32.

56 Lee, *Chronophobia*, 62-66. I thank Caroline Jones' breakdown in her essay in *A Second Modernism* for clarifying

operate by means of mathematics and engineering, drawing mostly on early neuroscience research and anti-aircraft fire control. Systems thinkers, meanwhile, retained an atomistic worldview, based on the biological sciences and vitalist analogies.[57] Systems also followed operations research, which dealt specifically with radar, pilot-firecraft integration, air-patrol resource allocation, and optimization studies. Mesmerized by the calculating power of early information processing machines, they mapped the entangled components as if physical particles, and simulated infinite variations to extrapolate larger patterns.[58] Within the discourse of management and organization, aspects of each would come to be defined within the greater system of knowledge production and evaluation named "systems analysis."

In 1948, cybernetics' figurehead, Norbert Wiener, was able to receive declassification of his work from the military, allowing him to publish *Cybernetics, or the Control and Communication of the Animal and Machine*, in 1948.[59] The second edition, *The Human Use of Human Beings*, published in 1950, and revised in 1954, was much less technical and scientific, aimed towards a non-scientific public. Wiener's book not only established the popular definition of cybernetics as the theory of communication and control between man and machine, it proposed that both could be analyzed by the same means in the terms provided by communications engineering. Society, he suggested, can only be understood as the exchange of messages between any combination of man and machine—between people, between machines, or a combination thereof. Here too, Wiener reinforced the idea of "feedback" as a regulating mechanism that contains the "tendency to disorder" by means of adjusting individual parts towards specific purposive ends; this point of individual adjustment is reiterated in Simon's book.[60]

and initiating this distinction.

57 Jones, 527-531, 531 fn. 64.

58 Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Applications*. (New York: G. Braziller, 1969), 49; as Cited in Lee, 322, fn. 67.

59 Warren Weaver lifted the classified status of this research, allowing Wiener to publish ahead of others.

60 Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society*, (Garden City, NY: Doubleday, 1954), 27. Wiener also established two descriptions of chaos—between entropic and negentropic—passive and active resistance; describing nature as passive, and the individual as active. Additionally, the description of the individual as a pattern, led to a further distinction that information on individuals, like patterns, could be transmitted, modified, and duplicated. Other pivotal texts within cybernetics include William Ross Ashby's *Introduction to Cybernetics* (Chapman & Hall, London: 1956).

Recalling Herbert Simon's distinctions of the inner and outer, cyberneticians claimed it unnecessary to know the actual components of the system. Rather, their organization and relationship between one another was enough to understand how components would function. The trans-disciplinary, "content-free" model also stipulated they the components would not be delimited by existing disciplines or distinctions, such as physical, ecological, or psychological. It is in this light that cybernetics can be better understood within the context of the fluctuating social sciences in the post-war period. Cybernetics occupied a parasitical and liminal position, being between, while occupying a part of all the social sciences—the electronic, the communicative, the psychological, and the mechanic—between theories of information, automation, calculation, and programming, regulation and productivity, political economy and sociology, and physiology and psychology. The common denominator of mathematics provided the means to understand the relation between an object and its environment within each of these fields of the social sciences.

Beyond the computational and instrumental discussions of cybernetics, or better stated, beneath these discussions, lay a broad faith that these scientific inquiries would reveal something distinct—some universal, hidden, "epistemic design," structures of perception that are distinguishably human. The scope of understanding than broadens beyond specific military purposiveness and back into a much longer history of a "science of society," that was already distorted much prior to the Cold War moment.[61] Within the mentality of social science, the science of society was to help understand the relationship between an individual's capacity to choose and reason within the bounds of freedom and constraint. [62]

Viewed from the lens of someone like Simon, the economist, psychologist, and author of The Sciences of the Artificial, this science could understand and represent the bounds of human reason with the underlying premise of enlarging its role. Simon's solutions—"Logical Theorist," "General Problem Solver"—

61 See Mark Solovey, and Hamilton Cravens, *Cold War Social Science: Knowledge Production, Liberal Democracy, and Human Nature* (New York: Palgrave Macmillan, 2012).

62 Auguste Comte's "science of society" placed sociology as the bearer of all—it was the most complex science. Emile Durkheim, too, sought to make sociology a true science by establishing veritable facts; the sociologist would have to "assume the state of mind of physicists, chemists, and physiologists," in order to not make shallow assumptions that "unlike the natural world, seemed immediately clear to the mind." Cited in Haney, 22.

attempted to break down reasoning into its most minute parts to be calculated, modeled, and simulated. Simulation allowed for the construction of a "history"; it could inscribe each step within the analysis of a problem in the computer's "memory," and retrieve these steps as necessary to extrapolate a theory. Simon was not alone in this endeavor, and in its multiple variations it falls within the broader field of "systems science," or "systems analysis."

Returning to Simon's definition of behavior between an inner and outer environment, he reveals economics to best illustrate the interaction between the two, the impetus alignment being legible through Simon's explication of economic rationality, or one's "adaptive artifice." The logic or imperative to action is based on a maximization of the utility function. As the driving factor of economics and economic purpose, both in the immediate post-war, and thereafter, was a form of resource allocation—whether that be wealth distribution amongst classes in the US, or the distribution of resources at large, "it is the task of rationality to allocate them."[63] The "performance" of this task became the principal concern of economics, and could be maximized at three levels: that of the individual actor, the market, and the entire economy. "At all these levels the outer environment is defined by available technologies and by the behavior or other economic actors, other markets, or other economies. The inner environment is defined by the system's goals and by its capabilities for rational, adaptive behavior."[64]

The interface is drawn at the "skin of the directing entrepreneur," and as performance exists at the function of the alignment between interior and exterior, it is the entrepreneur, or the economic actor that is responsible for best exercising this relationship in maximizing profit between the brain and the factory. Economic functions fully define both of these entities, as "the goal (profit maximization) fully defines the firm's inner environment; the cost and revenue curves define the outer environment to which it must adapt."[65]

63 Simon, 31.

64 Ibid.

65 Simon, 32. Also cited in Arindam Dutta, "Architecture's A Priori, Architecture's Priorities," *A Second Modernism*, 25.

And to reiterate, one need only knowledge of the exterior and the goal to be able to predict the behavior of the system.

By the 1960s, however, these methods, too, came under questioning. Within the cybernetic debate, this marked the shift from "first-order" to "second-order" cybernetics, which re-evaluated the position of the observer within the system. While "first-order" cybernetics positioned the subject outside of the system, and thus able to observe or control it, "second-order" cybernetics acknowledged the observer's participation in constructing and delimiting the system under study.[66]

The reception of cybernetics was also bound by Wiener's post-war refutation to participate in military-funded research. In the December 1946 issue of the *Atlantic Monthly*, Wiener addressed the position of the scientist in making research available to government bodies: "to provide scientific information is not a necessarily innocent act, and may entail the gravest consequences... The interchange of ideas...must of course receive certain limitations when the scientist becomes an arbiter of life and death."[67] Wiener reasoned his fellow scientists to follow suit. The final chapter of *Cybernetics*, too, expresses Wiener's hesitation to transfer knowledge from research on natural or technological processes to social issues. But in this case, the problem, was not an ethical dilemma, but rather a technical one: with existing tools and techniques, scientists would always have to deal with the imperfections and inadequacies of data.[68]

66 Within this larger reflexive moment, Thomas Kuhn's *Structure of Scientific Revolutions* was published in 1962, arguing that the structure of science lay in "paradigms" of normal science and quick moments of upheaval.

67 Norbert Wiener, "A Scientist Rebels," *Atlantic Monthly*, Dec. 1946; reprinted in *Bulletin of Atomic Scientists*, Jan. 1947, 31. Accessed http://books.google.com/books?id=6gsAAAAAMBAJ&lpg=PA1&rview=1&pg=PA31#v=onepage&q&f=false In his autobiography, *I Am a Mathematician*, Wiener writes of when he learned of the bombing of Hiroshima: "I was startled, but nor surprised...I had been clinging to the hope that at the last minute something in the atomic bomb would fail to work...I had already reflected considerably...on the meaning to society...to live under the shadow of the threat of limitless destruction," in "Moral Reflections of a Mathematician," *Bulletin*, Feb. 1956, 53-57. Accessed http://books.google.com/books?id=CwoAAAAAMBAJ&lpg=PA53&dq=norbert%20wiener&pg=PA53#v=onepage&q=norbert%20wiener&f=false, 1 May 2013.

68 See Reinhold Martin, "The Organizational Complex: Cybernetics, Space Discourse," *Assemblage* No. 37 December 1998, 102.

Symbol Systems

Alongside Wiener's Cybernetics, MIT electrical engineer Claude Shannon published "The Mathematical Theory of Communication."[69] Shannon's work provided the technical definition of a "communication system" as constructed of an information source, a transmitter, a receiver, and a destination. The fundamental problem posed by Shannon was that of reproducing "at one point either exactly or approximately a message selected at another point." The semantic aspects were irrelevant to the engineering problem; the most significant aspect was that the actual message was one that was selected from a larger set of possible messages. The system, Shannon concludes, has to be designed to operate for each possible selection and for all possible "unknowns" that could be determined at the time of design.[70]

This would later be re-articulated as within Simon's science of the artificial; Simon wrote that inherent to a natural history of the computer would be a natural history of its language—of symbol systems, or information-processing systems, and how they make decisions. "Symbol systems," writes Simon, "are almost the quintessential artifacts, for adaptivity to an environment is their whole raison d'etre. They are goal-seeking, information-processing systems, usually enlisted in the service of larger systems in which they are incorporated."[71] Symbols structures can, and commonly do, serve as internal representations or mental images of the environments to which the symbol system is seeking to adapt. Simon also seems to describe symbols systems as physical thing, real-world devices, "fabricated of glass and metal (computers) or flesh and blood (brains),"[72] not as disembodied systems of mathematics and abstract logic.

Communication was defined by the receiver possessing a "filing cabinet of prefabricated representations;" the receiver's job was to select from an "ensemble of possibilities" that had already been foreseen and decided upon by the sender of message. The role of the receiver was thus not a "constructional, but a selective operation," positioning an entity's ability and judgment in making the selection the point of

69 Claude E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27 (3), (July/October 1958), 379–423. This was later published as a book in 1959.

70 Shannon, "A Mathematical Theory of Communication," 379.

71 Simon, fn. 22.

72 Simon, 22.

scientific inquiry.[73] Repositioning the definition of judgment as that which takes place amongst a number of predetermined outcomes, Simon proposed that these selections, or reactions, were enough to understand the structure of one's behavior.

It is this concatenation of steps and actions, and several displaced metaphors occurring in several places by the late 1950s that secured "intelligence" as something that could be computationally defined and measured by binary choices. Following early cybernetics work, intelligence is thus defined as the ability for any entity to store, process, and selected any number of symbol systems—the more complex the storage device, the more intelligent the entity. Simon's work in behavioral science, combining computer science and individual action secured the idea of a brain as its own self-seeking reward economy that could be tested and analyzed. In claiming that the symbols systems are physical entities, Simon could also attempt to empirically prove his hypothesis—first, by constructing programs that are capable of "intelligent action," and second, by collecting data on human thinking that "tend to show that the human brain operates as a symbol system."[74]

This perhaps sheds more light on the neurophysiological claims of some of the cyberneticians and their relationship to the artifacts of the laboratory. Walter McCulloch and Walter Pitts, for example, built a physical model of their understanding of the brain. They claimed that this allowed the mental activity of the brain to be observable, and furthermore, knowable. If early cybernetics focused on the mental-physiological connections by means of feedback, the model of the mind opened new territory for the study of behavior—not as a single "function" and response, but as a historical database based on an accumulation of choices.

By the 1960s, the block diagram and the image of the algorithmic structure seemed to proliferate in fields far outside that of computation. Flow charts and feedback cycles "strikingly similar to the logic diagrams of a computer's architecture proliferated," not only in schools of industrial administration, business, behavioral science, but also in architecture and art. While some work seemed to mimic or tie itself to the

73 Donald MacKay in Claus Pias and Heinz Von Foerster. "Eight Conference on Cybernetics." *Cybernetics: The Macy-Conferences 1946-1953*, (1 Aufl. Zürich: Diaphanes, 2003), 481.

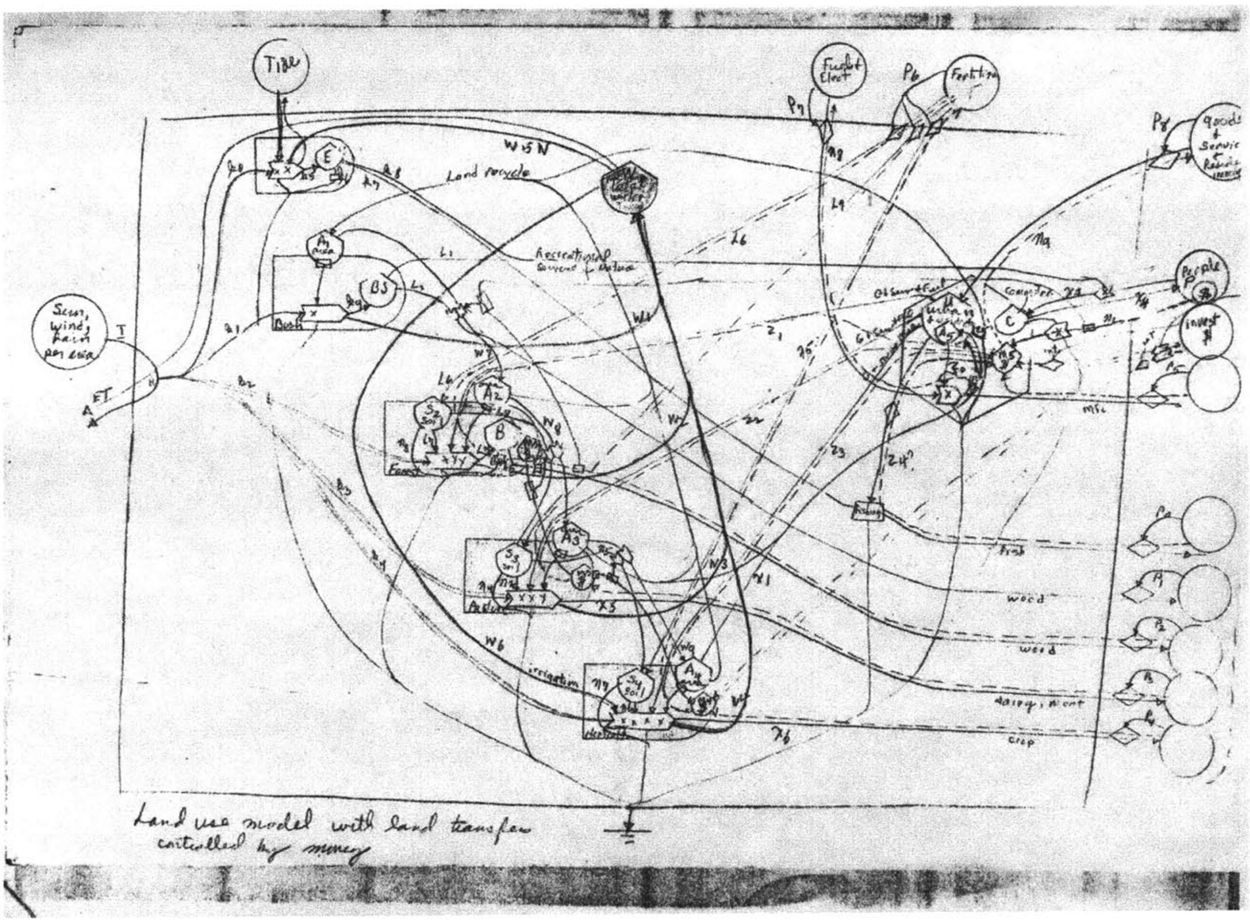
74 Simon, 23.

actual structures of the computer, most simply adopted its image as way to present work as systematic, and scientific.[75]

The diagram itself assumed a sort of systematicity and façade of scientific representation, that when adopted by architecture became the visual argument for a sort of scientism. In her essay "Envisioning Capital: Political Economy on Display," historian Susan Buck-Morss describes the necessary perceptual process of representational mapping that enables one to "see" an invented, scientific object, such as the economy. She writes, "[t]his is a doubling, but with a difference; the map shifts the point of view so that viewers can see the whole as if from the outside, in a way that allows them, from a specific position inside, to find their bearings."[76] Buck-Morss is describing the shifting representations of the economy; representations that at once invented and gave agency to a non-empirical object.

75 Lobsinger, 652-6.

76 Susan Buck-Morss, "Envisioning Capital: Political Economy on Display," *Critical Inquiry Vol.21 No.2, (1994/5), 440.*



Howard T. Odum, "Land use model with land transfer controlled by money," n.d. George F. Smathers Libraries, University of Florida Archives

2. Environment, Power, Society: the Odum Brothers and "Systems Ecology"

The post-war epistemological shift towards systems thinking also extended to natural systems, specifically in mapping the impact of society and industrial production on natural systems. While the post-war "Age of Ecology," remarks Donald Worster, began with a "dazzling fireball of light and a swelling mushroom cloud of radioactive gases;" "systems ecology," too, was launched while concurrently infusing the landscape with radioactive materials.[77]

Systems ecology marked the application of cybernetic and systems thinking onto the description of natural systems, or ecosystems. Its credited founders, Howard T. Odum, and his older brother Eugene, came from different academic backgrounds—one from biogeochemistry, tracing the cycles of metal elements through the ground, the other from ornithology. In 1954, their specializations coincided upon their hiring by the Atomic Energy Commission (AEC) to study the effects of radiation in landscapes spanning from the Eniwetok Atoll atomic bomb site in the Marshall Islands, and in the early 1960s, the El Verde Rainforest in Puerto Rico.[78]

For Howard Odum, at least, this "systems" inquiry was already present in his dissertation on the metal element Strontium under the supervision of ecologist G. Evelyn Hutchinson.[79] Hutchinson participated in the Macy Conferences, and Odum references the work of Norbert Wiener and Ludwig von Bertalanffy on systems theory in his dissertation to explain the cycling of this element through the ground. In adopting the prevailing model of systems analysis, ecology promised the same scientific systematicity as well as easy comparison between diverse parts.[80]

77 Daniel Worster is most often quoted with the birthdate for ecology: In *Nature's Economy*, he writes: "The Age of Ecology began on the desert outside Alamogordo, New Mexico on July 16, 1945, with a dazzling fireball of light and a swelling mushroom cloud of radioactive gases." Donald Worster, *Nature's Economy: A History of Ecological Ideas*, (Cambridge: Cambridge University Press, 1994), 342.

78 Nancy G. Slack, *G. Evelyn Hutchinson and the Invention of Modern Ecology* (New Haven; London: Yale University Press, 2010), 167.

79 G. Evelyn Hutchinson, was a well-known ecologist, and was one of the first to obtain radioisotopes for ecological experiments after the war. Hutchinson was a consultant to Brookhaven Laboratory.

80 To preface the rest of the chapter, Odum defines an ecosystem as a model constituted by 5 major components:

While many ecologists took on systems as a premise for exactitude in measurement and calculation, Odum is particularly interesting for the purposes of this discussion in that his work stretches to the extremes of systems ecology. Supported by funding from the Atomic Energy Commission, and working with research institutions and landscapes of the American south, Odum's work was praised and adopted by his fellow scientists. Following the language of systems, Odum positioned himself between biology, chemistry, geology, and meteorology. By the time he moved to the University of Florida in 1970, he refused to join the faculty unless ecology was instituted as its own major, and he, his own research center.[81] While at his past two institutions he straddled multiple departments, it was the establishment of a devoted research center that supported the proliferation of his work through secured funding and research.[82]

The brothers published their first joint textbook, *The Fundamentals of Ecology*, in 1953, and Howard Odum wrote prolifically from then on. In 1971, Odum published *Environment, Power, and Society*. This text can be read as a treatise for systems ecology; it is a comprehensive account of the application of his processes from the initial analogue descriptions of ecosystems to an increasingly abstracted exercise in the analysis and synthesis of socio-political models, ranging from typically comprehensible scale of voting systems to that of the decline of civilizations. Written in 1968, yet not published until March 1971, the book was a comprehensive culmination of research developing a pictorial symbolic language to represent his models of

the properties, or state variables; the forces, or any outside energy source; flow pathways, the lines that indicate energy and material transfer and connect properties to each other; interactions, which modify, amplify, or control flows, and feedback loops, which influence "upstream" components or flows. The properties or state variables are the entities enclosed with a box, which can be considered as identified groups. The forces, are the properties that exist outside of the system, and as Odum writes "drives" the system. The "energy source," is typically the sun. The flow pathways here are drawn as solid, curved lines that connect the various groupings or properties. The "interactions" are elements within the circuit that allow for control of the matter moving through the flow pathways, for example, controlling the force at which something moves from A to B. The interactions, depicted as deformed rectangle, show the forces that move into, are transformed and/or stored, and exit out. Finally, the feedback loops are "backward cycles," which feed processed material back into a previous process.

81 Center for Wetlands was established with a $1 million grant from the Rockefeller Foundation and the National Science Foundation. Howard T. Odum, in interview with Cynthia Barnett, December 13, 2001, 22. Oral History, George Smathers Libraries, University of Florida Archives and Special Collections.

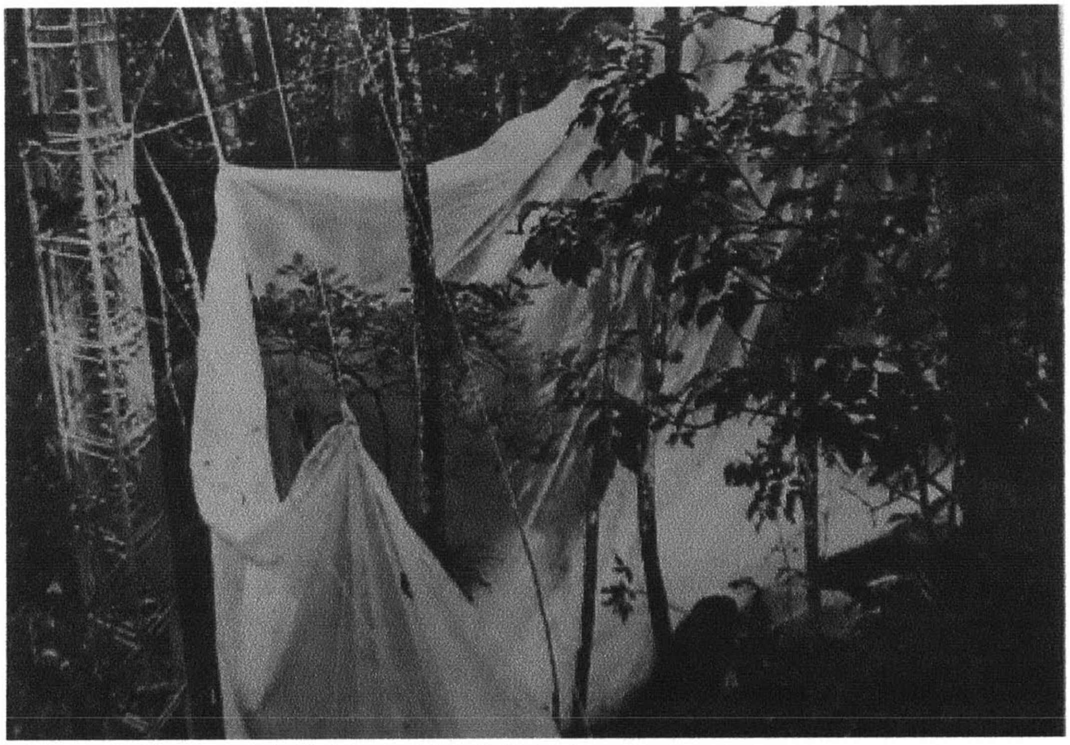
82 At the University of Carolina, Chapel Hill, Odum was part of Botany, Zoology, and Environmental Science and Engineering departments. "I learned from being interdepartmental that no one chairman would back you. So when I came to Florida, when they asked me if I wanted to be jointly appointed in other departments that I had once been a part of, like biology, I said no." Odum joined the Department of Environmental Engineering Sciences. Ibid., 26.

ecosystems—charting the flows of fuel, matter, materials, wastes, and metabolic processes of photosynthesis and respiration. Power, defined by the flow of energy, was the common denominator by which to equate all processes and materials. Such diagrams of various geometric shapes and snaking lines that begins this section suffuse the pages of the book, becoming progressively complex, and increasingly perplexing to its reader.

While this description still renders the book as a typical ecology text of the time, its most curious diagrams lay towards the end of the book. While at first Odum's abstractions followed his belief that economic, political, and social power flows are as equally measurable as those of the physical and chemical world, nearing the final chapters, the reader witnesses Odum at his evangelizing best. A chapter entitled "An Energetic Basis for Religion" is exemplary of Odum's totalizing vision, yet was perpetuated by a certain institutional context that allowed Odum the space, the funding and the research. As such, *Environment, Power, and Society* is peculiar source in that it was intended to be a textbook for undergraduate students in human ecology. The text was neither banished nor Odum barred, and remains a fascinating revelation into what could be considered top-funded and coveted research of the time. While these chapters seem easily outlandish to today's reader, this section attempts to broaden the development of systems ecology and Odum's work in explicating how the "environment" and natural systems were imbricated with systems thinking, and thereby translatable to any phenomena.

The use of the language of block and feedback diagrams in mapping the ecosystem marks the inheritance from electrical engineering methods and the profound effect on the ecologists in understanding and perceiving their definitions of the ecosystem—as Odum once described, "the electronic technician's nightmare," for all the perfectly assembled wires had been taken apart and re-assembled with no instruction manual for its correction. Thus, the section begins by examining the hieroglyphic language used to translate measurements to models, physical circuits to two-dimensional drawings, and energy language to the computer, and vice versa. As Howard T. Odum described the process, this translation was just "like changing English into Spanish which mainly require[d] someone to know the equivalent words."[83]

83 Howard T. Odum, *Environment, Power, and Society,* (New York: Wiley-Interscience, 1970), 267.



Polyethylene enclosure, from Howard T. Odum, *The Rain Forest Project: Renewal Proposal: Work in Progress, Scientific Results, and Proposals for FY-65 and FY-66*. Rio Piedras: Puerto Rico Nuclear Center, 1964.

Atomic Energy Commission

For Odum to construct *Environment, Power, and Society,* he had look at nature and society in a specific way. In 1951, when he completed his dissertation under ecologist G. Evelyn Hutchinson, he already viewed nature as something subject to measurement, and increasingly so, subject to his categorizations and ordering within the constraints of systems and the artifacts used to model them. This view was at least partially fostered by his radiation studies for the Atomic Energy Commission (AEC). As the instantaneous destruction and vast fallout of the atomic bomb triggered a growing fear, in civilians and politicians alike, as to the enduring effects of radiation, the AEC launched a number of national laboratories and field sites for radiation research.[84]

In modeling the relations and dynamics of ecosystems, the integrative science of ecology provided a methodology for the descriptive analysis of an environment, gaining funding and support from the AEC. Howard Odum's older brother, Eugene, began research for the AEC in 1951. Recalling Worster's claim to the rise of ecology, Eugene, too, acknowledged this relationship: "the exploitation of atomic energy was responsible for ecology's rise to a front-line position."[85] Positioned at the Savannah River Plant, Eugene Odum studied the "ecological inventories" of the Savannah River.[86] Following the input-model of information channels, ecological research entailed using radioactive tracers to study the cycle of contamination—from

84 The National Laboratories at Oak Ridge in Tennessee and Brookhaven in New York were the two central laboratories. The Atomic Energy Commission was established shortly after World War II. President Harry S. Truman signed the McMahon/Atomic Energy Act on August 1, 1946. Due to criticisms of its regulatory programs, the commission was dismantled in 1974; its functions were reassigned to the Energy Research and Development Administration and Nuclear Regulatory Commission. The AEC was granted complete power over regulation on nuclear science and technology, as well as technology transfer and knowledge exchange between the US and other countries. The paradox lay in security interests: while the commission was technically under "civilian" control, all the production facilities were government owned. The commission was also placed in charge of nuclear development, taking over the work of the wartime Manhattan project, in the development of Los Alamos Scientific Laboratory, Livermore National Laboratory, and the testing grounds of Nevada Test Site. See Joel Bartholemew Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology,* New Brunswick, NJ: Rutgers University Press, 1992.

85 Cited in Slack, *G. Evelyn Hutchinson and the Invention of Modern Ecology*, 166. Slack documents how "health physics," first examined the effects or radioactive substances on human and other organisms, was turned into "radiation ecology" by Stanley Auerbach and others at the Commission.

86 The early logo for the Savannah River Site project is that of the structure of the atom—the Savannah River Ecology Laboratory (SREL) at the nucleus of mathematics, rivers and fishery, forestry, and chemistry. See S. Kirsch, "Ecologists and the Experimental Landscape: The Nature of Science at the US Department of Energy's Savannah River Site," *Cultural Geographies, Vol.14 No. 4, 2007, 485-510.*

the injection of the tracer, to its presumed exit. Inventories denoted taking "stock" of all of the identified components of an ecosystem; the inventory was meant to provide an accurate picture of the relationships between an ecosystem's constituent parts as measured against the time necessary for the radioactive elements to filter through the site. Yet this system required a perception of the site as an isolated geographic location.[87]

In isolating a site, irradiating it, and measuring the input against the expenditure within a defined spatial and temporal boundary, ecologists could account for what the believed to be all the inputs and outputs. While for communication engineers these terms denoted the entry and exit of messages traveling through vacuum channels and cables, for the ecologists, it amounted the belief that they could account and further, adjust, anything entering or exiting a defined ecosystem.

Their work in Puerto Rico is perhaps exemplary—photographs of a major research project in the El Verde Rain Forest in Puerto Rico show Odum and his team building aluminum structures to hoist a vast 10-millimeter polyethylene sheet (sewn together by hand) to "enclose" a certain portion of the forest for testing.[88] The El Verde project compendium, a mammoth of over 1000 pages, includes photographs which document the "before" and "after" stages of irradiation.[89]

An Energetic Basis for Religion

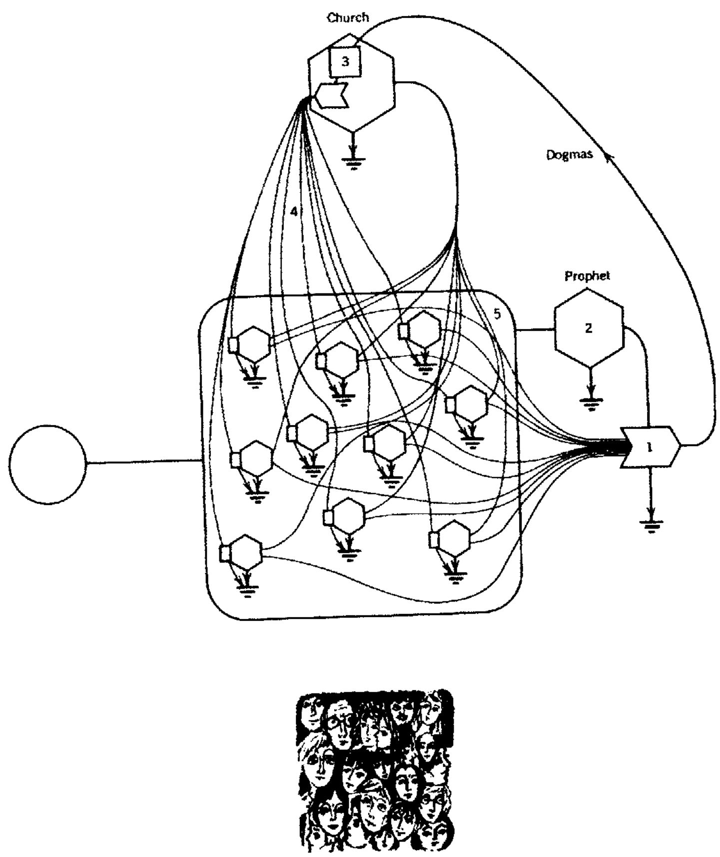
Recalling the logic of the feedback diagram, the chapter entitled "Energetic Basis for Religion" completes the idea of an individual adjustment to better fit the system at large, collapsing energetics and beliefs to make the individual commensurate with its new energetic environment. In one illustration, one large rectangular node is positioned at the center of the page, while sixteen smaller nodes are tightly packed inside. Slightly above

87 Elizabeth M. DeLoughrey, "The Myth of Isolates: Ecosystem Ecologies in the Nuclear Pacific" *Cultural Geographies Vol. 20, No. 2, 2013, 167-184.*

88 The project to study the forest metabolism began in the spring of 1964. The first plastic used, the polyethylene both damaged the support towers. In 1965, during another run of the test, the polyethylene failed, prompting them to buy a more expensive plastic in 1966.

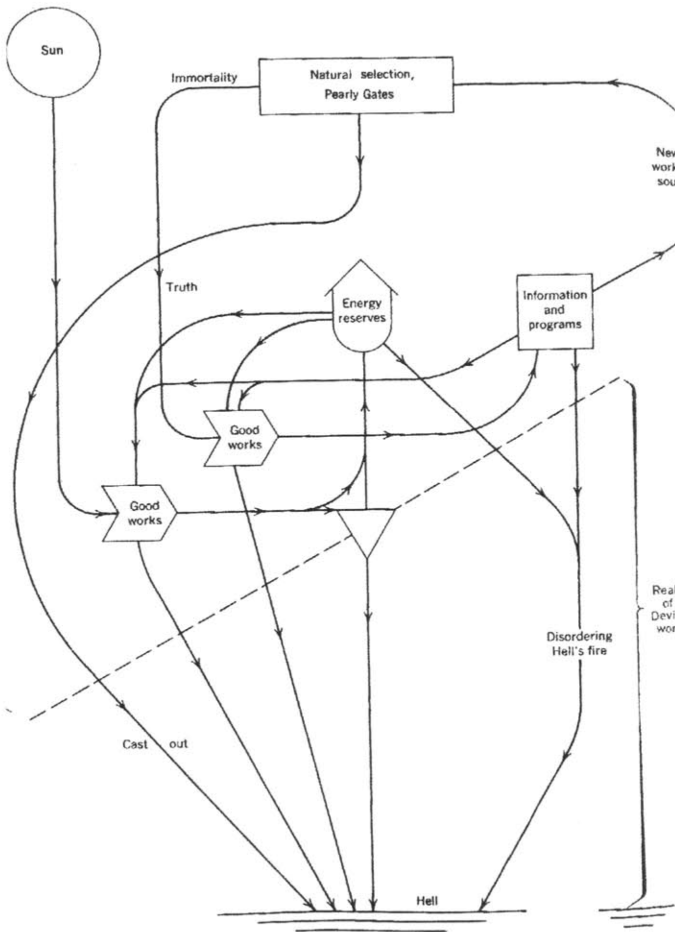
89 See Howard T, Odum, and Robert F. Pigeon. *A Tropical Rain Forest: A Study of Irradiation and Ecology at El Verde, Puerto Rico.* Oak Ridge, Tenn.: Division of Technical Information, U.S. Atomic Energy Commission; [available from Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 1970, and Howard T. Odum, *The Rain Forest Project: Renewal Proposal: Work in Progress, Scientific Results, and Proposals for FY-65 and FY-66.* Rio Piedras: Puerto Rico Nuclear Center, 1964.

and to the right of this central node are drawn three additional nodes, two hexagonal, labeled "Church," and "Prophet," and the third a combinatorial shape of a rectangle and arrow pushing outward that collects the visually muddled snaking lines and forces them into single node. A single directional line labeled "Dogmas" carries the eye from this node to the "Church." The message here seems quite legible—people within a society receive and follow certain ideas symbolized by a church.



Howard T. Odum, Energy model of "religious control group for a social system," from *Environment, Power, and Society*, 240.

In another illustration, "Common abstractions of energetics and religious teachings" the rectangular nodal point "Natural Selection, Pearly Gates" is positioned at the top of an elaborate web of purposeful, yet meandering lines. Leading into this node from the right is a single-point black line with two arrows, labeled "New works, soul." Leading out from this node is a more orderly, geometric line, labeled first, as "Immortality," and slightly further down, as "Truth." At the center of this web, bifurcated by a single, dashed, straight line is an unlabeled upside-down triangle. The line divides this illustration into two halves. The labels of the two halves, the "Realm of Angelic work" at the top, and the "Realm of Devil's works" at the bottom, bewilder the viewer. Focusing towards the bottom of the drawing, to the "Realm of Devil's works," the viewer sees the arrows of five of these lines vigorously forced downwards. Things considered to be "Cast out" or "Disordering Hell's fire" lead towards "Hell."



"Common abstractions of energetics and religious teachings showing angelic operations of order, evolution, and selection of information above and the evil processes of disorder, dissipation, and heat death below." Odum, *Environment, Power, and Society*, 241.

Odum provides a vivid explanation for these diagrams: these illustrations show "the angelic operations of order, evolution, and selection of information above and the evil processes of disorder, dissipation, and heat death below."[90] Equating the energy system with the omniscient powers, he writes:

> We can teach the energy truths through general science in the schools and teach the love of system and its requirements of us in the changing churches... The classical struggle between order and disorder, between angels and devils is still with us.[91]

90 Odum, *EPS, 252.*

91 Ibid., 243.

Odum repeats this again in 1977: "Order is often associated with angelic ideals and assigned high value... Disorder is sometimes associated with the devil or other representation of the random hot, and the unorganized."[92] A metabolic ideal, he reduces the complexities of all life to these oppositional binaries, only serving to reinforce in his readers the problematic dualism of nature and humanity, as if not mutually constituted. To institute these "energy truths," Odum presents to his readers the "Ten Commandments of the Energy Ethic for Survival of Man in Nature;" they are intended to incite a new value system based on these metabolic processes, one that correlates to the radical ecology beliefs in the "rights of nature."

Odum prefaces the commandments: "With the aim of relating the ethics of energy to modern needs, the properties are given in the form of commandments. Perhaps statements such as these can hasten the evolution of relevant religious dogma... In Table 8-1 are listed some properties that have generated loop reinforcement in the past, thus continuing themselves as network features of surviving religions."[93] These principles follow the same logic as earlier diagrams—the main goal is to generate actions that will effectively and certainly provide a "feedback loop," or action back into the system in order to allow it grow and prosper.[94]

Table 8-1 Ten Commandments of the Energy Ethic for Survival of Man in Nature

1. Thou shall not waste potential energy.

2. Thou shall know what is right by its part in survival of thy system.

3. Thou shall do unto others as best benefits the energy flows of thy system.

4. Thou shall revel in thy systems work rejoicing in happiness that only finds thee in this good service.

5. Thou shall treasure the other life of thy natural system as thine own, for only together shall thee all survive.

6. Thou shall judge value by the energies spent, the energies stored, and the energy flow which is possible, turning not to the incomplete measure of money.

7. Thou shall not unnecessarily cultivate high power, for error, destruction, noise, and excess vigilance are its evil wastes.

8. Thou shall not take from man or nature without returning service of equal value, for only then are thee one.

92 Ibid., 114.

93 Ibid., *244*.

94 In an interview in 2001, Odum remarked: "My fundamental ethic is that people should make a contribution to the larger system."

> 9. Thou shall treasure thy heritage of information, and the uniqueness of thy good works and complex roles will thy system reap that which is new and immortal in thee.
>
> 10. Thou must find in thy religion, stability over growth, organization over competition, diversity over uniformity, system over self, and survival process over individual peace.[95]

Here "system over self, and survival" completes the idea of an individual adjustment to better fit the system at large, collapsing energetics and beliefs to make the individual commensurate with its new energetic environment. The commandments are exemplary of how the techniques of systems quickly escalate to a model of mind, from promises of rational decisions and individual choice, to a directed mandate, prescribing how one should act, while establishing a hierarchy to govern who is allowed to act, and in what capacity.

In a single passage, Odum manages to evoke the image of himself as prophet, writing the commandments upon two tables stone, hearing only a voice that commanded him to perform this task. In an interview conducted one year before his death, Odum remarked: "We know that people are not going to switch from what they learned until everyone does, when the switch is forced on people."[96] This statement suggests that the enforcement of these commandments would be a way to convert Odum's ecology into a belief system.[97] The commandments allow Odum to engage an existing set of values, ones easier to be adopted that pretends to be in harmony with the scientific limits.

Reflecting on the public perception of scientists, he asks, "Why do some inhabitants of the church pulpits fight the new revelations simply because the temporary prophets are a million spiritually humble little people in laboratories and libraries, only vaguely aware of their role?" The "prophets" to whom Odum refers are the scientists and ecologists constructing the data, and developing his systems science. It is the specific choice of words that is most difficult—"Let us inject systems science in overdoses into the seminaries and see

95 Odum, *EPS, 244.*

96 Howard T. Odum, in interview with Cynthia Barnett, December 13, 2001, 111. Oral History, George Smathers Libraries, University of Florida Archives and Special Collections.

97 In the same interview, Odum continues to say, "you realize that you have the key (energy hierarchy concepts) to understand the earth and the universe as well, so why would you not do the best you can to get it out into society's long term memory?" "It must be nice to feel you have the key to the universe," remarks the interviewer, to which Odum replies, "People call that arrogance...so we try various ways to explain concepts." Interview, 112.

what happens," or "Why not open the church doors to the new religion and use the preadapted cathedrals and best ethics of the old to include the new?" Cathedrals here are spoken of as yet another species—as spaces that should adapt to a new view of science by the practitioners and dealers of this "systems science"—to become sites of indoctrination and conversion.

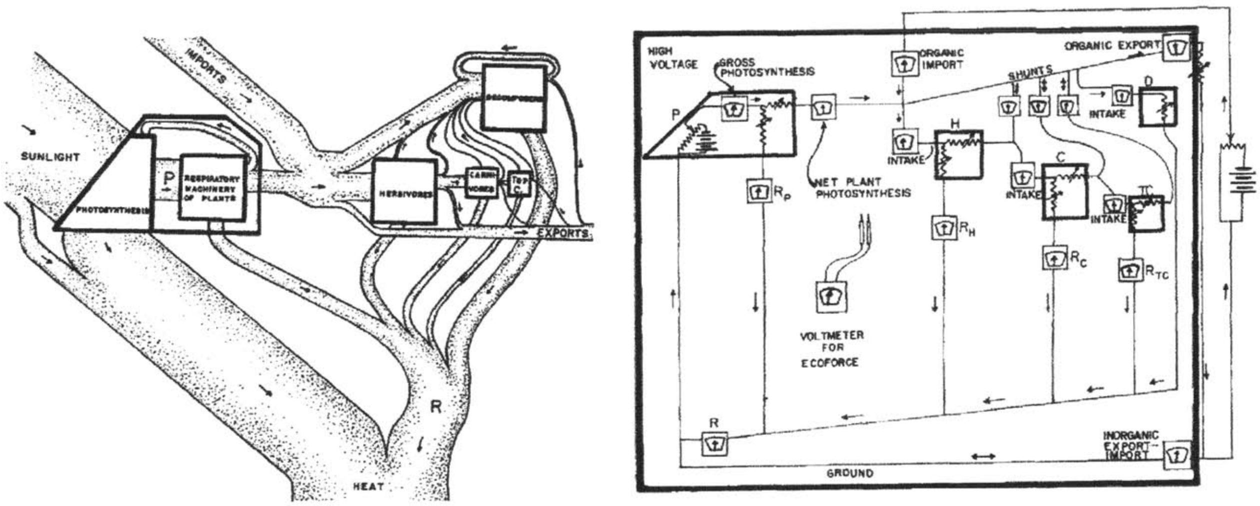
In his final plead, Odum asks for a prophet to step forward to disseminate these ideas to the millions of men, and hope to instill a "new and more powerful morality" into those that "endeavor zealously" for the new networks. He writes:

> While there is energy, we need to stimulate religious evolution. We may encourage faster religious change even now by injecting large doses of systems science into the training of religious leaders. What a glorious flood of new revelation of truth God (the essence of network) has handed man in the twentieth century through sciences and other creative endeavors… Why should we fear that deviation from rigid symbols of the old religion is deviation from morality? A new and more powerful morality may emerge through the dedication of the millions of men who have faith in the new networks and endeavor zealously for them. Prophet where art thou? [98]

As Odum's principal scholar suggests that Odum sees himself as this prophet, shedding new light and presenting what he believes will be humanity's savior. Within these bewildering chapters, Odum's system embodies its extreme radical end, one that truly envisions ensnared socio-political relationships as metabolic. Responding to societal changes in the late 1960s and early 1970s, Odum remarked that this was a pivotal time to teach by his methodology, for the "possibility of generalizing and teaching the nature of the universe in this way with relatively fewer principles is most exciting for a time when the energy to support the world's summit of knowledge may decline."[99] Everything, in this view, could, and should, be understood in energetic terms.

98 Odum, *EPS, 250.*

99 Ibid.



Howard Odum, Energy Flow Diagram of an ecosystem, 1956; and electrical analogue, 1960.

"Invisible Wires"[100]

Odum's early diagrams represent hydraulic systems, flowing rivers and estuaries, moments of condensed space producing a faster flow, and wider moments allowing for the slow, lazy flow of still water. These flow diagrams (below, left) are strictly representational; they allowed Odum to depict an observable, general phenomenon by means of a basic diagram of movement with which he was familiar—the hydraulic model.[101] Each delineated box in the drawing refers to a trophic level that corresponds to how organisms are arranged in an ecosystem to their roles of producing and consuming energy.

In the same text, Odum introduces the drawing of the electrical analogue circuit to the steady-state ecosystem (above, right), in which electrons represent the "flow" of carbon. Comparing the ecosystem to Ohm's Law, or the manner in which an electrical engineer would describe the movement of electrons through a circuit, Odum contends that an ecosystem functions in the same way.102 As with the flow diagram, denser areas increase consumption or speed up the flow of electrons, with almost no resistance, whereas slower and less dense areas tend diminish movement, and are met with high resistance.[103] The drawing of the electrical analogue, then, is based directly on the construction of a physical circuit.[104] It is also pivotal to note that

100 Howard T. Odum, *Environment, Power, & Society,* cited in Bernard C. Patten and Eugene P. Odum, "The Cybernetic Nature of Ecosystems." *American Naturalist,* 118.6 (1981), 890.

101 Howard T. Odum, "Ecological Potential And Analogue Circuits For The Ecosystem." *American Scientist* 48.1 (1960): 54A, 1-8.

102 See footnote 72 for the definition of an ecosystem.

103 This is also how an electrical engineer read and explained this diagram to me. In the drawn diagram, the battery on the right is supplying voltage, or potential force, to each of the components described by a dark outline. The small dial pictured aside each is an ammeter, measuring the current or quantity of electrons passing through the resistor at any one moment. The zigzag line, or the resistor, controls how much current is allowed to flow through, thereby producing areas of high density, like the narrow part of the river, and low density, the wide, lazy river. The line that is outside of the main circuit is the rheostat, an electrical variable resistor, which changes the amount of electricity that is exiting from the battery or the rest of the circuit, allowing for an interchange between the two. The voltage plugs at the center of the diagram could be connected to any two points within the circuit model to measure the voltage, or the "potential" at any one specific point.

104 While I did not find any photographs of Odum with a physical circuit, we can deduce from his texts as well as from several articles by past students, that Odum did in fact construct an analogue circuit to use and manipulate for various ecosystems.

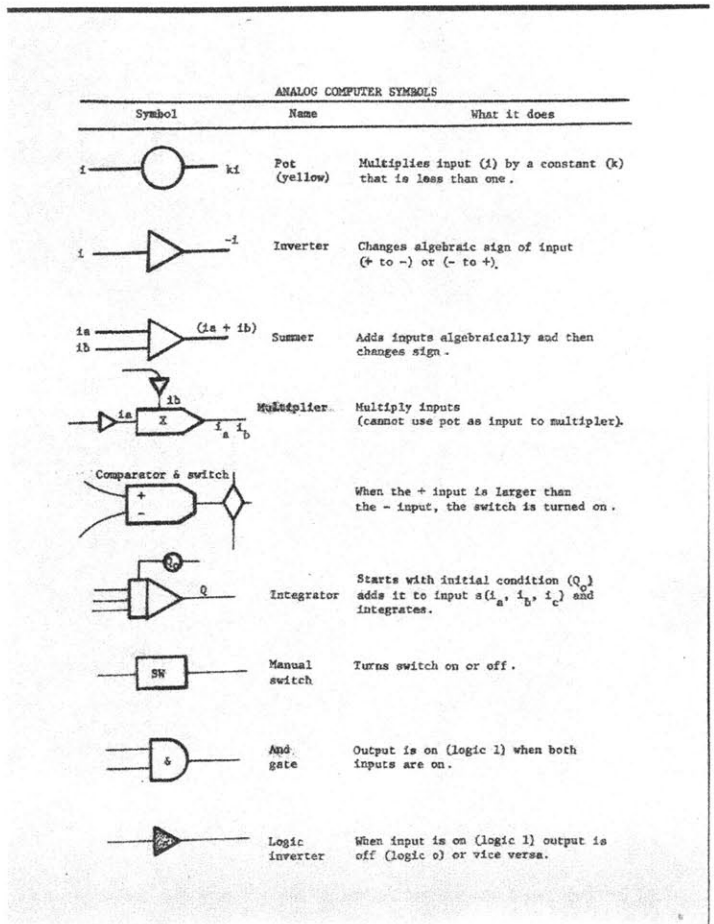
electrical circuits up until the early 1960s were not the flat, printed boards with which we are familiar. Until the invention and dissemination of the printed circuit board in the 1960s, electrical circuits were enormous physical systems, each vacuum tube and transistor an individual device to be mounted on a metal chassis, and connected by wire. Odum, as observer of his constructed system, could manipulate the resistors to adjust the flow amongst the various parts of the circuit. The whole circuit functions, with Odum's assistance, to maintain a steady state, to balance and distribute the electrons throughout the circuit. By varying and increasing change to encourage a constant redistribution of electrons, the circuit can maintain its "steady state." As Odum began to construct analog models to simulate ecosystems, he translated the hydraulic systems to mimetic electrical constructions, and finally to a universal energy language. While the flow diagrams attempted to capture a sense of movement through representational techniques, and register gravity, they did not include any mathematical components or possibilities for extracting or testing measurements. They were representational, not operational or instrumental. Odum sought a more "exact" understanding of how energy could be distributed, dissipate, and partitioned from an original source.[105]

While analog circuit models provided this exactitude, as each defined ecosystem could be translated to a manipulatable physical electrical transmission system, Odum's interpretation of the ecosystem, was by no means exact. The electrical transmission symbols themselves provide a rich site for interpretation between in the translation from the ecosystem to a circuit construction. Each newly identified part, population, relationship, or transaction required a slightly different description, and thus resulted in a collection of abstract and incredibly specific symbols. The eccentric set of glyphs developed by Odum draws from on a standard set of electrical engineering symbols.[106] The glyphs are both literal translations, such as the "Active Impedance" or the "One-Way Valve," others internalize additional meanings: a hexagon refers to "self-regulation," a dollar sign symbolizes an economic transaction.

105 Peter J. Taylor and Ann S. Blum. "Ecosystems as circuits: Diagrams and the limits of physical analogies." *Biology and Philosophy* 6 (1991): 275-94.

106 The main symbols include the following: the source, the heat sink, storage, interaction, money exchange transaction, producer, consumer, switching subsystem, cycling receptor, constant gain amplifier, and a miscellaneous symbol for subsystems.

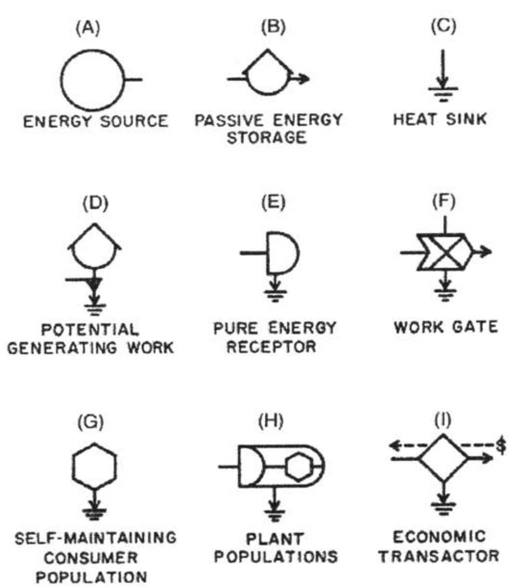
Howard T. Odum, "Analog Computer Symbols," n.d. George F. Smathers Libraries, University of Florida Archives

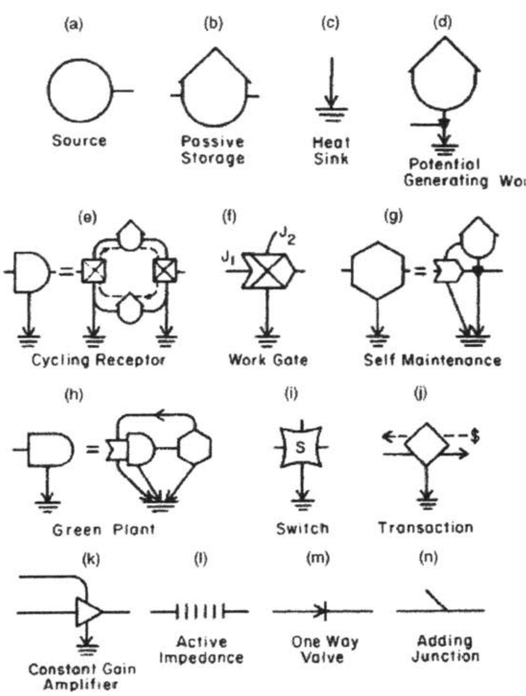


ANALOG COMPUTER SYMBOLS

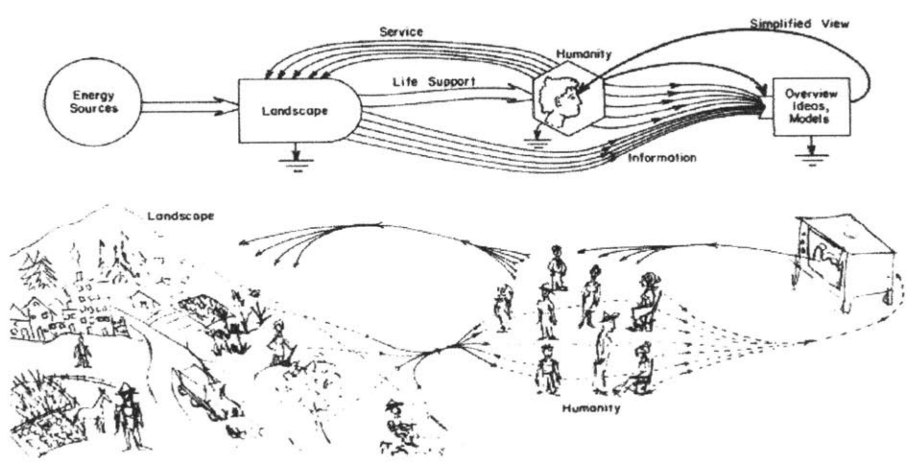
Symbol	Name	What it does
i — ki	Pot (yellow)	Multiplies input (i) by a constant (k) that is less than one.
i — -i	Inverter	Changes algebraic sign of input (+ to –) or (– to +).
ia, ib — (ia + ib)	Summer	Adds inputs algebraically and then changes sign.
ia, ib, X — $i_a i_b$	Multiplier	Multiply inputs (cannot use pot as input to multipler).
Comparator & switch (+, –)		When the + input is larger than the – input, the switch is turned on.
Q_o, Q	Integrator	Starts with initial condition (Q_o) adds it to input s(i_a, i_b, i_c) and integrates.
SW	Manual switch	Turns switch on or off.
&	And gate	Output is on (logic 1) when both inputs are on.
	Logic inverter	When input is on (logic 1) output is off (logic o) or vice versa.

Energy network symbols, and symbols of energy circuit language, 1967 and 1971, respectively.





To return to Odum's book, *Environment, Power, and Society*, we can move between his understanding of a single defined ecosystem, an enclosed forest, to read his later diagrams. Floating between sketches and network diagrams, they clearly lose their exactitude in the name of performing an idea. This diagram of the world as ecosystem, perhaps best summarizes his principles of the ideal society.



Howard T. Odum, "Analog Computer Symbols," n.d. George F. Smathers Libraries, University of Florida Archives

Humanity and Landscape, are the single elements within this constructed. They are in conversation; as we can tell that a number of bi-directional arrows indicate exchange between the two components of the system. A third unlabeled element in the sketch, is a television set; if we correlate it to the above diagram, it signifies for Odum "Overview, Ideas, and Models." To continue to compare the drawings in order to construct the diagram's message, we can deduce the following:

> Landscape provides Information to the Idea box, or which is drawn as a television. Information that is not consumed dissipates into the ground. Humanity also provides Information towards the construction of Ideas & Models. In turn for Landscapes' Life Support, Humanity must service the Landscape. The final major loop, and the only single, bold line in the drawing, is the Simplified View, that the Humanity receives by from the Television. Any part of this Simplified View which is not consumed by the self-regulated Humanity, signified by the Hexagon, is also dissipated, never to be rescued from the depths of Odum's Hell.

How can this diagram, the most general of view of society help us understand other implications for Odum's view?[107] By the 1950s, the television was transformed into a "citizen machine," seen to be transformed from

107 It might be helpful to recall Edward R. Murrow's famous address at the RTNDA Convention in Chicago, on October 15, 1958. Speaking to a full room of television employees he spoke of the responsibility inherent to their work, acknowledging that the television was a platform. If a historian would look back, Murrow stated, she would find

a debased commercial institution, to one that could prove useful as a venue for governing; specifically governing as a process of cultivation that presumes individual liberty and seeks to preserve it through the ever-evolving medium of citizenship.[108]

Selection in Odum's case means the society must reward those who bring benefit to society and punish what it deems as harmful practices. Specifically pushing towards the idea of what he believes to be a communities' remarkable powers of "self-design" and "self-regulation" he structures his arguments equally as when discussing a lake organism and an entire society without discussing the ongoing social and civic unrest occurring at the exact same moment across the United States. In using such analogies, cities, organisms, and civilizations, in Odum's view, were not as out-of-control as they appeared. Characterized by "natural laws of self-organization," a belief that each place would return to a homeostatic state, the determination of the state could now turn to "coordinating physical, economic, and social programs and rationalizing citizen participation."[109]

In Odum's models, each ecosystem is an ideal society—purely calculable and predictable—and based on classic economic ideals, in which each individual must form a "reward loop" in society's network. The means by which one earns recompense is not of significance, whether that be "seeding and weeding the soil in order to grow daily bread or by robbing..."[110] His methods of "information selection," analogous to messages attempting to only read the signal within the noise and trash anything not absolutely vital to the survival of the system or to the reading of the message is dispensed.

While the Odums' work bridges the links between human and non-human, and develops a way of thinking that includes the history of the object and its origins and involvements, it at the same time

"evidence of decadence, escapism and insulation from the realities of the world in which we live... television...insulates us from the realities of the world in which we live...this powerful instrument of communication to insulate the citizenry from hard and demanding realities. The instrument can teach, it can illuminate; But it can do so only to the extent that humans are determined to use it to those ends. Otherwise it is merely wires and lights in a box. The weapon of television could be useful." For Murrow, this was to be a weapon against "ignorance, intolerance, and indifference."

108 The Citizen Machine

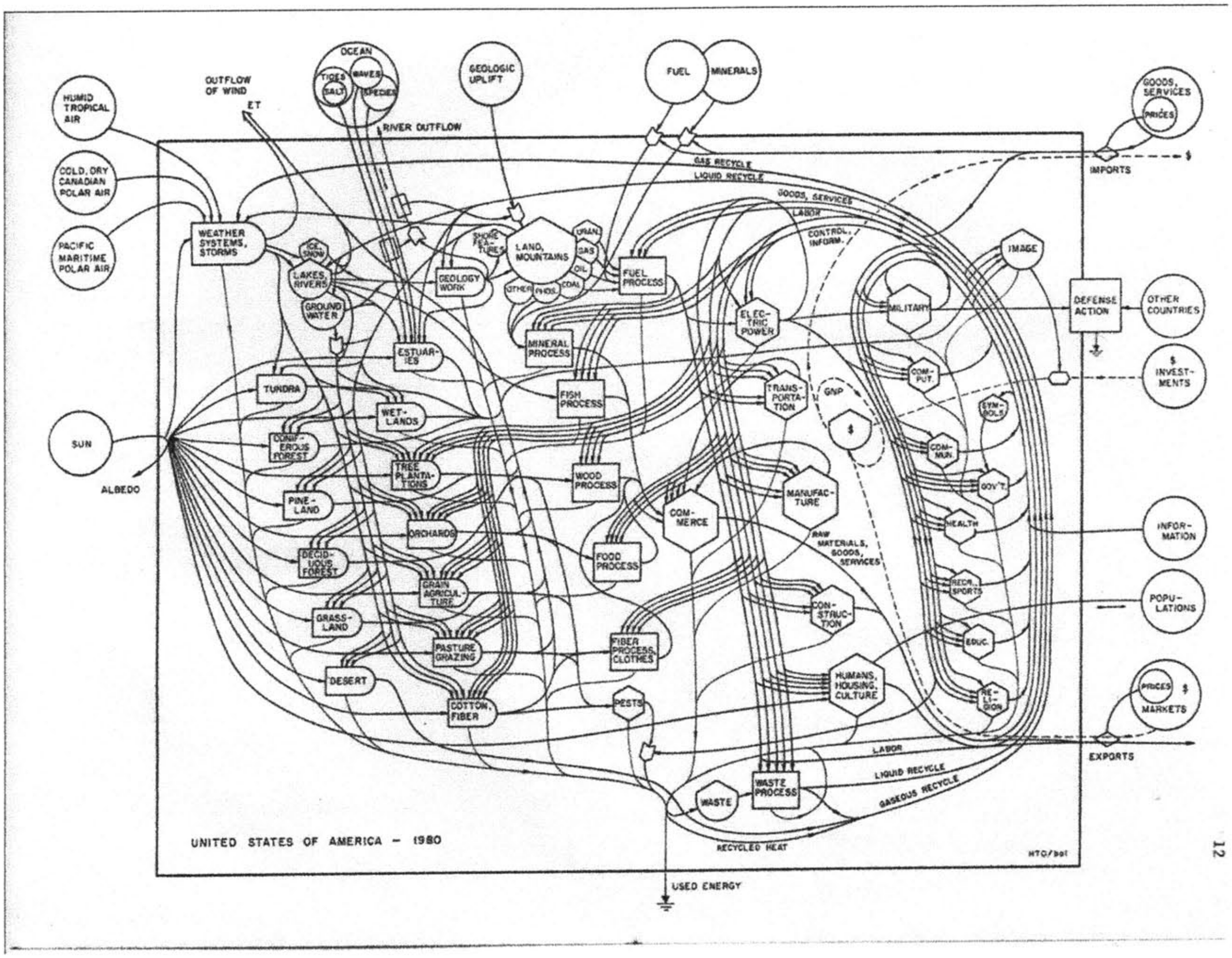
109 Jennifer Light, "Taking Games Seriously," Technology and Culture April 2008 Vol. 49, 351.

110 Egbert G. Leigh Jr. "The Energy Ethic." *Science 172.3984 (1971a): 664-6. Print.*

becomes ideology, as its abstracted state begins to be used to analyze a heterogeneous list of subjects. He presents his application of an universal energy language that is capable of all things: to capture and solve the contemporaneous crisis of population, resources, and environmental destruction; to unify the disciplines of economics, law, religion thereby eliminating the complexity of the world; create archetypes of systems; orient the world towards a General Systems Theory; and to apply this language at all possible scales of intervention, from biochemical interactions to the biosphere. As he pronounces, his studies "to consider the great problems of power, pollution, population, food, and war free from our fetters of indoctrination," and his teachings should be utilized in newly developed undergraduate courses in human ecology.

In his struggle to find a method to optimize efficiency and retain maximum power output, Odum focuses his attention on transforming dissipated energy into useful work, because for Odum, "[t]here can be no question that the system generating the most useful work is the desirable one and the one that will ultimately predominate."[111] When he begins to model civilizations and theories of history, he turns his attention to the energetic expenditures of a society to determine its success and reason for decline. The Roman Empire fell because it did not properly distribute the power from the input source of the sun. What turns out to be of most significance to him is how this harnessed energy can be systematically controlled and distributed—specifically the feedback loops by which "free energy" is channeled into "useful work." In other words, the potential of a culture lies in its efficient ability to channel thermodynamic state to a specific end or purpose. Instead of stressing competition amongst system components, Odum stresses the incentives capitalism provides for contribution of "useful work." Welfare for example, by his understanding, would not guarantee a feedback loop of useful work back into the system diagram, as these individuals are incapable. This is the act of dissipation, and would force an economy to fall.

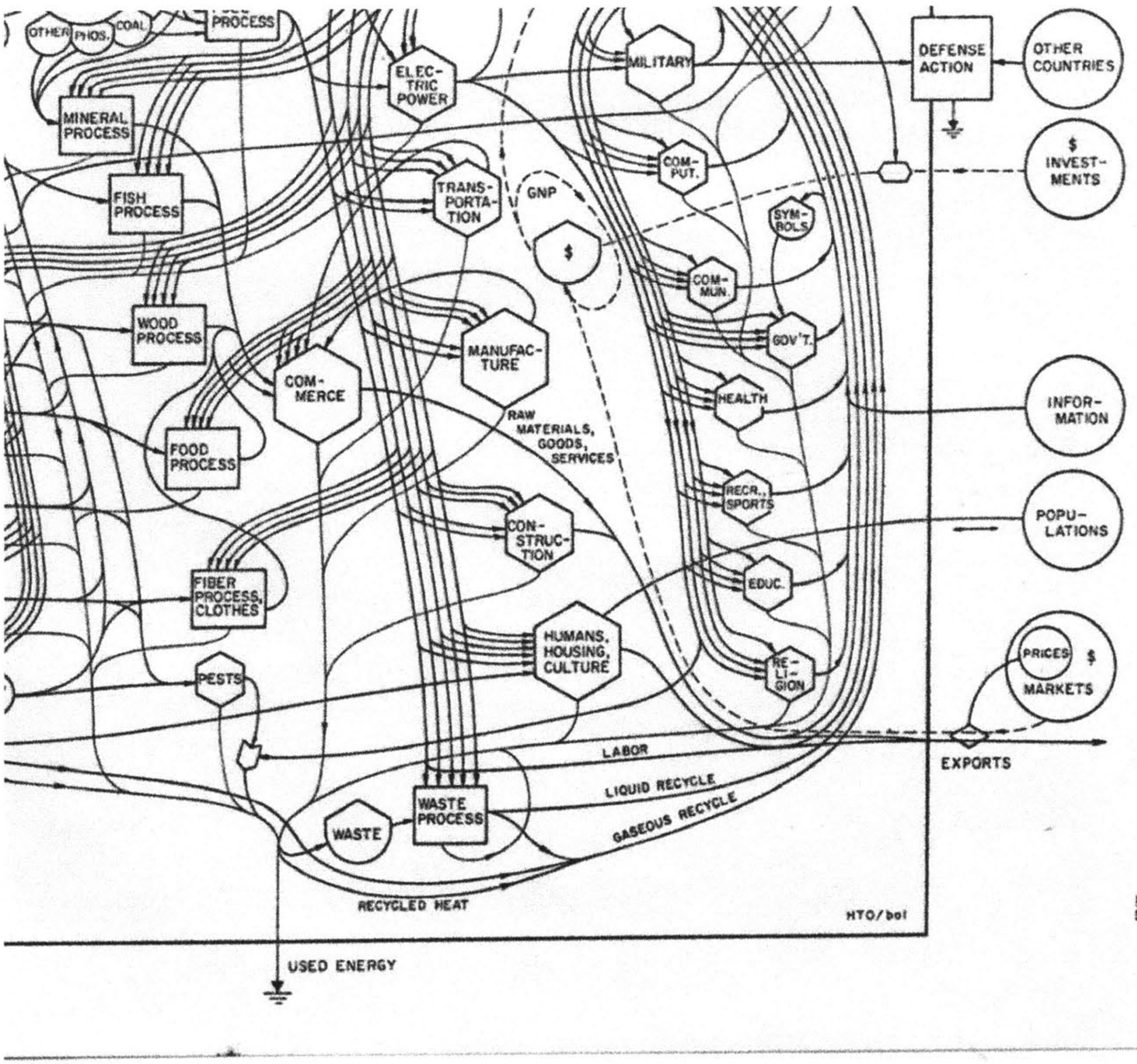
111 Ibid., 15.



Howard T. Odum, Systems Ecology Model of the United States of America, 1980.

United States of America, 1980

This model of the energetic nature of the United States is even more revealing of Odum's position, in which we see the country, isolated by a border, accepting inputs from climate, geology, investments, and imports, while itself a self-regulating system neatly managing its parts. In a section entitled the "The Modern Systems," Odum discusses how societies can retain control within the world economy; he writes, "As long as a civilization leads in innovations, it has an edge in marshaling and controlling energy flows to build and maintain an ever larger and more complex structure and world order." He reasons that if the United States could harness its energies, and visualize the whole system, it could invigorate innovation to retain



Howard T. Odum, Systems Ecology Model of the United States of America, 1980.

its security and position of "principal control"[112] by channeling energies to research "as a holding action until the lacework of world economics is able to develop a single world network that eliminates hazardous competitions."[113] Here the tools of systems and simulations become a model of mind, Odum imagines change the same way in the static electrical circuit as he does at the scale of the world.

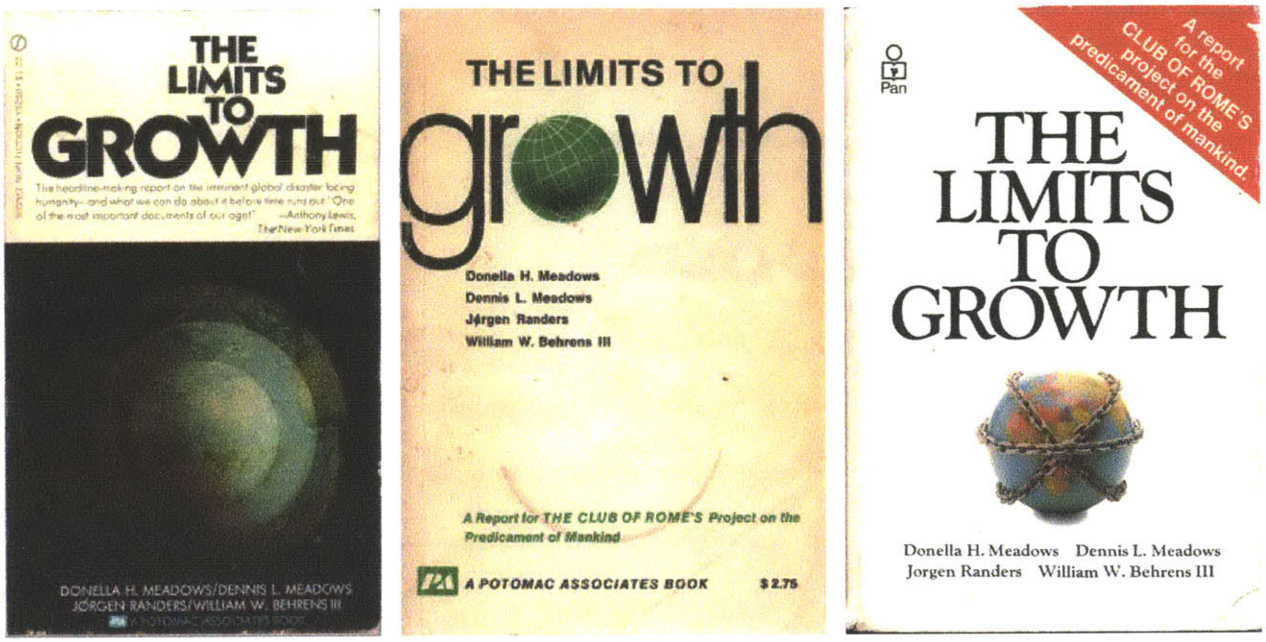
Such an event would be "a consequence not without risk," leading Odum to suggest that the United States could only maintain its "superior progress through research…as a holding action until the lacework of world economics is able to develop a single world network that eliminates hazardous competitions."[114] Given the weakening of the American economy after the military-infused postwar period of economic boom, Odum's reference to the emerging "lacework" of world economics refers to the increasing growth of other markets and countries as they slowly recovered from the war. At the same time, on X page section, he refers to one reform in which he seek to "internalize" industrial costs to make industrialists pay the true cost of the energy they use and the "unavoidable" pollution they cause; and he attempts to provide an objective scale of evaluating these costs. "Real cooperation between species seems too opportunistic, and poisons too frequent."[115]

112 Odum contends that the United States must either assist other countries in "catching up" in innovation, or "wait idly by," while other countries catch up in a manner "likely to threaten the United States security, or foster a one-world economy in which the position of the United States as principal control may be submerged." Odum, *Environment, Power, & Society*, 235.

113 Odum, *EPS*, 234-5.

114 Ibid..

115 Leigh.



Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, William W. Behrens III, *The Limits to Growth*, A Potomac Associates Book, Universe Books, NY 1972.

3. Coda; World3: Experts to Politicians

Perhaps one of the most popular representations of flow diagram appeared in the highly popularized 1972 report, *The Limits to Growth*, sponsored by the Club of Rome.[116] The group had first convened at the Accademia dei Lincei in Rome in 1968, an ensemble of thirty industrialists, scientists, and bureaucrats who shared a common concern, or interest, depending on one's point of view, in future studies and the future of humanity.[117] To reiterate the Club's proposition:

> As a matter of fact, by this time we should have realized that the problem mass we are up against is growing not only in size but also in complexity, dynamism, and threatening force; that it is immune to linear or sequential resolution; that the unceasing interplay and merging of its components create new problem areas; and finally that, unless a supreme effort is made, unmanageable, system-wide crises are bound to develop. The Club of Rome has called this mounting tide of interlocking problems and difficulties the World Problematique—and the anguish of modern man facing it his subconscious quest for an organized response to all these complexities and uncertainties, the Predicament to Mankind.[118]

Not only did it manage to capture the scaling issues now presented as environmental, it marked a watershed moment within political and economic changes by appearing to reconcile the counter-cultural critiques of consumerism and capitalism by linking these to a finite totality of resources on the planet. *The Limits to Growth* concluded:

> if the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial activity.[119]

116 The Club of Rome was described by its founder, Aurelio Peccei, as an informal, multinational, non-political group. The Club of Rome can be considered one of many post-war research institutions, think-tanks, and organizations that were created to provide a space for research. Especially in the post-war period, the think-tanks were partisan sites. See Andrew Rich, "The Evolution of Think Tanks," *Think Tanks, Public Policy, and the Politics of Expertise* (Cambridge, UK: Cambridge University, 2004).

117 The Accademia dei Lincei is the Italian science academy, or the Lincean Academy, founded in 1603 by Federico Cesi, and named after the lynx, whose sharp vision symbolized the observational prowess of science.

118 Alexander Peccei, *Successo*, June 1970, 154. MC439, Box 128.

119 *Limits*, 23. This message was followed by *Mankind at the Turning Point* two years later, written by the Meadows team. By this point, they were moved to Dartmouth.

The popularity of the report seemed to signify a global consensus reached in regards to the problem of environment and the distribution of resources; the image of an integrated whole and configurable parts provided a powerful image.[120] The report received much praise, and more criticism—ranging from its lack of data, to its nihilist projections, to the incorrect calculations within specific lines of code.[121] Rather, what the world model presented was a single articulation of its components, arguing that the particles within each of could be freely allocated, its various components shifted as if an integrated whole.

The interest here is not in the "truth" or exact validity of statements, or the instrumentality of such models. Rather, the report is significant in that it is the crystallization of a pivotal moment in which the malaise of society reaches a global consensus, yet in a form that welcomes the participation of all without specific guidelines as to how to act. Calling for "a new set of institutions and instrumentalities" to better understand and manage the "dynamic present and the kind of futures that may eventuate from it," *Limits*, can be read as the Club's attempt to fit itself into a political landscape.[122] Without active governance, it was, rather, through the translation and re-publication of the report that the Club sought to find its audience. Upon hiring a publisher in Washington D.C., the Club presented the report through a series of public showcases—three-day long symposia in Moscow and Rio de Janeiro in the summer of 1971, and at the Smithsonian Institute in DC in March 1972.[123] *The Limits to Growth* report was introduced to a room full of scientists, ambassadors,

120 Recalling Simon's definition of the function between the interior and exterior being driven by economic factors and demand curves. In this light, the *Limits* model was always already bound to economics and the economically sound distribution of resources.

121 There are a number of rebuttals in Forrester's papers at the MIT Archive, varying from personal commentary to full-essay length publications which sought inter-personal advice on drafts, tone, and poignancy. Perhaps the most significant rebuttal was that of William Nordhaus, which required a point-by-point resopnse from Forrester. What is interesting here is not the exact points of the rebuttals themselves, but merely to take notice of the defensive position taken up by Forrester in his attempt to single-handedly disprove each of criticism, point by point. Almost an entire box in Forrester's archive is dedicated to copies of the Nordhaus essay, Forrester's and his colleagues notes on his response, Forrester's three drafts, colleagues comments on his drafts, and the final essay and its publication in *Foreign Affairs*.

122 The plan to produce a book for the non-expert, the public, is traced back to a meeting in Montebello, Quebec, in April 1971, held at the invitation of Pierre Trudeau, then the prime minister of Canada. See Vernie Alison Oliveiro, *The United States, Multinational Corporations and the Politics of Globalization in the 1970s*, Ph.D Dissertation, Harvard University, 2010. It was only after the confusion of this presentation that the Meadows' began to write an expository novel explaining the concepts of the mode.

123 The costs of the conference were mostly covered by the Xerox Corporation. Cited in Elich, 106; also see Lesh, "Potomac Associates and Limits to Growth," Gordon Stanley Brown Papers MC 24-17-683 for organization details and

and public officials at the Smithsonian. Political scientist Richard Ashley, described the setting:

> Rarely does a social science movement get a more auspicious—or conspicuous—debut...The tone is serious, even urgent and understandably so. For the occasion is the premier of a scientific publication that has taken advantage of the most sophisticated models and forecasting techniques ...In somber silence the Smithsonian audience hears the practical implications...[124]

Ashley, taking apart the *Limits* controversy, also stressed that world modelers explicitly had not attempted to represent political and social processes in their models, concentrating on the demographic, economic, technological, natural "dynamics." In his 42-page review of five books focused on world modeling in simulation, published between 1977 and 1980, in sarcastic tone, he remarks: "most world modelers have hitherto largely ignored those questions that, if taken seriously, would call into question the historical significance, political content, and practical import of their own enterprise."[125] Commenting further on the disciplinary constitution of the group, "Only two [out of forty-three] describe themselves as political scientists; there are no historians, no sociologists. Such disciplinary concentration [engineering, economics, natural sciences] makes it most unlikely that the world modelers would be steeped in [names social theorists] who have pondered the social meaning and political significance of scientific-technological "progress."[126] As many recount, once the publication of *The Limits to Growth* in March 1972 became a public debate, the Club of Rome was no longer interested in its technical aspects. The technical report, which was to accompany and follow the publication was dropped, and only published two years later by the Meadows' in 1974.[127]

marketing strategies for the publication. The Club approached Potomac Associates and the Overseas Development Council to assist with a publicity strategy, which resulted in 6700 free copies delivered to the heads of state of all nations, the US state governors, journalists, UN officials, etc. in conjunction with the Woodrow Wilson Center.

124 Richard K. Ashley, "The Eye of Power: the Politics of World Modeling," *International Organization* 37.03 (1983) 495-6.

125 Ashley, 498.

126 Ibid.

127 Soon after the publication Meadows' group at MIT disbanded; the Meadows' went on to start a research group at Dartmouth. The technical report was published in 1974 as *Dynamics of Growth in a Finite World*, and included both the technical description of World3, as well as the empirical data.Subsequent publications include: *Toward Global Equilibrium: Collected Papers, in 1973, Alternatives to Growth in 1977,* and a *30-Year update,* recently.

The Limits to Growth is divided into four chapters; the first, examines the nature of growth, the second, identifies limits; the third, discusses growth in the world system; the fourth, technology as related to growth. The central diagram of the book, with which I began the thesis, makes clear the methodology. Taking the diagrams at face value, what kind of world does the diagram produce? Incorporating the mechanism of feedback, the authors of the report define a positive and negative feedback loop. The positive is that which pushes towards runaway growth, while the negative is the regulator—it assists in returning or holding the system at its steady state. As described by these diagrams, then, population is merely a function of fertility and mortality—births are an investment, a positive loop; while deaths are "depreciation," the negative loop. It is the same logic that is applied to industrial capital (factories, machines). New capital is an investment, while the depreciation or obsolescence of the machine stabilizes all that is being produced.

The success of Limits also rested upon a strong foundation of systems analysis. Jorgen Randers and Dennis Meadows, two researchers within the System Dynamics group at MIT wrote in an earlier report:

> Managers of business and of governments are accustomed to the necessity for decision-making within time deadlines...They have developed numerous management tools which help to bring together the diverse pieces of information already available about a problem, which assist in evaluating the relative importance of the pieces, and which provide a coherent picture of the problem even when some pieces of information are missing.[128]

These models were to assist the decision-makers, translating the work of the scientist, who could not "resolve the conflict between scientific ethics and personal concern."[129] It was within this context of value-free objective decision-making that the Club of Rome hired the MIT System Dynamics Group, directed by Jay Wright Forrester.

128 Jørgen Randers, and Dennis L. Meadows. *System Simulation to Test Environmental Policy: A Sample Study of DDT Movement in the Environment.* Cambridge, MA: System Dynamics Group, Alfred P. Sloan School of Management, MIT, 1971, 1.

129 Ibid.

Jay Wright Forrester & System Dynamics

Forrester's history at MIT, too, is long-winded, beginning in 1939.[130] Forrester had worked in the MIT Servomechanism Lab during the war on anti-aircraft systems, and continued this work in the Semi-Automated Ground Environment, a defense system for the US. Forrester thus serves as a hinge between the two poles of systems theory: military defense and social metaphor. Yet to understand why the Club of Rome chose Forrester's work—rests in three earlier depictions of the world problematique, each an early attempt to represent the interlocked nature and deep complexities of the problems the Club sought to attack.[131]

Hazan Ozbekhan's "The Revolutionary Mutation of Self-Contained Problems into an Involved Problematique" depicts five stages towards intermingling and results in the solidification of a new entity altogether. A sequence of diagrams includes a variety of shapes in different colors and sizes that symbolize different problem areas—by the final image, a composite core is formed. Ozbekhan urged for a model that would allow these areas of interdependence to be opened to understanding; to be modeled correctly in order to manipulate the models artificially—"so as to observe the behavior of the situations' components under differently structured configurations...thus attain a first rational base to elaborate suggestions for corrective action."[132]

Peccei's "The Maze of Continuous Critical Problems" once again symbolically attempts to depict the various problems that pervade society; the lines are drawn to show the multiple relations between the points, and the "whole" constitutes "the Problem" [sic]. A final "Cryptogram" schematically "indicates systems (dynamic aggregates of elements united by certain laws and finalities), problems (cases in the pathology of current reality) and new factors of exaltation (technological eruption)," and calls for a better understanding of the "new absolute values assumed by speeds, sizes and complexity, due to extraordinary technological behavior."[133]

130 See Alexander Hilton Wood, *The Engineers and the Social System, 1968-74*, MIT SMArchS Thesis 2012.

131 Unfortunately I did not secure rights to publish these images.

132 Alexander Peccei, *Successo*, February 1970, 155. MC439, Box 128.

133 Ibid, 124.

Upon seeing these symbolic representations of the Club's world problematique, the acceptance of Club member and MIT Professor Carroll Wilson's suggestion to examine the work of Forrester and the System Dynamics Group is much clearer. Against these images, Forrester presented a technology or process that could depict each individual problem or set of problems as an enclosed notation. Furthermore, the technology provided the means by which a process could be articulated and represented. The notational symbols could be isolated, assigned a value, and meaning secured for the purposes of sematic stability and operability. The implication of process, of a beginning and end signified by the chain of the algorithm is in opposition to the isolated worlds enclosed by borders.

After visiting MIT in the summer of 1970, during which time the System Dynamics Group presented their work in industrial management systems, and more recent urban sites, the Club commissioned the group to research the determining factors contributing to growth in the world system. The final model, World3, was written using DYNAMO, a computer language developed for the group in the 1960s, and consisted of 150 equations. The system "determinants"—natural resources, population, pollution, capital investment, and investment in agriculture—were constructed from empirical knowledge. When the program ran, it yielded disastrous results. Since natural resources were understood as finite, and the models were programmed to read growth as infinitely exponential, the World3 model predicted that the world system would move into overshoot mode. It was doomed to collapse unless the behavior and relationship of its determining factors could be re-adjusted. According to *The Limits to Growth*, humanity could only alter its fate in accepting the systems view. *The Limits to Growth* repositioned humans and nature as two separate entities pitted against one another, both at risk of collapse.

Environment, c.1972[134]

By the 1970s, the "environment" was described as "the most intrinsically international of all the issues that world community has ever faced,"[135] securing a victory for the activists of the 1960s who brought the unintended consequences of industrial production to the public. However, the contradictions of the term were immediately evident as a conflict between the "ecological imperative, and the economic, political, and national imperatives."[136] Speaking to Sweden's reasoning in calling for an international conference, one activist wrote, "National moralities are after all fragile in the face of economic imperatives."[137]

The 1972 Conference on the Human Environment wiped the world clean of existing problems, ignoring existing inequalities in considering each individual as a quantified equal.[138] Industrial emissions were conceived in the same way—even though this rendered the emissions of "subsistence" and "luxury" activities in an equal manner.[139] In this way, the discourse on environment quickly turned into a form of governance, positioned, as historian of science Sheila Jasanoff describes, in a gray zone between an electoral system and a

134 See Reinhold Martin, "Environment c.1973," *Grey Room*. 1.14 (2004): 78-101.

135 Maurice Strong, in interview with Sally Jacobsen, "Maurice F. Strong: Stockholm--A Year Later," *Bulletin of the Atomic Scientists* (June 1973), 35. Only several years later, Strong became a consultant for Exxon.

136 F. H. Knelman, "What Happened at Stockholm," *International Journal*, Vol. 28 No.1 Earth Politics (1972/1973), 31.

137 In his article, "What Happened at Stockholm," physicist and activist F. H. Knelman writes his surprise upon hearing the "loudest laughs from Swedish delegates" when he expressed his view of the integrity of Sweden's motives in launching this conference. "While they were flattered," Knelman wrote, "I was somewhat misinformed...The government of Sweden apparently was motivated more by the need to stabilize the status quo of the hierarchy of international economic power than by a pure moral concern for environmental quality. Sweden had learned the bitter lesson that the costs of domestic anti-pollution measures lowers profits and decreases one's competitive position in world trade." See F. H. Knelman, 31-32.

138 Over the course of 17 days, three conferences on the "environment" took place in June 1972 in Stockholm. The Dai Dong Independent Conference, sponsored by the International Fellowship for Reconciliation met between June 1 and 6, concluding a day before the United Nations Conference on the Human Environment, which convened from June 5 to 17. Parallel to the official conference was the Environmental Forum, which was organized by citizen groups, and nongovernmental organizations. Canadian industrialist Maurice Strong was selected by the UN General Assembly to serve a four-year term as Chairman. The Conference was attended by 1200 representatives of 114 countries, but only two heads of state were in attendance—Olaf Palme, the host, and Indira Gandhi, of India.

139 Sheila Jasanoff and Marybeth Long Martello, Introduction to *Earthly Politics: Local and Global in Environmental Governance* (Cambridge, MA: MIT, 20004). Also see: David Harvey, "What's Green and Makes the Environment Go Round?" in Fredric Jameson and Masao Miyoshi, eds., *The Culture of Globalization* (Durham and London: Duke UP, 1998): 327-355; Wolfgang Sachs, "Environment," *The Development Dictionary* (London: Zed Books, 1992), 26-37.

command and control model.[140] The 1972 Conference is widely credited with bringing international attention to the environmental; rather, it put forth the term "human environment" as a veil for individual interests.[141] The meeting was already bound within national interests, and while the attending representatives discussed the distribution of resources, population, and nationalism, enormous projects like the Trans-Alaska Pipeline, the James Bay project, chemical warfare in Indonesia, malaria outbreaks along the Nile, among others, were unmentionables at the conference—"all were glossed over, ignored, traded off as mutually unmentionable."[142]

The final declaration reveals many things about the conference—its irreconcilable differences and its implicit and explicit faith in traditional economic growth and technology. Principle 21, perhaps most frequently cited, ensured "the sovereign rights of states to exploit their own resources in line with their own environmental policies, [provided they] ensure that activities in their control do not damage the environment of other states."[143] Reflecting the absolute divergence of opinions on how to understand and work through the environment, "[t]he final declaration was a kind of compromise of irreconcilable positions, often akin to a Picasso painting, in that it faced both ways at the same time."[144] The issues that disunited nations were those that violated the "ecological imperative of indivisibility: nationalism, ideological differences, sovereignty, and maldistribution."[145] By the ten-

140 Ibid.

141 The 1972 Conference rested upon a foundation built in the post-war period, on a number of international conferences and agreements beginning with the establishment of the United Nations, UNESCO, and the Food and Agriculture Organization in 1945, the establishment of the World Health Organization in 1946; United Nations Scientific Conference on the Conservation and Utilization of Resources in 1949; International Technical Conference on the Conservation of the Living Resources of the Sea in 1955; Geneva Convention (Treaty) on Fishing and Conservation of the Living Resources of the High Seas in 1958; International Biological Program in 1964; The International Treaty on the Peaceful Use of Outer Space in 1966; World Weather Watch, World Meteorological Organization in 1967; UNESCO Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere in 1968; United Nations General Assembly Resolution 2398 on the Problems of Human Environment; and the Scientific Committee on Problems of the Environment (SCOPE) by the International Council of Scientific Unions in 1970, see Lynton K. Caldwell, *In Defense of Earth: International Protection of the Biosphere*, (Bloomington: Indiana University Press, 1972), 940-1.

142 Ibid., 45-7.

143 "Declaration of the United Nations Conference on the Human Environment," 21st plenary meeting, 16 June 1972, Chapter 11. See http://www.unep.org/Documents.Multilingual/Default.asp?documentid=97&articleid=1503. Accessed 20 May 2013.

144 Kelman, 49.

145 Kelman, 39.

year review of the UN Conference on the Human Environment, it was clear that little action had been taken and World Commission on Environment and Development reconvened to evaluate their actions.

Subsequent global events to address the figured "environment"—the Brundtland Report of 1987,[146] the Earth Summit in Rio de Janeiro in 1992—brought forth the reconciliation first presented by The Club of Rome's *The Limits to Growth* as if a debate into the pores of the public.[147] In a similar manner to the Club of Rome's book parade, the United Nations Commission who authored the Brundtland Report also spent two years traversing the world hosting public hearings, collecting written submissions and expert testimonies, collecting, analyzing, and synthesizing, or designing, the report to be published in 1987. The hearings came to be the trademark of the Commissions.[148] The report, reconfigured and published for the public as *Our Common Future* performed the same stroke of reconciliation in its intention of collapsing the ecological with the economic imperative. In doing so, the report launched the paradoxical "sustainable development" that defines architectural practice today.

146 Shiv Visvanathan's report is the most eloquent and biting critique of the production by the Brundtland Commission. Entitled "Mrs. Brundtland's Disenchanted Cosmos," Visvanathan calls for the simultaneous destruction, or "desilting," of forms of reified expertise—both the technological, like the Aswan Dam, and the bureaucratic, the World Bank and the IMF. "Deep down," writes Visvanthan, "the Brundtland Report still believes that the World Bank and the expert will save the world." The report proposes "a future colonized, mapped with cybernetics and systems theory;" a world that is divided into its systems and subsystems, into neatly maneuvered hierarchies made increasingly perplexing by the systems' means of representation. "They don't talk, they feed back." Here, the application of systems thinking upon naturalized population, only helps transform this world into a monetized economy by reducing its subjects under study to the fundamentals of the market, "where being is only if monetized." See Shiv Visvanathan, "Mrs. Brundtland's Disenchanted Cosmos," *Alternatives.* 16.3 (1991): 377-384.

147 The immediate period after the 1972 conference was marked by a proliferation of international environmental organizations, new techniques, and new standards. Before 1972, there were less than 36 trans-boundary environmental treaties. By the 1992, there were several hundred. See Jasanoff, *Earthly Politics.*

148 "Deliberative meetings, site visits, and/or Public Hearings of the Commission were held in Jakarta, Indonesia, 27-31 March 1985: Oslo, Norway, 21-28 June 1985; Sao Paulo and Brasilia, Brazil, 25 October-4 November 1985; Vancouver, Edmonton, Toronto, Ottawa, Halifax, and Quebec City, Canada, 21-31 May 3 1986; Harare, Zimbabwe, 15-19 September, Nairobi, Kenya, 20-23 September 1986; Moscow, USSR, 6-12 December 1986; and Tokyo, Japan, 23-28 February 1987. Special working group meetings of the Commission were also held in Geneva, Moscow, and Berlin (West)." Bruntland Report, *Our Common Future*, 1987.

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