Das Lied von der Nerd

Informational Improvisation in Bay Area Network Music

By Edward Breitweiser 2011 (Revised 2012)

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Abstract

In a step toward elaborating a theory of creative improvisation grounded in chaotic play and informal exploration, this paper will examine the network music of The League of Automatic Music Composers and The Hub. Uniquely situated to appropriate contemporaneous developments in personal computing, network technology, and radical social thought - all of which were significantly informed by information and communications theories - these Bay Area musicians cultivated musical and social structures that brought traditional relationships (composer/performer, ensemble member/individual agent, human/machine, network/node, sender/signal/receiver, etc.) into a gestalt informational model of improvisational performance. Through elaborately designed DIY assemblages of networked personal computers, electronic instruments, and data and signal chains, they pioneered the use of digital tools to sonically illustrate the complex nuances inherent in the newly-arrived world of high-speed human-computer interaction, networked data exchange, and bio-mechanical feedback within ever-expanding systems of social and political culture. Cast within a larger artistic traditions of improvisation, traditional musical ensembles, information art, and computer music, the output of these ensembles will be analyzed as "network-as-art" in which works of art are invoked through the medium of formalized systems of organization based upon user feedback, nodal agency, and dynamic metastructures.

Note on Methodology

The relative importance of a node does not stem from its specific features but from its ability to contribute to the network with valuable information.[1]

At its core, this paper concerns itself with the two most important projects in the establishment of "the network" as a musical entity: The League of Automatic Music Composers (active from 1978 to 1983) and The Hub (1987 to the present). As is often the case in attenuating the noise around a historical topic, delineating these groups and their activities into polished narratives is a very messy, imprecise business. Given the nature of their (net)work and the complex array of social, technological, cultural, and musicological threads that find their way into the fabric of their projects, I have attempted to present these groups not as a single history but as an overdetermined web of intertwined narratives, focusing in on particular events, shared attitudes, long-form trajectories, working methods, personal statements, interrupts, and open forms. The music of these groups is taken to be the method of integrating the otherwise disintegratable.

The result is less like a straight historical arrow and more like an ecology of key interconnections. Where appropriate, I will direct the reader to more in-depth discussions of given topics that are distributed outside of the present scope of this paper. I hope that this method of historical integration is not distracting and offers relevant insights that could not have been afforded by a more traditional application of research.

The paper contains five primary narratives:

I. Counter History: Processes, Systems, and The Rise of the Computer in Music

II. Being Both "Run" and "Followed" at Once: The Birth of the Digital Consumer

III. From Space Between to Flow Within: The Dawn of the Network

[1] Castells, Manuel. "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change." Coneixement | Societat 01, (January-April 2003): 14.

E.W.B.
Chicago, 2011

Introduction

Drum
On
The clocks and
Strum
On
The wires.[2]

[2] Channels, “Chivaree”, Album track, performed by Channels (2004; Washington, D.C.: DeSoto Records.), Audio recording.

IV. A.
Site of Presence I: Local

A network is a series of interconnected nodes and a node is the point where the curve crosses itself.[3]

July 3, 1978
Blind Lemon, "a cheap, hippy place"[4] in Berkeley, California

Three men stand at an imposingly cluttered table covered in a collection of metal- or wood-encased consumer-grade electronic equipment, exposed homebuilt circuits of microchips and raw electronic components, and printed circuit boards - about the size of a sheet of paper – with a small calculator-esque pad of buttons and a few chips.[5] Between all of these devices is an incoherent tangle of colored wires and cables that eventually find their way to a high-fidelity sound system.[6] The scene is reminiscent of the workbench of a hacker who has just returned home from an electronics surplus sale. Chances are you've only heard about microcomputers; if you've seen one, it's been in the pages of a magazine for electronics hobbyists or at a local gathering of these folks. Knowing that there are a few on the table, you try to figure out why the three men might be crunching numbers. Then the music starts.

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[3] Manuel Castells, "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change," Coneixement | Societat 01, (January-April 2003): 14.

[4] Ross Hannan and Corry Arnold, "Berkeley," Chicken on a Unicycle, 2011. Last updated September 13, 2011. Accessed December 13, 2011. http://www.chickenonaunicycle.com/Berkeley%20Art.htm

[5] George Lewis, quoted in Chris Brown and John Bischoff, "Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area," Crossfade. 2003, Accessed December 9, 2011, http://crossfade.walkerart.org/index.html and http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html.

[6] Technical specifications about the League's performance can be found in John Bischoff, Rich Gold, and Jim Horton, "Music for an Interactive Network of Microcomputers," In The Foundations of Computer Music, ed. Curtis Roads and John Strawn (Cambridge: The MIT Press, 1985), 589.

III. A.
Function Without Shell: The Network Society

> *In those heady early days, many of these hackers were less focused on the potential riches following from this technology than on its revolutionary potential: a dream of a new society built with the assistance of artificial intelligence and the free and open access to information.*[7]

The Bay Area in the late '70s and '80s was the geographic frontier of a wide berth of conversations about the global revolutionary potential of information-age technology and networked theories that were emerging from all corners of the arts and sciences. Steeped in a radical political, communal, technological, and intellectual culture profoundly influenced by a spirit of proto-Silicon Valley innovation, Northern Californians seemed to be particularly motivated to take the future into their own individual and collective hands. The revolutionary hacktivist "dream of a new society built with the assistance of artificial intelligence and the free and open access to information" was built upon the "belief...that complex phenomena can be understood by analyzing the dynamic interactions of relatively simple components connected in networks."[8] In particular, the sweeping macroscopic theories of “cybernetics (Norbert Wiener), complex systems theory (Ilya Prigigone), genetic algorithms (John Holland), synergetics (Buckminster Fuller), catastrophe theory (René Thom), neural networks (Warren S. McCullough), chaos theory (Jim Crutchfield, et al), [and] cultural ecology (Gregory Bateson)” held an esteemed place in the minds of these techno-utopians.[9] Perkis and Bischoff continue, “It's not much of a jump from saying we can analyze complex life-like process into simple interacting components, to imagine that we can create complex, life-like behavior by

[7] John Bischoff and Tim Perkis. “The League of Automatic Music Composers 1978-1983.” Liner notes accompanying The League of Automatic Music Composers. The League of Automatic Music Composers 1978-1983. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.
[8] Ibid.
[9] Ibid.

connecting simple components - and do so in a musical context."[10]

With this multifaceted richness, the Silicon-Valley-helmed Bay Area was a decisive ecology for the emergence of the post-industrialist "informationalist" network society. Echoing the observations of The League's historians in his formulation of 21st-century informationalism as the technological paradigm "which is constituted around the strategic importance of information and communication technologies", Manuel Castells links its genesis with the coincidence of three independent phenomena in the late 20th century.[11]

First was the Information Technology Revolution that produced the following: ARPANET (1969); the integrated circuit (1971); the personal computer (1974-76); and the software revolution that spawned vastly improved human interfacing with computer hardware via tools such as UNIX (1974) and TCP/IP protocols (1973-78).[12] Second was "the process of the socio-economic restructuring of…capitalism" in light of the technological resources just mentioned, a process that strategically and triumphantly cultivated innovative productivity to bring about the collapse of the Soviet Union and position information technology (and the network society) as a profound influence in global markets. Finally, Castells recognizes the dominant social and political values of American, European, and Asian social movement of the late-60's and early-'70s as reconfiguring notions of freedom, patriarchalism, productivism, and the contract between the individual, the state, and the corporate world.[13] The major economic consequence of this reconfiguration was "a new breed of business" with direct roots to technological innovation via a hacker culture built upon "co-operations and sharing, following the logic of open source and horizontal networking."[14]

As military and industrial communications and network technologies began to exert sweeping change in the prevailing global and national socio-economic orders, their influence was immediately felt in the arts. New media

[10] Ibid.
[11] Manuel Castells, "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change," Coneixement | Societat 01, (January-April 2003): 17.
[12] Ibid.
[13] Ibid.
[14] Ibid.

artists began to appropriate the tools and structures of mass communication, conceptualists co-opted the "aesthetics of administration" that permeated the emerging demands of highly-organized economic bureaucracy,[15] all while architects and designers became enamored with evolving strategies of simultaneous social interaction across myriad interconnected scales.[16] But the full breadth of coincidental convergences that were signaling the transition to a new socio-technological network paradigm were most fully embraced and investigated in the arts by an informal group of computer musicians centered around Mills College in Oakland, California that would perform as The League of Automatic Music Composers from 1978 to 1983 and as The Hub from 1987 to the present.

After a number of informal performances together in the late-'70s, Jim Horton, John Bischoff, and Rich Gold formed the first networked trio of microcomputers in a performance at Blind Lemon in Berkeley the spring of 1978. On November 26, 1978, the trio was joined by David Behrman – who had recently become Co-Director of the Center for Contemporary Music at Mills – and the League of Automatic Music Composers was born. By 1980, Gold and Behrman had left the group, and Horton and Bischoff were joined by Tim Perkis. This trio remained active until 1983, when Horton's rheumatoid arthritis became too crippling for him to continue working.

Over the next few years, Bischoff and Perkis continued to explore applications of networked data exchange, eventually introducing the idea of a common memory-mailbox that performers could access. They began to work on this "memory hub" concept with a loose collective of likeminded Bay Area automatic music composers. In 1987, Nicolas Collins and Phil Niblock invited the group – by then stabilized as a sextet featuring Bischoff, Perkis, Chris Brown, Scot Gresham-Lancaster, Mark Trayle, and Phil Stone – to New York City to stage a series of remote network pieces via telephone lines. The group agreed, and The Hub debuted on June 6, 1987 in the first performance of remotely networked computer music. This sextet performed regularly until late 1997, when a large-scale remote performance over the Internet funded by the

[15] Benjamin H. D. Buchloch, "Conceptual Art 1962-1969: From the Aesthetic of Administration to the Critique of Institutions," In Conceptual Art: A Critical Anthology, ed. Alexander Alberro and Blake Stimson (Cambridge: The MIT Press, 1999), 514-537.
[16] Mark Wigley, "Network Fever," Grey Room, no. 4 (Summer, 2001): 82-122.

Institute for Studies in the Arts at Arizona State University was sabotaged by technical problems. After a hiatus, the group reformed in 2004 and continues to perform intermittently.

II. A.
Indefinite Address: The Microcomputer Revolution

> *As yet unnamed, Silicon Valley was springing to life, where the almost daily announcements of new integrated circuits made possible the birth of a new subculture, where hobbyists and hackers outside of - or marginlly connected to - technology industries were creating the microcomputer revolution.*[17]

Launched by MOS Technology in 1976, the KIM-1 (short for "Keyboard Input Monitor") was a single printed circuit board[18] that, once connected to a third-party input device (such as a keyboard) and a compact-cassette-tape-based hard drive, constituted a fully functional computer system designed for use by engineers, educators, and developers.[19]

While the KIM-1 system was not practical for the general public, its launch was contemporaneous with the first generation of microcomputers designed for personal and recreational use, including the Apple I (1976), Apple II (1977), Atari 2600 video game console and Commodore 64 home computer (1977 and 1982, respectively[20]), and Nintendo Famicom and NES video game consoles (1983 and 1985, respectively[21]) all of which employed versions of the 8-bit MOS 6502 microprocessor that powered the KIM-1 system.[22] Released in 1975, the 6502's presence in all of these systems is a testament to its status as the CPU that ushered in the age of personal computing.[23] The ubiquity of this chip was a direct result of its design, which

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[17] John Bischoff and Tim Perkis. “The League of Automatic Music Composers 1978-1983.” Liner notes accompanying The League of Automatic Music Composers. The League of Automatic Music Composers 1978-1983. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.

[18] A printed circuit board, or "PCB", is the piece of plastic that contains the electronic components that constitute a circuit once current is introduced.

[19] Mike Naberezny, “The 6502 Microprocessor Resource,” *6502.org*, 2011. Last updated April 4, 2011. Accessed December 9, 2011. http://www.6502.org/

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] In recent years, retro-minded geeks have become enthralled by the 6502 microprocessor that powered their first experiences with computers. While the 6502's development was subject to stringent secrecy, an active community of nerds have reverse-engineered the CPU and revealed the chip's inner workings in a (typically) more interesting mode than the data sheet. Of note are Michael Steil's elephantine lecture from the 27th Chaos Communication

improved upon the flaws of other microprocessors (notably the Motorola 6800, which was designed by the same team as the MOS 6502 and released in 1974[24]) allowing for a smaller chip without necessitating additional components, resulting in a CPU chip that was available 14% of the cost as its predecessors.[25] Consequently, one could purchase a KIM-1 system (minus the input device and hard drive) for $250USD.[26,27]

Congress, "Reverse Engineering the MOS 6502 CPU: 3510 Transistors in 60 Minutes" (Information: http://events.ccc.de/congress/2010/Fahrplan//events/4159.en.html [Accessed January 23, 2012], and YouTube video documentation: http://www.youtube.com/watch?v=K5miMbqYB4E [Accessed December 31, 2011]), which goes into painstakingly precise detail about the subtleties of the chip's design and assembly coding architecture, and http://visual6502.org/ (Accessed January 23, 2012), an ongoing and thoroughly-documented project to reverse-engineer classic computer chips that began with an investigation into the unwieldy guts of a 6502.

[24] Ibid.

[25] Ibid.
The 6502 was introduced in 1975 at $25USD, at which time the Motorola 6800 and similar microprocessors were listed at $179USD. In 2011 USD, these prices are equivalent to $105.58 and $755.94, respectively. (Inflation rate calculated here: http://www.dollartimes.com/calculators/inflation.htm. Accessed December 9, 2011.)

[26] Ibid.

[27] $1,055.78 in 2011 USD. (Inflation rate calculated here: http://www.dollartimes.com/calculators/inflation.htm. Accessed December 9, 2011.)

I. A.

If Law Is Anywhere, Law Is Everywhere: Process Music and the Truth-Value

> *A far reaching, still unsolved question is whether electronic music as a universal source of all sounds possesses any coherent form-sustaining force corresponding to tonality - a self-sustaining system of timbres.*[28]

From its inception as a field of study and practice, music was founded upon principles that would allow for the codification of sonic experiences through organizational systems of time (understood as form and rhythm) and frequency (understood as pitch and harmony). In this manner, "music" established itself as non-chaotic sound. Traditional harmonic theory was in accordance with Boolean principles; modernist atonal and serial composer-theorists trimmed the fat off of this system, eventually extrapolating pitch-set theory, which is a simple application of modular arithmetic to unilateral musical relationships. While John Cage, Iannis Xenakis and others developed numerous applications of extra-musical chance and randomness flavored by their particular ideological agendas, their theories nonetheless fell within the spectrum of quantification, wherein all musical decisions could be explained by mathematical or arithmetical principles, and were thus representable as statements of truth values. With backgrounds in extra-musical forms of arithmetic and logical schema, academic computer composers simply took the abstract notion of "organization" and ran with it, conceiving ways that programs - simple or complex - could be written to cast data into meaningful sonic relationships. The computer flattened music-*qua*-organized-sound to the simplest principle: the truth-value.

Against the backdrop of restricted-access electronic and computational musical resources that were tightly linked to North American and European academic and research institutions, two key historical developments were to unfold. First, in 1966, the San Francisco Tape Music Center was moved to the

[28] Herbert Eimert, quoted in Peter Manning, Electronic & Computer Music (New York: Oxford University Press, 1985), 47.

Tape Music Center at Mills College in Oakland.[2930] Unlike comparable studios of its time, the SFTMC was developed to offer access to the public, inciting an atmosphere of collective experimentation between Mills affiliates and the broader artistic community.[31]

More broadly, the increased availability of inexpensive electronic components spawned a widespread interest in hobby electronics and circuit design beginning in the '60s. Excited by the potential of electronic media but frustrated by the restricted-access institutional studio model, a number of composers – notably David Tudor, David Behrman, and Gordon Mumma – began to experiment with the application of "homebrew" electronics for the generation of sonic material. Unbound by the confines of the studio, these musicians were able to use these devices in live performance beginning in the early-'60s.[32] Tudor's and Mumma's works during this period were particularly groundbreaking for their design of complete electronic systems; rather than focusing on particularities of traditional note-events, instruments, harmonic form, etc., they used the electronic circuit as an analog to the design of a comprehensive, self-sustaining closed musical system from which all organizational, meaning-making qualities could be derived at an instance.

The consequence was appropriately reciprocal: the total musical activity of a piece was the simple activity of a controlled feedback loop, and the total activity of the same controlled feedback loop was the simple musical activity of the piece. Sound had become an actor upon itself and the subsequent music that it could be organized into.

Tonality (and later seriality) was a form-sustaining force. Still under the spell of serialism's self-imposed crusade of liberating music from tonality by the nebbish submission to many of the same assumptions of Western harmonic practice (12 equally-tempered divisions to the octave, etc.), electronic musicians - primarily those in Germany - yearned for a "self-

[29] The Tape Music Center is now referred to as the Center for Contemporary Music (CCM) at Mills College.
[30] Peter Manning, Electronic & Computer Music (New York: Oxford University Press, 1985), p. 182.
[31] A thorough account of the SFTMC can be found in David W. Bernstein's *The San Francisco Tape Music Center: 1960s Counterculture and the Avant-Garde* (Berkley: University of California Press, 2008).
[32] Ibid., p. 196.

sustaining system of timbres" that could aid in the coherent organization of musical content.[33] In other words, they sought a model equivalent to tonality's ability to organize sounds according to their pitch content.[34]

With the introduction of Tudor and Mumma's electronic rigs, musical organization - meaningful sound - was no longer the purview of a collection of timbral/harmonic/pitch, or even time-based, relationships; rather, the "form-sustaining force" was, simply and elegantly, the self-sustaining system itself. The League accepted the mantle of the design of "form-sustaining forces" and "self-sustaining systems" in which the content of the music was the simultaneous indistinguishability of the micro-event and the macro-form of the automated network of similarly indistinguishable nodal subsystems.

[33] Ibid., p. 47.

[34] Although sincere, this endeavor falls flat because of its eagerness to adopt the principles of tonality that it is asserting as inadequate in order to overturn those very principles.

I. B.
Web Design: Post-Euclidean Music

> *The appeal of the computer is that it offered a new viewing point to survey the explosive rise of ever larger and less visible networks.*[35]

From the mid-'50s, the prevailing model of computer music practice was one that capitalized on the precision of a computer's control and manipulation of information in order to generate musical material (typically on the control, rather than the synthesis end) within the confines of a studio that would then be committed to magnetic tape. In other words, all of the processes that went into the composition and production of a piece of computer music would result in a static musical document in the same manner as the electronic music studios of the post-War era and the recording studio-based practice that prevails throughout the post-War popular music industry.

The League's music is deliberately positioned in opposition to this trend. These musicians eschewed the sophistication of contemporaneous digital sounds in favor of devoting computer systems to communications and control networks that were vastly more sophisticated than those available to the institutional computer musician or the recently instated "casual" user of consumer computer products. Leidecker notes that by the late '70s, although the practice of computer music was not yet thirty years old, the sound of systems only capable of 8-bit synthesis were dreadfully anachronous.[36] He continues, "If the League had returned to the initial vocabulary of computer music's first sounds made in the late fifties,[37] they did so to regain the use of the computer as a musical and social instrument. Even in recorded form, it is

[35] Mark Wigley, "Network Fever," Grey Room, no. 4 (Summer, 2001): 99.

[36] Jon Leidecker, "Producer's Notes," Liner notes accompanying The League of Automatic Music Composers, The League of Automatic Music Composers 1978-1983, CD, Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold (2007; New York: New World Records.) Audio recording.

[37] Leidecker concludes that, based upon the later proliferation of 8-bit sound in early video game consoles and subsequent nostalgic styles of so-called "8-bit music" that continue into the second decade of the 21st century, it is altogether probable that The Leagues computers sounded more dated during the group's heyday than in our time.

clear that this was music that has been performed live."[38] Indeed, The League's members have stated on numerous occasions that their interest was not in total, precise control and the sounds thereof, but in the unpredictability that would result from the live interaction of a number of human-machine nodal sub-systems. Such social interactions between bio-digital agents was simply impossible with the more ambitious sonic palette of mainframe computers, but the dynamism of The League's musical feedback systems undeniably leads to a sonic vitality that is unrivaled in tape-based computer music of the period.

The League's members have stated that their works cannot be properly regarded as "compositions" in the traditional sense (i.e. author writes the work, performer interprets the work on behalf of author), primarily because it became difficult to trace the seed of a work to a single individual and each group member was responsible for the crafting of his station's contribution to the performance. Members have attested that "a work" could best be described as a mode of interaction between the individual stations of each participant. Thus, when trying to pin down the compositional methodology of the band, we must come to grips with the fact that they did not operate according to the traditional model of the composer; further, they made no efforts to assert their non-traditional practice along traditional Western-compositional lines.

Following the examples of Mumma and Tudor, the League's bio-electronic cybernetic systems would be designed "as a musical actor, as opposed to merely a tool".[39] Here, electronic circuits are deliberately set up to alter, modulate, or otherwise interact with the musical signal. If the system was incomplete, there could be no music. All components were necessary, but none could be isolated as an individual sonic device. When it is turned on or plugged in, the system is closed; the musical electricity flows, and the circuit is music until it is opened. The system can thus act upon itself to affect the manner in which it operates. In this model of musical production, the

[38] Ibid.

[39] Chris Brown and John Bischoff, "Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area," Crossfade. 2003, Accessed December 9, 2011, http://crossfade.walkerart.org/index.html and http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html.

traditional role of the composer is set aside in favor of that of a designer of electronic-musical systems, that is, a designer of electronic systems specialized for musical application.

IV. B.
Site of Presence II: Remote[40]

Networks distribute performance and share decision-making along the nodes of the network in an interactive pattern.[41]

June 6 & 7, 1987
The Clocktower and Experimental Intermedia Foundation, in New York, New York

On both nights, three men are at The Clocktower and three men are at EIF. Each trio sits at a table with a small computer and a motley web of electronic devices scattered before each performer. On both nights, the two groups of three men perform the same pair of works; after the first piece, a lengthy intermission provides ample time to walk ten blocks to the other venue, where the other trio will perform the second piece. You can only be in one of these venues at a time. No matter which you choose, you will only hear half of the performers because they are linked by modem to a shared memory bank at the other remote location and are exchanging interactive data over the city's telephone wires. Your network experience is bound by the information that is locally present.

[40] Recordings of the pieces performed at this event have been included in The Hub, Boundary Layer, CD, Performed by John Bischoff, Chris Brown, Scot Gresham-Lancaster, Tim Perkis, Mark Trayle, and Phil Stone (2008. New York: Tzadik Records.), 3-disc audio recording.

[41] Manuel Castells, "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change," Coneixement | Societat 01, (January-April 2003): 14.

II. B.

The Ever Larger and Less Visible: Hacking Musical Culture[42]

> *The inexpensive microcomputer is a decentralizing influence on the way art involving technology is structured in society. This might help to balance the inherently centralist tendency of the arts and music in general.*[43]

At the dawn of the 20th century, West Coast Experimentalist composers had instilled the investigation of new musical resources as a paramount concern for modern music. This spirit "of being far from Europe"[44] and thus not beholden to its traditional assumptions was especially prominent in the work of Henry Cowell and Harry Partch[45], both of whom led subsequent generations of avant-gardists to explore the potentials of new and repurposed musical instruments for the generation of novel sounds. By the mid-'70s, the burgeoning market for inexpensive electronic components, transistors, and integrated circuits that would spawn the Information Technology Revolution in garages and industrial complexes around the Bay Area coupled with this resolute tradition of experimental resources and instrument design/construction. A new generation of tech-savvy avant-garde musicians began to look to KIM-1 microcomputers as the next logical progression from the system-as-art musical paradigm initiated by live electronic musicians during the '60s.[46]

With the caveat that users were required to directly program the KIM-1

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[42] For additional insights into the idiosyncrasies of programming the KIM-1 for musical applications, see John Bischoff, "Software as Sculpture: Creating Music from the Ground up," Leonardo Music Journal, Vol 1, no. 1 (1991): 37-40.

[43] John Bischoff, Rich Gold, and Jim Horton, "Music for an Interactive Network of Microcomputers," In The Foundations of Computer Music, ed. Curtis Roads and John Strawn (Cambridge: The MIT Press, 1985), 599.

[44] Chris Brown and John Bischoff, "Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area," Crossfade. 2003, Accessed December 9, 2011, http://crossfade.walkerart.org/index.html and http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html.

[45] Native Californian composers, instrument builders, and music theorists Cowell (1897-1965) and Partch (1901-1974) had an immensurable impact on the future of American avant-garde music and sound art. Of particular interest would be Cowell's New Musical Resources (1930) and Partch's Genesis of a Music (1949).

[46] John Bischoff and Tim Perkis. "The League of Automatic Music Composers 1978-1983." Liner notes accompanying The League of Automatic Music Composers. The League of Automatic Music Composers 1978-1983. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.

in machine code,[47] the computers came with an "Audio Out" interface that was used to write programs to cassette tape for storage. The crafty user could simply run a cable from this jack to an amplifier and write programs that would produce logical square-wave output that was within humans' audible frequency range.[48] Thus, with little more than the standard KIM-1 system, a user was equipped for: the creation of digitally synthesized sounds, the digital-to-analog control of sonic electronic circuits, and the generation and output of digital data. Remarkably, all of these capabilities could be utilized in real time, and the relative portability of the microcomputer systems meant that KIM-1 systems could be utilized in live performance at virtually any venue with AC outlets. Within months of the machines hitting the market, Jim Horton had begun to incorporate his KIM-1 into his live electronic improvisations.

[47] In other words, the complex native language of the processor into which every higher-level programming language must be translated in order for the CPU to operate.

[48] H.J. Butterfield, The First Book of KIM (Self-published, 1977), http://users.telenet.be/kim1-6502/6502/fbok.html, p88.
Alternatively, the KIM-1's user manual came with instructions for constructing a simple speaker circuit that could allow the user to control the frequency of square waves via analog inputs
(MOS Technology, KIM-1 Microcomputer Module User Manual [Norristown, PA: MOS Technology, 1976], http://users.telenet.be/kim1-6502/6502/usrman.html#F51, pp55-69).

III. B.

Cybernetic Bricolage: The Methodology of Musical Networks

> *Music has that wonderful ability that when you have three pieces of music working together you still have music.*
> *Though synthesizers always offered the potential of multisynthesizer group music, and there are some nice examples, microcomputers seem to fit the group-music situation even better...Microcomputers are conceptually both a module and an entire system.*
> *And ideally music should contain within itself all the information most important to a culture. An orchestra especially should have a structure that exhibits the best types of sociopolitical arrangements imaginable...*
> *…'The patterns of control in a system tend to reproduce the organizational chart of the institution that designed the system.' Hierarchical design derives from the myth that militaristic kings are better at getting things done. The theory of heterarchical and anarchistic systems design has been underexplored, although experimental musicians have been engaged in the processes for years.*[49]

While both The League and The Hub were informed by the same general interest in expanding the activity of social music-making via the real-time exchange of data through non-hierarchical computer networks, each group developed its own nuanced iteration of an interactive network architecture that would be performed live.

The League based their architecture upon permutations of data sending-receiving connections directly between individual human-computer "stations":

> Each player's "station" played its own composition, had its own sound-making equipment, and would send and receive information to and from the others. The meaning of this information might be completely different on one end of the exchange and the other: a pitch indication from one player might be controlling the rhythm of the other, for example. No one station would fulfill an executive function, or have an overall score. Any musical form that would

[49] John Bischoff, Rich Gold, and Jim Horton, "Music for an Interactive Network of Microcomputers," In The Foundations of Computer Music, ed. Curtis Roads and John Strawn (Cambridge: The MIT Press, 1985), 598.

> emerge often came very mysteriously, out of the interactions and mutual influence of the separate stations.[50]

For every performance, a non-hierarchical data-exchange pattern would be devised for three or four stations. As each station runs its program, an “all-at-once” automaton unfolds, allowing itself to be nudged this way or that via the manipulation of its self-propelling data and signals.

Each station is designed to interpret the activities of other stations and to translate that interpretation into a sonic product. The circuitous, dynamic array of other-causes and my-interpreted-effects would constitute the prodigious possibilities of the system's design. On the fly, one can change the way that his station interprets and reacts to a given data-thing, but he cannot absolutely control what data-things will be given to him (certainly, he can decide whether a certain type of data will make its way to him, but beyond preparing for the occurrence of that data he cannot ensure that it will definitively occur). Further, he can change the data-things that are issued forth from his station, but he cannot absolutely control what, if anything, will be done with them.

With the introduction of microcomputers, members of The League were able to extend the system-as-music model of Mumma and Tudor so that programmable microprocessor-based personal computers could operate within these systems as actors, either at the level of analog signal or digital data. Just as they were able to design systems of electronic music, The League were able to expand these systems to digital music and information. Once these individual micro-computer musicians began to combine their CPU-controlled electronic musical systems together in a manner that allowed for the exchange of data between computers, network music was born. "The electronic system as musical actor" had become "the interconnected network-array of modular interactive cybernetic systems as musical actor."

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[50] John Bischoff and Tim Perkis. “The League of Automatic Music Composers 1978-1983.” Liner notes accompanying The League of Automatic Music Composers. The League of Automatic Music Composers 1978-1983. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.

By the time of The Hub, technological hurtles that had burdened the League had begun to dissolve. Strides in consumer-industrial development (primarily at the level of hardware) and musical research (primarily at the level of software and programming languages) had resulted in personal computers that unto themselves, without recourse to external analog systems, were continually more capable of simultaneously addressing issues of high-speed processing of control, communication, and digital sound synthesis.

In an effort to address the limitations of the primitive and cumbersome communications protocol that The League had developed in order to interface with one another, former League members Bischoff and Perkis decided from the outset to design a more flexible method of networked data exchange. The result was “The Hub”, which was essentially a collective mailbox into which all performers could post data and from which this data could be taken and retooled.[51] Additionally, more direct connections between members would be maintained. By incorporating luxurious serial connections into this architecture, it became possible for other performers to simply “plug-n-play”.[52] The technical specification of this system were to go through a handful of progressions as network communication technology improved[53], but the basic architecture of the quasi-centralized communal messaging system was to remain the defining hallmark of the group.

While The League's history coincided with, and appropriately mirrors, the rise of consumer computer systems but operated along a local network model that prefigured the rise of the Internet, The Hub's history coincides with the rise of the Internet's consumer networking protocols. While The Hub was formalized in response to an offer to conduct the first performance of remote network music using ad-hoc communications protocol over serial connections,

[51] Chris Brown and John Bischoff, “Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area,” Crossfade. 2003, Accessed December 9, 2011, http://crossfade.walkerart.org/index.html and http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html.

[52] Ibid.

[53] The significantly more efficient “Son of Hub” system was incorporated in 1987, and a MIDI-Hub was developed in 1990. Being a standard computer interface, MIDI further opened up the possibility of new avenues of collective music making on personal computer networks.

it was not until The Hub's final project, Points of Presence, in 1997 that the selected communication network was the Internet. These two projects marked the first time that the network of locally perceptible stations is extrapolated into a larger remote network of liminal delocalized subsystems. In these instances, we are directly confronted with the abstract nature of the musical network that can sustain itself without an embodied local presence.

IV. C.
Site of Presence III: Internet

> *Networks work on a binary logic: inclusion/exclusion. As social forms, they are value-free. The results depend on the goals of a given network and on the elegance, economy, and self-reproductivity of the forms designed to perform these goals. In this sense, the network is an automaton. In a social structure, social actors and institutions program the networks. Once programmed, however, information networks powered by information technology impose their structural logic onto their human components, until their program is changed, usually at a high social and economic cost.*[54]

November 21, 1997
Center for Contemporary Music (CCM) at Mills College in Oakland, CA; CalArts in Valencia, CA; Institute for Studies in the Arts (ISA) at Arizona State University in Tempe, AZ

In Tempe, the music stops after ten minutes and there is no more sound for the duration of the performance; rather, the performance continues, but there is no music in Tempe. In lieu of music, the two men on stage provide a lengthy account of what should be happening. They should be able to communicate with the two performers in Valencia and the other two performers in Oakland by sending MIDI messages as udp packets over the Internet. But something isn't working. The performance is continuing in Valencia and Oakland, but Arizona is off the map.

[54] Manuel Castells, "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change," Coneixement | Societat 01, (January-April 2003): 15.

V.
Network Diagnostics: Issues That Arise in The Feedback Field

Since The League's first forays into network models of musical agency and ensemble dynamics, a number of issues – practical, theoretical, musical – have arisen that remain pertinent to contemporary discussions of artworks that use the network as their primary medium. I would like to informally address a handful of these issues here with insights as to how these musicians tackled them.

V.A.
Dissolution of the Point: Naming of the Network

> *When the elements of the network are not connected the music sounds like three completely independent processes, but when they are interconnected the music seems to present a "mindlike" aspect. Why this is so or why we can perceive some but not all activities as the product of an artificial intelligence is not understood.*[55]

In traditional music that assumes given organizational structures, events can be identified based upon their relatively clear meaning that is brought about by their codified relationship to these systems. In the art of systems that have been abstracted from clear causal schemata, while it may be immediately evident that there are indeed organizational structures, it's often unclear to the audience what these structures are and consequently what a particular thing means/is. But we are confident that the system, by its very existence, is the essence of organization and if it were disorganized it would not exist. The result is liminal, faith-based organization that is perceived chaotically; with the absence of traditional structural/formal tools at our

[55] John Bischoff, Rich Gold, and Jim Horton, "Music for an Interactive Network of Microcomputers," In The Foundations of Computer Music, ed. Curtis Roads and John Strawn (Cambridge: The MIT Press, 1985), 599.

disposal to assure us that events at all scales are meaningful, our only consolation comes from the knowledge that the system sustains itself and if it were not designed it would not exist and we would certainly not be able to hear it. What Brandon LaBelle refers to as "ephemeral architecture", or architecture/design that is abstract to the point of invisibility, is nonetheless architecture/design and must be accepted as such.

In the music of The League, for the listener the lines between the "sub"-compositions of each station are non-existent. Certainly, one can focus in on a given sonic cue - a sound, a note, a timber, a rhythmic figure - but its source is indisinguishable as a product of a discrete causality. This is not, for example, an instrumentalist in a Classical orchestra whose musical role and spatial location can be isolated from the rest of the ensemble in a manner rather akin to a pointillistic brush stroke, allowing it to blur into a gestalt field of social, musical, and spatial relationships that can be regarded as an ensemble, instrument, or composition unto itself. Instead, every "event" is taken as an indiscrete ripple in the feedback-fabric-field of a social, musical, spacial, digital, electronic gestalt that has been designed as an exercise in the liminal avoidance of perceptible points. We can never be certain that a heard unit is an absolute unto itself; where "a unit unto itself" can be the product of interactive processes without providing any indication of those constituent processes that resulted in its presentation as an absolute event, (and thus presents itself as nothing more that itself, when in fact it is only itself because of what something else did to another something else), all points become suspect. Time-event, frequency-event (which, obviously, is already impossible to consider "outside of time"), sequence, phrase, form, individual performer/actor, social ensemble, are all flattened to the same field; that of the relational interconnected network and its timeless presentness.

More specifically, within the network-as-musical-actor model, it becomes astoundingly difficult to discuss or name anything “smaller” than the total form of the network. As Collins points out, the musicians of The League made a calculated effort to instill their work with a deep musicality rather than

overt pedagogy.[56] As a result, their music often oscillates between moments of baffling “noise” and more directly perceptible cause-effect relationships. I find this sensitivity to the listener’s potentially overwhelming distance from the abstract construction of the network to be very satisfying.

This is not a value judgment on art that has yet to be made; it is merely a point that should be considered by future network artists.

V.B.
Local Presence and the Teleharmonium on the Other End of the Line

a/s/l/pic?

As Collins and Gann both observed after their attendance at The Hub’s debut at EIF/The Clocktower, the development of decentralized informational networks - not to mention the interest in artists employing such networks as a medium - has not discontinued local presence.[57,58] Rather, the “network society” or "informationalist society" is in fact a hybrid society in which disembodied networks exist in superimposed parallel to our embodied presence.

Remote performances stand in opposition to the urge for local communal interaction. From the ‘80s, these musicians had discovered the usefulness of "chat" software as a disembodied illusion of closeness that allows for displaced interpersonal communication. Apart from its quotidian applications, chat messaging has become a staple of contemporary networked performance set-ups. But it does not eliminate the need for other, more nuanced forms of communication for ensembles that desire interaction that will closely mimic embodied communication.

V. C.

[56] Nicolas Collins, “The Fly in the Ointment – Proto-Web Music by The Hub,” Nicolas Collins. Accessed December 9, 2011. http://www.nicolascollins.com/texts/flyintheointment.pdf
[57] Ibid.
[58] Kyle Gann, “The Hub Musica Telephonica,” Village Voice (New York, NY), June 23, 1987. Accessed December 9, 2011. http://www.o-art.org/history/Computer/Hub/HubTel.html

Bump Up Against the Envelope: Networks, Edges, and The Exclusivity Principle

> *Late twentieth-century machines have made thoroughly ambiguous the difference between natural and artificial, mind and body, self-developing and externally designed, and many other distinctions that used to apply to organisms and machines. Our machines are disturbingly lively, and we ourselves frighteningly inert.*[59]

The forays into developing networks by The League and The Hub illustrate the appeal and limitations of digital networked society. On the one hand, this was a fantastic new medium of social expression that paved the way for unimaginable reconfigurations of humans to one another. The payoff was the restrictive nature of the technology; in a dramatic linguistic metaphor, networked data necessarily demands the development of protocols that can allow shared exchanges between nodal machines. Without this shared, standardized code, communication is impossible.

Further, the rapid progress of technological research and development that continues to this day requires digital citizens to continually update their stations in order to maintain a relevant connection to the larger system. A failure to adapt to changing demands in hardware and software can result in overnight exclusion from the network. With the advent of the corporately-mediated Internet, which requires an ISP to whom one must pay for Internet access, vastly greater access to information and data points was subject to a fairly traditional commodity status. (Although promising developments of free ISPs have recently been announced[60], the exclusive nature of a capital-driven service remains the paradigm for the Internet for the forseeable future.) While the impermanence of technological paradigms has long been a concern of artists and archivists, The Hub member Mark Trayle's LMJ article illustrates the seemingly futile nuances that arise in the implementation of an "eternal"

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[59] Donna J. Haraway, Simians, Cyborgs, and Women (New York: Routledge Press, 1990), 152.

[60] Hackerspace Global Grid (Information: http://shackspace.de/wiki/doku.php?id=project:hgg. Accessed January 23, 2012) was proposed at the Chaos Communication Congress in December 2011, and FreedomPop (Information: http://freedompop.com/. Accessed January 23, 2012.) has plans to offer free broadband service to North American clients.

artwork that uses the Internet as its primary medium.[61] For even if something is permanently installed online, the Internet and its proto-web precursors depend upon technological architecture that is only available to privileged individuals. For example, an open-source work is only available to those who can meaningfully access and interpret its data.

Inspired by the techno-utopian dream of the unrestricted digital informational network, these pioneering artists discovered the practical limits of this dream; chiefly, that a network is defined by those areas that lay outside of its reach, by merit of the decisions of the network's designers, by a crash in an integral locale in the system (e.g. the Virilian "integral accident"), or by the failure of a station to meet the system's requirements. Returning to Castells' quotation that introduced section IV. C., the network operates upon a single binary principle: inclusion/exclusion.[62] Regardless of their agenda - be it the creation of a new pararchical society or a tightly regulated private subsystem within a larger public system – network designers must understand the exclusiveness of their decisions in determining public access. We have not yet seen networks, whether in the modest local connections of the improvisational music band or in the Internet's far-reaching striations of commoditized services, which are without edges.

During the composition of this paper, legislative debates in the U.S. congress (chiefly concerning the Protect Intellectual Property Act and Stop Online Piracy Act[63]) have laid bare the tenuous array commercial and political mediations that could prevent a typical Internet user from accessing online content. Even if such legislation does not pass and a new method of legalized censorship-mediation is not inserted into America's informational channels, the fact remains that such a large-scale coordinated rupture or blockage of these channels could be initiated by a governing body. (Indeed, numerous governments promote such restrictive strategies and impose them upon their

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[61] Mark Trayle, "Nature, Networks, Chamber Music," *Leonardo Music Journal*, Vol. 1, no. 1 (1991): 51-53.

[62] Manuel Castells, "The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change," Coneixement | Societat 01, (January-April 2003): 15.

[63] More information on these legislation can be found at http://thomas.loc.gov/cgi-bin/bdquery/z?d112:h.r.3261: and http://thomas.loc.gov/cgi-bin/bdquery/z?d112:s.968: (Accessed January 24, 2012).

citizens.) These issues serve to emphasize Castells' observation regarding the inclusion/exclusion principle of networks. Any network, understood as a system of relationships that have been designed by some sort of "architect", possesses within its very nature the potential to not be accessed. In the case of an oppressive governmental institution that has chosen to restrict the Internet usage of its citizens, such a scenario can only occur because the Internet was designed to operate in such a way that a government can restrict the access of its citizens. In other words, the Internet - our largest informational network - was designed and implemented in such a way that governing bodies can (and do) control the exclusivity (or inclusivity, depending upon how you look at it) of the Internet on the largest scale. Electric power distributors, ISPs, hacker groups, and other interstitial institutions can alter the exclusivity/inclusivity of the Internet, but not on the same macro-level as governing bodies.

I would argue that the expanded social consciousness sought by The League, The Hub, and their early compatriots in pioneering digital networks were undeniably successful in concretizing an informationalist society that values the mediation of human connectivity via cybernetic digital systems. However, the full utopian promise of these technologies have not been able to surmount the exclusivity principle; on the one hand, large-scale information networks such as the Internet require many standardized infrastructural components (protocols, servers, ISPs, up-to-date local machines and software, etc.) that must be coordinated with the cooperation of commercial and political institutions, and are thus subject to an overdetermined set of potential scenarios in which an individual could be denied access to (excluded from) the network. Standardization, serialization/repeatability, and generalization/flexibility are the hallmarks of an informational network infrastructure that can exist at the macro-scale; at this scale, increasingly sophisticated coordination in order to provide such an infrastructure results in a complex web with considerably fewer possibilities for order (inclusion: successful reception of information by the "user") than for disorder (exclusion: unsuccessful reception of information by this same user). Every level of coordination is a stage of mediation that can potentially fail, resulting in exclusion from the network. Of course, with increasingly sophisticated

methods of coordination (standardization, serialization/repeatability, and generalization/flexibility) comes the potential for broader scales of inclusion, with the caveat that one must fully submit to the mechanisms of coordination in order to remain included - in this sense, coordination is necessarily restrictive and hegemonic. The Hub's first attempt at a performance using the Internet illustrates the amount of coordination required to utilize a large-scale network and the pratfalls that are inevitable in such a feat of high-tech choreography.

On the other hand, small-scale information networks - such as a "LAN" band *à la* The League - are not subject to the same amount of coordinative mechanisms that are required to sustain large-scale networks. However, with fewer technological hurtles that must be perfectly coordinated comes a greater emphasis placed upon the coordination of those mechanisms. Where the large-scale network is built upon an infrastructure that emphasizes standardization, serialization/repeatability, and generalization/flexibility, small-scale network infrastructures can be idiosyncratic/specialized, static, and inflexible. A small-scale "niche" network can be designed to complete any customized network task in any manner that the designers see fit, without recourse to increasingly complicated levels of sophisticated coordination in order to appeal to a broad field of participants with varying needs and resources. (For example, a network could be designed to run one specialized program on four machines with similar hardware and identical operating systems, without requiring the use of a conventional ISP.) Here, the exclusivity principle is obvious; while a small-scale network can be custom-tailored to better suit the needs of a small user base, it cannot be extrapolated into the generalized sphere of broad public inclusion. This is the precise compromise that spurred The League's members to investigate new forms of networked musical interaction, an endeavor that ultimately begot The Hub.

Indeed, the principle of exclusion/inclusion is inescapable at both ends - small-scale (local) and large-scale (≥ global) - of the network. But this principle is cast in different hues at either end; one asks (technologically) more of its participants in order to potentially include more participants, while the other asks (technologically) less of its participants but can consequently include fewer participants. In my opinion, this highlights the major shortcoming

of these micro-network groups; namely, their inability to adequately address the essential limitation of "the network" as a medium for social action and musical activity in light of their techno-utopian ideals. Any network is fundamentally exclusive; thus, any networked social, political, or musical action is necessarily limited by the edges of the network within which it is situated. Perhaps it is too harsh to judge their earliest works given the highly experimental nature of pre-Internet digital communications technology, but by the time the Internet became the primary mode of large-scale digital networking in the mid-'90s, I am inclined to believe that utopic networkists lost their chance at touting their designs as a means of a totally connected free society given the inherent limitations of prevailing technological and economic paradigms. The dream was reigned in by the societal reality of the times, and we are currently sitting on the edge of our seats as the fragility of commoditized macroscopic networks become ominously transparent.

At the same time, we must remain humbled by these groups' pioneering forays into computer networking, informational improvisation, and experimental digital society. From their earliest pieces, they consciously confronted - and offered solutions to - so many of the issues that continue to inform the consciousness of the network society; issues that remain unresolved and hotly contested at all levels of culture. The ethos of techno-utopianism, founded upon the free and open exchange of information within a high-tech society, continues to drive innovators and inspire creative work outside of the sphere of the arts. Where sophisticated industrial-political mechanisms of large-scale networking aggressively promote an informationalist paradigm that is highly standardized and tightly regulated (or at least regulatable), we continue to hear of innovative projects such as One Laptop Per Child, FreedomPop, Hackerspace Global Grid, DIY manufacturing and fabrication resources, and increasingly inexpensive computer devices (smart phones, Raspberry Pi, etc.) that seek to challenge the necessity of "closed" networking that is bound by artificial exclusivity, such as exorbitant cost, phone jacks, power grids, censorship, commercial ISPs (network-as-commodity), etc. At the same time, widespread social protests beginning in 2011 illustrated the power of large-scale digital social networking's ability to transition into the streets and re-manifest itself as traditional, low-tech

channels of communication and hybridized organization.

The dream of a small subset of artists, hackers, and activists has not diminished and continues to inform our world in ways that may have seemed fantastic during the final quarter of the last century. I am continually exhilarated by the work of The League and The Hub because I find that these artists were remarkably prescient in their foretelling of our techno-social moment; too technologically mediated to be biological, but too human to be machine. Their music is a sonic cyborg letting out a hybrid howl at the rising moon of messy networks and sloppy cybernetics; an inter-dualistic digital drum circle that improvises on informational instruments.

Annotated Bibliography

Books

Butterfield, F.J. *The First Book of KIM*. Self-published, 1977. Accessed December 9, 2011. http://users.telenet.be/kim1-6502/6502/fbok.html

Cowell, Henry. *New Musical Resources*. New York: Cambridge University Press, 1996.

Haraway, Donna J. *Simians, Cyborgs, and Women*. New York: Routledge Press, 1990.

Manning, Peter. *Electronic & Computer Music*. New York: Oxford University Press, 1985.

MOS Technology, *KIM-1 Microcomputer Module User Manual.* Norristown, PA: MOS Technology, 1976. Accessed December 9, 2011. http://users.telenet.be/kim1-6502/6502/usrman.html#F51,

Partch, Harry. *Genesis of a Music.* New York: Da Capo Press, 1974.

Wiener, Norbert. *The Human Use of Human Beings*. New York: Da Capo Press, 1988.

Whittall, Arnold. *Musical Composition in the Twentieth Century*. New York: Oxford University Press, 1999.

Articles

Bischoff, John. “Software as Sculpture: Creating Music from the Ground up.” *Leonardo Music Journal*, Vol 1, no. 1 (1991): 37-40.

Bischoff, John, Rich Gold, and Jim Horton. “Music for an Interactive Network of Microcomputers.” In *The Foundations of Computer Music*, edited by Curtis Roads and John Strawn, 588-600. Cambridge: The MIT Press, 1985.

Bischoff, John and Tim Perkis. “The League of Automatic Music Composers 1978-1983.” Liner notes accompanying The League of Automatic Music Composers. *The League of Automatic Music Composers 1978-1983*. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.

Buchloch, Benjamin H. D. “Conceptual Art 1962-1969: From the Aesthetic of Administration to the Critique of Institutions.” In *Conceptual Art: A Critical Anthology*, edited by Alexander Alberro and Blake Stimson, 514-537. Cambridge: The MIT Press, 1999.

Castells, Manuel. “The Interaction Between Information and Communication Technologies and the Network Society: A Process of Historical Change,” *Coneixement* | *Societat* 01, (January-April 2003): 8-21.

Collins, Nicolas. “The Fly in the Ointment – Proto-Web Music by The Hub.” *Nicolas Collins*. Accessed December 9, 2011. http://www.nicolascollins.com/texts/flyintheointment.pdf

Gann, Kyle. “The Hub Musica Telephonica.” *Village Voice* (New York, NY), June 23, 1987. Accessed December 9, 2011. http://www.o-art.org/history/Computer/Hub/HubTel.html

Gresham-Lancaster, Scot. “The Aesthetics and History of the Hub: The Effects of Changing Technology on Network Computer Music.” *Leonardo Music Journal*, Vol. 8 (1998): 39-44.

Leidecker, Jon. “Producer’s Notes.” Liner notes accompanying The League of Automatic Music Composers. *The League of Automatic Music Composers 1978-1983*. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.

Trayle, Mark. “Nature, Networks, Chamber Music.” *Leonardo Music Journal*, Vol. 1, no. 1 (1991): 51-53.

Wigley, Mark. “Network Fever,” *Grey Room*, no. 4 (Summer, 2001): 82-122.

Websites

Brown, Chris and John Bischoff. “Indigenous to the Net: Early Network Music Bands in the San Francisco Bay Area.” *Crossfade*. 2003. Accessed December 9, 2011. http://crossfade.walkerart.org/index.html and http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html

Hannan, Ross and Corry Arnold. “Berkeley.” *Chicken on a Unicycle*, 2011. Last updated September 13, 2011. Accessed December 13, 2011. http://www.chickenonaunicycle.com/Berkeley%20Art.htm

James, Greg, Barry Silverman, and Brian Silverman. “Visual Transistor-Level Simulation of the 6502 CPU.” *Visual6502*, 2009. Last updated January 8, 2012. Accessed January 23, 2012. http://visual6502.org/welcome.html

Matthews, Ian. “The Rise of MOS Technology and the 6502.” *Commodore*, 2002. Last updated June 4, 2007. Accessed December 31, 2011. http://www.commodore.ca/history/company/mos/mos_technology.htm

Naberezny, Mike. “The 6502 Microprocessor Resource.” *6502.org*, 2011. Last updated April 4, 2011. Accessed December 9, 2011. http://www.6502.org/

Audio Recordings

Channels. “Chivaree”. Album track. Performed by Channels. 2004. Washington, D.C.: DeSoto Records. Audio recording.

The Hub. *Boundary Layer*. CD. Performed by John Bischoff, Chris Brown, Scot Gresham-Lancaster, Tim Perkis, Mark Trayle, and Phil Stone. 2008. New York: Tzadik Records. 3-disc audio recording.

The League of Automatic Music Composers. *The League of Automatic Music Composers 1978-1983*. CD. Performed by John Bischoff, Jim Horton, Tim Perkis, David Behrman, Paul DeMarinis, Rich Gold. 2007. New York: New World Records. Audio recording.