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DIY in Early Live Electroacoustic Music: John Cage, Gordon Mumma, David Tudor, and the Migration of Live Electronics from the Studio to Performance

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DIY IN EARLY LIVE ELECTROACOUSTIC MUSIC: JOHN CAGE, GORDON MUMMA, DAVID TUDOR, AND THE MIGRATION OF LIVE ELECTRONICS FROM THE STUDIO TO PERFORMANCE

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This dissertation is dedicated to the memory of my brother, Eric Hartman.
Now your legacy can live on not just in audio format—but in text as well.

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ABSTRACT

This research examines early live electronic works by Gordon Mumma, David Tudor, and John Cage—three influential American experimental music composers who designed, built, and recontextualized electronics for live performance—and the Do-It-Yourself (DIY) aesthetic embodied by their instruments and the compositions written for them. This dissertation serves as a presentation of original research into the earliest composers of live electronic works and the necessary DIY approach used in building independent systems. Previous research on the DIY perspectives in music often touch on the grass-roots nature of contemporary electroacoustic systems but there is not yet research specific to the DIY approach taken by these three composers, who collaborated together on the earliest live electronic systems used in performance in the late 1960s and 1970s.

Composers today continue to be influenced by the works of Mumma, Tudor, and Cage as they follow the same DIY traditions in the experimentation and implementation of circuitry and adaptation of emerging technologies in instrument design. The DIY tradition continues within the circuit design and engineering techniques that continue to be implemented in systems that are customized and tailored specifically for music performance. These individualistic and self-built systems are reflective of the composer's skills in and adaptability to nascent technologies.

Innovation and experimentalism have become standard procedure for today's composers, who are driven forward to create, as well as to adapt, electronics for performance and the underlying DIY aesthetic of electroacoustic systems can be credited as far back as the instruments and systems build for live performance in the late 1960s and 1970s (known as live electronics), which was a period of transition of electronics from the studio to live performance. The efforts of Mumma, Tudor, and Cage remain influential on composers and performers today

and it is important to recognize how the concept of DIY existed in their works as well as push forward a new area of research into the significance of DIY in music and technology.

CHAPTER 1. INTRODUCTION

Electroacoustic music has been defined by Simon Emmerson in the book *Living Electronic Music* as "a music heard through loudspeakers or sound made with the help of electronic means...that definition is extended here to include amplified acoustic music where the amplification changes, in essence, the experience of the sound and is integral to the performance."[1] He later goes on to define 'live electronic music' as a term that "has often meant *both* music produced and performed through real-time electroacoustic activity of some kind *and* music which combined live performers and fixed electroacoustic sound ('tape')."[2] In a footnote, Emmerson further explains the ambiguity and discrepancies in understanding fixed electroacoustic sources such as tape as live electronic music and explains that the term 'live electronics' was often used by composers in order to differentiate from compositions using fixed media tape for playback in performance.

For the development of live electronic instruments and systems, composers have had to experiment with a variety of available technologies, which has required them to develop a wider range of skills—specifically those needed for the electrical engineering of analog instruments. This has attributed to the inherent DIY (Do-it-Yourself) aesthetic in live electronic music. According to Gordon Mumma:

> Live performance with amplified small sounds aided by the development of new live-performance electronic equipment became an important activity during the 1960s. It gradually attracted the attention of many, who, philosophically committed to the tape medium, had previously dismissed live-performance electronics as an unworthy endeavor. Between 1960 and 1965 most live-electronic music activity occurred in the

1. Simon Emmerson, *Living Electronic Music* (Burlington, VT: Ashgate, 2007), xiii.
2. Ibid., 104.

> United States. It was nourished by both the spirited experimental music milieu and the solid-state electronic technology readily accessible there.[3]

Composers such as Gordon Mumma, David Tudor, and John Cage developed electroacoustic instruments and systems through available technologies. American music experimentalism and the drive for innovation are traditions that continue today. This DIY approach to engineering live electronics has ultimately led to customized, or, in the case of John Cage, repurposed and modified electronics meant for live performance.

This dissertation is an examination of three influential American composers who built, designed, and recontextualized electronics for live performance and the DIY aesthetic embodied by their instruments and the compositions written for them. Gordon Mumma, David Tudor, and John Cage performed both roles as composers and engineers when they built or designed specific instruments and systems from electronic components. I will further explain specific concepts and traditions that make up the DIY aesthetic of live electronic music and its instruments. This includes circuit design and configuration, physical instrument design, as well as hardware hacking/modification. The aim of this research is to explore the DIY practice in electroacoustic music and provide a documented history of Mumma, Tudor, and Cage, three composers who have experimented with and engineered new instruments and sounds.

Each chapter of this dissertation discusses an important composer of early live electroacoustic music and their contributions, beginning with Gordon Mumma followed by David Tudor and then John Cage. Live electroacoustic music as a concept is derived from taking technology, most often electronics from studios meant for the recording and playback of sound,

3. Gordon Mumma, "Two Decades of Live-Electronic Music, 1950-70," in *Cybersonic Arts: Adventures in American New Music*, ed. Michelle Fillion (Urbana, IL: University of Illinois Press, 2015), 83.

and incorporating them into a *live* performance. Gordon Mumma was chosen as the first composer discussed because of his highly influential work with cybersonic systems, which he used himself in performance. Also, his work in the late 1950s with the Cooperative Studio for Electronic Music and Cohen's Space Theater are a specific example of the migration of electronics from the studio to live performance. Tudor was directly influenced by Mumma, and his technological skills grew from his accessibility to Mumma's cybersonics, which he would take apart and then repurpose for his own performances. The chapter on Tudor shows his migration from a concert pianist to an electroacoustic performer and composer, as well as his important collaborations with Cage. As the father of American Experimental music, Cage was one of the most influential composers of twentieth-century electroacoustic works. Although he did not build electroacoustic systems to the scale of Mumma's and Tudor's, he did find new ways of rethinking electronics in performance and the philosophical implications of efforts still resonate with composers today. As the central trio of musicians for the Merce Cunningham Dance Company (MCDC) in the late 1960s and early 1970s, the collaborations between Mumma, Tudor, and Cage were significant for the exposure and dissemination of live electronic works.

Mumma joined Cage and Tudor as one of the three main musicians for the MCDC in 1966 and offered his own audio engineering skills which met the growing technological demands of recent music compositions for the MCDC. In the few years leading up to Mumma joining the MCDC, Mumma was often consulted with by Cage and Tudor for his expertise in electroacoustic systems which Mumma called cybersonics. Tudor had an interest in adapting cybersonics for his own performances and the first composition Mumma wrote for the MCDC, titled *Mesa* (1966), was performed by Tudor on bandoneon and used Mumma's cybersonics. Mumma's skills with cybersonics and tailor-made electroacoustic systems were one of the main reasons behind his involvement in the MCDC.

Before joining the MCDC, Mumma's first associations with Cage and Tudor began a decade earlier, however. Mumma was introduced to Tudor in February, 1953 by saxophonist Sigurd Rascher, who was a visiting performer with the University of Michigan Concert Band. At the time, Tudor was one of the most sought-after performers of post-war American and European experimental piano compositions known for his patient and meticulous study of complex and graphic notations, combined with his impressive ability to understand and reveal a composer's intentions in performance.

On March 22, 1953, Mumma attended Tudor's recital at the University of Illinois, where the Festival of Contemporary Arts was taking place. Tudor performed works by Pierre Boulez, Earle Brown, John Cage, Morton Feldman, and Christian Wolff. Mumma was also introduced to John Cage at the festival, who performed as pianist on *Sixteen Dances for Soloist and Company of Three* at Merce Cunningham's dance recital on the final night. Cunningham also performed the premiere of *Suite by Chance*, which included tape music by Christian Wolff. This festival and the introductions of Tudor and Cage are mentioned in Michelle Fillion's preamble to Gordon Mumma's book of collected writings, *Cybersonic Arts: Adventures in American New Music*, which served as "a short biography" of Mumma and shows the influence these introductions had on Mumma. Not mentioned in Fillion's preamble, however, was the premiere of Cage's *Williams Mix* (1952), which took place at that festival.[4] *Williams Mix* was a landmark piece for electroacoustic composition. Eight tracks of tape were made from between 500 to 600 recordings

4. John Cage, liner notes to *The 25-Year Retrospective Concert of the Music of John Cage*, Wergo WER 6247-2, CD, 1994, 17.

done by Louis and Bebe Barron. The tapes were put together by Earle Brown, Tudor, and Cage.[5] According to Thom Holmes, "the novelty of *Williams Mix* was that Cage relied on tape splicing techniques as a major compositional element of the piece rather than merely as a device for hiding transitions from one recorded sound to another."[6] Splicing the recorded tapes created different envelopes of sound, where the attacks and decays could be modified, similar to Mumma's *Mograph* compositions that would come later.

The performances that took place at the Festival of Contemporary Arts in 1953 were significant for Mumma, as is reflected in Mumma's brief biography, and the influence of David Tudor and John Cage would become more apparent and direct over the years as Mumma's own tape compositions for theatre, from as early as 1954, evolved into live electronic works that employed magnetic tape as a storage and playback medium, a transition that was reminiscent of Cage's *Williams Mix* (1952) to *Fontana Mix* (1958).

According to John Richards, "the grass-roots nature of DIY maker music...is rich in 'what ifs' and experimentation, a dynamic field that remains emergent."[7] Experimentalism is one of the key elements of a DIY aesthetic. The idea of experimentalism in music has been carried over from acoustic to electroacoustic compositions and instrument design. In the American experimental tradition, composers such as Harry Partch, John Cage, and Henry Cowell were active in expanding the traditional roles of instruments and tonality. Partch built instruments with new systems of intonation, while Cage and Cowell experimented with traditional instruments that were augmented or prepared in different manners to create newer sounds. In

5. Ibid.
6. Holmes, 108.
7. John Richards, "DIY and Maker Communities in Electronic Music," in *The Cambridge Companion to Electronic Music*, eds. Nick Collins and Julio d'Escriván (Cambridge: Cambridge University Press, 2017), 256.

Handmade Electronic Music: The Art of Hardware Hacking, Nicholas Collins specifically mentions John Cage as an important figure in the history of electronic music makers and hackers:

> The influence of John Cage (1912-92) on American avant-garde music cannot be overstated. Given the breadth of his impact as a composer and theoretician, his significance in the rise of hacker electronic culture is sometimes overlooked. Throughout his career Cage had a passionate curiosity for new sounds and compositional strategies. Lacking institutional support in the form of orchestral commissions and the like, Cage, the son of an inventor, chose to develop new instruments from everyday technological and commonplace objects.[8]

In the research presented here, Cage's *Imaginary Landscapes* serve as the earliest examples of live electronic music performance. Cage's earlier works using electronics are more reflective of the "hacker electronic" culture that Collins mentions, as can be seen in Cage's usage of modified turntables, however, these works are also important in setting up the later discussion of the modification, or hacking, of circuits seen in later works by Cage and David Tudor.

Most of the compositions presented in this research encompass 1960s-1970s live electronic instruments and systems that were custom-built by or for the composer, and embody Emmerson's definition for live electronics. However, earlier works by Cage which hack (or modify) and recontextualize commercially produced electronics are included as they demonstrate a shift away from using electronics in their originally intended format and show a growing interest in customized live electronic systems. It should be taken into consideration that the components and devices built by the composers were often approached as instruments. For example, David Tudor defined his transducers connected to resonant materials for the piece *Rainforest* as "instrumental loudspeakers."[9] Gordon Mumma also described his cybersonics as

8. Nicolas Collins, *Handmade Electronic Music: The Art of Hardware Hacking*, 2nd ed. (New York: Routledge, 2009), 38.

9. See block quote on page 41.

“‘instruments’...inseparable from the compositions themselves.”[10] Thus, a large number of live electronics and live electronic systems are in fact described as *instruments*.

As builders of electroacoustic devices today envision and create their own instruments, they are continuing both the experimental and DIY traditions demonstrated in works by Mumma, Tudor, and Cage. Today’s composers of live electronics works are prototyping, designing/reconfiguring circuits, and programming in the same DIY vein as earlier analog technologies. They are often responsible for both the composition of music as well as for the design of the instrument through which the music is created. The finished instruments are examples of thorough experimentation and hard work. The research presented here will be an examination of the early live electronic instruments and their compositions which were created at a time when electronics were being transitioned from out of the studio and into live performance. It largely focuses on the DIY practice intrinsic to a composer’s own engineering or design of tailor-made electronic instruments and systems.

This dissertation serves as a presentation of original research into the earliest composers of live electronic works and the necessary DIY approach used in building independent systems. Previous research on the DIY perspectives in music often touch on the grass-roots nature of contemporary electroacoustic systems but there is not yet research specific to the DIY approach taken by these three composers, who collaborated together on the earliest live electronic systems used in performance in the late 1960s and 1970s. The efforts of Mumma, Tudor, and Cage remain influential on composers and performers today and it is important to recognize how the concept of DIY existed in their works as well as push forward a new area of research into the significance of DIY in music and technology.

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10. See block quote on page 5.

CHAPTER 2. GORDON MUMMA

> My electronic music equipment is designed to be part of my process of composing music. I am like any composer who builds his own instruments, though most of my "instruments" are inseparable from the compositions themselves. My "end-product" is more than a package of electronic hardware: it is a musical performance for a live audience. On occasion my technical concerns may be differently oriented from those of the usual electronic engineer. Nonetheless, we are concerned with common ground: the applications of electronic technology, in my case to music.[11]
>
> –Gordon Mumma

Gordon Mumma is one of the most important figures of early live electronic and electroacoustic works as a composer, performer, and writer. The live electronic instruments he built for his compositions were a prolific contribution to the world of mid-20th century electroacoustic music, and his performances of these works in the touring groups the Merce Cunningham Dance Company and the Sonic Arts Union, of which Mumma was a founding member, allowed him the opportunity to spread his work and collaborate on an international scale in the 1960s and 1970s. Before his work with the Merce Cunningham Dance Company and Sonic Arts Union, Mumma's early career included being a founding member for the Cooperative Studio for Electronic Music, the ONCE Festivals, and the touring ONCE Group.

For his compositions, Mumma designed and built "cybersonics," a term he came up with and used to describe "the live-electronic processing of primarily acoustical sounds by which some aspects of the sounds are fed back into the electronic system and modified 'by characteristics derived directly from the sound itself.' "[12] These instruments demonstrate Mumma's unique grasp on electronic engineering in the design and structure of his circuitry, and his ability to create musical instruments for live performance through an assemblage of

11. Gordon Mumma, "Creative Aspects of Live-Performance Electronic Music Technology (1967)," in *Cybersonic Arts: Adventures in American New Music*, ed. Michelle Fillion (Urbana, IL: University of Illinois Press, 2015), 43.

12. Michelle Fillion, introduction to *Cybersonic Arts*, xxi.

hardware. Cybersonic compositions by Mumma that will be discussed are *Medium Size Mograph 1963*, *Mesa*, and *Hornpipe*, along with *Megaton for Wm. Burroughs*, a multimedia piece that uses live electronics and pre-recorded tape. All of these works are demonstrative of Mumma's command over electronics and circuit-design, which were developed through the experimentation and adaptation of technologies in the spirit of DIY.

2.1 Early Professional Life and the DIY Studio

While living in Ann Arbor, Michigan in 1954, Gordon Mumma's professional work with electronic experimental music began by creating film soundtracks and electronic music for theater.[13] That was the year Mumma left the University of Michigan, where he briefly studied composition with Ross Lee Finney and Leslie Bassett. According to Michelle Fillion, in the preamble to Gordon Mumma's book *Cybersonic Arts: Adventures in American New Music*, Mumma withdrew from the University of Michigan "in the fall of 1954, too busy with other creative activities to complete his degree. Thereafter he continued his association with the University of Michigan—and with academia in general—on his own terms."[14] Activities such as creating soundtracks and incidental music using the university's Theater Department's tape recorders gave him freedom to experiment with electronics in his earlier compositions. For Mumma, this was an opportunity to pursue his interest in composing with technology, one that was not being fulfilled in his previous studies. It was also the creative spark that would lead to years of successful collaborations on multimedia works.

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13. Mumma, "Creative Aspects," in *Cybersonic Arts*, 43.
14. Michelle Fillion, preamble to *Cybersonic Arts*, xxix.

Mumma also collaborated with the artist, sculptor, and University of Michigan faculty member Milton Cohen, beginning in 1957 for Cohen's Space Theater. The Space Theater was a "portable geodesic dome"[15] where multimedia performances made up of projections and music took place. "Cohen's intention for this project [was] to explore the mobile relationships of projected light and color in space and their dramatic integration with music."[16] To compose music for the space theater, Mumma, along with Robert Ashley—a graduate composition student in Finney's studio—formed the Cooperative Studio for Electronic Music, which they began building in 1958. The Cooperative Studio actually consisted of two separate studios, one for each composer, which contained equipment that was set up and engineered in a way unique to each composer's technical requirements. The Cooperative Studio, and the music created through it for Cohen's Space Theater, was Ashley and Mumma's first joint project. Many collaborations between Ashley and Mumma followed, including the establishment of the ONCE Festival and the Sonic Arts Union.

The design of the Cooperative Studio was the model and basis of Gordon Mumma's 1964 article, "An Electronic Music Studio for the Independent Composer," which was requested by Robert Moog to be published in the *Journal of the Audio Engineering Society*. The article served as a sort of DIY guide to building your own studio affordably, making it a possibility to anyone who had an interest in electronic music. At the time, most studios were attached to academic institutions, radio stations, or electronics manufacturers. They were made up of expensive and inaccessible equipment that was not always available for composers. According to Mumma:

> The composer has the alternative of building his own studio and assuming the engineering and financial responsibilities himself. This task is not as awesome as might at

15. Mumma, "Manifestations: Light and Sound, Milton Cohen's Space Theatre (1961)," in *Cybersonic Arts*, 9.
16. Ibid.

> first be imagined, particularly in the United States, where a wide selection of high-fidelity components is available at a reasonable cost. It should be understood, of course, that long-term stability and precise calibration are refinements that invariably mean higher cost and greater size. Where economy is a major consideration in the construction of an independent studio, compromises may be necessary.[17]

Mumma understood the dilemma of economic feasibility in such a project. One of the key components of DIY, in general, is the affordability of tools for your project. And for composers pursuing this particular DIY project—building an independent studio—the overall cost would have been a primary concern.

The common-held understanding was that all studio equipment was expensive, as was the case in the larger, established studios. Mumma, however, wanted composers to understand that a "wide selection of high-fidelity components" was readily accessible, even at a cost that would have been much more affordable than commercial studio equipment. Conversely, Mumma made sure to point out that a higher cost was directly related to the "long-term stability and precise calibration" of components. This presented the composer with two problems: the first was that they would have needed to make "compromises" on the quality of components—as Mumma mentioned—and the second was that they needed to be informed on what equipment would be most valuable for their studio.

Mumma's article acted as a DIY guide for the composer looking to build an independent studio. Even though it lacks schematics and diagrams for the engineering aspect of equipment set-up, it provided enough technical information in a straight-forward and well thought out way for the composer to design and build their own studio themselves—within their own financial constraints. The model, and inspiration, for the article was Robert Ashley and Gordon Mumma's

17. Mumma, "An Electronic Music Studio for the Independent Composer (1964)," in *Cybersonic Arts*, 15.

two studios built for the Cooperative Studio for Electronic Music. The first half of the article discusses studio equipment and the second is all about the studio configuration. He separates necessary studio components into four parts:

> (1) General manipulation apparatus: tape transports, recording and playback amplifiers, and mixers; (2) sound sources: electronic oscillators and stored material of acoustical origin; (3) modification apparatus: filters and equalizers, transposition devices, gating and envelope control, and reverberation; and (4) accessories: power supplies, monitoring and analysis equipment such as meters, loudspeakers, the oscilloscope, splicers, and the bulk eraser.[18]

Equipment needed correlated to the type of compositions the composer would be creating. Since Mumma mostly produced tape music at this time for the Space Theater, his equipment largely dealt with manipulation and modification apparatuses. He only suggested a few sound sources, listing oscillators and generators, but also later on mentioned portable tape recorders for "field work" in his configuration for Ashley's studio.

For the manipulation studio equipment, high-fidelity gear was available on the market, making it easier to find the tape transports, recording and playback amplifiers, and mixers. This brought focus onto how this manufactured equipment would be laid out. In the studio configuration section of the article, he focused on how to set up a personal work station in an ergonomic and intuitive way, stating that "consideration should thus be given to placement of the equipment allowing the most manipulation for the composer's chosen working procedure in a position that produces the least fatigue."[19] For this, Mumma understood that the tape transports, which took up considerable space and were a core component in terms of functionality, were the focus of the two studios. He stated that "The most important aspect of this first [Ashley's] studio configuration is that the tape transports are mounted in a fixed location above the mixing and

18. Mumma, "An Electronic Music Studio," in *Cybersonic Arts*, 15.
19. Ibid., 19.

amplification equipment on the apparatus panel…The tape transports are mounted vertically in such a way that elaborate loops can be routed conveniently above the entire apparatus panel."[20] He also later stated that "the most important aspect of the configuration of this second studio is that two tape transports are located below the mixing and amplification equipment within easy reach of my right hand …These transports are mounted on special brackets, tilted back at a slight angle from the vertical, and can be moved forward onto the worktable." Both Mumma and Ashley were able to personalize the layout of their equipment in their independent studios. Even with manufactured studio equipment, there was a DIY factor in understanding how the components fit together in an intuitive way that was comfortable for each composer.

Modification equipment, however, required a different kind of DIY from the manipulation equipment. In the introduction to his article, Mumma stated that "only in the area of sound modification, which employs filtering, transposition, modulation, compression and expansion, and envelope control procedures, is it necessary to construct special devices."[21] As manipulation gear was available on the market, "modulation apparatus suited for use in electronic music composition [was] not commercially available, but [was] neither difficult nor expensive to build."[22] The need for DIY in this case, was not for a financial reason, but rather it was because such equipment did not yet exist on the mass markets.

Mumma's article lacked schematics and diagrams, which would have provided much more insight on the types of modification equipment he used in his studio. Instead, he stated that "passive semiconductor modulators are useful for complex spectrum generation and are limited only by the quality and balance of their few simple components. With selective use, balanced

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20. Mumma, "An Electronic Music Studio," in *Cybersonic Arts*, 20-21.
21. Ibid., 16.
22. Ibid., 18.

diode bridge modulators or ring modulators can be applied to gating and frequency transposition as well."[23] Continuing on with a little more depth, Mumma wrote:

> Active modulators range from the simple twin-triode cathode modulator or transistor emitter modulator, for use in gating, compression, and expansion, to more elaborate devices such as the balanced push-pull output-type modulator with continuously variable control of the class of operation. This latter sophisticated device enables the composer to achieve sound-event sequencing without having to splice tape. The various types of passive and active balanced modulators, in conjunction with frequency filtering and wideband phase-shifting accessories, constitute an extremely important area of sound modification apparatus for electronic music composition.[24]

This is the most information provided by Mumma in the entire article about the design of DIY equipment, that is, non-commercially available equipment which would have been built by the composer. He does mention earlier in the article building one's own Wien bridge or phase-shift oscillator to achieve wider frequency ranges than the manufactured ones, however there is even less detail for building that equipment. It is important to note that Mumma's article originally appeared in the July, 1964 publication of the *Journal of the Audio Engineering Society*, a periodical that was comprised of highly-detailed and technical audio engineering articles. The audience for Mumma's article would have, therefore, most likely understood and been able to build such equipment without any further information. Even though it was not specifically a technical guide for assembling an affordable electronic music studio, it provided enough information on what was available at the time and what was built and used by Ashley and Mumma in their Cooperative Studio for Electronic Music and guided the independent composer in how a similar studio could be constructed.

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23. Mumma, "An Electronic Music Studio," in *Cybersonic Arts*, 18.
24. Ibid., 18.

2.2 From the DIY Studio to Live Electronics in Performance

> I am a composer and performing musician with considerable experience in acoustics and electronics, particularly solid-state technology. My professional work in electronic music began in 1954 with the making of film soundtracks and electronic music for theater. By 1957 I had established an electronic music studio. By the late 1950s I was exploring the resonant complexities of live-electronic music performance with Robert Ashley in Milton Cohen's Space Theatre productions. In that context I was developing and working with both acoustical and electronic sound modification procedures. Since that time my work with electronic music has evolved from its primacy as a magnetic tape medium to an almost complete preoccupation with the processing of acoustical sounds by live-performance electronic means.[25]
>
> –Gordon Mumma, "Creative Aspects of Live-Performance Electronic Music Technology"

In October, 1967, Gordon Mumma presented at the Thirty-Third National Convention of the Audio Engineering Society. Originally published among the Papers for the AES National Convention, Mumma republished his presentation in the "Cybersonics and the Sonic Arts (1966-1975)" chapter as an article in his book, *Cybersonic Arts*. His presentation, titled "Creative Aspects of Live-Performance Electronic Music Technology," recounted his compositional trajectory with electronics between 1954-1967, with focus on four of his live electronic compositions written between 1963-1967. In the performance of his earliest compositions, Mumma used tape solely for the playback and storage of music for film scores and at the Space Theatre. By 1957, Mumma was mostly using tape as a sound source for live electronics in Space Theatre performances. Pre-recorded sounds were played back and manipulated during performance with studio equipment kept at the Space Theater.

In 1959, Mumma began building electronic music equipment for live performances at Space Theatre built with transistors.[26] Having spent so much time in the studio experimenting with studio equipment, Mumma was able to build newer devices on a smaller scale, using the

25. Mumma, "Creative Aspects," in *Cybersonic Arts*, 43.
26. Mumma, "Manifestations," in *Cybersonic Arts*, 12.

transistors, which were portable and easier to use in performance than the original studio equipment configuration at the Space Theatre. A year later, Mumma, along with "electronic engineer William Ribbens founded Cybersonics, a small electronic design company in Ann Arbor for the design and production of sound-editing and processing equipment for live electronic music, film, and television."[27] As previously mentioned, cybersonics was a term created by Mumma to describe devices which used mostly acoustic sound sources that were both fed back and modified through a live processing system. Originally, Mumma's cybersonics were used for live performances at the Space Theatre (ca. 1959/1961)[28], but he soon began using them as a major part of his live compositions along with acoustic instruments.

2.2.1 *Medium Size Mograph 1963*

Gordon Mumma's first "fully cybersonic composition"[29] was *Medium Size Mograph 1963* for one piano, cybersonic console and two performers. Mumma wrote a series of *Mograph* compositions, which were inspired by his experiences as a research assistant at Willow Run Laboratories. The Acoustics and Seismology Lab operated out of Willow Run Labs and were experimenting with tape recordings of seismic activities from both naturally occurring events and underground nuclear testing. Although Mumma did not have the security clearance to work with

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27. Fillion, preamble to *Cybersonic Arts*, xxx.

28. According to Michelle Fillion, on page xxx in the Preamble to *Cybersonic Arts*, "In 1961 Mumma began experiments with cybersonic compositional procedures while designing electronic music equipment for the Cooperative Studio." Mumma, however, also says later in the text, on pages 11-12 in the second chapter of *Cybersonic Arts*, that "The last few years have seen the first commercial feasibility of transistor circuitry in electronics, and since 1959 I have been designing and building electronic music equipment and using this emerging technology in the Space Theatre." From this information, it can be determined that sometime around 1959/1961 is when he first started using cybesonics in the Space Theatre, a venue for which the Cooperative Studio was established.

29. Fillion, preamble to *Cybersonic Arts*, xxx.

the ASL, or access to their research, he was one day invited "to listen to speeded-up tape recordings of seismic activities, i.e., speeded up to be in human-audible range."[30] Within the title *Medium Size Mograph 1963*, the "size mograph" was a direct play on the word seismograph. The research being done by ASL involved the identification of seismic events based on audio data through markers such as attack, decay, and time, which correlate to Mumma's *Mographs*. Douglas Kahn explains that "in the *Mographs*, time is split between attacks, slowed down by the medium of the earth, sped up by techniques of the tape recorder, or arbitrarily set through a visual correlation of data and musical notation. The distances and spaces once associated with speed and duration are contracted and stretch. Yet, underneath this malleability is an earth-scale event."[31]

The score for *Medium Size Mograph 1963* includes a circuit diagram for Mumma's live electronics, or, as he originally called it, the *cybersonics*. "Vibration pickups attached near the soundboard and connected to 'cybersonic' circuitry in a small portable sound box. The inherent characteristic of piano sound—an initial attack followed by a resonant decay—is modified by the electronic circuitry."[32] Connected to the pickups and tape recorder, the circuitry consisted of an envelope follower which "changed the articulation of the piano sounds…readjusting the natural acoustical envelope of the piano's attack and decay, so as to have the attack characteristics occur slightly after the piano sound had already begun."[33] Played back over a loudspeaker, the result

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30. Douglas Kahn, *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts* (Berkeley: University of California Press, 2013), 155.

31. Kahn, 158.

32. Mumma, "Creative Aspects," in *Cybersonic* Arts, 44.

33. Gordon Mumma, program notes to *Medium Size Mograph 1963*. Found in: Kahn, *Earth Sound Earth Signal*, 159.

was a compressed piano attack, "its energy spread over into the late portion of the sound envelope, while the duration of the final part of the envelope is extended."[34]

Medium Size Mograph 1963 and its components were a result of Mumma's interest in DIY cybersonics and experimentation. Inspired by the tape-recorded experiments taking place at the ASL and his experimental work at the Space Theater, Mumma sought out to build a new relationship between performer and technology with a dedicated live electronics device. Wanting to reproduce the musical qualities he heard in the seismic recordings, Mumma built a cybersonic device that could manipulate the attacks and duration of the recorded piano sounds for playback. The patterns of attack, decay, and time shifting as sound waves moved underground were reproduced in the performance of the work by the performers and the accompanying electronics.

2.2.2 ONCE Festival

Even though Gordon Mumma's studies with Ross Lee Finney were brief, he maintained a relationship with Finney and his composition studio there, forming relationships with composers that would help Mumma in the establishment of the ONCE Festival of Ann Arbor. Mumma, collaborating with other composers, including Robert Ashley, founded the ONCE Festival which ran from 1961-65 and again in 1968. These two endeavors of his early career provided Mumma with both plenty of opportunity to experiment with studio equipment and live electronics. It also gave Mumma opportunities to perform his live electronic works at the successful ONCE Festivals, where a collaborative and creative milieu was forged for composers and performers of new music in the 1960s. Two significant compositions by Mumma completed during his ONCE

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34. Mumma, "Creative Aspects," in *Cybersonic* Arts: 44.

Festival years include the previously mentioned *Medium Size Mograph 1963* and *Megaton for Wm. Burroughs* (1963).

The ONCE Festival began in 1961 and was originally meant to occur one time, as a series of new music performances. Composers Robert Ashley, George Cacioppo, Gordon Mumma, Roger Reynolds, Donald Scavarda, and Bruce Wise worked alongside other Ann Arbor based artists from other disciplines to put on a four-performance new music series. According to Mumma, "The ONCE Festival happened because a community of artists took matters into their own hands. They extended their responsibilities beyond the limits of merely producing their art to its organization and promotion. For the most part they worked outside the established institutions of commerce and pedagogy, and with minimum funding."[35] The festival ending up being a successful endeavor and continued with five more festivals occurring 1962-1965. Well-known contemporary composers and performers such as La Monte Young, John Cage, and David Tudor came to Ann Arbor to participate. The ONCE Festival was a true collaborative festival that featured multi-media new works by many different composers and artists.

Many of Mumma's works were performed at the ONCE Festival, including *Megaton for Wm. Burroughs* (1963), a multi-media performance work that was premiered at the 1964 festival. The work was scored for "live performers, pre-recorded magnetic tape, film soundtrack, clickers, and ten communication channels."[36] Performers, wearing aircraft headsets to communicate with each other, would manipulate objects that were suspended on wires by throwing them, allowing them to swing back and forth. The swinging wires created vibrations that were amplified in combination with the prerecorded tape, which featured slowly-changing electronic sounds that

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35. Mumma, "The ONCE Festival and How It Happened," in *Cybersonic Arts*, 24.

36. Mumma, "Appendix: Selective List of Gordon Mumma's Musical Compositions," in *Cybersonic Arts*, 285.

morph into the sound of WWII propeller airplane engines, about 13-14 minutes into the piece. After a few minutes of engine drones, Mumma inserted an excerpt of a bomb raid from the British war film *DamBusters* (1954). Following that is a brief excerpt of orchestral music that signifies the success of the raid. The work closes out with a few minutes of another excerpt, this time a jazz percussionist on drumset, which provided a dynamic contrast from the previous barrage of both electronically-generated drones and theatrical WWII sounds.

The ONCE Festival provided Mumma with an opportunity to write and perform new live electronic works in a community that was open to experimentalism. It was also a unique destination for composer-performers from the US and Europe. Separated from institutions and ran by a community of artists, the ONCE Festival embraced experimental artists and audiences were keen to the exposure. The ONCE Festival was so successful, that they formed a collaborative touring ONCE Group in 1963 to fit the demand for outside performances. According to Mumma, the ensemble "circumvented that difficult problem arising from collaboration: the designation of credit for individual work. Each of our artists has generally been content to acknowledge production 'by the ONCE Group.' "[37] By 1967, the collaborative group had completed "more than two dozen performances on tour in the United States and a repertoire of ten original collaborative works."[38] Touring proved to be a fulfilling avenue for Mumma, and as the ONCE Festivals and ONCE tours were coming to an end, Robert Ashley, David Behrman, Alvin Lucier, and Mumma formed a new touring group called the Sonic Arts Group (1966-1976), later known as the Sonic Arts Union.

37. Mumma, "The ONCE Festival," in *Cybersonic Arts*, 33.
38. Ibid., 32.

The Sonic Arts Union provided an important solution to an economic problem composers and performers faced with live electronics at the time. Performances did not bring in a lot of money, and traveling was expensive, as was the potential cost for outside help in setup and performances with needed equipment. By bringing together their equipment and expertise, the SAU could "eliminate other costs by serving as both technicians and musicians. Because there was often little or no payment for such performances, the union served as a hedge against unnecessary expenses."[39] Unlike the ONCE Group, works were not composed by a collective, instead, the other members of the SAU most often acted as technical help during another composer's performance.

2.2.3 *Mesa*

Around the same time of the formation of the Sonic Arts Union, Gordon Mumma began his collaboration with the Merce Cunningham Dance Company (MCDC). The opportunity grew from his associations with both John Cage and David Tudor, members of the MCDC at the time. Gordon Mumma was a perfect fit for the MCDC, as is reflected in his chapter on Merce Cunningham, "From Where the Circus Went" (1975)[40]:

> How I joined the Cunningham Dance Company was never very clear. My previous relationship to John Cage and David Tudor had been as a musical collaborator and technical assistant in several concerts. I had built special electronic music equipment for them, and at Tudor's request I was at work on a composition for his bandoneon. On several occasions Tudor had mentioned that they were considering someone to assist them with the increasingly complex sound equipment of the dance company repertory. It was through a mutual friend, Anne Wehrer, that word first reached me of their interest in inviting me to join the company for their European tour in the summer of 1966.[41]

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39. Thom Holmes, *Electronic and Experimental Music: Technology, Music, and Culture*, 5th ed. (New York: Routledge, 2016), 442.
40. Mumma, "From Where the Circus Went (1975)," in *Cybersonic Arts*, 109-36.
41. Ibid., 109.

The official request to join came from John Cage in June of 1966[42]. Cunningham soon after requested a composition by Mumma. With only two months to complete the work, Mumma chose to rework a cybersonics composition he started for David Tudor to perform on bandoneon, titled *Mesa*. According to Mumma, "the predominant character of the music involves sustained sounds at one dynamic level interrupted by sounds of greatly contrasting loudness. I had already given up the idea of a composition on magnetic tape, which would have proved incapable of producing the kind of dynamic range I wanted."[43] In order to achieve the "frequency spectrum and sound density"[44] Mumma desired, the work used six microphones, a cybersonics console for processing, and loudspeakers placed throughout the audience.

In *Mesa*, the sounds from the bandoneon provided control signals for sound modification functions, which is a process Mumma called 'cybersonic.' The cybersonic console was a culmination of his experiments in electronic circuits and self-designed systems. The result of this work was a carefully designed system. As a live performance piece, the composition itself lived within the electronics. The electronics were not just a means of amplification, but rather, a console for creating new sounds with the bandoneon. For Mumma, building a cybersonic system was another form of composition. In explaining his "system concepts," Mumma stated that "my engineering decisions concerning electronic procedures, circuitry, and configurations are strongly influenced by the requirements of music making. Thus my designing and building of circuits is "composing" that employs electronic technology in the achievement of my musical art."[45]

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42. As recalled by Mumma himself in "From Where the Circus Went."
43. Mumma, "Creative Aspects," in *Cybersonic* Arts, 46.
44. Ibid.
45. Ibid., 44.

The title for *Mesa* was a reference to the geological features seen in the Southwestern United States and its' characteristic expanse of elevated lands. As inspiration, Mumma used his cybersonic console to create sustained sounds that were manipulated, gradually, over long periods of time. The loudspeakers were placed throughout the auditorium, resulting in "dispersed sounds" that mixed "in various spatially disorienting ways to produce the impression of continually changing size within the sound space."[46] In performance by the Merce Cunningham Dance Company, *Mesa* was the music that, along with choreography, lighting, and stage design, formed the larger work that Cunningham officially titled *Place*. The work was premiered in Saint-Paul de Vence, France on August 6, 1966. For three years, *Place* was performed on tour by the MCDC in the United States, Europe, and Latin America in nearly thirty performances.[47]

The Merce Cunningham Dance Company provided resources for transporting larger live electronic systems, such as the one Mumma designed for *Mesa*. Large containers of equipment used by the MCDC were loaded onto a truck for transportation. The MCDC afforded the musicians the ability to transport hundreds of pounds of electronic equipment. At the venues, however, the musicians were responsible for carrying, unpacking, and setting up their own sound equipment. Although these systems were able to be moved around, they were by no means easy to carry.

2.2.4 *Hornpipe*

One of innovative tasks in live electronic system designs taken on by Mumma during his touring years, was that of creating portable live electronics. Not just systems that could be transported to venues, but also portable during the performance. One such device was the

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46. Mumma, "From Where the Circus Went," in *Cybersonic Arts*, 119.
47. Ibid.

portable cybersonics console that Mumma wore around his waist on a belt for the piece *Hornpipe*. This more compact and streamlined approach to engineering allowed Mumma to perform French horn while moving about the stage.

The device itself was a control unit that consisted of a small metal box housing a small analog-type computer and signal processor.[48] Two small microphones were attached and placed on the belt. Line-level outputs from the console ran through a long cable, which Mumma called the "umbilical cable," and connected to the amplifier and loudspeakers. *Hornpipe,* an improvisatory work, began with "a solo for horn, during which the cybersonic console is silently 'listening,' monitoring the resonances of the horn in the acoustical space and adjusting its electronic circuits to complement these resonances. When it has stored sufficient information, a gate opens and the electronic 'response' of the console is heard from the loudspeakers."[49] The performer could then respond to what was heard on the loudspeakers, making decisions on how to proceed, via "assessing the resonances of the performance space and choosing sonorities that…support, rebalance, or subvert the activities of the cybersonic console. The hornist is also able to deactivate the cybersonic circuitry by playing sounds that are outside the resonant constellation. The performance ends when the hornist provides new sound information that purposely contradicts the accumulated resonances and effectively shuts down the response activity of the console."[50] *Hornpipe* was premiered at Pomona College in Claremont, CA on December 5, 1967. It was one of Mumma's main touring pieces from 1967-1976, and was performed over thirty times across the United States, in Europe, and in Japan.[51]

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48. Mumma, "Two Cybersonic Works: Horn *and* Hornpipe," in *Cybersonic Arts*, 56.
49. Mumma, "Two Cybersonic Works," in *Cybersonic Arts*, 59.
50. Ibid.
51. Ibid.

2.3 Expo ’70, Osaka and *Sun(flower) Burst*

Sunf(flower) Burst was a composition intended to be performed at the Pepsi Pavilion, a venue coordinated by the Experiments in Art and Technology, for the Expo ’70 in Osaka Japan. The performance was never actualized, however, and what exists of it now is a seven-step, written proposal[52] for the work which can be found in Chapter 10 of Mumma’s book, *Cybersonic Arts*. *Sun(flower) Burst* was intended to make use of the visual and lighting features of the Pavilion, along with its innovative sound system, all designed specifically for the space. Mumma was going to include tape and live electronics in the performance, which featured dancers as well. Although the work was never performed, it does show how Mumma was going to make use of a live electronics system on a much larger scale. One that was designed, built, and then transported from the United States to Osaka, Japan.

The sound system for the Pepsi Pavilion was designed and coordinated by David Tudor. Larry Owens, Fred Waldhauer, and Gordon Mumma were responsible for designing and building different elements of the sound system which included the analogic and digital interfaces, a loudspeaker system of thirty-seven loudspeakers on a rhombic grid, and the sound modifier console. The console was designed and built by Mumma and consisted of an eight-channel system with twelve controls for each channel.[53] Inputs and outputs were programmable by cards and tape, eight channels summing up to four sound sources resulting in thirty-two volume controls, and three modifiers—frequency modulation, amplitude modulation, and a high-pass filter.

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52. See “Proposal for Live Programming: *Sun(flower) Burst*”: Mumma, “A Brief Introduction to the Sound-Modifier Console and *Sun(flower) Burst*,” in *Cybersonic Arts*, 71-72.

53. Mumma, “A Brief Introduction to the Sound-Modifier Console,” in *Cybersonic Arts*, 66.

Fred Waldhauer, an engineer at Bell Laboratories assisted Mumma in obtaining the newest transistor technology at the time for the console, which was then "soldered to survive the flight to Japan and was accompanied by [Mumma's] scrupulous installation instructions."[54] Unfortunately, the instructions were ultimately disregarded and the newer transistors ended up being blown out on their first installation and replacements had to be sent. This illustrates both the difficulty of portability of self-built systems and the installation of such systems without the designer being present.

2.4 Final Thoughts

Gordon Mumma is a prolific writer and collaborator of live electronic music. As a collaborator, Mumma performed a key-role in the establishment of many important performance groups, events, and venues for new music. This included the Milton Cohen Space Theater, the Cooperative Studio for Electronic Music, the ONCE Festival and ONCE Group, the Sonic Arts Union, and later on, the Pepsi Pavilion at the Expo '70 in Osaka. His collaborative efforts also included composing works and building live electronic systems for the Merce Cunningham Dance Company. His writings from and about the 1960s are key in understanding the milieu of DIY composers during that time. This included how to build a studio with what was available to consumers, and working on a large-scale project attaining the newest technology for the Pepsi Pavilion.

Gordon Mumma's conceptual approach to engineering as a form of musical composition was both innovative and creative. The cybersonic systems mentioned consisted of designated

54. Mumma, "A Brief Introduction to the Sound-Modifier Console," in *Cybersonic Arts*, 66.

circuitry and simple analog computers which could assist the performer(s) in creating music that expanded outside of the boundaries of conventional acoustic instruments. New sounds were imagined and achieved with Mumma's ability to design and engineer such systems. In *Medium Size Mograph 1963* and *Hornpipe*, acoustic instruments were complimented by cybersonic systems that used the audio input as both sound sources for playback, as well used for acoustic information that could trigger modifier circuits, manipulating the resulting sound. These works, and their accompanying cybersonics have been an integral part of live electronic compositional history.

CHAPTER 3. DAVID TUDOR

There are two distinct facets to David Tudor's musical career. From the early 1950s, he established himself as a virtuosic pianist to whom many postwar avant-garde works were dedicated. He then began performing experimental works for piano and live electronics, eventually becoming a composer of live electronic works himself. One of the most influential relationships in Tudor's life was that with his friend and fellow composer, John Cage. The two met in 1950 and were two formative members in the Merce Cunningham Dance Company in 1953.

After meeting Tudor, Cage began his first indeterminate composition, *Music of Changes*. Tudor was very influential during Cage's composition of the piece, as can be seen in their correspondence.[55] It was written for and premiered in full by Tudor on January 1, 1952. Their correspondence on this work showed a collaborative effort, where Cage was strongly influenced by how Tudor felt of groundbreaking composition. Eventually, their trust and respect for one another led to successful endeavor as the first two composers for the Merce Cunningham Dance Company. In addition to their work with MCDC, Tudor assisted Cage on his electronic works *Williams Mix* (1952), *Cartridge Music* (1960), and *Variations II* (1961).

Encouraged and inspired by his live electronic collaborations with John Cage, Tudor eventually found his voice as composer/performer of his own works, first with *Fluorescent Sound* (1964). After *Fluorescent Sound*, Tudor was hesitant to think of himself as a composer. It wasn't until after composing two influential works—*Bandoneon! [a combine]* (1966) and *Rainforest* (1968)—that Tudor was able to embrace his status as a composer.

55. Refer to second chapter of Martin Iddon, "Correspondence, 1951-1953," in *John Cage and David Tudor: Correspondence on Interpretation and Performance* (New York: Cambridge University Press, 2013).

In 1970, Tudor was a part of the Pepsi Pavilion project. Built for the Expo ’70, a world’s fair held in Osaka, Japan, the pavilion was a collaborative effort between artists and engineers from the nonprofit E.A.T. (Experiments in Arts and Technology). A large geodesic dome was built to be an immersive sound, performance, and art venue. David Tudor was responsible for overseeing the design and construction of the sound system. He was assisted by Gordon Mumma and Fred Waldhauer. This large-scale construction was a unique collaboration between artists and engineers and Tudor’s shift from performer to composer of live electronics is exemplified by his work with E.A.T.

Throughout both periods as pianist and composer, Tudor was driven to always create something new—either as an experience for the audience through his interpretations of piano works, or through his circuitry with which he composed his live electronic works. Talking about his migration “from piano to electronics” in a 1972 interview, Tudor stated “Also I think I’m happiest when I’m doing something I haven’t done before, because when people are asking you to do things, then you have the opportunity to enter into action with other people; whereas what was happening was that I was more and more playing the same things all the time. First it was Boulez, who had a very small output. They were marvelous pieces, but how many times do you want to play the same piece?”[56] Behind Tudor’s shift from performer to composer was a drive for innovation. He didn’t want to become complacent in constantly performing the same works, instead, he had an interest in new and more experimental works—and who better to create them than the virtuoso performer himself.

56. David Tudor and Victor Schonfeld, “From Piano to Electronics,” *Music and Musicians* 20, no. 12 (August 1972): 25.

3.1 Collaborations with John Cage

> When I came to the Cage [composition] I had to work on the moment-to-moment differences. *Music of Changes* was a great discipline, because you can't do it unless you're ready for anything at each instant. You can't carry over any emotional impediments, though at the same time you have to be ready to accept them each instant, as they arise. Being an instrumentalist carries with it the job of making physical preparations for the next instant, so I had to learn how to be able to cancel my consciousness of a previous moment, in order to be able to produce the next one. What this did for me was to bring about freedom, the freedom to do anything, and that's how I learned to be free for a whole hour at a time.[57]
>
> -David Tudor

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By the time John Cage's *Music of Changes* was completed in 1951, Cage and Tudor had established a strong musical relationship. Cage valued Tudor's feedback on his first indeterminate composition, and Tudor found inspiration and discovered a new interest in indeterminate works. The freedom Tudor felt performing *Changes* came from the indeterminacy of the work. In traditional compositions, a performer knows what is coming and, as mentioned in the above quote, is physically preparing for the next event. There was freedom in the experimental nature of this work in that the music flowed into a new and unexpected direction during the performance. The performer was not so tied up in what was coming next. Tudor's fascination with the indeterminacy of the composition was something that would carry directly over into the imprecise nature of the way in which live home-built circuits and electronics would perform.

Tudor's earliest experiences with electronic works came from his collaborations with Cage. One of those collaborations was for *Williams Mix* (1952). Tudor—along with Earle Brown, Morton Feldman, and Christian Wolff—assisted Cage in the preparation of the work. The electronic work consisted of eight tracks of magnetic tape that were performed

57. Tudor and Schonfeld, "From Piano to Electronics," 24.

simultaneously. The tapes were made from hundreds of field recordings made by Bebe and Louis Barron. Recordings were spliced together in ways that would alter their sound envelopes. For the eight tapes, Cage created a 192-page graphical score.

Years later, Tudor again assisted Cage on the composition of another electronic work, *Cartridge Music* (1960). The name of the work comes from the cartridges used in phonographs, which held a needle and acted as a pick-up. The cartridges were manipulated by placing small objects in them and running them along objects in performance. Tudor was involved in the preparation and rehearsals of *Cartridge Music*. He was also tasked with finding transducers from local junk shops and assisted in designing the set up for mixers and amplifiers. During this period, Tudor became interested in the idea of experimenting with different resonant objects in electroacoustic compositions.

Tudor was also influential during the composition of Cage's *Variations*, the first of which—*Variations I* (1958)—was dedicated to David Tudor. Following that was *Variations II* (1961), a composition "for any number of players and any sound producing means."[58] Tudor's realization for amplified piano is the one of the most influential early live electronic works.

> In preparing the composition for performance, David Tudor's realization of the score evolved from his initial decision concerning the instrumentation. Having previously used amplification in several performances of Cage piano pieces, Tudor decided to make a version of *Variations II* for amplified piano, in which the total configuration would be regarded as the instrument. Therefore, any sound generated in the system (such as audio feedback) would be accepted and utilized in the performance.[59]

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58. John Cage, *Variations II* (Middletown, CT: Henmar Press Inc., 1961), title page.

59. Richard Teitelbaum, back matter to *New Electronic Music from Leaders of the Avant-Garde – John Cage: Variations II – Henri Pousseur: Trois Visages de Liège – Milton Babbitt: Ensembles for Synthesizer*, produced by David Behrman, Columbia Masterworks MS 7051, 33 rpm, 1967.

Standard microphones, contact microphones, and phonograph cartridges were used for the setup of Tudor's realization of *Variations II*. For the altered piano sounds, contact microphones were attached to both the piano and stiff wire automobile springs called "curb-scrapers," which were used on the strings of the piano. Phonograph cartridges were used in a way similar to *Cartridge Music*, where objects were inserted into them and then placed in contact with the piano strings. All audio signals were then mixed and amplified. As mentioned previously, "the total configuration would be regarded as the instrument."

Tudor's approach to Cage's work allowed him the opportunity to devise his own configuration for acoustic and electronic elements. It was yet another exploration, for Tudor, of live electronics mixed with resonant objects. These compositions would prove to be a major influence on his later work *Rainforest* (1968). Not only did electronics allow Tudor to expand his expertise on piano performance, but it also allowed him creativity in finding his own unique sound. There was a unique DIY element behind the set-up of the amplified piano in Tudor's realization of *Variations II*, and Tudor was proving his own capacity for electroacoustic setups. Not only that, but Tudor's realization of *Variations II* proves itself to be an early example of Tudor's live electronic compositional abilities, as *Variations II* was another of Cage's indeterminate works—where the performer was required to make their own compositional choices in the performance of the work.

3.2 Tudor's Migration "From Piano to Electronics"[60]

> That's how I became aware that…historically I should claim it…I had no intention of, it's like I had no intention of composing anything and signing my name to it, but now it appears that I should have. Because in fact that was my first composition that I could

60. Section heading comes from the title of the Tudor and Schonfeld article "From Piano to Electronics."

> claim as my own. So the only documentation that I have was that I had the diagrams of the switch boxes, whereas the next piece that I did was in '66, the bandoneon piece…there's circuit diagrams for not only the electronic hookup but for many of the electronic components. In those days I was making a lot of my own components…a lot of electronic activity evolved from Gordon Mumma's participation, which happened before he worked for the Cunningham Company.[61]
>
> -David Tudor on the components and composition of *Fluorescent Sound*

In a 1994 interview with Matt Rogalsky, David Tudor commented that the migration to composer happened unintentionally in September of 1964 with his first work *Fluorescent Sound*. It was an experimental electronic piece created for a one time performance of a Robert Rauschenberg happening at the Modern Museum in Stockholm. For Tudor, it was meant to be an explorative piece that accompanied Rauschenberg's performance work *Elgin Tie*. In *Elgin Tie*, a live Swedish cow was led across the stage as Rauschenberg descended from a skylight down a rope into a barrel of water on a farm wagon. After exiting the water, Rauschenberg slipped into a pair of boots nailed onto the farm wagon, allowing an impressive angle to lean forward as the wagon was led out by an assistant. Rauschenberg requested that Tudor compose music for his performance—the resulting composition was *Fluorescent Sound*.

At the time of the performance, Cage, Tudor, and Rauschenberg were all members of the Merce Cunningham Dance Company(MCDC)—Cage and Tudor as composers and Rauschenberg as a designer. The performance of *Elgin Tie* and *Fluorescent Sound* happened while the MCDC was on tour in Europe—although it was not an MCDC performance itself. During the 1960s, the MCDC was experimenting with electronics in performance. *Fluorescent Sound* was a natural extension of the live electronics works Tudor performed with Cage and

61. David Tudor, interview with Matt Rogalsky, November 2, 1994, found in Matt Rogalsky, " '…in rehearsals, or preparation, or setup, or from one performance to another': Live Electronic Music Practice and Musicians of the Merce Cunningham Dance Company," (master's thesis, Wesleyan University, 1995), 126.

within the MCDC. Tudor was instrumental in the performance and circuit design of numerous works as a collaborator. *Fluorescent Sound* was his first foray into composition, and would prove to be the turning point as Tudor migrated from acoustic piano performance to electronics. In the introduction to the 1972 article "From Piano to Electronics"—an interview with Tudor by Victor Schonfield—he acknowledges the turning point to be around 1965, when Tudor "abandoned piano and turned to his own compositions."[62]

Tudor was experienced in engineering works for live electronics through his collaborations with Cage—specifically in Cage's *Cartridge Music* and *Variations II*. Based on that experience, Tudor composed *Fluorescent Sound*, an experimental work where Tudor used contact microphones connected to non-instrumental sources—fluorescent lights. The work explored the sounds of the lights as they were turned off and on. Over three days, Tudor connected over 200 fluorescent light bulbs to contact microphones for the performance. During the performance, Tudor turned the fluorescent bulbs on and off via 75 switches in a switch box—each one controlling approximately six bulbs. The unique popping resonances and electrical sounds that occurred during the process were picked up by the contact microphones and then amplified. Although "unintentional," the result was Tudor's first work as a composer—for which the only existing score today is the switch box diagrams Tudor used for the setup and performance of the work.

3.2.1 *Bandoneon! [a combine]*

> A group of artists were solicited by Billy Klüver, who was working for Bell Laboratories, who loved the New York art scene very much. And so, he wanted to make technology available to them and through the cooperation of many engineers at Bell Laboratories he created this festival, *9 evenings: theatre & engineering*. We had to work on the audio

62. Tudor and Schonfeld, "From Piano to Electronics," 24.

systems and the programming of the audio systems and I had a large part in the basic design parameters so we decided how to go for clean audio whether to make it portable—I was working with the electronic end of it. And I noticed how the whole system had been created because each artist wanted certain things to happen, but they required different components. Well I noticed that nobody was really using a lot of the features of the system so I set out to put everything to use. So, I made *Bandoneon!*[63]

-David Tudor

Bandoneon! (to be read as *Bandoneon Factorial*), was Tudor's first full performance work as a composer.[64] The *!* in the title is the mathematical symbol for factorial, which represents the multiplication of integers, similar to the concept behind the complex work featuring the multiplication of audio and visual signals. The festival where the work was performed, *9 Evenings: theatres & engineering*, featured "ten New York artists and thirty engineers and scientists from Bell Telephone Laboratories [who] collaborated on a series of innovative dance, music and theatre performances."[65] The festival took place at the 69th Regiment Armory in New York City, October 13-23, 1966.

Tudor, who had a role in setting up and programming the audio systems for the festival, saw an opportunity to compose a large-scale work for multimedia. Tudor performed on the bandoneon, which was modified with contact microphones and programmed audio circuits. Fred Waldhauer, an engineer at Bell Labs, performed on his "Proportional Control System", which was a table-top interface meant to be controlled by an electronic pen:

It was essentially used to spatialize sound: 12 zones were allocated to 12 speakers distributed around the performance area…in *Bandoneon!*, the Proportional Control System allowed the luminous intensity of certain projectors, volume and sound

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63. David Tudor, *Bandoneon! [a combine]*, DVD, presented by Experiments in Art and Technology and ARTPIX (San Francisco: Microcinema International, 2009).

64. Holmes, 440.

65. Back matter to *Bandoneon! [a combine]*, DVD.

spatialization to be controlled. In this performance, the input was not the pen, but rather the sound signal emanating from the bandoneon and captured by four microphones.[66]

Robert Kieronski, also an engineer from Bell Labs, used his “Vochrome” instrument for the performance of *Bandoneon!*:

> Bob Kieronski, a friend of mine, designed a device which he called the "Vochrome." It was a set of harmonium reeds, pirated from a harmonium, in an enclosure that was made to be as soundproof as possible, because my desire was not to have the sound of the reeds present. And I attached two contact microphones inside the bandoneon to vibrate the reeds. Bob designed the Vochrome so that it would mechanically vibrate relays, and then he recalled that he had in his basement some old relays and that he could connect them to the Vochrome. One day, when we were trying it out, he said that the only problem with the relays was that they're in sequence and you have to start a sequence from the beginning, so would you like it if I put a switch on your bandoneon so that you can reset the relays to zero. That was one of the most important things, because by touching that button I could stop the sound. The silence was deafening, because the sound in the Armory was extraordinary, so reverberant. Once you started something oscillating, it would go on forever.[67]

Visual elements were contributed by Lowell Cross, who performed his “TV Oscillator” instrument. The “TV Oscillator” generated abstract images from the bandoneon’s audio signal—those images were then projected during the performance.

Accompanying Tudor, Waldhauer, Kieronski, and Cross for the first performance of *Bandoneon!* on October 14, were five other collaborators who controlled motorized wireless sculptures with joysticks. The sculptures, originally used for Deborah Hay’s piece *Solo*, were remote-controlled carts that moved dancers around the performance space. For *Bandoneon!*, Tudor mounted sculptures made out of different resonant materials upon the carts. Transducers

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66. Vincent Bonin, “Proportional Control System,” The Daniel Langlois Foundation for Art, Science, and Technology, http://www.fondation-langlois.org/html/e/page.php?NumPage=592 (accessed August 30, 2018).

67. David Tudor, “David Tudor Interviewed by Joel Chadabe: Tomkin’s Cove, 9/8/93,” The David Tudor Pages, https://davidtudor.org/Articles/chadabe.html (accessed October 10, 2018).

were attached to the sculptures, resulting in what were a unique set of audio-producing sculptures which operated similarly to loudspeakers, minus the loudspeaker's cone. Controlled by joystick remotes, the carts holding the sculptures were guided about the armory, giving differing sound spatializations—or audio perspectives—to the audience.

Tudor's exposure to the bandoneon came from the composer Mauricio Kagel, who dedicated his work *Pandorasbox, bandoneonpiece*[68] (1960) to Tudor. Fascinated both by the instrument itself and the theatrical nature of Kagel's work, Tudor originally intended to perform a realization of the piece at the 1966 *9 Evenings* festival. Through the collaborations with the *9 Evenings* engineers, however, Tudor became more interested in how he could use the advanced systems being built, and was inspired to write a work of his own—*Bandoneon!*.

In addition to his work with Kagel, Tudor also collaborated with other composers on works for bandoneon. After meeting Tudor in 1963, Pauline Oliveros was inspired to write a duo for Tudor on bandoneon and herself on accordion. The piece, titled *Duo for Bandoneon and Accordion with Possible Mynah Bird Obbligato (See-Saw Version)*, was premiered at Tudor Fest[69] in 1964 at the San Francisco Tape Music Center. Another work written for Tudor to perform on bandoneon was the previously mentioned *Mesa*, by Gordon Mumma. This work, which used Mumma's cybersonics, was the catalyst for getting Mumma involved with the Merce Cunningham Dance Company. *Mesa* was premiered two months before *Bandoneon!*, in August 1966, by the Merce Cunningham Dance Company.

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68. Title of piece appears as cited from Jonathan Goldman, "The Buttons on Pandora's Box: David Tudor and the Bandoneon," *American Music* 30, no. 1 (Spring 2012): 31.

69. According to the article, "Still Listening: Pauline Oliveros Reflects on the Life and Music of David Tudor," which was published in the May 1998 edition of *Musicworks*, Tudor Fest was a festival curated and performed at by David Tudor. In the article, Oliveros stated the title of the festival was chosen "out of respect for David's formidable powers as a performer."

Mumma was a major influence on Tudor and his work with electronics in the years leading up to *Bandoneon!*. He often built systems—cybersonics—and shared them with Tudor at his request. Tudor learned how to take the devices apart and rework or expand upon them—that was his DIY approach to engineering components for live electronic works. According to Mumma:

> When David and John were in Ann Arbor at the ONCE Festival performing, I had some electronic equipment that did unusual things, that I had made myself. And he[Tudor] asked me could you build a copy—it was like a, I don't know, maybe a ring modulator, it could have been something simple like that. I made him a copy, right? I sent him little things like that, of course, he used them, but he also studied them, he took them apart, he redid things. Pretty soon he was connecting with other little kits, and putting them [together]…it's how he reassembled existing materials—that was the creative part of his work.[70]
>
> -Gordon Mumma

Through Mumma, Tudor had the chance to rework electronics—those components eventually contributed to the system he built for *Bandoneon!*.

Just as Tudor grew experienced with re-engineering components in live electronics through his exposure to Mumma's cybersonics, his ability to develop large-scale systems was influenced by his work with the engineers with whom he developed the audio systems for *9 Evenings*. For Tudor, *Bandoneon!* was an exploration in multimedia and environment. Fred Waldhauer's *Proportional Control System* allowed for the spatialization of sound over the large venue. The engineers measured an echo that was up to six seconds long within the armory.[71] What resulted, between Waldhauer's spatialization system, and electronics built by Robert Kieronski and David Tudor, was essentially a massive feedback system that could be approached as an instrument itself, the complexity of which was explained in one excerpt where it is

70. Gordon Mumma, interview from *Bandoneon! [a combine]*, DVD.
71. Billy Klüver, interview from *Bandoneon! [a combine]*, DVD.

discussed by David Tudor, Matt Rogalsky, Gordon Mumma, and John D. S. Adams in the DVD *Bandoneon! [a combine] by David Tudor*, presented by Experiments in Art and Technology (E.A.T.) and ARTPIX, and transcribed below:

> David Tudor: *Bandoneon* dealt with the bandoneon itself, which is one of the very few instruments which are two-sided. The bandoneon opens in two directions, but the reed assembly is available on two sides. So, I modulated one side against the other side, and that was the beginning of the piece *Bandoneon*.
>
> Matt Rogalsky: There were ten microphones on the instrument, on the bandoneon, including contact microphones, the same type of technology that they were using for John Cage's *Cartridge Music*, and which he had used for a piece he had done with Rauschenberg in Stockholm in 1964. And these are of the nature of a phonograph cartridge which has a place where you can insert a needle, so that would be a point of contact onto the bandoneon.
>
> Gordon Mumma: One side of the bandoneon was going into the frequency modulator, the other side—another complex sound—and the results of cross modulating two things that are quite different…complex acoustical spectrum…you can hear it…it becomes [a] massively complex spectral output.
>
> Rogalsky: So there are several of these contact microphones and also some air microphones.
>
> Mumma: The air microphones pick up what was coming out of the bandoneon, it also picked up what was in the air, it was already a kind of mixer you didn't have to plug into the wall or have batteries [for]. It was a kind of mixer with a delay line, mind you.
>
> Rogalsky: The whole armory became a feedback instrument that he could perform with. Within *Bandoneon!* he had circuits that were feeding back, producing sound on their own.
>
> John D. S. Adams: He would create feedback internally through an electronic circuit.
>
> Tudor: A lot of the sound modification devices had to deal with the home-built equipment I had built myself. And I had discovered the principal of what's called a saturated amplifier, where you arrange feedback around an amplifier to the point where the circuit oscillates of itself. All you have to do is activate it by putting a signal in and it can keep oscillating forever and ever, which is one of the features of the piece.[72]

72. *Bandoneon! [a combine]*, DVD.

Taking it a step even further, mobilized resonant sculptures were fitted with transducers and moved about the performance space. *Bandoneon!* was a massive feat for Tudor, with systems that would be impressive even by today's standards. It was a unique experimentation in multimedia systems for performances. *9 Evenings* provided Tudor with the opportunity to collaborate with Bell Labs engineers and expand his own knowledge of home-built electronics, as well as adapt them to large-scale venues and performances. Creativity and experimentation with electronics was the basis for Tudor's work, and the electronics and components themselves were his compositional tools.

3.2.2 *Rainforest*

> One of the ideas in my *Rainforest* series is that loudspeakers should be individuals, they should be instruments. So if you need a hundred of them to fill a hall, each one should have its own individual voice. How do you achieve this? You construct them. After all what is a loudspeaker? At present it's a reproducing instrument, but my feeling all along has been that you should regard it as a generating instrument. All musical instruments work by generating sound waves, and so does a loudspeaker, so if you regard it from that point of view your whole notion of how to construct one would change. Why shouldn't there be a thousand or more ways of building loudspeakers? Instead of what we consider to be electronic music at present, you would then make your music geared to what the particular loudspeaker can produce, and the whole input becomes simple instead of complex.[73]
>
> -David Tudor

In 1968, two years after the premiere of *Bandoneon!*, Tudor expanded upon one of the smaller features of the *9 Evenings* composition and cultivated it into his most well-known work—*Rainforest* (1968). It was an experimental work that further investigated the usage of transducers and resonant objects, similar to the sculptures used by Tudor in the performance of *Bandoneon!*. The piece itself was an exploration of the way in which different materials sounded when

73. Tudor and Schonfeld, "From Piano to Electronics," 26.

transducers were attached and audio signals vibrated through them. To paraphrase Tudor: why couldn't loudspeakers be approached as musical instruments themselves? That was the grain of thought that prompted Tudor's *Rainforest*.

Knowing the physical design of a loudspeaker is fundamental for understanding the concept and construction behind *Rainforest*. According to John David Weinland in his 1969 article:[74] "a loudspeaker is an electro-mechanical transducer consisting of a thin membrane (usually paper) set in motion by a coil of wire which is attached to the membrane and placed in a magnetic field. The amplitude of the sound depends on the distance travelled by the membrane (or its excursion), which in turn depends on the amount of current flowing in the coil of wire."[75] Another explanation, published more recently: "A speaker is a type of transducer that converts electrical energy (the audio signal) into mechanical energy (vibration of the speaker cone/diaphragm). This vibration transfers kinetic energy to the surrounding air, which results in creating sound waves that can be heard. The speed of vibration determines the frequency."[76]

The basic idea behind a loudspeaker, and its relation to *Rainforest*, is that a transducer functions by converting electrical signals—audio signals in this case—into "mechanical energy," or more specifically, the vibrations of the loudspeaker's paper cone. *Rainforest* was a rethinking of the traditional loudspeaker and how materials different from the typical paper cones reacted and resonated when transducers were connected directly to them.

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74. Source chosen for its proximity in date of publication to the composition of *Rainforest*.

75. John David Weinland, "An Electronic Music Primer," *Journal of Music Theory* 13, no. 2 (1969): 252.

76. Gary Altunian, "What Is a Transducer? (Definition)," Lifewire, https://www.lifewire.com/transducer-definition-3134818 (accessed October 8, 2018).

The first performance of *Rainforest* took place on March 9, 1968, and was commissioned by Merce Cunningham for his dance *RainForest*.[77] After receiving Cunningham's request a year earlier, in 1967, Tudor wanted to build upon his earlier work with transducers seen in *Bandoneon!*, which formed loudspeaker type objects from transducers and resonant materials. In the first performances of *Rainforest*, Mumma and Tudor sent audio signal via signal generators to transducers hooked up to various resonant objects—at least eight. Contact microphones attached to the objects were used to amplify the resulting sound. The focus of the "loudspeaker objects" were the resonant materials and how their materials accentuated or dampened particular frequency ranges—essentially forming a new "loudspeaker-instrument." The instrument was unique in regard to the way in which the acoustic material was being used, as Gordon Mumma described, in regards to the innovation within *Rainforest*:

> *Rainforest* is an example of acoustic modification of electronically generated sound. In its earliest form, the sounds of *Rainforest* were electronically generated and applied by special transducers to various resonant objects of wood, metal, and plastic. Each of the combinations of transducer and resonant object was an 'instrumental loudspeaker' that added and subtracted harmonics and occasionally created complex inter-modulations with the electronic sound sources. Further, attached to each 'instrumental loudspeaker' was a small microphone that allowed the acoustically modified sound to be further amplified and resonantly distributed by conventional loudspeakers throughout the performance space. He recycled his acoustical sounds through the mixer as if within an ecological system, returning them to the resonating objects and adding more sounds to the widening cycles.[78]

The "acoustic modification of electronically generated sound" formed from "combinations of transducer and resonant object" was an inherently experimental rethinking of a traditional loudspeaker executed by Tudor in *Rainforest*—and the whole driving force behind the work.

77. Tudor adopted the *RainForest* title that Cunningham originally came up with, taking away the capitalization of the letter F, spelling it instead as *Rainforest*.

78. Gordon Mumma, "David Tudor the Composer along the Path to *Rainforest* (2006/2013)," in *Cybersonic Arts*, 154.

The intrinsic DIY nature behind composing experimental live electronic works should not be glossed over. Although the concept behind *Rainforest* was simple—applying resonant objects as acoustic filters[79]—the preparation of the piece was more complex and thoroughly researched. Among the David Tudor Papers archive at the Getty Research Institute in Los Angeles, Bill Viola noted "there were folders of Radio Shack receipts for electronic components and materials…There were also many circuit diagrams, some with multiple changes and crossings out…[Included] was a small notebook where David had handcopied excerpts and sometimes entire articles, including illustrations and captions, from *Popular Electronics* magazine and other publications like it in the 1950s and 1960s."[80]

Similarly, Matt Rogalsky noted that a particular DIY article titled "Build a Coneless Loudspeaker" from the June 1966 issue of *Popular Mechanics* was found among Tudor's papers.[81] Published in June 1966, four months before *Bandoneon!* was premiered at the *9 Evenings* festival,[82] the article would have most likely have been influential in Tudor's experimental work with transducers. The article served as a how-to for a project by William Ashworth that appeared in *Popular Mechanics* six months earlier. Kits were also being offered for sale under the Parts List at the end of the article for $3.95.[83] The article offered experimental uses for a coneless loudspeaker:

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79. Matt Rogalsky, "Idea and Community: The Growth of David Tudor's *Rainforest*, 1965 to 2006," (PhD diss., City, University of London, 2006), 115.

80. Bill Viola, "David Tudor: The Delicate Art of Falling," *Leonardo Music Journal* 14, (2004): 53.

81. John Driscoll and Matt Rogalsky, "David Tudor's *Rainforest*: An Evolving Exploration of Resonance," *Leonardo Music Journal* 14, (2004): 26.

82. As previously mentioned, the festival took place October 13-23, 1966 in New York City.

83. "Build a Coneless Loudspeaker," *Popular Mechanics* 125, no. 6 (June 1966): 170.

> In a child's record player, cement the disc to one side of the case. This makes the entire case a sound-producing element. You'll be surprised at the improvement in the sound.
>
> If you cement one of these units to a wood door or the rear of a large plywood panel, the entire door or panel becomes a sound-producing source. You can do the same thing with most hard materials—such as doors, mirrors, windows.
>
> If you connect the speaker to the bottom of a coffee table, the tabletop will become a speaker.
>
> Among early proposals for potential coneless loudspeaker applications was one from a discotheque operator who said he could use it to turn his dance floor into one giant speaker so that dancers would then feel, as well as hear, the music. Obviously, this will take a much larger unit, but he might just be able to do it.[84]

The article served as a jumping point for DIY projects using the audio transducers. Publications such as *Popular Mechanics* are invaluable resources in understanding the context around Tudor's experimental work with live electronic compositions. It illustrates how Tudor was able to supplement his previous work with Cage in *Cartridge Music* and *Variations II*, and the types of sources he used for expanding his engineering knowledge.

After illustrating the concepts behind *Rainforest* and its initial performances, it is important to note that *Rainforest* later evolved and became referred to as a series with different performance versions. Although the delineations in performance titles to dates originally performed for *Rainforest II* and *Rainforest III* is fuzzy—the original intent was not to title each version *Rainforest [#]*. Rather, that occurred later. According to Matt Rogalsky:

> The numbering of *Rainforest* versions is, as Gordon Mumma has reinforced on more than one occasion, somewhat artificial and even misleading, in the sense that Tudor was well-known for continuous development of his works from performance to performance, and did not necessarily proceed in the discrete, deliberate steps which might be implied by the existence of the titles *Rainforest 1*, *2*, *3* and *4*. Tudor clearly found it useful to mark waypoints in the life of the piece in this way, however, so I follow, while keeping in mind the dynamic nature of Tudor's practice and his manner of developing new extensions to his works through experimentation in performance.[85]

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84. "Build a Coneless Loudspeaker," 170.
85. Rogalsky, "Idea and Community," 23.

A more simplified way of defining the versions *Rainforest II* and *Rainforest III* lies within the audio source materials.[86] *Rainforest II* called for voice input—specifically John Cage's voice—as source material performed through the transducers. The version known as *Rainforest III*, is known for the addition of tape materials as sound sources. *Rainforest IV*, was a collective performed work that first occurred in the summer of 1973 in Chocorua, New Hampshire. It was performed during a New Music in New Hampshire workshop by Tudor. It is important to note, however, that similar to other versions of *Rainforest*, the version title—*Rainforest IV*—did not appear until later. According to John Driscoll, "the title *Rainforest IV* only appeared in print during negotiations with René Block over the *Rainforest* LP that he produced on Edition Block in 1981."[87] Driscoll also notes that the original performance was nearly five hours long and took place in a barn. The title of the work for the first performance was *Sliding Pitches in the Rainforest in the Field*.[88]

Rainforest IV grew out of Tudors 1973 New Hampshire workshop, and was strikingly different from previous versions in that it was approached as a group composition—twelve students participated in the original performance. During the workshop, Tudor guided students in developing their own instruments, instructing them to use found materials for their transducers. "Instead of bringing back objects that could be used on a tabletop, as Tudor had expected, many returned with such things as a metal bedspring, a heavy wine barrel, cast-iron wagon wheel rims, metal cables, and more. Tudor immediately moved the workshop to a barn and the oversized, installation nature of the new *Rainforest* was established."[89]

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86. For more in-depth research on the different versions of *Rainforest*, reference Matt Rogalsky's PhD diss., "Idea and Community."
87. Driscoll and Rogalsky, "David Tudor's *Rainforest*," 28.
88. Ibid.
89. Holmes, 396.

The collective approach to the work was a significant evolution in the *Rainforest* series. Following the initial performance, *Rainforest IV* continued to be performed by the group, which became officially known as the Composers Inside Electronics in 1976, when they performed the work at the Festival D'Automne in Paris. Composers Inside Electronics grew from the original DIY approach set out by Tudor with the first performances of *Rainforest IV* into an established community for the purpose of making and performing works of their own. They performed through 1981 and, after re-forming in 1996, continue to perform as of now.[90]

The performance concepts behind *Bandoneon!* and *Rainforest* differ. *Bandoneon!* established Tudor as a composer and was a large-scale multimedia piece meant to explore and experiment with all available resources at the *9 Evenings* performances. Tudor incorporated as many different types of media as was made possible for the performance. As strikingly different the performance was of *Bandoneon!*, however, it was a direct precursor to *Rainforest*. Expanding on the idea of resonant sculptures used in *Bandoneon!*, Tudor composed *Rainforest* as an experimental and explorative study of the way in which music could be created out of found objects. *Rainforest* was a more narrowed-down study in home-built circuits. Tudor took a single concept: re-thinking the loudspeaker, and applied it towards the exploration of resonant qualities of different materials. Essentially, *Rainforest* was a DIY study in building acoustic filters using the same transducers as did *Bandoneon!*, and the nature of the music was determined by the performers' selection of found objects. In regards to Tudor and the innate musical qualities of his electroacoustic instruments, Nic Collins wrote: "Although Tudor was not the first composer to

90. Although the main website for Composers Inside Electronics has not provided an updated current performances list since 2014, there is a blog that mentions a CIE performance which took place in March, 2018: Sara O'Brien, "Sounding Out: CIE at the Kitchen," The Kitchen Center for Art, Video, Music, Dance, Performance, Film and Literature, http://thekitchen.org/blog/80 (accessed August 30, 2018).

make his own electronic instruments…in no other composer's work is the ethos of music *implicit* in technology so fundamental and clear."[91]

3.3 Pepsi Pavilion

One of the most unique "arts-meets-engineering" feats of Tudor's and Mumma's careers would have to be the Pepsi Pavilion. Built for the Expo '70 in Osaka, Japan, the dome shaped Pavilion was meant to operate as Pepsi's headquarters for the world's fair with an additional public space for performances. The initial idea behind the project was "to be nothing more than a shell, a set of bleachers, and a bandstand."[92] The project eventually fell into the hands of David Thomas, the Vice-President of Pepsi-Cola International in charge of marketing and distribution. Thomas consulted with his neighbor, artist and filmmaker Robert Breer, and ultimately decided to go in a new direction: "Instead of going the gimmick route [we wanted] to do something genuinely prestigious; to create a piece of contemporary art, one very much in keeping with an avant-garde group, but one also understandable by the people in Japan."[93] David Thomas coerced Breer into being a part of the project, and Breer recruited Billy Klüver, along with the E.A.T. organization. The Pepsi Pavilion project grew into a massive geodesic dome structure engulfed by artificial fog; inside was a multi-sensory experience consisting of a large helium-inflated spherical mylar mirror, kinetic sculptures, and a sound-modifier console connected to a 37-speaker sound system.

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91. Nicolas Collins, *Handmade Electronic Music: The Art of Hardware Hacking*, 2nd ed. (New York: Routledge, 2009), 48.

92. Nilo Lindgren, "Into the Collaboration," *Pavilion*, ed. Billy Klüver, Julie Martin, and Barbara Rose (New York: E.P. Dutton, 1972), 5-6.

93. David Thomas, as cited in Lindgren, "Into the Collaboration," 7.

E.A.T. was officially established in 1967 by engineers and artists involved in the 1966 *9 Evenings* performances. Tudor—who was the designer and programmer of the *9 evenings* audio system—was the go-to person for designing the Pavilion's audio system. Three other central figures were responsible for different elements of the Pavilion's design: Robert Breer, Frosty Myers, and Robert Whitman. Tudor, who was the lead for the audio system worked closely with Fred Waldhauer, Gordon Mumma, and Larry Owens on the system's development. Tudor and Mumma viewed the sound system as an instrument which could be performed.

> The sound-modifier system was proposed by composer David Tudor. When the time came to think about equipment for the sound system, Tudor brought Gordon Mumma into the project. Mumma suggested a system that would modify the pitch (frequency), the loudness, and the color (formants) of each of the eight channels of the sound system, so as to give the "player" a more flexible instrument.[94]

With twelve controls to each of the eight channels of sound—96 controls in total—performers with programmed works would have had an expansive instrument to work with. Unfortunately, not all of the twenty-four works that were programmed for the Pavilion were able to be performed as the arts program was suddenly terminated and all access to the venue was pulled after only a few weeks—resulting in a scramble to save recordings. A story of which was recounted by Matt Rogalsky:

> The tapes had to be "rescued" when PepsiCo decided they would take over control of their pavilion from EAT. Peter Poole recalls a 3 AM phone call from artist Robert Whitman saying "Gotta get the tapes out!"; they were accosted by a policeman as they threw tapes over the pavilion perimeter. Ritty Burchfield remembers smuggling other tapes out a few at a time, in the pavilion cleaners' carts.[95]

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94. Lindgren, 49.
95. Driscoll and Rogalsky, "David Tudor's *Rainforest*," 27.

Before the dissolution of the Pepsi Pavilion's artist-collaboration, Tudor had intended for nine works to be performed.[96] Three works were successfully performed and recorded by Sony: *Pepsibird, Pepscillator*, and *Anima Pepsi*.

One of the unique issues in artist-engineer collaborations is that of vision vs. execution, especially in a project of this scope—an issue that is uniquely discussed in Nilo Lindgren's chapter "Into the Collaboration" in the book *Pavilion*. Putting it into context, Lindgren wrote that the "collaboration was a four-way event, between artists and engineers, between a group of artists and a major business organization, and between them and businessmen, artists, and engineers in Japan."[97] He further explained: "It brought many engineers and scientists together with a group of artists whose concern for the 'environment' of the Pavilion stretched the limits of a straight engineering task."[98] Echoing Lindgren's thoughts, the priority for the Pavilion project differed between the engineers and artists; the engineers were concerned with the execution and overall engineering of the venue, whereas the artists were considering the "environment," or, essentially, the venue and its atmosphere—most likely from the point of view of the people experiencing the multi-sensory performances.

In addressing the issues of artist-engineer collaborations from the engineer's point of view, Lindgren wrote:

> Owens talked about the pressures of the collaboration on him. He found, of course, that it was a real learning process, because "the artist" he said is a person who "doesn't really want to make up his mind six or eight months in advance, and, yet, in a project of this magnitude, the technology demands such decisions in order to meet schedules." Owens went on, "occasionally, we've made unilateral decisions. The environmental concept as originally envisioned has altered, partly due to engineering decisions. The artist is much more vague than the engineer, so you are not making decisions based on facts. Sometimes you are making decisions based on the absence of facts! What the engineer

96. Lindgren, 58.
97. Ibid., 59.
98. Ibid.

> does in this case is to invent facts, make a decision, implement the decision, and then come back to the artist and say 'Is this what you meant?'" One of the problems, he feels, is that the artist does not know what engineering is, and then furthermore, "The artist doesn't visualize things in terms of words. The artist deals with things."[99]

Owens felt the pressure of the time-constraints on this project, and perhaps believed that the artists were being too abstract in their design plans for the audio systems—worried that they weren't defined enough for execution. However, the statement that "the artist does not know what engineering is" is incorrect; on the contrary, it should have been stated that the artist had a different approach to engineering. The artist(s)—specifically Tudor and Mumma—were familiar with engineering from a more experimental and need-based perspective. They engineered electronics as instruments.

In the same previously quoted article, Lindgren followed Owens' thoughts with Tudor's rebuttal:

> David Tudor felt that Owens' attitude—that the artist cannot participate in the engineering—precluded artistic alternatives in a situation with pressing deadlines. "At the beginning, one lays down the things one wants to work with," Tudor said, "then the engineering becomes an interpretation of this. If you then can't go inside the engineering problems and are never allowed to offer an alternative along the engineering road, the thing takes the engineer's shape. It was a one-way street, and my original ideas were leaving one by one. Of course there were strict time considerations and delays…but Larry wanted, above all, to present me with a finished product and warded off all 'meddling.'"[100]

Tudor's idea that "the engineering becomes the interpretation" illustrates his own approach to engineering, where the artist comes up with an original idea and then uses engineering as the tool for creation, versus Owens' idea that engineering is only possible once all of the facts are pre-determined. Additionally, Tudor mentioned the preclusion of "artistic alternatives," resulting from Owens' attitude towards the collaboration—which was that the artist was not supposed to

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99. Lindgren, 57-58.
100. Ibid., 58.

"meddle" in the engineering of the audio systems. Ultimately, Tudor's original concept for a much larger speaker array was unable to be executed, as the time-constraints and distance problems between the U.S. and Japan proved to be too large an obstacle to be overcome. However, whether or not Owens' stance on separation of engineers and artists was the principal factor in meeting those demands remains to be seen. Sources such as this, where the points of views specific to engineers and artists are presented, are beneficial in further understanding the scope of such a project as this. Lindgren's article offers a whole new perspective on the construction of the Pavilion and grants insight into the issues behind the collaborative milieu between artists and engineers.

3.4 Final Thoughts

Rainforest is arguably the most well-known series of works by Tudor, having undergone its own years-long evolution from the original MCDC performance version of 1968 (*Rainforest*) to the 1973 group composition performed in Chocorua, NH (*Rainforest IV*). Performances of *Rainforest IV* led to the development of the performance group Composers Inside Electronics (CIE),[101] who, between the years 1973-2011, had performed *Rainforest IV* over 40 times.[102] The propagation of *Rainforest*, however, did not end with *Rainforest IV*. Another version, *Rainforest V*, was premiered in 2009, thirteen years after the passing of David Tudor. It was the first installed version, described as "a self-running sound environment conceived by the late David Tudor and realized by the group Composers Inside Electronics. Each composer designs and

101. As previously mentioned, the name *Composers Inside Electronics* was officially adopted in 1976 but the group began performing together in 1973.

102. "*Rainforest* Chronology: *Rainforest* Performances/Installations (8/2011)," Composers Inside Electronics, http://www.composers-inside-electronics.net/cieweb/Rainforest/CHRONOLOGY.html (accessed October 26, 2018).

constructs a set of sculptures which functions as instrumental loudspeakers, and each independently produces sound material to display their sculpture's resonant characteristics."[103] With the creation of *Rainforest V*, Composers Inside Electronics remained true to the tradition of Tudor's *Rainforest* series as an experimental investigation into the resonances of acoustic materials (found objects) when audio signals are applied via electronics (transducers)—which Gordon Mumma succinctly defined as "acoustic modification of electronically generated sound."[104]

The formation of and continued performances by Composers Inside Electronics is an illustrative example of Tudor's presence and influence within the world of electroacoustic music. Typically, the lifespan of live electronics works lasts only as long as the technology itself, making it ever-increasingly difficult to reimagine works from the same period as Tudor's early works (1960s-1970s), yet CIE is dedicated to continuing in the Tudor tradition. The conceptual approach and experimentalism of Tudor's works continue to influence others. According to Pauline Oliveros:

> David tirelessly championed many composers by performing their works and becoming a mentor to other performers who were also composers and budding technologists. He helped to create the "audio art" genre as well as live electronic music. Many of the ingenious circuits for his compositions remain mysterious black boxes without schematic diagrams. He was dedicated to finding and using the inner and salient characteristics of materials and electronic circuits to make sounds. His inspiration for works such as *Rainforest* seeded many other works by those of us who performed with David and loved him for his generosity of spirit.[105]

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103. "*Rainforest V*," Composers Inside Electronics, http://www.composers-inside-electronics.net/cieweb/Rainforest/RAINFOREST_V.html (accessed October 26, 2018).

104. Mumma, "David Tudor the Composer," in *Cybersonic Arts*, 154.

105. Pauline Oliveros, "Still Listening: Reflections on the Life and Music of David Tudor," in *Sounding the Margins: Collected Writings 1992-2009*, ed. Lawton Hall (Kingston, NY: Deep Listening Publications, 2010), 12.

Tudor found his own electroacoustic methods through which new sounds and instruments were able to be realized after having learned first how to approach electronics in music composition from Cage and later on Mumma. Composers and performers today continue to engage a DIY approach where the inherent qualities of acoustic and electronic materials are exploited to create new musical experiences, which exemplifies the understated DIY ethos of Tudor's works.

CHAPTER 4. JOHN CAGE

In 1937, John Cage delivered a talk at a Seattle arts society meeting, the text of which was later printed in *Silence: Lectures and Writings* as "The Future of Music: Credo." Although the following quote did not appear in its published form as one continuous block, it was distinguishable from the remainder of the text by Cage's use of all capital letters. The remainder of the text in "Credo" further emphasizes the quoted text:

> I believe that the use of noise to make music will continue and increase until we reach a music produced through the aid of electrical instruments which will make available for musical purposes any and all sounds that can be heard. Photoelectric, film, and mechanical mediums for the synthetic production of music will be explored. Whereas, in the past, the point of disagreement has been between dissonance and consonance, it will be, in the immediate future, between noise and so-called musical sounds. The present methods of writing music, principally those which employ harmony and its reference to particular steps in the field of sound, will be inadequate for the composer, who will be faced with the entire field of sound. New methods will be discovered, bearing a definite relation to Schoenberg's twelve-tone system and present methods of writing percussion music and any other methods which are free from the concept of a fundamental tone. The principle of form will be our only constant connection with the past. Although the great form of the future will not be as it was in the past, at one time the fugue and at another the sonata, it will be related to these as they are to each other; through the principle of organization or man's common ability to think.[106]

This was Cage's prognostication of the increasing roles of noise and electronics in music and how a more expansive source of sounds would create a need for newer compositional forms and methods in music.

In describing future music produced through the aid of electrical instruments, Cage explains that the Novachord and Solovox, electronic keyboard instruments developed in 1939 and 1940 respectively, were specifically built and used for the "imitation" of eighteenth and

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106. John Cage, "The Future of Music: Credo," in *Silence: Lectures and Writings* (Middletown, CT: Wesleyan University Press, 1961), 3-5.

nineteenth century instruments.[107] He also mentions the Theremin—an electronic instrument first built in 1920 and later issued a U.S. patent in 1928 that was controlled via proximity to two antennae—and the possibilities it provided for new sound experiences which, according to Cage, were yet to be achieved as the instrument was being used to imitate traditional acoustic music. Cage predicted that electronic instruments would break free from the expected traditional roles of acoustic instruments and, instead of imitating them, would create entirely new sounds for which new compositional methods would be created.

At the end of Cage's "Credo," he described a need for "centers of experimental music" where music could be composed for performance using "twentieth-century means."[108] He envisioned these centers as places where electronics for sound synthesis (oscillators and generators), playback (turntables and film phonographs), and amplification could be held and provided specifically for the composition of music. This idea of a dedicated space for electronic music was similar to, and inspired by, radio stations and recording studios—including the newly developed radio lab at the Cornish School, where Cage taught.

In 1937, Cage had a brief experience working as a film-editing apprentice under Oskar Fischinger for the abstract animated film *An Optical Poem* (1938). While working for Fischinger, Cage experienced using film and audio technology:

> Late in his career, John Cage often recalled his brief interaction with German abstract animator Oskar Fischinger in 1937 as the primary impetus for his early percussion works. Further examination of this connection reveals an important technological foundation to Cage's call for the expansion of musical resources. Fischinger's experiments with film phonography (the manipulation of the optical portion of sound film to synthesize sounds)

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107. As the talk was originally given in 1937, supporting text, including references to the Novachord (1939) and the Solovox (1940), would have been added later for the printed brochure of the recording: John Cage, "The Future of Music: Credo," booklet for *The 25-Year Retrospective Concert of the Music of John Cage*, produced by George Avakian, Box 374, Radio City Station, 33 rpm, 1959.

108. John Cage, "Credo," in *Silence*, 6.

> mirrored contemporaneous refinements in recording and synthesis technology of electron beam tubes for film and television.[109]

Cage's experiences in 1937 with radio and film directly influenced his thoughts about the future of electronics in music as well as his concept for a dedicated space where composers would have access to technology, all of which is reflected in his "Credo."

4.1 New Methods Discovered

Cage's desire to break away from strict compositional practices in music opened up an opportunity for innovation and invention. In the article, "Goal: New Music, New Dance," originally printed in 1939 and reprinted in *Silence*, Cage writes about the connection between invention and the future of music:

> At the present stage of revolution, a healthy lawlessness is warranted. Experiment must necessarily be carried on by hitting anything—tin pans, rice bowls, iron pipes—anything we can lay our hands on. Not only hitting, but rubbing, smashing, making sound in every possible way. In short, we must explore the materials of music. What we can't do ourselves will be done by machines and electrical instruments which we will invent...New and original sounds will be labeled as "noise." But our common answer to every criticism must be to continue working and listening, making music with its materials, sound and rhythm, disregarding the cumbersome, top-heavy structure of musical prohibitions.[110]

On the path to invention was the need for the rethinking of the fundamental materials in music. After changing the concept of how and from what music is made, Cage identified that innovation in composition would only be limited to what the composer could design and build. In Cage's terms, "machines and electrical instruments which we will invent" is reflective of the independent approach intrinsic to DIY. For Cage, the usage of technology in music would open

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109. Richard H. Brown, "The Spirit inside Each Object: John Cage, Oskar Fischinger, and 'The Future of Music'," *Journal of the Society for American Music* 6, no. 1 (February 2012): 83, accessed November 9, 2018, https://doi.org/10.1017/S1752196311000411.

110. John Cage, "Goal: New Music, New Dance," in *Silence*, 87.

up entirely new sounds and methods of creating music, starting with his work *Imaginary Landscape No. 1* which was written the same year as his "Goal: New Music, New Dance" article. Although it did not require the invention of new machines or electrical instruments, it did constitute an experimental re-examination of technology commonly used for music playback—the phonograph.

4.1.1 *Imaginary Landscape Nos. 1-3*

One of the earliest compositions for live electronics was John Cage's *Imaginary Landscape No. 1* (1939), which was composed while Cage was teaching at the Cornish School in Seattle. It was written "for records of constant and variable frequency, large Chinese cymbal, [and] string piano"[111] to be "performed in a radio studio," the performance of which was to be "broadcasted and/or recorded".[112] The location Cage originally had in mind for performance was at the Cornish School's own radio school—the first of its kind in the United States.[113]

> Access to the recording studio of the Cornish School led me to write a series of compositions which I called *Imaginary Landscapes*. These employed records of constant and variable frequencies on turntables, the speed of which could be varied. Durations were controlled by lowering or raising the pick-up. This was a use of recording equipment for creative rather than the customary reproducing purposes. I was also able to work with small sounds which to be heard required amplification.[114]

For the performance of the piece, two performers played audio test records identified in the score as "Victor frequency record 84522" and "Victor Constant Note Record No. 24 (84519)"[115] on

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111. John Cage, *Imaginary Landscape No. 1* (New York: Henmar Press, 1960), 1.
112. Ibid., 2
113. Kay Larson, *Where the Heart Beats: John Cage, Zen Buddhism, and the Inner Life of Artists*, (New York: The Penguin Press, 2012), 70.
114. John Cage, "A Composer's Confessions (1948)," in *John Cage, Writer: Previously Uncollected Pieces*, selected and introduced by Richard Kostelanetz (New York: Limelight Editions, 1993), 33.
115. Cage, *Imaginary Landscape No. 1*, 2.

two separate variable-speed turntables while the Chinese cymbal and piano were performed by two additional performers. Two microphones were required: one microphone used for the turntable performers and another for the cymbal and piano performers.

Cage's creative rethinking of music technology and "materials" was foreshadowed in his 1937 "Credo" and was later put into practice in *Imaginary Landscape No. 1*, where Cage approached the turntable as not just a "material" for playback, but as an instrument which could be performed. Although the work was not originally intended for live performance in a traditional venue, it did use technology in a live and un-edited format for performance. As performers manipulated the speeds of the turntables, sounds similar to that of a variable sine wave oscillator were produced. Cage was able to use the technology made available to him through the Cornish School as new resources for sound production; essentially, these electronic resources became instruments in live performance.

The title *Imaginary Landscape No. 2* originally appeared on a work premiered in 1940. It was a percussion quartet similar to *Imaginary Landscape No. 1* that Cage recorded in a radio studio. The work called for one percussionist on tam-tam and Chinese cymbal, one performer on prepared piano, and two performers on variable-speed turntables. Just as in the first *Imaginary Landscape*, frequency test-tone recordings were to be performed on the turntables. Cage later scrapped the work and replaced it with *Imaginary Landscape No. 2 (March No. 1)*[116], which premiered on May 7, 1942 in San Francisco. This work became the one commonly referred to as *Landscape No. 2*, which is the work Cage described in his 1962 C. F. Peters catalog:

116. Before renaming it *Imaginary Landscape No. 2 (March No. 1)*, Cage's title for the work was *Fourth Construction*.

> *March (Imaginary Landscape No. 2)* (percussion [quintet][117], 1942) has a rhythmic structure of 3, 4, 2, 3, 5. The percussion instruments (tin cans, conch shell, ratchet, bass drum, buzzers, water gong, metal wastebasket, lion's roar) are combined with an amplified coil of wire.[118]

The newer version features a percussion quintet. Three percussionists perform on tin cans and one also on conch shell. The fourth performer performs the ratchet, bass drum, water gong, and metal wastebasket. The fifth and final performer performs on buzzer, lion's roar, and amplified coil of wire, which was a coil of wire attached in place of the stylus to the phonograph's tone arm.

Cage had previously used an amplified coil of wire in *Imaginary Landscape No. 3*, which was first performed in Chicago on March 1, 1942—just two months before the revised *Imaginary Landscape No. 2*.

> *Imaginary Landscape No. 3* (percussion sextet, 1942): The rhythmic structure is 12 times 12 (3, 2, 4, 3). The percussion instruments, tin cans and a muted gong, are combined with electronic and mechanical devices including audio frequency oscillators, variable speed turntables for the playing of frequency recordings and generator whines, and a buzzer. An amplified coil of wire and a marimbula amplified by means of a contact microphone are also used.[119]

Imaginary Landscape No. 3 was technologically more complex than *Imaginary Landscape Nos. 1* and *2*. Out of the 6 players, four were using technology in performance. Electronics used included an audio frequency oscillator, variable speed turntables, a battery-operated buzzer, a radio aerial coil attached to a phonograph pick up arm, a contact microphone, amplifiers, and loudspeakers.

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117. The cited source incorrectly states quartet instead of quintet. The title page for the score says *Imaginary Landscape No. 2 (or March no. 1): for Percussion Quintet*. It can be assumed that "quartet" was a misprint. See: John Cage, *Imaginary Landscape No. 2 (or March no.1)* (New York: Henmar Press, 1960).

118. John Cage, "Notes on Compositions I," in *John Cage, Writer*, 8.

119. Ibid.

Imaginary Landscape No. 3 was a radical and progressive work in the scope of electroacoustic history and, more specifically, for the history of live electronic works. It was an experimental work that expanded the role and function of live electronics by introducing the frequency oscillator as a source of sound synthesis along with a modified existing technology—the phonograph.

4.1.2 *Credo in Us*

In 1938, Cage met Merce Cunningham —a dance student at the time—while he was teaching at the Cornish School. The following year Cunningham moved to New York to join the Martha Graham Dance Company. In 1942, Cunningham wrote to Cage and requested music for choreography created by Cunningham and fellow Martha Graham Dance Company dancer Jean Erdman. The piece, titled *Credo in Us*, was first performed at Bennington College in Vermont on August 1, 1942.[120] Cage was unable to be a part of the first performance of *Credo in Us*. The following year, however, a concert was put together by Cage and Cunningham. *Credo in Us* was performed,[121] marking their first collaborative work.

An entry in Cage's catalog of works, published by C. F. Peters (Henmar Press) in 1962 and reprinted in *John Cage, Writer* describes Cage's *Credo in Us*:

> *Credo in Us* (1942) is a suite of satirical character composed within the phraseology of the dance by Merce Cunningham and Jean Erdman for which it was written. The instruments used are muted gongs, tin cans, tom-toms, an electric buzzer, piano and radio or phonograph.[122]

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120. "Database of Works: *Credo in Us*," John Cage Trust, accessed November 9, 2018, http://johncage.org/pp/John-Cage-Work-Detail.cfm?work_ID=50.

121. Merce Cunningham, interview with Peter Dickinson, ed., *CageTalk: Dialogues with and about John Cage* (Rochester, NY: University of Rochester Press, 2006), 57.

122. John Cage, "Notes on Compositions I," in *John Cage, Writer*, 8.

The satirical nature of the work comes from the juxtaposition of polyrhythms and simple melodies of the two percussionists and pianist against the playback materials being operated by another performer on turntable or radio. "Classic" works suggested as playback material included works by Dvořák, Beethoven, Sibelius, or Shostakovich. Live electronics for *Credo*, included the radio and the turntable, which was also used in *Imaginary Landscape Nos. 1* and *3*. The difference between *Imaginary Landscape Nos. 1-3* and *Credo in Us*, however, was that the playback material used in *Credo* was meant to be traditional acoustic works, which Cage referred to as "classic" works. *Credo in Us* was the first collaborative work by Cage and Cunningham and their first work that featured electronics in live performance for dance accompaniment.

4.1.3 *Music for "Works of Calder"*[123]

For a period of time after *Credo in Us*, Cage wrote a number of works for prepared piano. One of those works, *Music for "Works of Calder"*[124] (1949-1950), was used for the soundtrack to a short film about the American sculptor Alexander Calder. Prepared piano, percussion, and magnetic tape were used to produce the soundtrack. The tape material was made from the sounds of mobiles hitting each other and was recorded in Calder's studio in January 1950.[125] This took

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123. Parts of the original soundtrack recording, including Cage's tape composition and percussion interlude, can be found in Volume 25 of Mode Records' *The Complete John Cage Edition*. It is found along with Margaret Leng Tan's performance of the first and final (I and III) movements for prepared piano. John Cage, *The Complete John Cage Edition, Vol. 25: The Works for Piano 4*, performed by John Cage, Margaret Leng Tan, and Burgess Meredith, Mode Records MOD-CD-106, 2002, CD.

124. Although *Music for "Works of Calder"* is not a live electronics work it is important to examine when Cage began experimenting with tape as well as his compositional approach to the medium. It shows his familiarity with the technology and provides important background information for the discussion on *Imaginary Landscape No. 5*.

125. "Database of Works: *Music for 'Works of Calder'*," John Cage Trust, accessed November 9, 2018, http://johncage.org/pp/John-Cage-Work-Detail.cfm?work_ID=267.

place not long after Cage met Pierre Schaeffer, who Cage credited as being the one to introduce him to the idea of composing with tape:

> I must have encountered [tape] in Paris in the late forties, when I met Pierre Schaeffer, who was the first to do any serious work from a musical point of view in relation to magnetic tape. He made every effort he could to get me interested in working along those lines, but I wasn't yet really ready...I was gradually moving toward the shift from music as structure to music as process and to the use, as a result, of chance operations in composition. I might have been more cooperative with Schaeffer, but I wasn't. It didn't really dawn on me...my mind was being used in a different way; so that I wasn't as open as I might have been to the notion of music on magnetic tape then. That's '49. In '52...we made several pieces...with funding from Paul Williams. I made the Williams Mix (1953) then. All of that work was done with excitement over the possibilities of magnetic tape, and they were various...I was very open at the time, and very interested in splicing tape and in making the music manually. I found various ways of changing sound not with dials, but, rather, by physically cutting the tape.[126]

It is important to note that *Music for "Works of Calder"* predates Cage's *Williams Mix*, a work for magnetic tape that was composed in 1952 and premiered in 1953. *Music for "Works of Calder"* was one of Cage's earliest works involving composition on tape. The period between 1942 (when *Imaginary Landscape Nos. 2* and *3* and *Credo in Us* were premiered) and 1950 (when *Music for "Works of Calder"* was composed) is when Cage largely focused on writing prepared piano works. Beginning with *Music for "Works of Calder*,*"* a work that continued Cage's tradition of writing for prepared piano and that introduced his experimentation with composed tape, Cage returned to composing for and with electronics. Another experimental electroacoustic work, *Imaginary Landscape No. 4*, was premiered the following year at Columbia University in New York on May 10, 1951.

126. John Cage, interview with Richard Kostelanetz, "John Cage and Richard Kostelanetz: A Conversation about Radio," *The Music Quarterly* 72, no. 2 (1986): 221, accessed August 11, 2018, https://www.jstor.org/stable/948120.

4.1.4 *Imaginary Landscape Nos. 4* and *5*

> *Imaginary Landscape No. 4 (March No. 2)* (1951), for 12 Radios, 24 Players and Conductor: The rhythmic structure—2, 1, 3—is expressed in changing tempi. The notation is in space where ½ inch equals a quarter note. Kilocycle, amplitude, and timbre changes are notated. Two players are required for each radio. The composing means are the same as for *Music of Changes* and are the subject of an article which appears in *Silence* (Wesleyan University Press).[127]

Imaginary Landscape No. 4 was the first large ensemble piece in the *Imaginary Landscapes* series. Unlike the earlier works in the series, the piece did not use percussion instruments. In "Credo," Cage described how the "unpredictable" nature of *Music of Changes* and *Imaginary Landscape No. 4* resulted from his application of *I-Ching (Book of Changes)* methodology in his compositional process. For the performance of the work, twenty-four performers operate twelve radios. There are two performers per radio: one person was responsible for the tuning of the radio, and the other controlled the amplitude (volume) and high-frequency overtones (timbre). Cage's use of the radio as an instrument was similar to that of the variable speed phonograph in *Imaginary Landscape Nos. 1* and *3*—where a commercially available and standard household object was manipulated to create music in performance. Although it did not feature the manipulation of electronic components as in *Imaginary Landscape No. 2*, Cage did rethink the electronic materials used in *Imaginary Landscape No. 4* and found a way to manipulate them in live performance.

Imaginary Landscape No. 5—the last of the *Imaginary Landscapes* series—was also composed using Cage's chance operations derived from the *I-Ching*. It premiered on January 18, 1952 as music for a dance by Jean Erdman titled *Portrait of a Lady*. The score is a guide to realizing a fixed media tape using source material from 42 phonograph records. It consists of

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127. John Cage, "Notes on Compositions II," in *John Cage, Writer*, 52.

blocks and numbers drawn on graph paper and is divided into eight tracks. Cage, however, did not provide instructions on how the tape was to be assembled or recorded—he left that to be determined by the performer. Essentially, the score provided the organization of materials but not the content. For the original performance, jazz records were used and the tape "was made by the composer and David Tudor with the technical assistance of Louis and Bebe Barron."[128]

It is important to note that in order to perform this work, the performer would have needed enough technical proficiency to either splice or record the material to tape as organized in Cage's score. They would have also needed access to the equipment for such a task. Taking that into account, the performance of this work, which includes the assembling of the tape, is a fundamentally DIY endeavor. From that perspective, this work was a significant contribution to the scope of electroacoustic works following the DIY tradition.

4.1.5 Analysis

In "Credo" and "Goal: New Music, New Dance," Cage assessed the future of electronics in music. He wrote about expanding sound resources through technology and moving away from electrical instruments meant to "imitate" eighteenth and nineteenth century instruments. This was to be done either through the exploration of the materials of music or through the invention of new machines and electrical instruments—the first, of which, is most recognizable in Cage's early works for electronics. Throughout the *Imaginary Landscapes* series, Cage's exploration of electronics evolved from re-examining the usage of playback systems to the "hacking," or modification of components, in the phonograph. In *Imaginary Landscape Nos. 1* and *3*, Cage used variable-speed turntables in a non-traditional way to emphasize frequency shifts of test-tone

128. John Cage, "Notes on Compositions II," in *John Cage, Writer*, 53.

recordings as speeds were altered. For *Imaginary Landscape Nos. 2* and *3*, a coil of wire was inserted into the phonograph tone arm.

Another important point taken from Cage's "Credo" was the need for "new methods" of composition in future music employing electronics. He understood that earlier compositional styles and traditional notation would no longer suffice. Cage's answer to that was his usage of chance operations derived from the *I-Ching*, as seen in *Imaginary Landscape Nos. 4* and *5*. Although Cage used the phrase "new methods" in reference to the future of composition, it could also be applicable to describing the new methods of performance that would come about through the usage of electronics. Cage brought commercial items common to the household, such as turntables and radios, into performance. Used in non-traditional ways, these items became instruments in performance. The practice of transforming audio electronics continued in Cage's later electronic works—one of which, *Cartridge Music* (1960) would further explore the hacking of phonograph cartridges.

4.2 Rethinking Live Electronics in Performance

The following works to be discussed show an evolution of live electronics in Cage's 1960s compositions. From *Cartridge Music* (1960) to *Variations VII* (1966), there was a leap in available resources and a shift towards collaboration. *Cartridge Music* was an exploration of small sounds using a primary form of technology—phonograph cartridges; *Variations VII* employed a massive scope of resources including photocells, capacitive-sensing antennas, household appliances, bio-feedback, communications devices including a network of dedicated telephone lines, and much more. Both of these works were collaborative. David Tudor assisted Cage in modifying electronics for *Cartridge Music* and *Variations VII* was put together by Cage, Robert Moog and the engineers participating in the Experiments in Arts and Technology *9 Evenings* performances.

During that same time period, Cage was producing music for the Merce Cunningham Dance Company (MCDC) along with fellow collaborator David Tudor. In 1966, Gordon Mumma began touring with them to help assist with Cage's large-scale multi-media work, *Variations V* (1965), which required capacitive-sensing antennas, photocells, oscillators, radios, and tape. The engineers that helped build the systems being used by the MCDC for Cage's *Variations V* would later collaborate on *Variations VII*. The growing use of and advancement in live electronics for music is reflected in MCDC's performances. Although works discussed from *Variations V* on were largely collaborative in the design and construction of their live electronic instruments, they continued the DIY tradition through the individuals that were building these systems specifically for Cage's works.

4.2.1 *Cartridge Music*

Cartridge Music was completed in July, 1960 and first performed on September 15, 1960 in Germany as a broadcast on Radio Bremen.[129] The first performance to take place in front of a live audience occurred on October 6, 1960 in Cologne and was performed by Cornelius Cardew, Hans G. Helms, Mauricio Kagel, Nam June Paik, Benjamin Patterson, Kurt Schwertsik, David Tudor, Christian Wolff, and Cage.[130] The score consists of twenty sheets containing shapes in addition to four transparencies. Cage provided instructions on the assembly of materials for performance. First, the performer selected the page containing a number of biomorphic shapes

129. David W. Bernstein, "John Cage's *Cartridge Music* (1960): 'A Galaxy Reconfigured,'" *Contemporary Music Review* 33, nos. 5-6 (2014): 557.
130. Ibid., 558.

equal to the number of phonograph cartridges to be used in performance. The four transparencies contained shapes in the form of points, circles, stop-watch, and a dotted line were to be superimposed over the sheet corresponding to the number of cartridges used. Cage provided further instructions that explained how the assembled score was to be performed.

In performance, phonograph cartridges were modified by inserting "instead of a playing needle, any object that will fit into a cartridge... (e.g., a coil of wire, a toothpick, a pipe-cleaner, a twig, etc.)."[131] Sound was then "produced in any manner on the object inserted"[132] and amplified through a loudspeaker. The score indicated when the amplifier's amplitude and tone were to be manipulated. Cage also noted that auxiliary sounds could be produced and amplified. In the performance instructions to the work, he suggested how to employ these sounds. Text indicated that "it is convenient for the production of 'auxiliary sounds' to place contact microphones on the objects (microphone stand, table, etc.) to which the cartridges are attached. If this is done, many 'auxiliary sounds' having an electronic character are easily produced." *Cartridge Music* was a pioneering work by Cage in its exploration of small sounds that otherwise could not have been heard without amplification.

According to Gordon Mumma, *Cartridge Music*, along with *Winter Music*, *Variations II*, and *Music for Amplified Toy Pianos*, "were performed widely, particularly by Tudor and the composer, and were a considerable stimulus to experimentation in live-electronic music."[133] Cage's usage of live electronics for the realization of this work was also an important development for electroacoustic instruments. The modification of the phonograph was seen in

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131. John Cage, *Cartridge Music* (New York: Henmar Press, 1960), performance instructions.

132. Ibid.

133. Mumma, "Two Decades of Live-Electronic Music, 1950-70," in *Cybersonic Arts*, 83.

his earlier *Imaginary Landscapes*; however in this composition the modification itself was the focus of the work. The amplified small sounds that were produced through the manipulation of the material inserted into the cartridge were often “electronic” in nature. Although live electronic instruments were not built specifically for use in *Cartridge Music*, it used modified electronics in live performance. This resulted in electronic-like sounds produced through their interactions with acoustic materials. This idea served as a bridge to Cage’s later works which used engineered live electronics.

4.2.2 *Variations V*

Variations V is a large-scale multi-media work composed by John Cage and was premiered on July 23, 1966 at the Lincoln Center in New York. It is a multi-media work consisting of visual and audio technology in addition to dance choreography. Cage was assisted in the design and creation of electronics by David Tudor, Robert Moog, and Bell Labs engineers. The audio technology used for *Variations V* consisted of: “homebrewed” electronic sound generators; playback apparatuses including radios; studio equipment such as oscillators, contact microphones, and tape machines; a 96-port input mixer designed by Bell Labs engineer Max Mathews; two engineered systems used to trigger sound consisting of photocell light receivers and capacitive-sensing antennas.[134] It was a largely collaborative work meant for a one-time performance by the Merce Cunningham Dance Company. After the premiere, Cunningham decided that *Variations V* would be added to the MCDC touring musical repertoire. This

134. Holmes, 433.

prompted the addition of Gordon Mumma to the touring music ensemble, who helped repair fragile equipment and minimize redundancy.[135]

One of the most significant technological design concepts behind Cage's work was the use of dancers' movements to generate music. This precipitated collaboration with Robert Moog and Bell Labs engineers, who designed systems employing sensor technology for the triggering of sound based on physical movement. Antennas in the form of five-foot high capacitive-sensing poles were constructed by Robert Moog. Cage envisioned an instrument similar to Theremin's Terpsitone and Thereminvox:

> Cage approached Moog concerning the possibility of adapting the "Terpsitone," a special device that Leon Theremin had designed in the 1930s for use in activating musical sounds with dance. The Terpsitone was a younger sibling to Theremin's more famous "Thereminvox," a capacitance-technology proximity-sensor from the late 1920s that produced solo melodic lines without physical touch. Cage had heard the Thereminvox in Los Angeles while doing research for his father's electronic inventions in the 1930s.[136]

Cage was familiar with technology through electronics patents research he did for his father—an engineer and inventor—and was able to communicate with Moog the engineering design he envisioned.[137] He wanted to use capacitance-sensing technology in a similar way to Theremin's instruments, except on a larger-scale. The poles that were constructed by Moog had a capacitive-sensing radius of four-feet, large enough for the dancers to maneuver around.

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135. Mumma, "John Cage, Electronic Technology, and Live-Electronic Music," in *Cybersonic Arts*, 171.

136. Ibid., 170.

137. Similar thoughts were conveyed in a letter from Cage to Dr. T. A. Benham: "What I imagine now is a plurality of devices which will produce sounds as a result of the dancers movements in space. In this connection we are interested in the device having as large a "field" as possible to which it responds. (I saw a Theremin-like instrument that responded only to movements within one foot of it.) It would be interesting too to have these devise movable and/or automotive, going, for instance round as lighthouse beams do." John Cage, "To Dr. T. A. Benham: May 28, 1965," *The Selected Letters of John Cage*, ed. Laura Kuhn (Middletown, CT: Wesleyan University Press, 2016), 318.

At the base of the poles were photoelectric cells (photocells)—sensors that could detect the changes in light intensity resulting from the dancers' movement through light beams directed at the sensors. The photocells were developed by Bell Labs engineers, whose collaborative efforts were prompted by Billy Klüver's[138] involvement with *Variations V*:

> There were two systems that allowed the dancers to trigger sound: Robert Moog designed ten capacitive antennas that were placed around the stage and were activated when the dancers passed close to then. Cecil Coker at Bell Laboratories designed photoelectric cells that were placed at the foot of the antennas and aimed at lights around the edge of the stage. When the dancers passed in front of the cells and broke the light beam, they triggered switches that could turn on and off the radios and tape-recorders. All the equipment was set up at the back of the stage behind the dancers; and the musicians and engineers worked there during the performance.[139]

The photocells, designed by Cecil Coker, triggered audio electronics—a unique mix of commercial and "homebrewed" technology—on and off while they were being operated by musicians during performance. The same photocell technology was used a year later for Cage's *Variations VII* (1966).

4.2.3 *Variations VII*

> The interesting thing about that piece is [that it] didn't use any magnetic tape that [is to say] no recorded sounds were part of it. All the sounds were so to speak 'in the air' or in oscillators that were producing sounds at the instant of their being heard by the performers and by the audience—and that is its principal interest.[140]
>
> -John Cage

Variations VII was premiered on October 15th at *9 Evenings*, the same Experiments in Art and Technology series where Tudor's *Bandoneon! [a combine]* was premiered. Electronic

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138. Billy Klüver was a Bell Labs engineer who frequently collaborated with artists and musicians, including Robert Rauschenberg and Andy Warhol. He co-founded Experiments in Art and Technology (E.A.T.) in 1966 and later became the president of E.A.T.

139. Billy Klüver, *Variations VII*, DVD, presented by Experiments in Art and Technology and ARTPIX (San Francisco: Microcinema International, 2008), inside cover.

140. John Cage, transcribed from *Variations VII*, DVD.

systems for Cage's performance were made by Bell Laboratories engineers, including Billy Klüver, as well as engineers who also contributed systems for Cage's *Variations V* and *VI*. The work was performed by David Behrman, Lowell Cross, Anthony Gnazzo, David Tudor, and Cage. Cecil Coker, one of the contributing engineers from Bell Labs, was the performance engineer.

Cage conceptualized that all of the audio source material for the work would come from what was happening at the time of performance, where sounds produced both within and outside of the armory were being performed. This was done through long- and short-wave radios, dedicated telephone lines, and televisions. Sounds generated within the armory were produced by contact mics connected to household appliances (blender, juicer, toaster, fan, etc.), contact mics connected to the performance platform, oscillators, pulse generators, Geiger counters, and amplified feedback generated from electrodes used to monitor brainwave activity.

Although Cage did not design or construct the systems used, he was responsible for providing an opportunity to experiment with and further explore the applications of live electronics for music performance. According to Billy Klüver:

> The point about John Cage's involvement with technology is that although he has always been quick to use new means of making sound, he stands outside technology. He is not involved, as many are today, in working with electronics, building devices and shaping them to produce sounds. Rather John Cage continues to explore the extent to which a given means can be used for the greatest freedom, variety, and pleasure.[141]

Cage was able to apply technology in creative and innovative ways. Two examples of the innovative systems used for music in *Variations VII* were David Tudor's modification system and the photocells designed by the Bell Labs engineers.

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141. Klüver, *Variations VII*, DVD, inside cover.

David Tudor contributed live electronics in the form of a sound modification system. According to fellow performer Lowell Cross:

> In the 9 Evenings program, where the flow-chart schematic diagram of John's piece was set forth, there is a rectangle in this flow-chart that says "David's Own." This meant David Tudor's own collection of gadgets and many of which he would connect up in various non-linear feedback modes, so that he could make oscillation sounds that may have sounded out of control but that is exactly what David wanted.

Sound sources processed through Tudor's system included phone lines that were installed by New York Telephone. For the performance, the lines were used to call ten locations around New York City. At those locations, the phones were left off of their hooks during performance, transmitting the ambient sounds that occurred as the performance was happening. Locations that were connected by phone included Merce Cunningham's studio, Luchow's restaurant, an aviary, the sanitation department, and the turtle tank in Terry Riley's studio. Magnetic pickups were used on the receivers to send audio signal for processing.

Thirty photocells were used for the performance of *Variations VII*. The photocells, which were originally designed by Cecil Coker at Bell Labs for *Variations V*, were sensors that detected light beams. The powerful lights were placed on the floor and the light beams were broken as performers moved about the platform. The photocells were used to trigger the contact mics on and off. The creative use of this type of technology was groundbreaking for its time, as recalled by David Behrman:

> In 1966, I was learning electronics and it was directly applicable to that. I was very interested in the relationship between sound and light. I worked also with photocells at that time, or a little later, and I was, you know, that was the first time in history where electronics were inexpensive, small, [and] lightweight, because the transistor was rather new then.[142]

142. David Behrman, interview from *Variations VII*, DVD.

The *9 Evenings* collaboration between Bell Labs engineers and composers was indicative of the way in which composers were expanding their technological resources as well as their own engineering capabilities. One particular instance when everyone's assistance was needed to assemble additional wires in preparation for Cage's work reflects these concepts:

> The size of the armory was huge and somehow the sound had to be transmitted from the control console, or John Cage's platform, up to the speakers. So, we needed lots of wiring for the sound, but we also had to put on connectors in both ends, of course. This turned out to be a last-minute affair, and everybody had to help to crimp on connectors, or mini-plugs as we called them. So, everybody got mobilized, including John Cage.[143]

Although building cables was not necessarily a large engineering or design feat, it was an instance when others contributed to the building of materials for the performance.

4.3 Final Thoughts

Cage's live electronics compositions from 1939 to 1966 followed the contemporaneous audio technological advancements of the day. These early works served as a recontextualization of technologies—from the usage of a variable-speed turntable in *Imaginary Landscape No. 1*, through the "hacking" of a phonograph tone-arm in *Imaginary Landscape Nos. 2* and *3*, to the usage of radios in *Imaginary Landscape No. 4* and tape in *Imaginary Landscape No. 5* (where a fixed media tape was produced through the realization of Cage's score). By the time *Variations V* and *VII* were being composed, there was a wide array of technologies made available to Cage through the engineers at Bell Labs—a scientific research company responsible for many of the emerging technologies at the time.

143. Billy Klüver, interview from *Variations VII*, DVD.

Variations V and *VII* also show a unique blend of commercially available and DIY audio technologies. In *Variations V*, systems contributed by Cecil Coker, Billy Klüver, Max Mathews, and Robert Moog were interconnected with homebrewed electronics, playback-apparatuses and commercially-produced sound generators controlled by Cage, David Tudor, and later on Gordon Mumma in performance. For *Variations VII*, the technologies used were expanded to include telephone communications as well as a large-scale sound system built for the E.A.T. *9 Evenings* series by David Tudor. Live electronics were invented—or more precisely, developed and then engineered—at Cage's request for these two *Variations*. All of the systems used were efforts that best demonstrated Cage's thoughts from the 1939 article "Goal: New Music, New Dance," where he correctly identified the future connection of invention and electronic music.

CHAPTER 5. CONCLUSION

Technological advancements since the 1960s have held influence over the creation of experimental electroacoustic works. Since the 1970s, these instruments and compositions have largely shifted from analog to digital, computer-based technologies. Still, the DIY spirit found in works by Mumma, Tudor, and Cage remains an important influence for composers. The drive to construct and implement self-designed technologies for the purpose of music performance remains unchanged. Most of the electronic and electroacoustic instruments produced today are largely computer-based and come in many forms including hardware designed to interface with a computer, computer-embedded electroacoustic instruments, and completely virtual instruments that exist only in software. Electronics continue to be used in live performance and the conceptual approach to the composition and engineering of new digital instruments remains much like that of the live electronic instruments of the 1960s.

Throughout the research presented, a continuing theme has been the employment of the most recent available technology by Mumma, Tudor, and Cage. Composers have always been quick to adopt new resources as they emerge on the market, and the transition from analogous to digital musical instruments has closely followed the same timeline as the development and production of emerging technologies. For example, Cage's usage of live electronics evolved from his application of playback and recording materials in his *Imaginary Landscape* series to his application of photocells that were being developed by engineers at the research company Bell Labs in Cage's *Variations VII*. Although the phonograph was not new at the time he composed *Imaginary Landscape No. 1*, the radio lab he had access to at the Cornish School was a new and emerging technological space. From early on, Cage was interested in technology and looked for the latest available resources to which he had access.

Present-day applications of DIY electroacoustics are embodied in the evolving genre of laptop orchestras. These ensembles were created as a way to use a contemporary technology, the laptop, both as an instrument and meta-instrument in a traditional and familiar setting. Laptop orchestras have their origins in the late 1970s in the experimental networked computer ensemble the League of Automatic Music Composers (LAMC). The LAMC first created music through the use of what was, at the time, a brand-new technology—the micro-computer. KIM-1 single-board computers were programmed and connected to one another through "ad-hoc" networks. The LAMC later transitioned to a wired, hub-based network in 1986 (prompting the ensemble to change their name to "the Hub"). Present-day laptop ensembles now use wireless networks to connect their machines to controllers, musical interfaces, and one another. One such ensemble, the Laptop Orchestra of Louisiana has used high-speed wireless networks not only for performances, but for the management of files, applications, and custom software. The GRid EN-abled Deployment for Laptop (GRENDL) project was created to design a "distribution and configuration"[144] system that could meet the technical needs of laptop orchestras through a collaboration between computer music and computer network researchers at the Center for Computation & Technology. This mirrors the same collaborative efforts between Bell Labs engineers and composers for the Experiments in Arts and Technology (E.A.T.) performances. The transformation and emergence of network-based musical ensembles has undergone a dynamic shift from the founding of the League of Automatic Music Composers (LAMC, later

144. Stephen David Beck, Chris Branton, and Sharath Maddineni, "Tangible Performance Management of Grid-based Laptop Orchestras," *Proceedings of the International Conference on New Interfaces for Musical Expression*, (May/June 2011): 207, accessed November 12, 2018, http://www.nime.org/proceedings/2011/nime2011_207.pdf.

the Hub) in 1978[145] to the development of laptop orchestras in the early 2000s.[146] Networked performance ensembles continue to explore new and emerging technologies and follow in the same engineer-composer collaborative spirit.

Contemporary institutions and organizations encourage DIY efforts by providing outlets for the research and development of new instruments using technology. Located in Amsterdam, the STudio for Electro-Instrumental Music (STEIM) has been active since 1969 and continues to thrive as a space where “artists who are both the players and makers of their own expressive tools”[147] are encouraged to experiment and develop art and music through a “human-focused approach to technology.”[148] They promote “technology...tailored to the individual,”[149] which is, in essence, a concise way of expressing what the phrase *DIY in live electronics* embodies.

The New Interfaces for Musical Expression (NIME) international conferences are hosted in different locations every year “by research groups dedicated to interface design, human-computer interaction, and computer music.”[150] It is a niche event where composer-engineers are able to present their own recent developments in experimental technology—specific to the design and implementation of interfaces. These often come in such forms as external hardware or graphical user interfaces (GUIs) meant for computers and mobile devices. The interfaces enable the interactions between people and computers for the purpose of making music. Composers who

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145. Scot Gresham-Lancaster, "The Aesthetics and History of the Hub: The Effects of Changing Technology on Network Computer Music," *Leonardo Music Journal* 8 (1998): 40.

146. Dan Trueman, “Why a Laptop Orchestra?”, *Organised Sound* 12, no. 2 (August, 2007): 171-179, accessed November 12, 2018, http://plork.princeton.edu/papers/WhyALaptopOrchestra.pdf.

147. “About STEIM,” STEIM Foundation, http://steim.org/what-is-steim/ (accessed November 13, 2018).

148. Ibid.

149. Ibid.

150. “About,” NIME 2019: New Interfaces for Musical Expression, https://www.ufrgs.br/nime2019/index.html (accessed November 13, 2018).

present at NIME conferences continue the DIY electroacoustic tradition by taking it upon themselves to learn and experiment with software and hardware engineering. They follow the same approaches to the organization and transformation of audio signals as the live electronics of the 1960s. Composers are now able to use digital audio signal processing through computers instead of the analog electronics used then. NIME provides conferences as an outlet for this type of research, which cultivates the current DIY generation of composer-engineers.

Current research specific to the examination of DIY in electronic music is most often applied to the study of the way in which electronics are used in "indie," "punk-rock," and "underground" music performance. There are some examples, however, that have pioneered the path for the research of DIY electroacoustic music specific to the application of live electronics used in the same vein as traditional acoustic instruments. These are best exemplified by the writings of Matt Rogalsky, Nic Collins, and John Richards. Rogalsky's thesis[151] covers a more limited area of early electroacoustic live performance, specifically regarding the musicians who performed with the Merce Cunningham Dance Company. He examined both the milieu and practice of self-made (which I refer to as DIY) live electronics and viewed the MCDC composer-performers as nurturing a "school of live electronic music."[152]

Handmade Electronic Music: The Art of Hardware Hacking by Nicolas Collins was first published in 2006 and was subsequently followed by the second edition, published in 2009. It serves as a how-to guide for building "sound-producing electronic construction projects."[153]

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151. See: Matt Rogalsky, "'…in rehearsals, or preparation, or setup, or from one performance to another': Live Electronic Music Practice and Musicians of the Merce Cunningham Dance Company," (master's thesis, Wesleyan University, 1995).

152. Rogalsky, "'…in rehearsals, or preparation, or setup," 3.

153. "Handmade Electronic Music," Nicolas Collins Website, https://www.nicolascollins.com/handmade.htm (accessed November 13, 2018).

Collins also demonstrates how similar DIY approaches were undertaken by artists (including composers) of the past. According to Collins, within the book's text, he provides examples that "put the technologies into historical and aesthetic context through information about, and audio and video samples by, artists who have used similar devices to make significant musical breakthroughs."[154]

John Richards is a musician/composer and instrument builder who writes about DIY in electronic music. He has written articles for *Leonardo Music Journal* and *Organised Sound*. Often, his writings are about his "dirty electronics" approach to instrument building. Richards defines dirty electronics as being "a metaphor describing a trend in electronic music...[that] encompasses a notion of the postdigital, the self-made and do-it-yourself in contrast to the mass-produced, and the reinvigoration of the role of the human body in the process of electronic music."[155] He has put together workshops for the purpose of building dirty electronics and music ensembles based around the performance of those live electronics. Richards has also written a chapter dedicated to DIY and electronic music for the second edition of *The Cambridge Companion to Electronic Music* which was published in 2017, entitled "DIY and Maker Communities in Electronic Music."

The goal of the research presented in this dissertation has been to acknowledge the DIY tradition within the early history of live electronic music. This was done by showing how the building of and composing for live electronics by Mumma, Tudor, and Cage fit within the DIY framework. The idea of a DIY aesthetic as it applies to these three composers follows any combination of the following three approaches to live electroacoustic music: using self-built

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154. Ibid.
155. John Richards, "Getting the Hands Dirty," *Leonardo Music Journal* 18 (2008): 25.

electronics for live performance, modifying electronics for live performance, or collaborating with engineers on the concept and design for electronics to be used in the live performance of their own composition.

The next step for research will be to further investigate how to maintain a specific composer's DIY aesthetic in the preservation of the instruments themselves, as well as in the modern digital realizations of previous analog technologies used. It is also important to take a philosophical approach to understanding what continues to drive the DIY ethos in music. These avenues of future research would best be benefited by the development and usage of common research methodologies and terminology. As an increasingly popular field of study (demonstrated by the work of Rogalsky, Collins and Richards), there is a need for an organized approach to researching DIY electroacoustic instruments in order to maintain the intent and integrity of the composer's work.

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VITA

Lindsey Hartman, a native of Baton Rouge, Louisiana, is currently pursuing her PhD in Experimental Music & Digital Media at Louisiana State University. She received her Master of Music degree in flute performance from Louisiana State University, where she studied with Dr. Katherine Kemler, and her Bachelor of Music degree in flute performance from California State University, Long Beach, where she studied with Dr. John Barcellona.

As a researcher and designer of electroacoustic art, she has a strong interest in understanding the interactions between musicians and technology. She has developed modern Max realizations for compositions built for electronic systems that are no longer commercially available and is interested in the preservation of and accessibility to mid- and late-20th century works.
Her research focuses on the DIY aesthetic of early live-electronics and the active engineering role composers played in their development. Lindsey's art has been an explorative application of her research and is reflective in the materials, circuit designs, and aesthetics of her electroacoustic instruments.

Upon the completion of her PhD in May 2019, she plans to pursue a Master's degree in Library and Information Science with the intent to develop and put into practice a better understanding of the preservation and archiving needs for electroacoustic instruments and compositions.