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A COMPLEX AND INTERACTIVE NETWORK: CARLA SCALETTI, THE KYMA SYSTEM, AND THE KYMA USER COMMUNITY

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List of Abbreviations

CERL: Computer-Based Education Research Laboratory

SSC: Symbolic Sound Corporation

STS: Science and Technology Studies

UIUC: University of Illinois, Urbana-Champaign

VCS: Virtual Control Surface

BBS: Bulletin Board System

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A Complex and Interactive Network: Carla Scaletti, the Kyma System, and the Kyma User Community

Abstract

"A Complex and Interactive Network: Carla Scaletti, the Kyma System, and the Kyma User Community" is a study of composer and computer scientist Carla Scaletti, the Kyma music programming language, and the Kyma user community. Chapter One is a historical and biographical study of Scaletti and the creation of Kyma. I examine how experiences throughout Scaletti's life and education as a musician, composer, and computer scientist, as well as the technology available at the time shaped Kyma's design. Chapter Two is an analysis of Scaletti's musical output, which not only sheds light on Scaletti's unique approach to composition, it also demonstrates how Scaletti's compositional philosophy influenced Kyma. Chapter Three is an ethnography of the Kyma user community. I study the social, cultural, and technological forces that shaped the formation and growth of the Kyma community as well as the mechanisms that enabled a mutually influential relationship between Kyma users and Scaletti, which indicates how Kyma users contribute to the development of Kyma. For this study I employed an interdisciplinary methodology that heavily relied on participant-observation ethnography at in-person Kyma user gatherings and online.

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Introduction

Overview

In 1986, composer and computer scientist Carla Scaletti (b. 1956) designed a music programming language called Kyma. In 1987, Scaletti realized the first Kyma system, a hybrid of Scaletti's software and a hardware microprocessor designed by her partner, electrical engineer Kurt Hebel (b. 1960). As with other cutting edge programming languages of its time, with Kyma one could program and synthesize sound in real time. It also employed an object-oriented programming paradigm, which enabled abstraction and the creation of complex musical systems. In 1989, Scaletti and Hebel founded the Symbolic Sound Corporation (SSC) to develop and sell Kyma. By 1991, the Kyma system became available to the public and a small, international user base began to form.

There are several remarkable aspects of Kyma's development and history that will be discussed at length throughout this dissertation. First, Scaletti designed Kyma using new technology as an object-oriented language, with a graphical, patching environment interface for real-time programming and sound synthesis. Scaletti and Hebel also opted to start a business and develop Kyma commercially and independently rather than at a university or on the research team of a large technology company, which gave them full control of Kyma's development. Although it impacted their access to resources and to some degree their perceived legitimacy in the computer music world, founding SSC also enabled the formation of a dedicated, close-knit user community. The Kyma user community is sustained through both

online and in-person interactions. Scaletti and Hebel's use of cutting edge online communication technology to facilitate connections among users is also remarkable. Lastly, in spite of Kyma's proprietary nature, there is a significant culture of sharing among users, as well as feedback mechanisms that enable users to contribute to Kyma's evolution, suggesting that Kyma's development is an ongoing collaborative process.

The documentation and analysis of Scaletti's work as a composer and computer scientist is one of the primary purposes of this study. She has been an integral member of the computer music field in both capacities, and proactive in defining that field through her written publications and the Kyma system. Although Scaletti and her work are at the center of this dissertation, considerable attention is paid to how the development of technology, in this case the Kyma system, evolved as the result of the collaboration between cultural, technological, economic, and institutional forces.

To fully appreciate the impact of Scaletti's work it is necessary to study how and why Kyma is used, both by Scaletti and other Kyma users. This dissertation is organized into three chapters; each takes into account the facets of a feedback network that exists among Scaletti, the Kyma system, and the Kyma user community. In this feedback network, these three elements exert considerable influence on each other: Scaletti imposes her compositional philosophy and values onto users through Kyma, yet Kyma users loop back and influence Kyma in return through alpha and beta testing, technical support, and requests for new features. Each chapter provides a different perspective on the design and evolution of the Kyma system, as well as the

many roles Scaletti performs in her capacities as composer, computer-scientist, and entrepreneur. Chapter One is a biography of Scaletti and a history of Kyma, which includes a cursory analysis of the Kyma system; in Chapter Two I analyze Scaletti's musical compositions and how she employs Kyma; Chapter Three is a study of the Kyma user community. As a whole, this dissertation sheds light on a network made up of SSC, Kyma, and its users as well as how this network has been influenced by social and technological factors.

Review of Literature

This review of literature includes works that shaped the overarching character of my dissertation. I include literature reviews in Chapters Two and Three that detail the relevant scholarship concerning the topics discussed in those chapters.

The cultural study of music technology is an emerging topic in the field of musicology.[1] Until recently, studies of music and technology, and music programming languages in particular tended to be written by composers or computer scientists who either focused on design or use. Studies focused on design discussed the creators of a language and its principles but did not mention the people who used the language or how it was used. Or, conversely, an article might survey composers using computer technology and their compositions, but pay little attention to the

[1] A potential movement has gained momentum over the last two decades, and various terms have been employed to indicate such a movement: Rene Lysloff and Leslie Gay Jr. used music and "technoculture" (2003), Kiri Miller used the term "technomusicology," (2012), and Andrew Raffo Dewar suggested the term "historical ethnography" (2009).

programming language or other technology used.[2] Although these studies have contributed to the documentation of music programming languages, separating design and use only allowed for partial understandings of the interactions among technologies and users. I, along with a growing number of scholars, believe that the study of music technology should be more holistic, taking into account the cultural milieu in which Kyma was created and eventually used, and the many social and technological circumstances that shaped its evolution. Scholars including Kiri Miller, Andrew Raffo Dewar, Theodore Gordon, Catherine Provenzano, Mike D'Errico, Ezra Teboul, Lauren Flood, and others are turning towards interdisciplinary methodologies to take on such holistic studies and frame the development and use of technology as culturally situated and highly collaborative. As Dewar explains about recent studies of experimental music: "…these recent works illustrate a turn in the discourse toward a valuation and examination of the cultural context within which these technical achievements exist, the communities that created them, and their role in a broader global cultural tapestry."[3] While a unified movement or sub-discipline has yet to emerge for these interdisciplinary studies, they invariably turn to ethnographic methods and Science and Technology Studies (STS) for their theoretical and methodological foundation.

As with other ethnographies of technology, my understanding of the development of the Kyma system and the formation of the Kyma user community is

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[2] Gareth Loy, "Composing with Computers—a Survey of Some Compositional Formalisms and Music Programming Languages," in *Current Directions in Computer Music Research*, editors, Max V. Mathews an John R. Pierce (Cambridge, MIT Press, 1989); Charles Ames, "Automated Composition in Retrospect: 1956–1986." *Leonardo* 20:2 (1987): 169–185.
[3] Andrew Raffo Dewar, *Handmade Sounds: The Sonic Arts Union and American Technoculture*, PhD Dissertation, (Wesleyan University, 2009), 3.

informed by literature related to the *Social Construction of Technology* (SCOT), Actor-Network Theory (ANT), and advancements in STS, particularly Feminist STS. This literature provided a framework to illuminate the multiplicity of forces that shaped the development of Kyma (in Chapter One), Scaletti's use of technology (in Chapter Two), and the Kyma Community (in Chapter Three). According to ANT, people, technologies, social, political, and economic elements are all actors in a system.[4] Actors include both animate and inanimate objects. ANT simply enables the consideration of the aforementioned actors as nodes on a network made up of technological, social, cultural, and economic forces that influenced Kyma's development as well as how Kyma exerts influence on users.

In *The Social Construction of Technological Systems* (1987), sociologists Wiebe E. Bijker and Trevor J. Pinch, propose that technologies are culturally constructed rather than the inevitable result of a single genius inventor. Bijker and Pinch "point out that social groups give meaning to technology and that problems are defined within the context of the meaning assigned by a social group or a combination of social groups."[5] As users learn and use a given technology, Bijker and Pinch highlight "problem solving" and the resulting exchanges between creators and users as the point in which users contribute to a technology. With Kyma, technical support is a crucial vehicle by which users interact with SSC and each other; it is a

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[4] Wiebe E. Bijker, Thomas P. Huges, and Trevor J. Pinch, eds, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, (Cambridge, MA: The MIT Press, 1987); Benjamin Piekut, "Actor-Networks in Music History: Clarifications and Critiques." *Twentieth-Century Music* 11:2 (September 2014): 191–215.

[5] Wiebe E. Bijker, Thomas P. Huges, and Trevor J. Pinch, eds, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, (Cambridge, MA: The MIT Press, 1987), 12.

key component in the formation and maintenance of the Kyma community, and an essential element in the feedback loop by which users influence the Kyma system.

The work of STS scholars Christopher Kelty and Janet Abbate significantly shaped my methodological approach as well as my understanding of the digital technologies involved in this study. Christopher Kelty's *Two Bits: The Cultural Significance of Free Software* (2008) is a study of the impact of free software on contemporary society.[6] Kelty employs ethnographic methodologies, which he asserts are necessary to understand both the community of users and the phenomenon of free software. His book unfolds as a reflexive narrative of anecdotes and encounters with programmers, hackers, copyright lawyers, and scholars. In *Inventing the Internet* (1999) and *Recoding Gender* (2012), Abbate also employs ethnography to study the development of internet technology and the role of women in the history of computing. In *Inventing the Internet*, she charts the evolution of the Internet from a military tool that allowed scientists to run programs on remote computers to a communication medium used by civilians and run by commercial interests. Both Kelty and Abbate resist narratives of technological determinism, instead charting how technologies continually evolve through the influence of many actors (users, institutions, researchers, computer scientists, etc.).

In *Strange Sounds: Music, Technology, and Culture* (2001), a study of the intersection of music and technology in culture, musicologist Timothy Taylor proposes that technologies cannot be understood if removed from their social contexts:

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[6] Christopher Kelty, *Two Bits: The Cultural Significance of Free Software* (Durham: Duke University Press, 2008).

> Whatever music technology is, it is not one thing alone. It is not separate from the social groups that use it; it is not separate from the individuals who use it; it is not separate from the social groups and individuals who invented it, tested it, marketed it, distributed it, sold it, repaired it, listened to it, bought it, or revived it. In short, music technology—any technology—is not simply an artifact or a collection of artifacts; it is, rather always bound up in a social system.[7]

Similarly, media theorist Aden Evans asserts: "Creativity in coding is not an expressive act of the programmer but lies between the programmer and machine, each folded into the other via technical innovations in the history of software engineering."[8] Evans, Taylor, SCOT, and ANT provide insight into how the development of technology and creativity are collaborative processes rather than products of a lone genius.

Methodology

As the literature review suggests, I drew from several disciplines to develop the methodology for this dissertation. In addition to more traditional musicological methods including archival research and musical analysis, I also drew from media studies, computer science, and STS, and relied heavily on ethnographic methods. As Taylor's statement suggests, analysis of a programming language's design or architecture without taking into account how and why it is actually employed by its users could only demonstrate partial understanding of the language and its evolution. Technology imposes itself onto users and suggests certain ways of use, yet people also use technology in unintended ways to suit their needs. Ethnography provided an

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[7] Timothy Taylor, *Strange Sounds: Music, Technology & Culture,* (New York: Routledge, 2001), 7.
[8] Aden Evans, "Object-Oriented Ontology, or Programming's Creative Fold," *Angelaki* 11:1 (2010): 90.

indispensible tool for understanding how Kyma works, what its defining features are, and the mutual influence between Scaletti and the Kyma user community.

I conducted participant-observation ethnography at in-person Kyma user gatherings and online. I performed research at three Kyma International Sound Symposiums (KISS), the annual gathering of Kyma users in which they share presentations, workshops, and concerts. This first involved learning how to use Kyma, which I did in collaboration with composer Kristin Grace Erickson in 2015. Although we initially undertook this process by reading the manual, *Kyma X Revealed*, we also composed a piece together, which ultimately proved the best way to learn Kyma. At KISS2015, we presented our composition *AQULAQUTAQU*—an electronic operetta we composed in collaboration with David Kant and Matthew Galvin—as well as a talk about the generative algorithms Erickson and I employed in the piece. Attending KISS 2015 as a presenter provided insight into the experiences of users and the role of KISS in the maintenance of the Kyma user community. Additionally, by the end of KISS2015, Erickson and I gained legitimacy as fellow Kyma users and were considered part of the community. This enabled me to develop bonds with Kyma users that became invaluable throughout my research: as a fellow Kyma user, they trusted me and told me about their lives and work, and their experiences using Kyma.

At KISS2016, I attended as a participant and observer and did not present a piece, which allowed me to focus on engaging with Kyma users and observing the dynamics of the attendees. I also conducted formal and informal interviews, and a survey. After the symposium I conducted follow up interviews through email and

Facebook Messenger. KISS2016 provided me with insight into how the location of the symposium affects the make-up of participants and changes the dynamics of group interactions. My research at KISS 2016 also suggested that there are different trends in the kinds of music and sound made, and in how Kyma is used in different locales. I co-hosted KISS2018 at UC Santa Cruz along with Scaletti, Hebel, Kristin Erickson, Matthew Galvin, and David Kant. By co-hosting I was able to witness and participate in the inner workings of the production of KISS, the values Scaletti and Hebel impart on the symposium, and the role of the host institution. It also provided new insight into the scope and range of Kyma users involved and the time and resources that are required to produce their work. Most importantly, co-hosting KISS2018 gave me an opportunity to give back to the community in a meaningful way.

In addition to participant-observation ethnography at KISS, I conducted ethnography online on Kyma forums, the Kyma Q&A, Youtube and Vimeo, and the official and unofficial Facebook pages. The qualitative and quantitative methods I employed to analyze these data are discussed in detail in Chapter Three. Online platforms enable users to create and maintain connections with each other. These platforms are also a mechanism for users to influence the development of Kyma by raising issues they encounter and discussing features they would like added to the system. Conducting this online research and participating in the community as a performer and composer provided me with insight and access into the dynamics of this community. If I had not gone to KISS, I doubt I could have fully appreciated how important the community has been to Kyma's development, nor the extent to which,

in spite of many cultural and musical differences and values, there is a genuinely supportive and friendly atmosphere among community members.

In addition to ethnography of the Kyma community, I spent a considerable amount of time with Scaletti and Hebel. I recorded over twenty-five hours of interviews with Scaletti and conducted regular email correspondence with her for approximately three years. I also made an eight-day visit to SSC headquarters in Champaign, IL, during which I observed Scaletti and Hebel's working dynamics, combed through Scaletti's personal archives and the archives at the University of Illinois, Urbana-Champaign, conducted interviews with Scaletti and Hebel, and spent time with Scaletti looking at and listening to the programs she created for her compositions.

I would like to provide a disclaimer to frame the contents of this dissertation: This dissertation documents the perspectives and experiences of Scaletti and Kyma users. By document, I do not mean some transparent representation of Scaletti's life, rather one possible description of Scaletti's work and the Kyma user community that I have constructed. My depiction was pieced together using the methodology outlined above. Throughout this dissertation I rely on Scaletti's words to capture her perspectives and particular use of language. I do so in part out of necessity: since Kyma is a proprietary system, few of her works have published scores, and I did not have access to the programs for Scaletti's compositions. Scaletti and Hebel were often the only available source for information.[9] This was a contributing factor to the

[9] Scaletti graciously spent time walking me through several of her pieces and she showed me aspects of the program for these pieces during my visit to SSC headquarters in January 2018.

focus of this dissertation, which is myopic at times, however, my hope is to expand the scope of this study in my future research.

Chapter Descriptions

Chapter One, "Carla Scaletti and the Development of the Kyma System," is a historical and biographical study of Scaletti and the creation of Kyma. I examine how Scaletti's 1986 paper "Kyma: A Computer Language for the Representation of Music," laid the foundation for the essential features in the Kyma software, and how experiences throughout Scaletti's education as a musician, composer, and computer scientist shaped Kyma's design. The creation of Kyma was motivated by the technology of the time: in part as a reaction to the shortcomings of analog synthesizers and existing music programming languages, as well as new innovations in object-oriented programming and personal computers. This chapter includes a cursory analysis of Kyma with descriptions of its basic features, the motivation for the inclusion of such features, and the influence of Smalltalk 80 on Kyma's design.

Chapter Two, "'Hearing the Music of Our Spheres:' The Music of Carla Scaletti" is an analysis of Scaletti's music. Scaletti considers her compositions a synthesis of music and science fiction; she bases each piece on a "what if" hypothesis in which she questions how the physical world operates, how humans fit in, and how scientific concepts can be explored musically. I analyze pieces by Scaletti including *Lysogeny* (1983), *Quantum* (2013), *Autocatalysis* (2010), and *Cyclonic* (2008), in order to demonstrate her unique approach to the digital modeling of meteorological,

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Scaletti and Hebel were the source of information through their published articles, the Kyma Manual, online Kyma platforms, emails, and interviews.

biological, and physical systems. By examining pieces before and after the creation of Kyma I demonstrate why Scaletti felt it necessary to create Kyma to realize her compositional ideas, and how the Kyma software embodies Scaletti's compositional philosophy.

Chapter Three, "The Coding of Community" is an ethnography of the Kyma user community. Kyma is a critical example of how digital technology—including personal computers and the internet—transformed not only how computer music was made, but how computer music-making communities form and operate. No longer tied to large mainframe computers, these communities formed outside the studio, lab, and university. In this chapter I examine how the Kyma community formed in the early 1990s, facilitated by cutting edge communication technology. My focus differs from existing studies of technology and musical communities, which tend to focus on how technology mediates the participatory experiences of either listening to or making music, and communities that form in fixed geographic locations, in groups with shared cultural heritage, or affinity groups that form around a particular genre. In this chapter, I study the role Scaletti's deliberate cultivation of community played in the formation of a heterogeneous, international community of Kyma users, and how her work made itself manifest in the nature of the community and its musical output.

Conclusion

Scaletti and Kyma culturally and technologically exist between the academic and commercial computer music worlds, meaning that they are not fully legible to

either. According to Scaletti, her experience "is of being the outsider."[10] To understand this insider/outsider position, I will bring in my recent research about gender and the institutions that support electronic and computer music, which is based on Nirmal Puwar's concept of women and other minorities as "space invaders."[11] I also rely on research by Tara Rodgers, Frida Abtan and others to discuss the mechanisms of power that flag women as space invaders in institutions that historically served as (white) male-dominated spaces.[12] This new research helps make sense of Scaletti's experiences of alienation from the centers of computer music, the critiques that have been leveled at Kyma's expense and idiosyncrasies, and Scaletti's legibility as a technologist and composer.

My close examination of Scaletti's life and work also shed new light on feminist science scholar Donna Haraway's "Cyborg Manifesto," which I resisted for the majority of this project as a too obvious framework for talking about women composers and their relationship with technology. The crux of Haraway's *Cyborg Manifesto* (1987) is about (re)claiming humor, irony, fantasy, and science fiction to envision alternative regimes of authority and reality. Haraway states, "A cyborg is a cybernetic organism, a hybrid of machine and organism….The cyborg is a matter of fiction and lived experience that changes what counts as women's experience…This is a struggle over life and death, but the boundary between science fiction and social

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[10] Scaletti, interview with Heying, September 4th, 2016.
[11] Nirmal Puwar, *Space Invaders: Race, Gender, and Bodies Out of Place* (Oxford: Berg, 2004).
[12] Madison Heying, "A Room of One's Own: The Independent Studios of Women Making Electronic and Computer Music," paper presented at the annual meeting of the *American Musicological Society*, (San Antonio, Texas, November 1–4, 2018).

reality is an optical illusion."[13] The cyborg is such an enduring and powerful figure because it is about resistance, about not bowing to expectations and disciplining of established institutions, and choosing not to operate by normative rules. Scaletti's compositions in particular are sophisticated examples of cyborg feminism due to her reliance on science fiction, humor, hard science, and complex technological systems. With these tools she creates sonic worlds through which she imagines alternative realities and proposes creative solutions to current political, environmental, and interpersonal crises. Scaletti's early adoption of the internet and online communication platforms demonstrate how she looks to technology to provide new ways for humans to stay connected in the future. Haraway's work helped me understand Scaletti's approach to programming, composition, and leadership, not as shying away from the institutions from which she may have been excluded, but explicit challenges to their authority and domination of the values and norms in computer music.

[13] Donna Haraway, "A Cyborg Manifesto: Science, Technology, and Socialtist-Feminism in the Late Twentieth Century," in *Cyborgs, Simians, and Women: The Reinvention of Nature* (London: Free Association Books, 1991), 149.

Chapter One
Carla Scaletti and the Development of the Kyma System

> The first time I witnessed a sequence of symbols being transformed into an actual sound pressure wave that I could hear, I felt like I was witnessing a miracle… By simply manipulating symbols, software can effect change in the physical world.[14]

On May 13, 1986, Carla Scaletti submitted a term paper for Computer Science 325 at the University of Illinois, Urbana-Champaign, titled "Kyma: A Computer Language for the Representation of Music." This paper outlined Scaletti's vision for a music programming language that would allow users to generate algorithmic and computer music in real-time. Kyma evolved after 1986, from Scaletti's implementation of Kyma's design in Smalltalk-80 to the creation of the full Kyma system with a dedicated microprocessor designed by Kurt Hebel. The design of Kyma marked a turning point in Scaletti's career as the develop of Kyma began to supersede Scaletti's other aspirations and ultimately led Scaletti to found the Symbolic Sound Corporation with Hebel.

In this chapter, I consider how Scaletti's 1986 term paper laid the foundation for the essential elements and structures in the Kyma system. I examine how experiences throughout her education as a musician, composer, and computer scientist shaped Kyma's invention. I address how the technology available to Scaletti at the time she conceptualized Kyma motivated its design. Kyma was, in part, a

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[14] Scaletti, "Looking Back, Looking Forward: A Keynote Address for the 2015 International Computer Music Conference," *Computer Music Journal* 40:1 (Spring 2016): 14.

reaction to the shortcomings of analog synthesizers and existing programming languages, as well as innovations in object-oriented programming and personal computers with great processing power and graphical displays. I also discuss the influence of the object-oriented Smalltalk-80 programming language on Kyma's design and the implications founding Symbolic Sound and developing Kyma as a commercial product had on the language. I provide a cursory analysis of Kyma and descriptions of Kyma's core features and interface. Lastly, in this chapter I consider how a creator's compositional philosophy is embedded in music programming language such as Kyma.

Scaletti's Early Life

Scaletti was born on April 28, 1956 in Ithaca, New York to Rita and Joseph Scaletti.[15] In 1964, the Scaletti family moved to Albuquerque, New Mexico where Joseph, a microbiology professor, founded the medical school at the University of New Mexico (UNM). Upon moving to Albuquerque, Rita opened a school for at-risk youth. Scaletti characterizes her parents as "entrepreneurial educators," because they both started new programs or schools to facilitate their unique pedagogical approaches. Scaletti grew up in a strict household, yet her parents valued and encouraged learning for its own sake; in the face of imposed social restrictions she turned to books and music. She studied piano, violin, and harp, and started composing at a young age.

[15] All biographical information is from the author's interviews with Scaletti unless otherwise specified.

Scaletti also developed a fascination for science at an early age, and assumed that she would grow up to be a scientist like her father. Joseph Scaletti greatly influenced and encouraged Scaletti's enthusiasm for science; in particular, visits to his lab at UNM left a big impression. Scaletti vividly remembers one visit in which she used a microscope to examine the bacteria left by her fingerprint on a slide. Scaletti and her father also performed "experiments" on their reel-to-reel AMPEX tape recorder, testing things such as microphone placement and recording their piano.[16] Additionally, Scaletti had her own small cassette recorder, because she explains: "my dad didn't let me use the reel-to-reel for anything but 'serious' music."[17] In spite of the imposed restrictions, Scaletti's parents fostered her interest in science and encouraged intellectual curiosity by giving her experiences with music technology. These experiences also instilled in Scaletti a life-long love of working with magnetic tape.

Joseph Scaletti's position at the university gave Scaletti access to exceptional educational and musical resources. She studied piano with UNM professor George Robert, a German expatriate who studied with Anton Webern. In addition to teaching Scaletti standard techniques and Classical and Romantic repertoire, Robert exposed her to contemporary music. Record companies sent him albums to review and he often played new experimental and electronic compositions for Scaletti during her lessons. One instance that stands out in Scaletti's memory is hearing *Come Out* by Steve Reich, partially because she was fascinated by Reich's use of tape loops and

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[16] Scaletti, interview with Elizabeth Hinkle-Turner, *SEAMUS Newsletter*, August 17, 2017.
[17] Ibid.

partially because Robert's wife barged in while they listened and yelled at him in German to turn off the music.

Although she did not have the resources at the time, as a teenager Scaletti realized she wanted to compose electronic music because it combined her interests in music and science. Scaletti also had something of a spiritual experience that further encouraged this desire; she describes her experience in the following statement:

> When I was 16 or so, at that age when you are sort of trying to figure out, what is my purpose? I couldn't sleep one night, and I was looking out my window and trying to figure out what my mission was. That's when I thought, there are these patterns and some people are scientists and they are figuring out the patterns by doing research and science, and I'm a musician, but maybe I could make these patterns audible in a way, a contribution, that I could recognize these patterns and make them understandable.[18]

This revelatory experience has taken on the status of a personal myth for Scaletti; she recounts it often as a critical juncture in her development as a creator. As the result of her desire to translate universal patterns into sound, she began crafting algorithmic compositions intuitively by hand. For instance, if she noticed numerical patterns that resulted from an equation she studied in algebra class, she charted out different ways the numbers could be mapped to music notation and wrote pieces based on these mappings.[19] Scaletti also actively pursued knowledge about electronic music and the associated technology; she attended lectures at UNM including a lecture-demonstration about electronic music by John Donald Rob, an early Moog synthesizer owner and enthusiast. Prior to this lecture, Scaletti had only read about analog synthesizers or heard them on recordings; with Rob's demonstration she had

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[18] Scaletti, email to Heying, February 2, 2016.

[19] "At that time, I was just noticing things, like from my algebra. I would notice patterns in the binomial equation or something. And I'd say, "Oh there's a pattern in there, could you reflect that in sound?" Scaletti in interview with Heying, May 20, 2017.

the opportunity to see how a synthesizer worked and hear the Moog in person.[20] This experience increased her appreciation of electronically generated sound and inspired a curiosity for using new technology to realize her budding compositional goals.

Upon graduating from high school, Scaletti stayed in Albuquerque to attend UNM. She studied composition with music theory professor Scott Wilkinson who stimulated Scaletti's desire to map numbers to sound by giving her assignments in the form of musical puzzles. She explained: "He would give these puzzles or challenges, like write a study where instead of single notes you use minor thirds as a single note and do counterpoint with that."[21] Throughout her teens, Scaletti pursued composition as a hobby while she pursued a career in science. This changed when Wilkinson informed Scaletti that one could have a career as a composer, an option Scaletti did not realize was possible before. When it came to declare a major at UNM, she settled on music. While at UNM Scaletti also played harp professionally in the New Mexico Symphony Orchestra. This early professional opportunity strengthened her musicianship and knowledge of repertoire. Additionally, playing the harp contributed to Scaletti's desire for hands-on and interactive experiences with music technology.

Throughout her undergraduate and graduate studies, Scaletti tailored her education to provide her with the musical, mathematic, scientific, and technological knowledge to achieve her goal of making universal patterns audible. She modeled her education on the medieval Quadrivium, taking additional classes in astronomy,

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[20] In the early 1970s, the only place someone could see or hear and a synthesizer live would have been at one of the growing number of universities or studios that had a synthesizer or perhaps at a rock concert.

[21] Scaletti, interview with Heying, May 20, 2017.

mathematics, psychoacoustics, human genetics, electrical engineering, and acoustics.[22]

After completing a Bachelor's degree in Music at UNM, Scaletti enrolled in a Masters in Music program at Texas Tech University in 1977. Scaletti studied composition with Mary Jeanne van Appledorn. Although Scaletti focused on music composition at Texas Tech, she also received training in the tools and techniques of electronic and computer music. Scaletti learned to use synthesizers, including the ARP 2600 and a Moog synthesizer, as well as studio recording techniques. Encountering this technology proved a pivotal experience for Scaletti, as she explains: "When I discovered [the ARP 2600] it was like everything came into focus for me; I suddenly saw a way to combine my (seemingly) competing interests. Electronic and computer music was that perfect melding of music and science."[23] Analog synthesizers and magnetic tape allowed her to "get her hands on the sound" and directly manipulate it, just as she was able to do with an acoustic instrument like the harp. At Texas Tech Scaletti also learned how to program a computer for the first time. Unlike the liberating, hands-on experience with synthesizers and magnetic tape, Scaletti felt that making music with a computer using a music programming language like Music IVBF was like taking a step backwards because she could not generate sound or compose in real-time.

While at Texas Tech a friend told Scaletti about a book called *Music by Computers*, an edited collection by Heinz von Foerster and James Beauchamp—

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[22] Tara Rodgers, *Pink Noises: Women on Electronic Music and Sound* (Durham: Duke University Press, 2010), 44.
[23] Scaletti, as quoted in Rodgers, *Pink Noises*, 45.

engineering professors at the University of Illinois, Urbana-Champaign (UIUC).[24] Von Foerster founded and ran the Biological Computer Lab at UIUC from 1958–1974. The BCL served as a hub for second wave cybernetics; it hosted projects from students and professors, fostering interdisciplinary relationships across the UIUC campus. Lejaren Hiller and Herbert Brün along with Beauchamp were particularly active in exploring cybernetics through musical systems. *Music by Computers* contains essays by Hiller, Brün, Max Mathews, and others directly connected with the early history of computer music. Reading *Music by Computers* proved invaluable to Scaletti because it pointed to UIUC as an institution that supported making music with computers. Shortly after reading *Music by Computers* Scaletti applied to UIUC and subsequently enrolled in their Doctorate of Music Arts program.

University of Illinois, Urbana-Champaign

Scaletti's education at the UIUC in composition and later computer science, as well as her involvement with the Computer Education Research Laboratory (CERL) Sound Group, shaped her approach to software design and the creation of Kyma. UIUC played a critical role in electronic and computer music history. In 1955–1956, chemistry professors Lejaren Hiller and Leonard Isaacson wrote one of the first pieces of computer music, the *Illiac Suite.* For the *Suite,* Hiller and Isaacson developed a set of computer programs that employed compositional logic to emulate known musical styles; the output consisted of lists of numbers, later transcribed into musical notation to be played by a string quartet. They thought of this piece and

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[24] James Beauchamp and Heinz Foerster, eds., *Music By Computers* (New York: John Wiley and Sons, 1969).

further developments in computer music and software as "experiments."[25] A well-publicized premiere concert of the *Illiac Suite* in 1956 gave UIUC a reputation as a hub for making music with computers.

In 1958, Hiller founded the Experimental Music Studio, one of the first electronic and computer music studios in the United States. The curriculum taught in the studio included courses in psychoacoustics and information theory, as well as sound synthesis, electronic and computer music techniques, and composition. Throughout the 1970s and early 1980s, UIUC thrived as an environment for composers interested in experimental music to develop computer music tools and compositional techniques. When Scaletti began her doctorate at UIUC in 1979, she thought of the Music School as an "electronic playground," where all of her dreams of making experimental music with computers and electronics would come true.[26] Although Scaletti received some training in electronic music at Texas Tech, most of her previous training was in the compositional styles and techniques of Western Classical instrumental music. She acquired most of her knowledge of electronic and computer music through reading books, listening to LPs, and attending lectures.

At UIUC, Scaletti continued to work with Moog and Buchla synthesizers and she created several tape pieces. Scaletti also experimented with computer-aided compositions using music programming languages Music IVBF and Music 360 on

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[25] Lejaren Hiller and Leonard Isaacson, *Experimental Music: Composition with an Electronic Computer* (New York: McGraw-Hill Book Company, Inc., 1959), 5, 36–37. In Chapter 3, "Experimental Music," Hiller and Isaacson's use of the computer to make music is connected to an experimental music-making tradition as well as the history of using electronics and tape in musical composition.

[26] Scaletti, interview with Heying May 20, 2017.

the school's mainframe computer.[27] In interviews Scaletti stresses that one of the most influential aspects of the program at UIUC was the creative atmosphere in which "everyone I knew was either building hardware or writing software."[28] As she recalls: "It wasn't weird to talk about, 'What would be the ideal music language?'" over a beer at Treno's, a restaurant located near the music building.[29] For Scaletti, this productive environment not only shaped her ideas about composition and ideal compositional tools, it demonstrated that it was possible and beneficial for composers to construct their own technological systems.

Scaletti worked closely with professors John Melby, James Beauchamp, and Scott Wyatt. She also studied composition with Sal Martirano who became her mentor. According to Scaletti, as her teacher, Martirano took on the role of the *pater familias*. He saw in Scaletti a brilliant young talent, and felt responsible for preparing her for the life of an academic composer by encouraging her to write "serious," dense, and complicated compositions. As a result, Scaletti explained:

> That was always kind of frustrating because we never talked about electronic music. It was always, come in and play your piece on the piano. So I was frustrated because I wanted to play him tape pieces instead. And sometimes he'd give me weird advice! One time he said: 'You should make this sound extremely dense and complex or else people won't respect you.' Which I thought was wrong advice. I though the music is what it needs to be for a particular piece.[30]

Although Martirano discouraged Scaletti from presenting tape pieces in their composition lessons, she enjoyed studying with him. After Scaletti graduated, they

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[27] Joel Chadabe, *Electric Sound* (Upper Saddle River, NJ: Prentice-Hall Inc., 1997), 265.
[28] Scaletti, interview with Heying, February 1, 2016.
[29] Ibid.
[30] Scaletti, interview with Heying, May 20, 2017.

collaborated on an algorithmic improvisation system involving Martirano's SalMar construction and digital systems including the Yamaha DX7 and the Kyma system.

Scaletti recalls her time at UIUC positively as an exciting exchange of ideas with professors and students, however her situation appears to have been more complicated. The UIUC Music department was notoriously contentious, with territorial faculty that pitted students against each other.[31] For example, during her first semester she took a seminar with Brün; according to Scaletti, the atmosphere of the class was extremely stressful because students were encouraged to "psychologically batter" each other during in-class discussions. She considered dropping out of the seminar. Distraught, she discussed dropping the class with her father, who responded by saying: "tempered steel has to go through fire," giving Scaletti little psychological freedom to drop the class.[32] In spite of the aggressive atmosphere of the seminar, Scaletti maintains that she learned a lot from working with Brün, and that it was a productive experience because it prepared her to respond on the fly to combative reactions to conference papers and presentations. She also found it productive because she composed a tape piece for her final project. Students had to write a piece for a progressive political group in Champaign; Scaletti explained:

> I picked the Prairie Alliance on Nuclear Energy or something, and I used tape feedback, sort of like the *I am Sitting in a Room* idea. I had a friend read in the names of these different radioactive elements and read their half-lives, how many years it would take before it was no longer dangerous. And it was all these elements that were in the waste from a nuclear power plant. And just let

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[31] Elizabeth Hinkle-Turner, email with Heying, June 5, 2017; Scaletti, interview with Heying, May 20, 2017. Denise Von Glahn, *Libby Larsen: Composing a Life* (Urbana: University of Illinois Press, 2017), 243–251.
[32] Scaletti, interview with Heying, May 20, 2017.

> them die out. So you'd hear it repeat, repeat, repeat, but then you'd just hear this kind of menacing sounding tones. At the end you just hear the resonance of the room.[33]

By staying focused on her music and goals, she mitigated the challenges of the interpersonal tensions in the department.[34]

Additionally, Scaletti experienced some of the effects of ongoing gender bias in the EMS and composition departments at UIUC. Former UIUC composition student composer Elizabeth Hinkle-Turner described the department as: "[A] very strange, misogynist atmosphere. It was a horrible, hostile atmosphere. Women were not being taken seriously musically or intellectually."[35] Hinkle-Turner's experience can be traced back to the founding of the music department and EMS at UIUC. Hiller and the Experimental Music Studio established many of the social norms surrounding making computer music—on the one hand, these norms included creating software, doing experiments, and interdisciplinary collaboration; on the other hand such norms established expectation around who should have access to making music with

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[33] Ibid.
[34] Ibid.
[35] Elizabth Hinkle Turner quoted in Von Glahn, *Libby Larsen*, 248. In her book, Von Glahn details Larsen's short residency at the UIUC Music School in 1990 in which Larsen was verbally "attacked" by faculty and students during her presentation in the Composer's Forum. At the time Larsen was working full time as a composer, funding her work with commissions; in her talk she expressed "belief in music as communication and a social act" and that composers should give audiences "access" to their work. This ran counter to the high-modernist politics of the music department and students and faculty berated Larsen, calling her compositions "cute," and like "fast food" for the masses. The forum was infamous for these kinds of attacks, which happened to other composers including George Crumb, Charles Wuorinen, and Pauline Oliveros among others. In a follow up presentation composer Sever Tipei referred to Larsen as a "respectable whore," which sparked outrage in Heidi von Gunden (then adjunct faculty) who said his remarks amounted to sexual harassment. Von Glahn highlights the belittling gendered language used and how it suggests the "misogynist atmosphere" of the department.

computers as well as the kinds of compositions that should be made.[36] Composer and historian Margaret Schedel explains these norms in terms of "operational characteristics":

> Each traditionally professional studio had its own signature sound which came not only from the equipment itself — but also from the 'operational characteristics of a particular studio [which] exert a considerable influence on the range and type of compositional operations which may be satisfactorily executed.[37]

Although operational characteristics help establish a studio's identity, they can also serve as grounds for exclusion if someone does not meet the aesthetic or educational expectations of a studio.

The EMS and at UIUC was founded by men and staffed by an all-male faculty throughout its history, which established certain gendered norms in the studio. Sociologist Nirmal Puwar uses the term "space invaders," to describe how women and people of color are marked "out of place" by not adhering to the norms of traditionally white, male dominated spaces.[38] Electronic music historian Tara Rodgers

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[36] As computer historian Janet Abbate explains, women involved in the computer industry during the 1940s, 50s, and 60s were often relegated to the role of assistants even though in many cases they did most of the actual computer programming. Janet Abbate, *Recoding Gender*: *Women's Changing Participation in Computing* (Cambridge: MIT Press, 2012), 14. Many women were not given credit for their work, however, some like Laetitia Snow, who assisted Hiller and John Cage with their multi-media *HPSCHD* (1987–69), were acknowledged in liner notes as the computer programmer. Cage, Hiller, et. al, Liner Notes. *HPSCHD: For Harpsichords & Computer-Generated Sound Tapes*. Nonesuch, 1969. LP.

[37] Margaret Schedel, "Electronic Music and the Studio," in *The Cambridge Companion to Electronic Music*, edited by Nick Collins and Julio d'Escriván (Cambridge: Cambridge University Press, 2007) 26. Schedel quotes Peter Manning, *Electronic and Computer Music* (Oxford: Oxford University Press, 2004), 152.

[38] Where Schedel explains studio norms in terms of "operational characteristics," Puwar explains it and the associated sense of belonging as "natural occupancy." She explains: "Social spaces are not blank and open for any body to occupy. While all can, in theory, enter, it is certain types of bodies that are tacitly designed as being the 'natural' occupants of specific positions… Some bodies are deemed as having the right to belong, while others are

explains: "The figure of the composer or technological innovator…is always already figured as a man…These deep-seated norms are at the root of the ongoing dissonance between the words *woman* and *composer*, or *woman* and *inventor*."[39] Taken together Schedel, Puwar, and Rodger's statements partly suggest how ongoing gender bias likely operated in the EMS and composition department at UIUC. Although women, notable women such as Maggi Payne, Hinkle-Turner, Mary Ellen Childs, and Mara Helmuth have studied or worked at the EMS or as composition students, the faculty and student body are still overwhelmingly male.[40]

Scaletti acknowledges that this gender bias and misogynist atmosphere at UIUC, as well as gendered societal norms (along with other factors such as education), have shaped her life and experiences. However, she prefers not to dwell on or discuss such aspects of her past.[41] In her interview with Rodgers in *Pink Noises*, when asked how gender influences her work, she explained: "Whenever I run into a roadblock, my strategy has always been to go around it."[42] Scaletti does not want to be pigeonholed as a woman composer or for any past discrimination to distract from her work by categorizing her as separate from her male counterparts.

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marked out as trespassers, who are imagined as being 'out of place;" Puwar, *Space Invaders*, 16.

[39] Tara Rodgers, "Tinkering with Cultural Memory: Gender and the Politics of Synthesizer Historiography." *Feminist Media Histories* 1:4 (Fall 2015): 11.

[40] In 2019, the EMS and composition faculty is made up entirely of men. Along with Von Glahn's account of composer and historian Heidi von Gunden's adjunct position, there appears to be an ongoing pattern of gender bias at in the music department, where men are given permanent faculty positions and women are hired in contingent roles, where they teach theory and musicianship, but not composition or studio classes.

[41] Scaletti, interview with Heying, October 24, 2018.

[42] Rodgers, "Pink Noises," 53.

CERL (Computer-based Education Research Laboratory)

In 1983, Scaletti began frequenting the Computer-based Education Research Laboratory (CERL), part of the Graduate College at UIUC, in order to make a computer-generated score for her DMA thesis piece *Lysogeny* (1983) for harp and tape. CERL was largely run by students under the loose guidance of a faculty advisor; they had a lot of freedom and funding, which supported an array of projects and research assistantships. This freedom and access to resources created a chaotic, yet productive working environment where students could explore new ways to use digital technology. The different research clusters included the CERL Sound Group, where engineers, computer scientists, and composers collaborated to create notation software, hybrid analog-digital synthesizers, audio controllers, and other digital sound processing hardware.

CERL and its history are tied to PLATO (Programmed Logic for Automatic Teaching Operations), an educational computer system that consisted of a network of computers held at universities and research institutions. All of the projects undertaken at CERL related to and used PLATO in some way.[43] It employed an early form of internet technology, and played a major role in the development of the internet and digital communication technology, including online forums, screen-sharing, multiplayer games, email, chat rooms, and instant messaging.[44] It is widely acknowledged that even though the system was to be used for educational purposes,

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[43] Brian Dear, *The Friendly Orange Glow: The Untold Story of the PLATO System and the Dawn of Cyber Culture* (New York: Pantheon Books, 2017).
[44] David R. Wooley, "PLATO: The Emergence of Online Community," http://just.thinkofit.com/plato-the-emergence-of-online-community, posted January 10, 1994, accessed November 18, 2017.

students and faculty were most excited about its alternative uses. As Scaletti relayed in an interview, at 10PM every night once restrictions were lifted, students flooded the PLATO terminals to play multiplayer games and send electronic messages to their friends at other universities with computers in the network.[45]

In the CERL Sound Group, Scaletti became part of this close-knit community and considered it something of a haven outside the music school. She explained that in the music school, computers were operated with a kind of unapproachable reverence that discouraged experimentation; computers were to be used to for "serious" compositional projects.[46] By contrast, in the CERL Sound Group students used computers in a hands-on and practical way. Computers were just seen as "tools to solve problems."[47] As Scaletti recalled, compared to the music school:

> At CERL it was in a way disrespectful. There were people with stickers on the computers, and pictures, and stuff falling out of the disc drives. And I thought, these people are really relaxed around these computers. They really use them, they are not in awe of them. The very first thing they would do is try [out a problem] on the computer. In the school of music it was a *very big deal* to use a computer.[48]

The difference between the students in CERL and the music school likely stems from the fact that in the music school people typically used computers to further their own work, whereas at CERL, students designed software and hardware for others to use. Tools designed at CERL had to be straightforward and general enough that people with different musical goals and levels of technical experience could use them. CERL proved to be productive working environment for Scaletti. She cultivated her ideas

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[45] Scaletti, "Looking Back, Looking Forward: A Keynote Address for the 2015 International Computer Music Conference," *Computer Music Journal* 40:1 (Spring 2016): 13.
[46] Scaletti, interview with Heying, February 1, 2016.
[47] Scaletti, as quoted in Rodgers, *Pink Noises*, 47.
[48] Scaletti, interview with Heying, February 1, 2016.

about utilizing computers to make music while working there as a research assistant. Although Scaletti attests that CERL was "far more welcoming than the music composition or computer science departments,"[49] CERL was not a utopia. Computer historian Joy Rankin recently exposed a culture of exclusion and gender discrimination at CERL throughout its history.[50] In an article for *Wired*, CERL historian Brian Dear mentions an ASCII printout of a naked women that hung on of CERL's walls. Dear's observation and Rankin's work suggest that CERL was potentially an uncomfortable environment for women where their ideas were commonly dismissed and technical expertise called into question.[51]

At CERL Scaletti worked with engineering students Lippold Haken and Kurt Hebel. Scaletti and Hebel met at an open house at the CERL Lab. While working on *Lysogeny*, she became curious about the lab's use of the PLATO computer for music printing. She set up a meeting with Lippold Haken so that he could demonstrate the system to her. Haken failed to appear for their meeting, but Hebel happened to be in the lab and showed Scaletti the system. Scaletti and Hebel instantly connected through their shared interest in digital signal processing and computer music. Shortly after meeting, their friendship became romantic. Scaletti and Hebel's personal and professional partnership has spanned almost four decades.

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[49] Scaletti, email to Heying, December 1, 2018.
[50] Professor Joy Rankin reported sexual harassment at CERL, sparking a heated public debate with CERL historian Brian Dear. Sarah Brown, "Things Got Our of Control," https://www.chronicle.com/article/Things-Got-Out-of/245212?cid=wsinglestory_hp_1, accessed March 31, 2019.
[51] Brian Dear, "When Spock met PLATO," *Wired Magazine*, December 27, 2017, https://www.wired.com/story/when-spock-met-plato/, accessed March 12, 2019.

The history of the Kyma system is inextricably linked to the history of the CERL Sound Group. CERL served as a supportive and collaborative environment for Scaletti to experiment with sound using technology. The Kyma hardware is also tied to the legacy of hybrid digital analog sound synthesis systems that were created at CERL. Computer engineer Sherwin Gooch founded the CERL Sound Group in 1974. He designed several digital synthesizers including the Gooch Synthetic Woodwind (GSW) and the Gooch Cybernetic Synthesizer (GCS). The GCS consisted of a microprocessor inside the PLATO terminal and hardware oscillators that could be programmed.[52] In 1981, Haken, Hebel, and other electrical engineering and computer science students developed a digital synthesizer called the Interactive Music Synthesizer (IMS), the successor of the GCS, which was capable of a greater variety of synthesis techniques. The IMS is the predecessor of the Platypus Multiprocessor—the first version of Kyma's dedicated hardware—designed for digital signal processing. Development on the Platypus began in 1983. Scaletti's work as a composer directly influenced the creation of the Platypus; by observing Scaletti's process of using batch programming and waiting to use a digital-analog-converter to hear the results, Hebel recognized that it was a cumbersome to program music with existing paradigms and the Platypus represented his first attempt at a solution. By writing software for the new microprocessor, the creation of the Platypus is also one of the first instances in which Scaletti collaborated with Hebel and Haken.[53] Both the IMS and Platypus multiprocessors consisted of general chips that could be

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[52] Students at CERL used the GCS as part of their instruction in music theory until 1983. Scaletti, "The CERL Music Project at the University of Illinois," *Computer Music Journal* 9:1 (Spring 1985): 45.
[53] Scaletti, "Looking Back, Looking Forward," 14.

programmed with software to do the specific tasks of a synthesizer.[54] Gooch's work and the values of the CERL Sound Group directly influenced Hebel and Haken's Platypus and the design of the Kyma system.

Part Two: Kyma

"Kyma: A Computer Language for the Representation of Music" (1986)

In this half of the chapter I detail Scaletti's creation of Kyma, from her initial design to its implementation in software and later hardware. I briefly interrupt this history of Kyma's development to discuss the Sound object—Kyma's core computational structure. I then discuss how Kyma relates to other music technologies, as well as object-oriented programming and the affinities between Smalltalk and Scaletti's design of Kyma. The chapter ends with a brief discussion of several key Kyma features.

The initial impetus to create Kyma stemmed from personal need; by the time Scaletti graduated from UIUC she had a clear sense of how she wanted to compose and recognized that no electronic system or programming language available enabled her particular approach. Scaletti came to this realization while working as a visiting assistant professor in the UIUC Music Department and a research assistant at CERL. She claims she "started to realize that, to do the things I really wanted to do in computer music, I was going to have to learn to make the tools myself."[55] In the music school and at CERL, Scaletti surrounded herself with people who made their own computer music systems or sound synthesis tools rather than using the inventions

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[54] Scaletti, "The CERL Music Project at the University of Illinois," 46.
[55] Scaletti, "Looking Back, Looking Forward," 14.

of others.[56] Encouraged by the epiphany that she needed to create her own programming language and frustrated by the academic job market, Scaletti enrolled in the Computer Science Program at UIUC in 1984.

Scaletti's 1986 computer science term paper, "Kyma: A Computer Language for the Representation of Music," marks the initial design of the Kyma programming language. *Kyma* is the Greek word for wave. Scaletti conceived of Kyma as modular and "recombinant" with a graphical interface and the ability to interactively and directly manipulate sound in real-time. "Recombinant" is a word taken from biology and genetics, typically used in reference to artificially altered DNA. Scaletti employs the term recombinant to "capture the idea of generating infinite variation from a finite set of elements," as she explains:

> Recombinant has the advantage that it captures the generative power afforded by modularity & combinatoriality, but it does so in a single word whose biological connotations also suggest growth, generative processes and infinite variation….And I was trying to get across the idea of getting more deeply into the spectral structure of the sound where you could manipulate the sound itself.[57]

Scaletti's conception of recombinance indicates how she envisioned Kyma as a flexible language that facilitated endless variation or manipulation of Sound objects and the creation of hierarchical grouping.[58] In her term paper Scaletti included analog circuit simulation, score representation, rule-based composition, and manipulation of

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[56] Examples of people writing their own music languages or developing their own hardware in the music department include: Herbert Brün's SAWDUST, Sal Martirano's SalMar construction, John Melby's development of score manipulation subroutines, James Beauchamp's work with analog synthesizers and hybrid analog-digital systems, Sever Teipei's Mp1 language. Scaletti, "Computer Music Languages, Kyma, and the Future," *Computer Music Journal* 26:4 (Winter 2002): 72.

[57] Scaletti, email to Heying, March 20, 2019.

[58] Scaletti, "Kyma: A Computer Language for the Representation of Music," Term paper for Computer Science 325: Programming Language Principles, University of Illinois, Urbana-Champaign, May 3, 1986, 2.

waveforms as some of the possible uses for Kyma.[59] Scaletti aspired to create a simple and clear language in which users with many levels of programming experience could start making sound immediately.

The core concept in Kyma is the Sound object—as in Pierre Schaeffer's *objet sonore*—which defines the language.[60] A Sound object is a computational structure recursively defined as either a SoundAtom or a transform of a SoundAtom. A SoundAtom is the most basic Sound object, which cannot be broken down into other Sounds.[61] The Sound object is a universal computational structure that represents everything from synthesis algorithms to functions, filters, waveform generators, sound analysis tools, and sequencers. In Scaletti's words: "The Sound object serves as a uniform, abstract structure for organizing all levels of a composition—from the composition of timbre to the composition of an entire piece."[62] Sound objects are code modules that exemplify recombinance: any Sound can be combined with any other Sound in an infinite variety of configurations.

In the implementation of the Kyma software in the object-oriented Smalltalk-80 programming language, each Sound is a Smalltalk object, represented by an icon or as an element in a list.[63] Kyma Sounds can be "patched" together in subgroups to

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[59] Scaletti, "Computer Music Languages, Kyma, and the Future," 72.
[60] Due to the central role of Sound objects, Kyma is often referred to as a sound design language, used for "creating, manipulating, and combining sounds." Scaletti, *Kyma X Revealed* (Champaign: The Symbolic Sound Corporation, 2004), 19.
[61] "It also suggested a more abstract conceptual grouping of atomic or compound sound objects that could be manipulated or viewed as a single entity and then 'zoomed' to reveal arbitrary levels of detail." Scaletti, "Computer Music Languages, Kyma, and the Future," 72.
[62] Scaletti, "The Kyma/Platypus Computer Music Workstation," *Computer Music Journal* 13:2 (Summer 1989): 37.
[63] When working with Sounds directly, one often selects one from a list like the Sound Browser or from a collection of icons as with the Prototype bar. When editing one often works with the Sounds as represented by icons.

make new Sounds; on a higher level, an entire piece could be encapsulated into a single Sound. Every Sound object represents a stream of samples, and each Sound has some of the same basic behaviors, including the ability to send and receive messages, trigger the processor to load the next sample, and to "play." Parameters within a Sound object can be specified by typing values or dragging a different Sound object into a designated field. When a Sound is played, one does not hear a sample or recording (although one can use a Sound that plays a sample or recording): playing triggers real-time generative processes—most will not sound exactly the same twice—and each Sound includes, and can be programmed with variable parameters that can be altered while playing. Sound objects can also be generated algorithmically. Basically, a Sound encompasses an algorithm or set of algorithms that generate material to be further manipulated.

The concept of the Sound object is indicative of Scaletti's compositional philosophy. She defines the process of composition as the creation and manipulation of Sound objects, which is directly related to *musique concréte*. However, instead of a linear collage on magnetic tape, Kyma Sound objects are encapsulated and hierarchical arrangements of algorithms and functions generating sound and controls in real-time. Rather than a series of numbers as used by Total Serialists, Scaletti conceived of the Sound object, which represents an algorithm or function, to control or organize all parameters of a piece. An early example in her oeuvre is *sunSurgeAutomata* (1987), in which Scaletti uses a cellular automata to arrange clicks; to control gates on a recording; and to control a synthesis algorithm. Kyma enabled Scaletti to apply the same algorithm to different parameters or signals

seamlessly and in a more sophisticated manner than with the Platypus or other music programming languages. Scaletti rarely uses a single Sound object as the unifying principle for an entire composition, rather she uses various algorithms and functions throughout, more like musical themes or leitmotifs.

Once Kyma became a commercial product used by a heterogeneous group of creators, users discovered other ways of using the system, and Scaletti and Hebel incorporated controls that allow for different ways of viewing data or manipulating Sounds. Additionally, by combining and creating new structures of Sounds encapsulated in other Sounds, each Kyma user essentially assembles their own Kyma Sound library from which they construct their work, and their own structures and systems that are not imposed by the language.[64] To some degree, Scaletti's compositional approach influences Kyma users due to the centrality of Sound objects and other features. However, as will be discussed in more detail in Chapter Three, this is not a unidirectional influence, new Sound objects, controls, tools are added to the language in response to user needs and requests, suggesting a feedback loop among users, SSC, and Kyma.

[64] Scaletti, "Kyma: A Computer Language for the Representation of Music," 11.

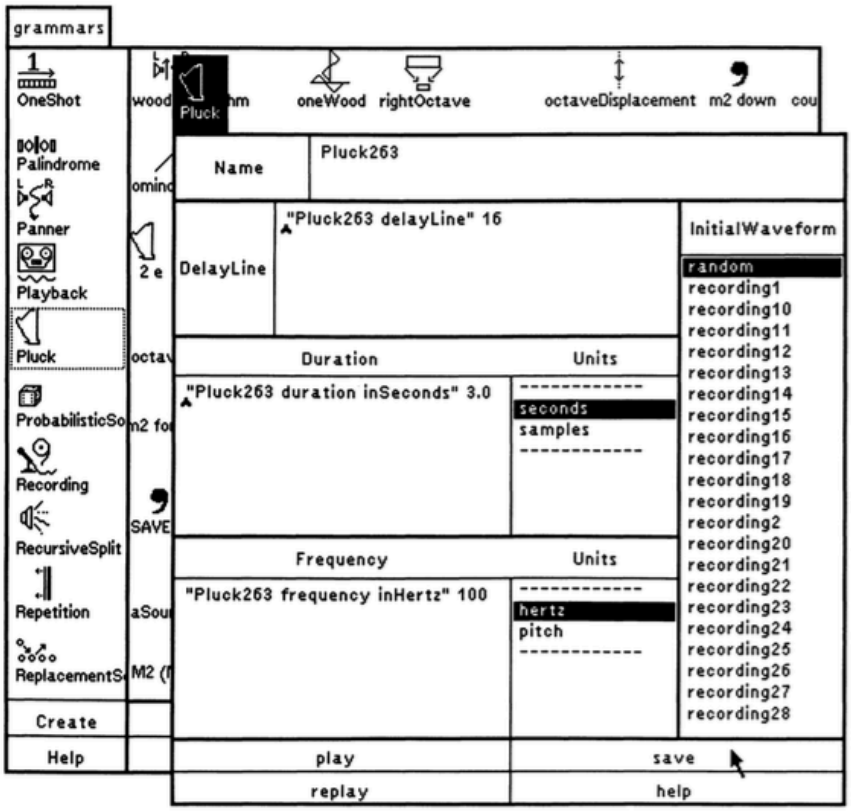

Figure 1.1: The "Creation View" of a Kyma Sound from 1989[65]

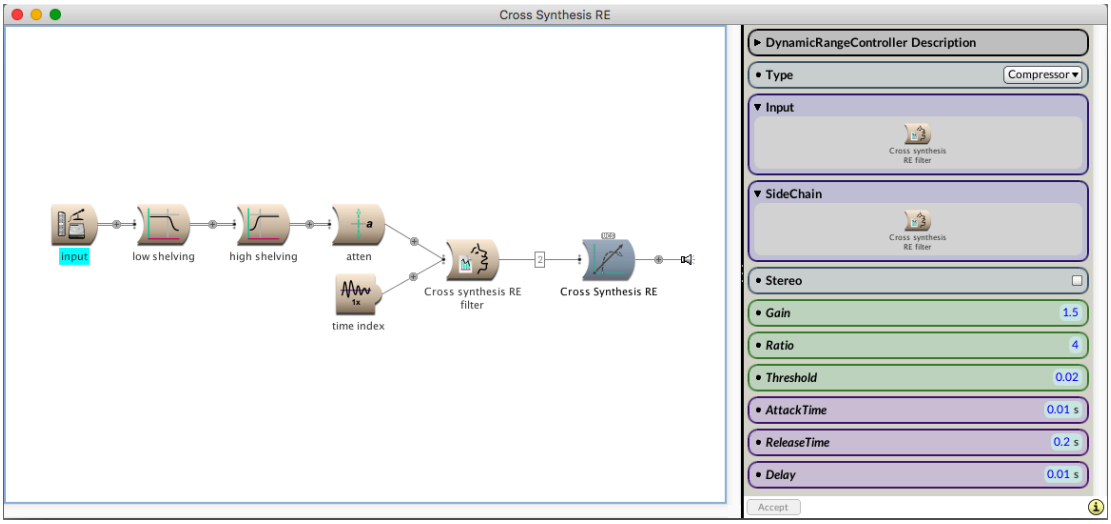

Figure 1.2: A Sound Object in Kyma 7, Screenshot taken March 29, 2019

[65] Scaletti, "The Kyma/Platypus Computer Music Workstation," 28.

Kyma: Motivation and Design

Kyma is, in part, a reaction the technology available to Scaletti at the time of its creation. At Texas Tech and UIUC, Scaletti used music programming languages in the Music-N family—Music IV BF and Music 360, which ran on the campus's mainframe IBM computer.[66] The Music-N languages use a "score" and "instrument" paradigm. The design is based on the digital modeling of analog circuitry in the form of the unit-generator; users design a series of unit generators, "the orchestra," which are controlled (turned on or off) by a separate program called the "score." To use Music 360 at UIUC, Scaletti had to sign up for lab time and run her program in batches, and then separately use a digital-to-analog converter to hear the results of her program. This was not only a cumbersome process it was also time-consuming and could take days or even weeks to hear one's program. Thus, creating real-time systems, in which one could hear results immediately and interactively while they programmed, was a priority for many in the computer music world. In the late 1970s and early 1980s, systems to program music in real-time were only available in specialized labs; many of these systems were hybrid analog-digital systems like the IMS at CERL or the G.R.O.O.V.E system at Bell Labs in which computers controlled analog synthesizers.[67]

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[66] The Music-N are a family of music programming languages developed by Max Mathews and Joan Miller at Bell Telephone Laboratories from 1957–1966. The Music-N family extends beyond Mathews' languages to languages designed by others based on the design of the Music-N including Music IVBF and Music 360. Gareth Loy, "Composing with Computers—a Survey," in *Current Directions in Computer Music Research*, edited by Max V. Mathews and John R. Pierce (Cambridge: The MIT Press, 1989), 326–332.

[67] By the mid-1980s, MIDI (Musical Instrument Digital Interface), the standard protocol for connecting electronic instruments to computers was widely available. MIDI provided new options and accessibility to control digitally synthesized sound or algorithms with specialized tools and controllers.

However, in the 1980s, the landscape of music programming languages was rapidly changing, and by the time Scaletti and Hebel released the first system in the early 1990s, other real-time programming environments such as HMSL and Max/FTS were available. According to computer engineer Robert Baron,

> The 1980s was a decade of change in the computer industry. The personal computer revolution had begun. Software development became a billion-dollar industry, and chip technology evolved from having thousands of transistors on a chip to having millions. Memory speeds increased and prices radically dropped.[68]

Developments in chip technology not only made personal computers more accessible, for Scaletti and Hebel it also facilitated the creation of faster, more affordable hardware. Additionally, with the Apple II and other personal computers that had well-developed graphics, bit-mapped screens, and increased processing power facilitated both the use of the computer to generate sound and the development of a graphical user interfaces (GUIs), which allowed greater control over digital sound synthesis and manipulation. Personal computers also made it possible for people to use these digital tools at home.

Kyma is one example in a generation of sophisticated music programming languages that could operate in real-time and manage complex hierarchical systems. In the mid-1980s, Larry Polansky, Phil Burk, and David Rosenboom developed HMSL (Hierarchical Music Specification Language) at Mills College. Written in Forth, HMSL is a real-time interactive music programming language. Like Kyma, HMSL is object-oriented, which facilitated the implementation of James Tenney's theories about musical perception based on Gestalt psychology as the structure of the

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[68] Robert J. Baron and Lee Higbie, *Computer Architecture: Case Studies* (Reading, MA: Addison-Wesley Publishing Co., 1992), 221.

language, as well as the creation of complex hierarchical musical systems.[69] Miller Puckette developed Max at IRCAM in Paris in the late 1980s. Puckette created the Patcher environment at the core of the Max programming language; Puckette's design is a graphical implementation of the Music-N data structure, the unit-generator. David Zicarelli licensed Puckette's software and released the first Max programming environment as a commercial product in 1990.[70] These early iterations of Max were not capable of real-time audio generation; later versions including Max/FTS (Faster Than Sound), which was developed and available at IRCAM in 1990, and Max/MPS, available commercially in 1997, had real-time audio synthesis capabilities.[71] Like Max, Kyma contains a graphical data-flow or patching interface as one method of creating or manipulating Sound objects, however the two languages have different underlying data structures.

Scaletti points to diagrams in DSP textbooks, tree graphs from computer science, and the diagrams of Music-N unit-generators as part of the inspiration for Kyma's graphical representation of Sounds as Directed Acyclic Graphs (DAGs).[72] The DAG visualizes the hierarchical grouping of SoundAtoms into subSounds that make up a Kyma Sound object. It is worth noting that other composers made systems for personal use to realize their own compositions and perform with computers live,

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[69] Larry Polansky, "Live Interactive Computer Music in HMSL, 1984–1992," *Computer Music Journal* 18:2 (Summer 1994), 59.
[70] Puckette further adapted the design of Max to his open source PureData programming environment in the mid-1990s.
[71] Douglas Keislar, "A Historical View of Computer Music Technology," in *The Oxford Handbook of Computer Music*, edited by Roger T. Dean (Oxford: Oxford University Press, 2009), 28.
[72] Scaletti, "Computer Music Languages, Kyma, and the Future," 75.

examples including George Lewis, Laurie Spiegel, David Behrman, and the League of Automatic Composers.

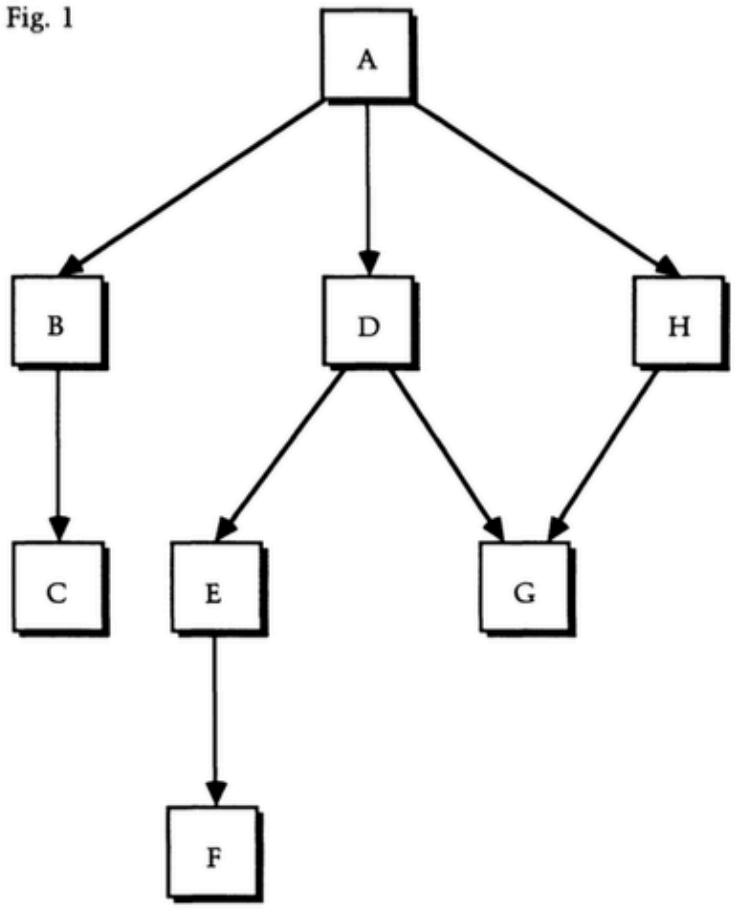

Figure 1.3: A Directed Acyclic Graph (DAG) representing Sound objects in Kyma. Each box represents a Kyma Sound. F, C, and G are SoundAtoms encapsulated in B,D,E, and H, which are further hierarchically encapsulated in A.[73]

Beyond the frustration of not being able to program in real-time, Scaletti felt locked in to the score and instrument framework of the Music-N languages; she did not want to have to make music with "notes."[74] She liked the flexibility to make and manipulate timbre in real-time with synthesizers, but she felt synthesizers did not allow for the creation of complex hierarchical structures or data mapping without

[73] Scaletti, "The Kyma/Platypus Computer Music Workstation," 24.
[74] Scaletti, email to Heying, October 20, 2017.

using magnetic tape, removing any possibility for live performance. With Kyma, Scaletti stated: "What I wanted at that time was to be able to work with sound directly and interactively, and to be able to build new kinds of structures based on sound, not based on music notation and not limited to a model of instruments playing scores."[75] Essentially, Scaletti wanted the flexibility of using a modular synthesizer for sound design with computational power of a computer, and the ability to implement algorithms with hierarchical structures, all encapsulated in the Sound object.

Scaletti's desire for a flexible system also suggests that the creation of Kyma stemmed from her practice of making experimental music. Scaletti's notion of experimentalism, like many composers of her and subsequent generations, melds aspects of a Cagean experimentalism with other avant-garde approaches to composition. For Scaletti, compositional experimentalism centers on posing a "what-if" hypothesis, which questions how the physical world operates, how humans fit in, and how scientific concepts can be explored musically. She approaches experimental composition like a scientist, by creating model musical worlds in which to test her hypotheses. Scaletti maintains Cage's definition of an experimental composition, based on the notion that the outcome of a procedure or musical experiment cannot be foreseen at the outset. However, she is typically not interested the kind of improvisation or indeterminacy in performance that characterizes the work of Cage and other computer musicians of the time, such as the Hub or George Lewis. Although most of Scaletti's compositions have a crucial live performance element and real-time generative processes, her compositions tend to be relatively fixed. I will

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[75] Scaletti, "Looking Back, Looking Forward." 14.

discuss more about Scaletti's approach to experimentation and composition in Chapter Two and Three of this dissertation. Lastly, one of Scaletti's main goals with Kyma was to provide maximum flexibility so that Kyma could be used by people with diverse approaches to experimentation, composition, and sound design.

Smalltalk-80 and Kyma

Kyma is written in an object-oriented programming language called Smalltalk. There is a clear affinity between Scaletti's ideas and values, which align with Smalltalk and its creators that include Alan Kay and Adele Goldberg. By writing Kyma in Smalltalk, Scaletti effectively imposed these shared values as embodied in the architecture of Smalltalk onto the design of Kyma. Scaletti first encountered Smalltalk prior to writing "Kyma: A Computer Language for the Representation of Music," and she and Hebel were in the process of learning Smalltalk while she designed the first version of the Kyma software in her paper. Scaletti's descriptions of a graphical language that consists of Sound objects, as well as the details about their behavior, the modularity and encapsulation of objects, the reusability of components, and her focus on large hierarchical systems, indicate that the design of Smalltalk strongly influenced the design of Kyma.[76] Beyond the influence of Smalltalk creator Alan Kay on the Kyma software, his dictum that "people who are really serious about software should make their own hardware," also serves as a rationale for the hybrid Kyma system with dedicated hardware.[77]

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[76] Scaletti, interview with Heying, February1, 2016, and May 20, 2017.
[77] Alan Kay, from an untitled talk delivered at a computer industry seminar called *Creative Think,* July 20, 1982.

Smalltalk-80 was one of the first fully developed and commercially available object-oriented programming languages.[78] According to composer and computer scientist Stephen T. Pope: "Object-oriented programming (OOP) was perhaps the most important new software engineering technology of the 1980s…because it mixes the modeling and categorization techniques of psychological classification theory with those of traditional software analysis and design."[79] Smalltalk consists of objects with a prescribed set of behaviors that send and receive messages. Smalltalk included the notions of class, inheritance, and encapsulation, and employed a graphical user interface. Each object in Kyma belongs to at least one class. In Kyma, "a Sound's icon, parameter names, and underlying algorithm are all associated with its class…the name of a Sound and the values of its parameters are associated with the specific instance."[80] Each class designates a set of protocols that can be passed down or *inherited* by new subclasses. In particular, this concept of inheritance revolutionized computer programming:

> Inheritance saves a great deal of labor, but its advantages go well beyond labor-saving. For it means that programming is now largely a matter of operating on structure, that the programmer's cognitive field has shifted, from an attention to the details of binary logic to an attention to structural relationships among semi-autonomous objects divided into characteristic categories. Object categories hide the technical details of the operation of the computer behind structures that come closer to the structures of the human

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[78] Alan Kay, Adele Goldberg, et. al developed Smalltalk at XEROX PARC in the late 1970s and early 1980s; it saw limited release in 1981 and the full release in 1983 of Smalltalk-80 version 2. It was not commercially successful, but it left a lasting impact on future programming languages.
[79] Stephen Travis Pope, "Introduction," *Well-Tempered Object*, ed. Stephen Travis Pope (Cambridge, MA: The MIT Press, 1991), 1.
[80] Scaletti, *Kyma X Revealed*, 98.

> world, or at least to those human structures that are also part of the computer world.[81]

Inheritance played a crucial role in facilitating the creation of hierarchical structures that are intrinsic to music in general and computer music in particular.

Most importantly, Smalltalk enabled Scaletti to realize her vision for a music programming language based on Sound objects. The use of classes, inheritance, encapsulation, polymorphism, and a graphical user interface with menus and Sound libraries of pre-fabricated Sounds indicate some of the many implications of the structures and organization of Smalltalk on Kyma. Scaletti describes Smalltalk, "like a database of code modules that you can recombine, modify, and add to; the things you add and the changes you make become part of the system."[82] In Kyma, these "code modules" are the Sound objects; each Sound is represented by an icon. When the icon is clicked, the encapsulated underlying structure of the Sound object appears in a new window. The underlying structure consists of a data-flow chart of other Sound objects; once inside a Sound, the user can click on individual sub-sound icons and alter parameter values or functions with bits of Capytalk (a real-time event language that runs on the Kyma hardware).[83] The graphical user interface or GUI allowed for clarity of structure and ease of use by representing signal flow graphically as icons connected by "patch cords" that replicated aspects of analog synthesis and digital signal processing. Messages sent between objects are the primary means of control. By encapsulating groups of Sound objects within other Sound objects, the

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[81] Evens, "Object-Oriented Ontology or Programming's Creative Fold." *Angelaki* 11:1 (2010). 93.
[82] Scaletti, "Looking Back, Looking Forward," 16.
[83] Scaletti, *Kyma X Revealed*, 225.

hierarchy and technical information of a given Sound is hidden, which made computer programming accessible to greater numbers of people. Kyma contains menus and sound libraries to draw from, further facilitating ease of use. Scaletti admired that, "the designers of Smalltalk did not presume to specify one universal set of classes for all applications. Rather they provided a kernel set of classes that can be extended and modified by the user."[84] She therefore also designed Kyma to have a core library of "Prototypes," basic Sound objects that could easily be employed as the building blocks of new Sounds and classes.

As an OOP, Kyma users also have multiple access points to the data or structure of the Sounds they create or use, and they are able to move quickly from high-level meta information to lower-level technical details. Although some of these aspects of Kyma are geared toward beginning programmers, there are access points for various skill levels. There is a significant learning curve that occurs when the user moves from making new Sound objects out of connecting other Sounds or altering existing Sounds, to making a piece of music using those Sounds. More advanced programmers could make their own tools, essentially making a new Sound object from scratch instead of from combining existing objects.

In "Object-Oriented Ontologies," media scholar Aden Evens studies the implications of OOPs on users; every programming paradigm imparts a certain ontology and way of using the language on its users. According to Evens, with OOPs: "The object is not only a formal grouping of code text, it is also a guiding principle of the code and of the coding. Objects must be organized to make a program, but in turn

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[84] Scaletti, "The Kyma/Platypus Computer Music Workstation," 33.

they organize much of the programming, determining what gets coded and where and how."[85] Evans explains that a given programming paradigm changes how a programmer codes and how they think about what they are coding—just like one might communicate the same directions a little differently in Japanese or German, and in order to communicate in a given language, the way in which one conceived of the directions might be different.

One of the affinities between Scaletti's values and the design of Smalltalk is the importance of clarity and simplicity as a way of affording access to users. Scaletti did not want Kyma to be prohibitively complicated, or complex for complexity's sake. According to Pope: "Smalltalk [was] designed with the goal of making the simplest and most consistent language possible by the radical application of a small number of concepts to all facets of the language, software libraries, and the programming environment."[86] She explains further:

> The syntax of Smalltalk is super simple…it's kind of a database of code that you can recombine in new ways. That was the power of it, almost like these modules that you could combine to make new modules, new objects, and then those objects could become part of the language. And because it's object-oriented, its state is hidden, an object's state is hidden and you can only access it through the protocol that the programmer provided and that reduces the interdependencies between objects. So you could change this object without breaking the system.
>
> So that's part of the philosophy of Kyma Sounds being so uniform, and being functional, and having parameters inside each sound to reduce dependency so that you can replace any sound with any other no matter how complex the sound is.[87]

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[85] Evens, "Programming and the Fold," paper presented at *Digital Arts and Culture* (Irvine, California, December 12–15, 2009), 4.
[86] Stephen Travis Pope, "Introduction," in *Well-Tempered Object*, ed. Stephen Travis Pope (Cambridge, MA: The MIT Press, 1991), 2.
[87] Scaletti, interview with Heying, May 20, 2017.

This philosophy aligns strongly with Scaletti's desire to make music programming accessible to composers who did not have strong background in computer science or mathematics. With object-oriented languages like Smalltalk and Kyma, the technique of encapsulation "hides" the technical information within an object so that beginners can use a Sound without fully understanding how it works. This makes programming less intimidating to someone with little to no previous programming experience. Beyond making programming accessible, Scaletti emphasizes the creators of Smalltalk's mandate: to make using the computer an "effective and joyful" experience.[88] A sense of joy and discovery permeates Scaletti's writings including the Kyma manual, and lectures. For Scaletti, this joy is tied to the possibility for users of Kyma (and Smalltalk) to extend and modify a system for their personal needs.

Scaletti thought about the various ways someone might learn or teach Kyma, and how to aid that process. Her motivation aligns with the creators of Smalltalk's mission that it could be used for educational purposes. Beyond suggestions for how one could learn or use Kyma in her published articles and the Kyma manual, Scaletti provides instructions "inside" each Sound in Kyma. In the Editor view of Sounds there is a drop-down window that gives a brief description about the Sound, what each of its parameters are and what they do, as well as some suggestions for how the Sound could be used or edited. There is also an icon at the bottom right-hand corner of the Sound Editor that provides more information. There are also numerous example Sounds, Timelines, Sound analysis files, and scripts that are specifically designed for beginners or to be used as instructional tools.

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[88] Scaletti, "The Kyma/Platypus Computer Music Workstation," 33.

Scaletti's statement also suggests how she considered Smalltalk-80 and Kyma "biological," because, as she explains, it is "like a living system that you could continually extend and modify."[89] In "Kyma: A Computer Language for the Representation of Music," she refers to configurations of objects in Kyma as DNA (Distributed Network of Algorithms) and the control massages they pass as mRNA (Messages Relayed as Notifiers or Acceptors). The use of genetic language speaks both to Scaletti's conception of Kyma as biological and the notion of inheritance. Kyma embodies the scientific analogies and metaphors that are central to her compositions and the modeling of complex biological systems in her music. These biological metaphors and frameworks are imposed on users through the structuring and naming of Sound Objects in the general Kyma Sound Library. Scaletti's framing of Kyma as biological also indicates an undercurrent of cybernetics in Scaletti's work, which reflects her enduring interest in science, as well as the legacy of UIUC from the Biological Computer Lab to the interest in information theory and cybernetics in the music school, and at the CERL Sound Group.

The Kyma System

Scaletti wrote the first version of Kyma in Smalltalk-80 on a Macintosh 512K computer; this software-only version was incapable of making sound in real-time. In 1987, Scaletti and Hebel collaborated to adapt the software-only version of Kyma to the now standard system, Kyma with a multiprocessor. This multiprocessor is basically a separate computer that is solely used to compute and process audio, which

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[89]Scaletti, "Looking Back, Looking Forward," 7.

leaves the host computer free to run the graphical Kyma software. Hebel and Scaletti made their own Platypus multiprocessor for the first iteration of the Kyma system. Like its predecessor, the IMS of the CERL Sound Group, the Platypus consisted of general-purpose sound processing hardware that could be programmed to do specific tasks with microcode. Scaletti was already familiar with the Platypus because she used it to compose *sunSurgeAutomata* in 1986.[90] According to Scaletti, the experience of composing with the Platypus's limited memory and flexibility encouraged her to create the first Kyma system

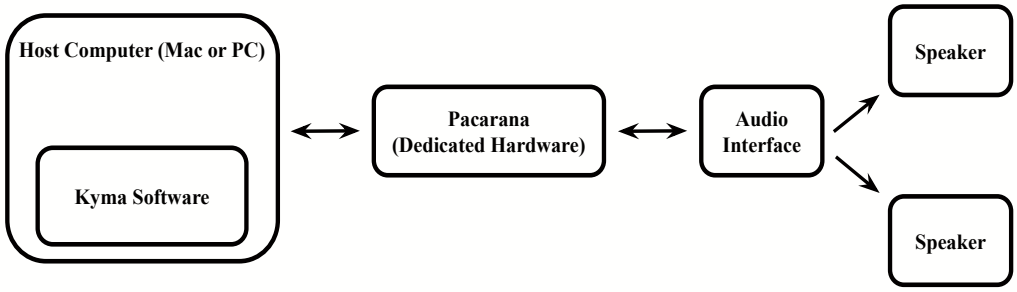

Figure 1.4: This is a basic configuration of the Kyma System. Note that a MIDI interface could be used with the audio interface, and the audio interface could be connected to a mixer instead of the speakers. The system can also be connected to more than two speakers.

By using the Platypus, dedicated to processing sound, the new Kyma system was powerful, and Scaletti could program and hear the results in real-time as she programmed. With the Kyma system, a user writes a program and then runs it on the multiprocessor by "playing" the Sound object; while it runs they can interact with the program through an audio input like MIDI or by changing parameter values with the Virtual Control Surface. In Kyma each object contains a pointer to the next sample, which is translated along with other Kyma code into values in registers that are sent

[90] She programmed the Platypus to translate a one-dimensional cellular automata into clicks and rhythm using the C language and microcode.

to the Platypus and processed.[91] Kyma is polymorphic, which means that it does not matter if the Sound is an algorithm or function, it will be handled as a stream of samples by the multiprocessor.

Incorporating an external microprocessor with the Kyma software meant that Scaletti and Hebel had to integrate machine language and several other layers of software components written in Motorola 56001 assembly language, C, and Forth, so that the Platypus, later the Capybara and Pacarana could communicate with the Kyma software written in Smalltalk. The entire underlying architecture of Kyma had to change so that all digital signal processing happened on the Capybara. Designing the system as series of software modules allowed for flexibility so that if just one part needed to be changed they would not have to restructure the entire system. Hebel designed the Platypus and Capybara to be compatible with other software—if the designers implemented a software interface to be able to communicate with the hardware—Scaletti and Hebel specifically listed Max and HMSL as potential examples.[92]

The development of the Platypus, Capybara, and Pacarana reflects the increased processing power that accompanied the developments in chip technology in the late 1980s and early 1990s. Computer chips became smaller and more powerful, so that one could fit more onto a board and inside a computer. The architecture of the Capybara and Pacarana are scalable: additional processors can be added to the

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[91] "On the Platypus, a Sound became a data structure with a pointer to the microcode that could generate the next sample in its stream." Scaletti, "Looking Back, Looking Forward," 16.

[92] Kurt Hebel and Scaletti, "The Software Architecture of Kyma," *Proceedings of the International Computer Music Conference*, (Tokyo, Japan, 1993), 167.

Capybara, and Pacaranas can be daisy-chained together to increase the audio processing speed and power. With several versions of the Capybara, users could write code directly to the chips, which opened up new ways of interacting with the system.

Although Scaletti designed and developed the Kyma software, the complete system reflects a combination of Scaletti and Hebel's specialties—Scaletti with software and Hebel with digital-signal-processing hardware. The division of labor is not quite so separate, as they each have a deep knowledge of the hardware and software components of the system. Hebel and Scaletti previously collaborated on projects like the Platypus and other tools to help Scaletti realize her compositions. They had been married for several years before Scaletti designed Kyma. Hebel often acted as Scaletti's sounding board as she first conceived of Kyma, while she wrote the 1986 term paper, and implemented Kyma in Smalltalk. He most certainly played a major role in shaping the language and how Scaletti thought about the sound design language, and DSP in particular. And, as discussed earlier, Scaletti's approach to composition inspired Hebel's design of the Platypus. The addition of the Platypus and the integration of hardware into the Kyma architecture represents the fusion of Scaletti and Hebel's areas of expertise. They have a unique relationship, in part because of its longevity and their ability to work so closely together on a personal and professional level; they also have a deep appreciation for the other's contribution to the Kyma system and ways of thinking about sound, music, problem solving, and computers.

Symbolic Sound Corporation

In 1990, Scaletti and Hebel founded the Symbolic Sound Corporation (SSC) to develop Kyma and sell it commercially.[93] At the time, Scaletti had not secured a tenure-track position at a university and it was announced that CERL, her current employer, would be closing. Scaletti and Hebel were given one final year of paid assistantships from CERL, which enabled them to fund most of the initial development of the Kyma system themselves. Due to their limited budget, from 1987–1991, Scaletti and Hebel operated SSC out of their student apartment. They "assembled hardware in the kitchen, developed software in the spare bedroom, and used a closet stuffed with sound-absorbing blankets as [their] recording studio," and used the living room for administrative tasks.[94] In order to prepare for starting SSC, Scaletti and Hebel took a business class at UIUC and created a business plan while they developed the first commercial system.

In 1987, they also received a fellowship from the Apple Corporation to design a graphical user interface for Kyma that proved crucial to launching Kyma as a commercial product.[95] In the late 1980s, software companies such as Apple competed and pushed developers to create "computer workstations," either programs or programming languages that facilitated making or editing music with a computer. For the Apple fellowship and throughout the 1990s, SSC marketed Kyma as such a workstation. In the 2000s it became more common to refer to "the Kyma system" or

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[93] Their business was originally called "Kymatics," but they changed the name to Symbolic Sound Corporation in 1990 when they incorporated. Chadabe, *Electronic Sound*, 267.
[94] Scaletti, "Computer Music Languages, Kyma, and the Future," 72.
[95] Scaletti, "Kyma: an Object-oriented Language for Music Composition," 2; Chadabe, *Electronic Sound*, 267.

"Kyma environment." Scaletti designed Kyma's interface to match the Apple Macintosh operating system—at that time Kyma could only be used on a Macintosh. Scaletti wanted users to have a seamless experience integrating Kyma into their workflow on the computer.[96]

After the development of the first system in 1987, and prior to founding SSC, several technology corporations including Apple and Microsoft attempted to recruit Scaletti and Hebel. They considered working for one of these companies, however by doing so, Scaletti and Hebel would lose a great deal of their independence and autonomy. They would either have to stop developing Kyma or develop it under the ownership of the corporation. In retrospect, they would also have missed out the close relationships they have with many Kyma users.

When they launched SSC, Scaletti and Hebel began developing a new version of Kyma software and a new multiprocessor, the Capybara. According to Scaletti: "On the morning of June 6, 1989, Kurt defended his dissertation, and his idea of celebrating was to go straight to his office, sit down at the big drawing table and start designing the Capybara."[97] The Capybara had more than triple the processing power of the Platypus; it contained eight digital signal processors arranged in a line so that the output of one processor fed into the input of another. Once Hebel completed the design of the Capybara, they ordered custom chip boards so that they could assemble the hardware in their apartment. When the boards arrived and they discovered an error, they had to fix each one by hand because they did not have the finances to get

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[96] Scaletti, interview with Heying, May 20, 2017.
[97] Scaletti, "Looking Back, Looking Forward," 17. Hebel's dissertation is titled: "An Environment for the Development of Digital Signal Processing Software."

them repaired.[98] This anecdote demonstrates Hebel and Scaletti's industriousness and their willingness to tackle all aspects of starting a technology company. It also suggests some of the challenges of starting an independent business without the support of a lab or university with funding from salaries or grants, and resources such as equipment or studio space. SSC sold the first Kyma system in the fall of 1990.

The decision to create a business to develop and sell Kyma has had many implications for the language and set it apart from the work of many of Scaletti's academic mentors and peers who developed software or electronics for performance part time. Although starting SSC gave Scaletti and Hebel independence and time dedicated to Kyma's development, it also put a great deal of pressure on the success of Kyma: if SSC and Kyma failed, they had no faculty, lab, or studio position to fall back on. One of the implications of developing Kyma as a commercial product is that Scaletti and Hebel had to accommodate users' needs and requests in newer versions of Kyma. This poses the challenge of maintaining their original vision of Kyma while addressing users' demands. Scaletti considers the challenge positive in that it pushes Kyma forward rather than keeping it stagnant. The development of Kyma is the result of SSC's active approach to customer service and the close relationship Scaletti and Hebel have with many Kyma users. Thus, Kyma in its current state reflects not only Scaletti and Hebel's design, but also the way Kyma is used by SSC's clients.

Through the early 1990s, Kyma acquired a small following of dedicated users, however two occurrences played major roles in substantially building Kyma's user base. One was a major software update. Actually, most major software overhauls

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[98] Ibid., 17.

including the most recent, Kyma 7 in 2015, result in growth in the user base. Kyma's use in big-budget Hollywood films has also been an important vehicle for publicity and boosts in sales of Kyma systems. Starting in 1998-9, Lucas Films sound designer Ben Burtt used Kyma in the *Star Wars Episode 1: The Phantom Menace*, and the subsequent *Star Wars* prequels and sequels. Although Kyma sound designers in the film, video game, and music industries already used Kyma before Burtt's soundtrack for the Star Wars prequels, it subsequently became a standard tool for sound designers. Sound designers used Kyma in other commercial films including *Wall-E*, *The Dark Night*, *Super 8*, *Hateful Eight*, and *127 Hours*.

Kyma and the Notion of "Free Software"

In the twenty-first century, free-software or cheap software is not only common it is expected and often necessary for a company to survive in competitive software industries. Scaletti and Hebel created the Kyma system before the notion of free software inundated mainstream society, which occurred in 1998.[99] Kyma was also developed before most people had the internet, which facilitates the online sharing and virtual communities required for the development and maintenance of free software.[100] For example, with Supercollider, a core group of users handle most of the customer support on their own time and dime. Pd Extended is an example of how tenuous these communities can be; in the last several years, the core group of users that maintained Pd Extended stopped updating the software, rendering it

[99] Christopher Kelty, *Two Bits: The Cultural Significance of Free Software* (Durham: Duke University Press, 2008), 4.
[100] Ibid.

effectively unusable. The SSC mission statement hints at Scaletti and Hebel's motivations for developing Kyma as a commercial product, and its high price point:

> For us, it's all about the sound, it's about the ideas, and it's about learning and developing our product and ourselves. Some companies sell whatever it takes to make money and please shareholders; we sell the results of our life's work in order to make it possible for us to continue to refine and improve on that work and to share our results with others, so that they, in turn, can use it in their own creative or scientific work.[101]

Kyma users operate remarkably similar to free software communities; they develop tools and answer each other's questions on forums and community pages. I will go into much greater detail about the characteristics of the Kyma user community in Chapter Three.

Key Features: Kyma Through the Years

In this section, I discuss several of Kyma's key features and additions made across different Kyma upgrades to address its core principles and user needs. These features will be referred to throughout the rest of the dissertation. As SSC's mission statement indicates, the development of the Kyma system has continued over the last thirty years. Over the last three decades, SSC made seven major software updates, and three versions of the dedicated microprocessor: the Platypus, Capybara, and Pacarana. With each update, Scaletti and Hebel dramatically increased the possibilities for how to access, manipulate, and employ Sounds, in addition to adding to the Sound Libraries that are built into the language. When discussing how she deals with and incorporates user feedback into Kyma updates, Scaletti maintains:

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[101] Scaletti and Kurt Hebel, "About," symbolicsound.com, accessed October 16, 2017.

> I think of software as being not so much utilitarian, I think people in public might think of software as being a machine, a utility. But, I think of it as being much more like writing a book or philosophy, a lot more of your personality gets embedded in the software. So I think it is very important for software developers or designers to resist, there is a pressure that pushes the software to become the same everything else. There is this pressure to make everything look exactly the same, so I think it is important for there to be a plurality of different models and different paradigms, and different ways of thinking about music and sound.[102]

SSC do not remove Kyma Sounds from the software—pieces composed using older systems will still work fine on the newest system. Added features do not alter the core principles of Kyma, rather the additions tend to be new means of controlling or manipulating Sound objects through changes in the Kyma interface or the incorporation of new control paradigms and Sounds. This practice is undertaken partially out of consideration for their long-time customers; SSC does not want to interrupt one user's workflow or pieces by addressing another user's requests for changes or additions to the system.

SSC's resistance to change is part of the Kyma legacy. In an interview with Rodgers, Scaletti conceded: "There is some work that I feel driven to do and I have kind of stubbornly persisted in doing it."[103] Scaletti is proud to have maintained Kyma's identity in an industry that pressures everything to look the same. Kyma's identity is directly tied to the way Scaletti and Hebel think about sound and Scaletti's compositional philosophy. As Scaletti stated above, she sees the Kyma system as a representation of her personality, thus for her, the stakes are high when making changes to the system. She is resistant to making changes that do not resemble her personality or philosophy and when accommodating user needs, she adapts them to

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[102] Scaletti, interview with Heying, September 24, 2016.
[103] Rodgers, *Pink Noises*, 53.

the existing frameworks and structures in Kyma. The tradeoff to SSC's approach is that Kyma appears to have experienced some difficulty throughout its history with legible in the computer music industry writ large. SSC's steadfast adherence to their initial vision for the system is likely one factor. Although Scaletti and Hebel keep the Kyma software up to date with new developments in DSP, synthesis, and audio analysis, SSC's insistence on the necessity of dedicated hardware in particular is difficult for people in the computer music world to understand since other music programming languages do not require dedicated hardware. SSC remains largely unfazed by criticism of the system; they seem content to work with Kyma's dedicated user base, which continues to grow every year.

The following assessment of Kyma is based on the most recent major software update, Kyma 7. From the earliest implementation in Smalltalk, Kyma included several menus that contained libraries of Sound classes and sample Sound objects for use as the building blocks to create new Sounds. Earlier versions had "scrollable strip" along the edge that contained existing Sound objects and Sound Collections. More recent versions of Kyma contain a main Sound Library with a Sound Browser, which contains pre-fabricated Sounds that users might alter, manipulate or incorporate into existing Sounds or pieces. The Prototypes window consists of more basic Sound classes that tend to be simpler, lower level structures such as an oscillator, mixer, reverb, etc., that are conducive to building new Sounds. In theory, any Kyma Sound can be combined with any other to create a new more complex Sound. In practice, however, this can be difficult, if parameters do not match, the

Sound will not play. The user can edit the Sounds to make it work, but the process can be time consuming and might not produce a satisfying result.

The Kyma interface evolved as Scaletti developed new ways to translate her thoughts about the structures in Kyma into interactive graphical representations, which often took several iterations or generations for her to settle on intuitive, user friendly results. Scaletti described the first Kyma GUI as a "select-from-list" interface. Next, Scaletti created a "Russian doll" style interface, where the Sounds could be considered containers of other sounds. The interface contained a "Sound Plane" where the objects could be connected and "creation view" where one entered values into parameters. Finally, Scaletti settled on the "patching" style interface, which was inspired by tree graphs in computer science; by connecting Sounds, users effectively "draw" a signal flow path, which makes evident the hierarchy of the Sounds structure in relation to itself and its class in relation to other classes and the recursion that defined the Sound's architecture.[104] The basic features of the interface of Kyma 7 are very similar to Kyma 5 (2000). The patching interface and the idea of a Sound as a container that "opens" when clicked is still central to editing Sounds. Kyma still contains the Timeline, Sound Browser with sub-libraries, Virtual Control Surface, Sound Editor, etc., however improvements and tweaks have been made over the years.

In addition to the Sound editor and Sound Libraries, there are other means for manipulating or creating Sounds including the Virtual Control Surface (VCS), a window that opens when a Sound is played. The VCS contains a widget for each of

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[104] Scaletti, "Computer Music Languages, Kyma, and the Future," 73.

the controllable parameters of a Sound, usually represented by a virtual knob or slider that the user can manipulate to change the values for the Sound's parameters such as volume, pitch, BPM, the range of a filter, etc. Each Sound contains an object called the EventValue, which represents these controllable parameters. If a user adds a parameter, a corresponding widget is also added. Kyma also contains ways of conducting and viewing spectral analyses, oscilloscopes, and other 3D visualizations, many of which also contain ways to edit a Sound. In Kyma, users can also create a Tool, allowing them to create something like a Sound from scratch without using the prototypes or pre-fabricated Kyma Sounds that come with the language.

Since Kyma's initial creation, Scaletti added several control interfaces for performance and organizing Kyma Sounds over time, including the Timeline (2000) and the Multigrid (2015). In the first several versions of Kyma, users had to schedule events using delay lines or other objects such as TimeOffset. With the Timeline users can layer and sequence Kyma Sound and automate how the Sounds evolve over the course of a piece. The timeline consists of horizontal bars that represent different tracks or layers of a piece. It looks like a Digital Audio Workstation such as GarageBand, Logic, or Reaper. However, instead of recording in live audio or dragging in samples, with the Kyma Timeline, users can drag and drop in Kyma Sounds that generate algorithms, functions, audio synthesis, or some control paradigm in real-time. Like the Sound object interface, the idea for the Timeline stemmed from how Scaletti visually sketched the sequence of Sounds she used in a demonstration for a composition.[105] According to Scaletti, "the Timeline was not so

[105] Ibid., 76.

much a change to Kyma as it was the addition of an alternate view on the original underlying Sound structure."[106] The Timeline also includes controls for when to start and stop a Sound, such as the WaitUntil, which halts playing a Sound until the performer plays the specified trigger such as a MIDI note. The Timeline also includes controls for spatialization and automation of audio. Scaletti introduced another performance interface in Kyma 7 called the Multigrid. The Multigrid has, in Scaletti's words "random access time," which means that users can prepare Sounds for performance, but the Sounds do not have to be in a particular order or time slot.

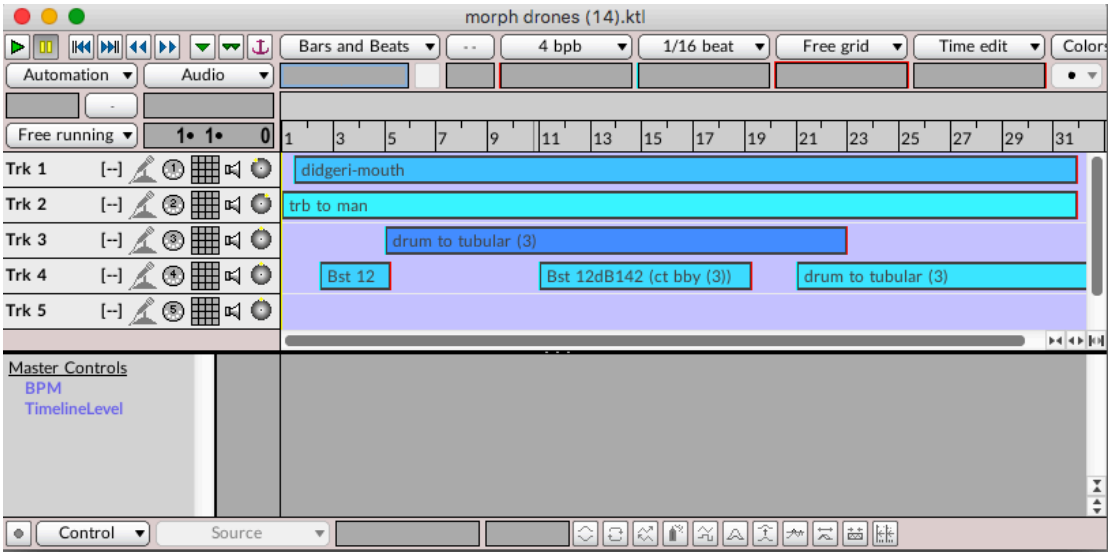

Figure 1.5: Screenshot of a simple Kyma Timeline, taken March 29, 2019

[106] Ibid.

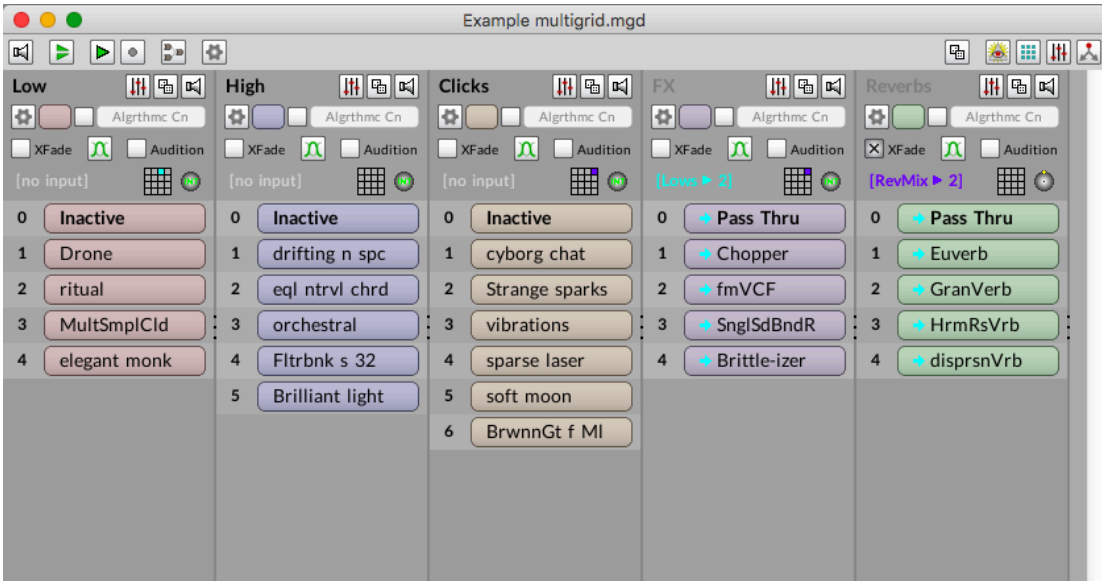

Figure 1.6: Screenshot of a Multigrid, taken March 29, 2019

This section included a cursory description of some of the key features in Kyma. Specific Kyma Sounds will also be discussed in detail throughout Chapter Two, and touched on in Chapter Three.

Conclusion

Scaletti concludes "Kyma: A Computer Language for the Representation of Music" by questioning the relevance of computer science to music and vice-versa. She asserts:

> Music is a highly developed symbolic system and as such provides yet another window into human intelligence...in short, music is a complex and little understood human endeavor and provides a rich area of potential research for computer scientists whether they be interested in signal processing, languages, artificial intelligence, or in purely theoretical notions of structure and process.[107]

[107] Scaletti, "Kyma: A Computer Language for the Representation of Music," 12.

In almost every article Scaletti has published, she concludes with imagining how her questions of the present will lead to developments in technology and understanding of human bodies and minds in the future.

Any programming language acts as a mediator between humans and computers; programming languages are simply a code that makes machine language and digital technology more accessible to humans. As a music programming language, Kyma not only facilitates this kind of access to digital technology, it also enables the creation of music through its particular design and interface. Kyma embodies Scaletti's compositional philosophy and how she thinks about sound and composition; it is a philosophy based on designing Sound objects that can be manipulated and arranged into new compositions. Kyma is the result of Scaletti's desire for a recombinant music-programming paradigm that allowed users to implement compositional algorithms, hierarchical musical structures, and synthesize novel sounds. Object-oriented programming greatly facilitated Scaletti's desire and the core design of Kyma centered on Sound objects. Although Scaletti and Hebel have made significant changes to Kyma, the core identity is the same.

Chapter Two
"Hearing the Music of Our Spheres": The Music of Carla Scaletti

> Scientists have long been baffled by the existence of spontaneous order in the universe. The laws of thermodynamics seem to dictate the opposite, that nature should inexorably degenerate toward a state of greater disorder, greater entropy. Yet all around us we see magnificent structures—galaxies, cells, ecosystems, human beings—that have somehow managed to assemble themselves. –Steven Strogatz[108]

> To me, *art* is *art*ificial; ordinarily that word has negative connotations, but I think of it in a positive sense as synthesizing or creating a world. –Carla Scaletti[109]

Introduction

Scaletti refers to her compositions as *mu-psi*, a combination of music and science fiction. She bases each piece on a "what if" hypothesis in which she questions how the physical world operates, how humans fit in, and how scientific concepts can be explored through sound. As an algorithmic composer with a deep understanding of science and computers, and driven by an insatiable curiosity, many of Scaletti's compositions are sonic models of intricate biological processes such as cell behavior or the DNA transcription of E. coli. Scaletti extends these models in imaginative and speculative ways, hence the fictional aspect of mu-psi. Scaletti's compositions encourage a sense of wonder. Her hope is to provide an audience with a novel listening experience that sparks new appreciation of the intricate and remarkable interworking of the natural world, and how humans are connected to networks of other ongoing systems. For Scaletti, seeing how humans fit into larger nested

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[108] Steven Strogatz, *Sync: How Order Emerges from Chaos in the Universe, Nature, And Daily Life* (New York: Hachette, 2003), 1.
[109] Scaletti, email to Heying, February 4, 2017.

ecosystems and cultural systems—in other words, the experience of wonder—is one of the most powerful and meaningful human experiences, one that creates new awareness of a human's place in the world that can shape one's future behavior.

Scaletti, like many other composers since the mid-twentieth century, turned to science and the natural world to provide new structures for her music. Her work is related to that of composers such as Alvin Lucier, Barry Truax, David Dunn, Annea Lockwood, and Laurie Spiegel, to name a few. She is not interested in evocations of wilderness, creating soundscape ecologies, preservation and activism, or impressionistic evocations of space or the non-human world. Rather, she is interested in exploring deep science; her focus tends to be microscopic, including how particles, bacteria, or cells function. She is interested in the connections between the human and the non-human world, and exploring these relationships through sound. As described in Chapter One, as a teenager, Scaletti had an epiphany that led her to realize she could combine her interests in music, science, and human behavior through making "universal patterns" audible.[110] Scaletti is interested in the underlying structures of natural processes and in the sets of relationships such structures reveal. Scaletti explores such relationships through sound by doing data sonification, or crafting musical models of physical or chemical phenomena, or biological processes.

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[110] Scaletti, interview with Heying, Santa Cruz, CA, February 1, 2016. As I quoted in Chapter One, Scaletti explained: "When I was sixteen or so, at that age when you are sort of trying to figure out, what is my purpose? I couldn't sleep one night, and I was looking out my window and trying to figure out what my mission was. That's when I thought, there are these patterns and some people are scientists and they are figuring out the patterns by doing research and science, and I'm a musician, but maybe I could make these patterns audible in a way, a contribution, that I could recognize these patterns and make them understandable.

Scaletti's stated artistic mission is to create alternative sonic worlds that "entertain by stimulating the intellect."[111] These sonic worlds are based on metaphors of universal patterns and concepts. For Scaletti, universal patterns are the similarities in processes that not only organize the natural world and laws of physics, but also organize human behavior and cognition. Scaletti's imaginative worlds offer solutions to current political, societal, medical, environment, or scientific problems, suggesting new possibilities for interaction, communication, and understanding. Scaletti feels responsible to "guide" listeners through the conceptual and sonic spaces she creates. To that end, she often provides detailed program notes, and her pieces combine the familiar with the unfamiliar, often unfolding with a nonverbal, nonliterary narrative arch. Her hope is that these compositions will take audiences on an "intellectually challenging journey," that will provide them with an "ecstatic experience," as in an experience "outside or beyond oneself." Lastly, in her mission statement, Scaletti mentions the importance of play and experimentation, which she believes should result not only in exploring ramifications of an experiment, but violating one's self-imposed constraints.

Scaletti's artistic mission provides a window into her approach to musical experimentation. In some ways her work is like a science experiment in which she tests a hypothesis. The hypothesis is often speculative, not necessarily based solely in scientific fact or contemporary understandings of reality. Like Cage, and others in the American experimental tradition, the initial outcome of the experiment is not foreseen. For example, when asked if she ever changes the sonic results of an

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[111] Scaletti, "Mu-Psi Manifesto," carlascaletti.com, accessed January 8, 2019. All of the following quotations are taken from Scaletti's mission statement.

algorithm or model she designed, she emphatically replied that she rarely changes the outcome of such processes, rather if she is unhappy with the result she reworks the algorithm or mapping of the model. However, Scaletti differs from trends in this tradition because the results of the experiment are often just a starting place; as her mission statement suggests, in her pieces she explores the ramifications of the experiment and models but she also extends and plays with the applications of the model, shaping the sonic results. This distinguishes Scaletti from more process-based artists who sought to remove their intentions from their work; she makes no pretense of doing so, and relies heavily on her musical preferences and intuitions when composing. Although Scaletti imaginatively extends the models she creates, scientific, mathematical, and musical rigor underlie her work, and serve as the basis of the musical material she creates.

According to Scaletti, her desire for new compositional tools was the initial impetus for creating Kyma. Scaletti credits her use of the Platypus multiprocessor (the Kyma system's first dedicated hardware) for *sunSurgeAutomata* (1986–1987), as the impetus for creating the system because it illustrated the power of software to create a "virtual machine."[112] She first used the Kyma system for *Trinity* (1989). As discussed in Chapter One, Kyma is, by design, ideally and completely suited for Scaletti's compositional approach. Each time Scaletti creates a new piece, new Sound objects are also introduced into Kyma, emerging out of necessity. Through time, Scaletti's pieces have become significantly more complex and multi-layered, aided by the tools she developed in Kyma. Kyma Sounds and processes are discussed in great

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[112] Scaletti, "Looking Back, Looking Forward: A Keynote Address for the 2015 International Computer Music Conference," *Computer Music Journal* 40:1 (Spring 2016): 15.

detail throughout this chapter, which will shed light on aspects of Kyma touched on in Chapter One.

In her effort to convey universal patterns through sound, Scaletti studied human cognition and the mechanisms humans use to develop meaning. Scaletti's compositions are particularly influenced by the work of philosopher and cognitive scientist Mark Johnson. In *Body in the Mind* (1987) and *The Meaning in the Body* (2007), Johnson studies the role of a deeply situated human body in the creation of meaning, and the development of rationality and understanding. Embodied cognition is based on the notion that thinking requires one's entire body (rather than just their brain), and arises from the body's interactions with its environment.

Johnson explains the mechanisms of embodied cognition through what he calls *image schema*, or basic patterns used to structure thought and meaning. He defines an image schema as "a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience."[113] According to Johnson, humans make sense of concrete physical experiences by translating image schemata into abstract understanding using *metaphorical projections* in which we "project patterns from one domain of experience in order to structure another domain of a different kind."[114] Johnson uses the example of "more is up:" humans understand quantity in terms of a vertical schema. Johnson asserts that metaphorical projections and image schemata are "a misleading shorthand way of naming a complex experiential web of connections that

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[113] Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason* (Chicago: University of Chicago Press, 1987), xiv.
[114] Ibid., xiv–xv.

is not itself primarily propositional."[115] Image schemata are gestalt structures that work on several levels to create hierarchy of meaning and understanding. Johnson's 2007 book, *The Meaning in the Body* furthers his earlier work on embodied cognition and the construction of meaning by focusing on human interaction with the environment. Johnson operates from the premise that humans are not separate from their environment, rather they are deeply embedded in it and cognition is simply processes that emerge through interaction with one's environment.[116]

Johnson's work provided Scaletti with language for identifying patterns found across the natural world and human behavior, and how they orient human cognition. Scaletti stated: "Somehow discovering those patterns [Johnson's schema], it was almost like it made me realize that your intuition is logical. That things didn't have to come from mathematics necessarily, although mathematics is an interesting way to generate structure."[117] Since Johnson's schema point to universal patterns, the listener can map their own experiences to Scaletti's work and make it meaningful in their own way. Scaletti's work also shares an affinity with Johnson's embodied approach of framing the human mind and body as embedded and interconnected into larger ecosystems.

Johnson's schemas also serve as the basis for the sound synthesis techniques and effects Scaletti employs in her compositions. Some of Johnson's schemas include: cycles, counterforce, full/empty, surface, scale, center-periphery, contact, balance, path, merging, object, and splitting. One common schema Scaletti points to

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[115] Ibid., xv.
[116] Mark Johnson, *The Meaning of the Body: Aesthetics of Human Understanding* (Chicago: University of Chicago Press, 2007), 117–124.
[117] Scaletti, interview with Heying, Champaign, IL, January 7, 2018.

in her work are *cycle* patterns, from natural oscillators explored in *Double-Well* (2016) and the Brusselator, a chemical oscillator Scaletti modeled in *Autocatalysis* (2010), or weather patterns in *Cyclonic* (2008)**.** She also employs "more is up," often correlating "up" with pitch or amplitude. Scaletti sees Johnson's schemata and more conventional musical techniques as a way to make her experimental compositions accessible to a general audience. Employing Johnson's schemata make unfamiliar sounds or processes more concrete.

Several of Scaletti's early compositions incorporated ideas from Lewis Thomas's *Lives of a Cell*, a collection of 29 essays originally published in the *New England Journal of Medicine* from 1971–1973. Like Scaletti, Thomas freely makes unconventional and fanciful connections between biological phenomenon and animal and human behavior. Throughout *Lives of a Cell*, Thomas highlights the interconnectedness of all living things, a theme common in Scaletti's work. Thomas is humorous and playful; he also writes in a conversational tone that gears his book towards a general audience. For example, when discussing the hive mentality in a beehive he stated: "It is an intelligence, a kind of live computer, with crawling bits for wits."[118] Thomas's playful, approachable tone and creative, quirky analogies align with Scaletti's perspective on science, technology, and human nature.

There is an underlying cybernetic quality to Scaletti's work. She rarely cites cybernetics directly, however most of her compositions employ systems thinking and the replication of biological or cognitive structures in technology. Scaletti is interested in the relationships between humans and technology and humans and their

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[118] Lewis Thomas, *Lives of a Cell: Notes of a Biology Watcher* (New York: Viking Press, 1974), 12.

environment. Pieces like *Autocatalysis*, *Double-Well*, and *Conductus* employ dynamical systems, allowing Scaletti to sonically investigate mechanisms of communication, feedback, self-organization, automation, and emergence.

New Program Music

Scaletti writes program notes for each piece and expects the audience to read them. She wants her compositions to be accessible to a general audience and she considers the listener when composing. When asked about the need for program notes, Scaletti stated: "You kind of owe it to the audience. [The work] is something different, not just a repeat or small variation of what they've heard before."[119] Her intention is not prescriptive of how pieces should be interpreted, but to inform the audience of the complicated processes she implemented and the various connections she explored. Her program notes function like a scientific journal article introduction where the scientist explains the hypothesis that is going to be explored in an experiment. Scaletti's program notes indicate what listening to a model or mapping scientific processes can teach listeners, and how one can explore connection between scientific concepts and human experience through sound. Scaletti also attempts to include various elements in her pieces to reach different kinds of audience members, she explains:

> I try to build multiple layers into the pieces (social, political, emotional, and purely formal) so that people can experience it in different ways (or more than one way simultaneously). The hope is that the formal structures can be heard and felt at some unconscious level. The analogies to social or scientific processes might stimulate people to think about other analogies.[120]

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[119] Ibid. Cage is notable in this context due to his production of copious written materials designed to explain his compositional procedures and philosophies.
[120] Scaletti, email to Heying, October 23, 2017.

As the above statement indicates, Scaletti's compositions tend towards maximalism with many layers of meaning, symbolism, and musical processes.[121] Program notes make the various layers of meaning behind the piece explicit and suggest what the audience might listen for. Additionally, Scaletti's pieces often seem simple on the surface, but are actually governed by complex underlying processes. Scaletti's expectation is not that the audience will fully appreciate or care about all of the layers, but she hopes at least one will be meaningful to each person listening. She explains:

> It seems that people hear in the music what they expect to hear. Some people hear *only* the humorous or playful layers. Whereas other people get that there are some serious ideas and formal structure, and they really think about it and reflect on it. It's just a reflection of life and thought that there are multiple layers going on simultaneously. And you can be playful and happy even when doing serious, complex things.[122]

Scaletti's statement demonstrates the balance between each of the different layers in her work and her tendency to include humor, complexity, literal sonic metaphors, and abstract sonic phenomena.

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[121] Maximalism is an ill-defined, but commonly used term in musicology. Richard Taruskin employed the term to describe the extension of traditional forms and harmony in the late 19th and early 20th century. Music critic Kyle Gann has used the term to describe everything from orchestral works by Mahler, Bartok, and Stravinsky, to trends adjacent to minimalism such as the works of John Zorn and Glenn Branca, to the recent works of Steve Reich, Philip Glass, and John Adams. Richard Taruskin, "Maximalism," *Music in the Early Twentieth Century: The Oxford History of Western Music* (Oxford, Oxford University Press, 2009), 5–6; See Kyle Gann's blog, *Post Classic*, https://www.artsjournal.com/postclassic/. I use the term here to capture the abundance of metaphors and musical processes Scaletti explores in each of her compositions.

[122] Ibid.

Scaletti's Cyborg Feminism

As discussed in the Introduction, I believe cyborg feminism is at the heart of Scaletti's compositions. Like Haraway's cyborg, Scaletti's compositions are seemingly borne out of a contradiction: on the one hand Scaletti's compositions are works of science fiction, yet they are also based on rigorous scientific and mathematical modeling and a deep understanding of hard science. Haraway explains: "A cyborg world might be about the lived social and bodily realities in which people are not afraid of their joint kinship with animals and machines, not afraid of permanently partial identities and contradictory standpoints."[123] Like Haraway's cyborg worlds, Scaletti sonically creates "worlds ambiguously natural and crafted."[124] Scaletti eschews the command to "be serious" in subtle ways, engaging in what Haraway calls "serious play." Her work is imbued with imagination and a sense of play and humor. Ultimately, Scaletti's work evokes a sense of wonder, which may give an audience new appreciation of how humans are related to larger ecosystems and cultural systems, potentially altering their behavior in the future.

The compositions discussed in this chapter are divided into three categories: pieces that explore biological phenomena; pieces that model physical phenomena; and data sonification and data-driven music. These are not neat categories; rather they are imposed to highlight several overarching tendencies in Scaletti's work. However, I believe they are representative of Scaletti's oeuvre. Additionally, partly due to my use of these categories, many of Scaletti's works will not be discussed. [For a full list

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[123] Ibid., 154.
[124] Donna Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in *Cyborgs, Simians, and Women: The Reinvention of Nature* (London: Free Association Books, 1991), 149.

of pieces see Appendix One.] The following aspects of Scaletti's compositions are relatively absent in this chapter: her interest in communication technology; her use of novel controllers (fingerboard continuum, balloons); and live performance with Kyma.

I. Biological Processes and Phenomena

As mentioned in Chapter One, Scaletti became interested in science—biology in particular—at an early age due to encouragement from her father, Joseph Scaletti, who worked as a microbiologist. Throughout his life, Scaletti and her father bonded through discussions about biology and science, and several of the concepts Joseph taught her served as the basis for her musical compositions. Joseph Scaletti's work also likely influenced Scaletti's desire to make microscopic biological phenomena audible as part of her larger project of making universal patterns audible.

To model biological phenomena musically, Scaletti translates the procedures and parameters of the processes into music notation or other musical parameters. For instance, by mapping bacteria or virus DNA to pitch or frequency, or making an existing model, such as a CA audible, Scaletti revels in the basic natural patterns she believes mirror human behavior. She therefore includes evocative elements that connect biological principles and processes to more relatable human interactions such as a telephone conversation or cultural phenomena. This sometimes involves extending or applying her models in imaginative and scientifically inaccurate ways.

Scaletti's biological pieces in particular explore themes of morphogenesis, evolution, and mutation. She is interested in how life forms take on definitive

characteristics and how such characteristics emerge and evolve over time. Mutation introduces new elements into a system and Scaletti is fascinated by how systems adapt and cope with these new elements. Some of the systems Scaletti creates are self-organizing or self-regulating, requiring complex feedback networks, mimicking feedback networks present in the natural world. Since music is time-based it is the ideal medium for exploring this kind of change.

In each of the following pieces Scaletti also explores self-similarity. In mathematics, self-similarity refers to a pattern that is identical and symmetrical across scale, or as journalist James Gleick simply states: "[self-similarity] implies recursion, pattern inside pattern."[125] Self-similarity is often demonstrated visually in mathematical diagrams or fractal artwork. In her work, Scaletti makes self-similarity audible using pitch, rhythm, and other musical parameters to sonically represent algorithms or other self-similar processes.

***Lysogeny* (1983)**

Scaletti composed *Lysogeny* as her DMA thesis, for live harp and tape. Since the piece explores the themes of genetic and musical mutation, Scaletti dedicated *Lysogeny* to her father. Scaletti employed FORTRAN, Music 360, and LIME (the PLATO System) to generate the harp score and the tape, and she printed the score using the Interactive Music System at CERL. Both the harp score and computer-synthesized sounds were generated algorithmically. The organization of the piece is based on the effect of a lysogenic virus on bacterial DNA.

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[125] James Gleick, *Chaos: Making a New Science* (New York: Viking Press, 1987), 103.

Scaletti's music-generating algorithm translated the process of a lysogenic virus into music notation. With a lysogenic virus, when a bacterial cell begins to replicate, virus DNA attaches to the bacteria's circular DNA, integrating into its chromosome, and replicating along with the cell's DNA.[126] As a result, over many generations the bacteria may take on some of the phenotypic and behavioral characteristics of the virus. Eventually, the viral DNA may enter a lytic phase, becoming active and separating from the bacterial DNA, killing the bacteria and spreading the virus. Just as the bacteria took on some of the characteristics of the virus, after the virus breaks away from the bacteria in the lytic phase, it also takes on some of the characteristics of the bacteria. For *Lysogeny*, Scaletti treated groups of pitches as DNA strands, which she joined at the ends in loop to mimic the circular nature of bacterial DNA. Scaletti generated the pitch material through a process she called "mutual alteration," which she first applied to individual notes, then to small collections of pitches, and then larger collections of pitches. She applied a function shape of +2, -1 to the pitch material, treating each whole integer as a whole musical step (so the function translates to a major second that is transposed to down a minor second). For example: F, G becomes F G, E F#, which is then transposed down a half step, F G E F#, E F# Eb F. Since the same function shape is applied to collections of pitches at multiple scales (i.e. smaller and then larger collections of pitches), Scaletti's method produces self-similar musical patterns.

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[126] John W. Little, "Lysogeny, Prophage Induction, and Lysogenic Conversion," in *Phages: Their Role in Bacterial Pathogenesis and Biotechnology*, edited by Matthew K. Waldor, David I. Friedman, and Sankar L. Adhya (Washington, D. C.: ASM Press, 2005), 37.

Throughout *Lysogeny* the musical "DNA" is replicated and transposed, causing the pitch center to slowly shift. In addition to adding new pitch patterns that mimic a virus' linear DNA, Scaletti musically represents the virus through the gradual introduction of "noise elements"; examples include knocking on the harp's soundboard and unpitched sounds on the tape. Other elements including sequences with larger intervals, new pitch material, and the reordering of previously used pitch material are added at random points. Over time the quality of the music changes as these "foreign genes" and "transcription errors" become more prominent in the music.[127]

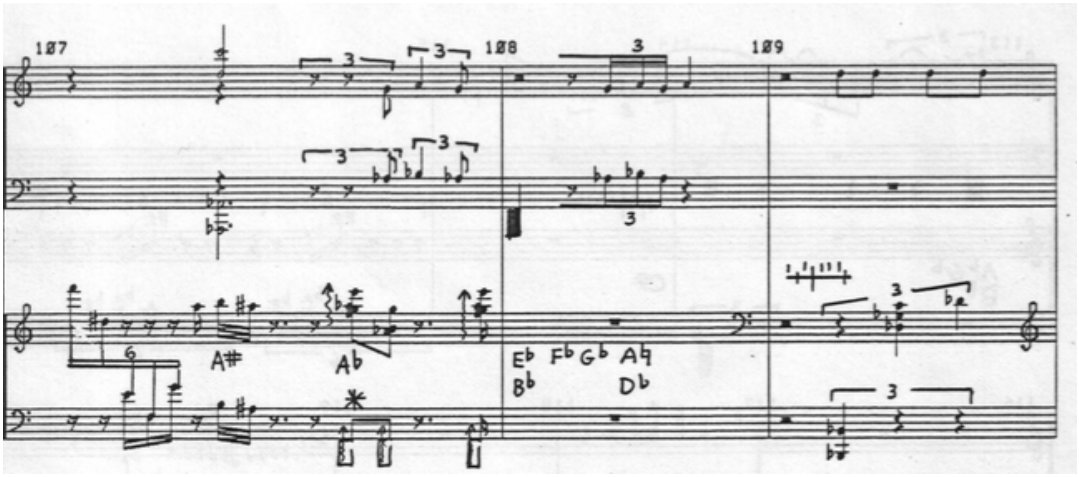

Figure 2.1: *Lysogeny* score, MM 107–109, features "noise elements" including Salzedo's "Whistle Effect" and striking the strings with palms

In order to create rhythmic variety and make the music more expressive, Scaletti altered the music by hand and through separate computer programs. This move was partially a response to what Scaletti called "a rude reminder" from a visiting composer at UIUC named Bogdan Mazurek, that humans and computers execute scores differently so it would be difficult for a musician to precisely

[127] Scaletti, "Lysogeny," program note, carlascaletti.com, accessed December 16, 2018; Little, "Lysogeny," 37.

synchronize with the tape.[128] Scaletti also responded to a suggestion that she add random variation to make the music easier to play with. However, she explained that she "was not satisfied that a little random variation would add 'life' to the music." Instead Scaletti created "performance subroutine" programs in FORTRAN to emphasize the beginnings and endings of each phrase. Scaletti designed the subroutines to parse strings of notes into short and long phrases, to designate tuplets, and pick out the highest pitch within each phrase.[129] Scaletti altered the results by hand by adding tone clusters and octave displacement in addition to other "small adjustments…to the durations and amplitudes to make the phrases more identifiable to the listener and the computer-generated part sound more 'expressive' and lively."[130] Scaletti's alteration of the score and application of "performance subroutines" suggests something about her musical values: she did not want the piece to be purely abstract or unnecessarily difficult to listen to. Rather than altering the mapping, Scaletti manipulated musical parameters like rhythm, dynamics, and harmony to further evoke the lysogenic virus.

Scaletti designed the computer-generated sound on the tape as an extension of the live harp and thought of it as "live signal processing."[131] Live signal processing was not possible with the tools available to Scaletti at the time. As a result, the piece

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[128] Scaletti explains that Mazurek told her: "that I was creating the electronics part in the wrong way! He said the electronics had to be less precise, less rhythmic, and more along the lines of what was then the current aesthetic in electronics (drones, very slow evolving, textures). He told me it was too hard for live performers to synchronize with fixed media so I should make the fixed media part amorphous so the synchronization did not matter so much." Scaletti, email to Heying, January 30, 2018.
[129] The performance subroutines did not model the lysogenic virus.
[130] Scaletti, "Lysogeny," program note, carlascaletti.com, accessed December 5, 2018.
[131] Scaletti, email to Heying, Jan 30, 2018.

is demanding for the performer, as it requires precise synchronization. Scaletti employed the same pitch collection for the harp and tape and altered both via the same algorithms.[132] Framing the computer generated sound and fixed-media as an extension of the live harp is indicative of a trend in Scaletti's compositions. She tends to explore synthesized sound and field-recorded sound or live sound as a continuum in which she emphasizes the similarities and distinctions between them. Or she employs synthesized sound to make sounds that would be impossible to make on an instrument, but have a similar timbral quality.

Scaletti also thought of the lysogenic process as a metaphor for distributed consciousness, or the way in which ideas pass from one person to another. She stated:

> A new idea attaches itself to your mental DNA, changing the way you think. Later, when you pass this idea along, it's been subtly changed — altered by your own experience and ideas. In this way, ideas spread through the population not just as isolated memes but carrying along bits and pieces of information, ideas, and experience from each mind they 'infect' along the way.[133]

Scaletti's connection possibly stems from a passage in Thomas's *Lives of a Cell* in which he argues that viruses should be considered "mobile genes" rather than agents of death and disease. Thomas relates this spreading of genes to the interactions of social insects like bees or people mingling at a party.[134]

Lysogeny represents one of Scaletti's early attempts to make natural processes audible and it is indicative of the compositional themes and approaches she continues

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[132] Scaletti was unable to locate the printouts of the computer programs she devised to create the computer synthesized sound and does not remember the compositional or synthesis techniques she used on the tape beyond the shared use of the lysogenic virus algorithms and the same pitch collection.
[133] Scaletti, "Lysogeny," program note, carlascaletti.com, accessed December 16, 2018.
[134] Thomas, *Lives of a Cell*, 12.

to employ. Although her work is based partly on the implementation of scientific models or phenomena, she often abandons literal application of a model to extend and demonstrate natural phenomenon in an evocative way. Patterns from nature or science simply serve as the basis for generating the basic musical material that she manipulates. *Lysogeny* is also emblematic of the relationship between live and synthesized sound Scaletti favors in her work—as a continuum.

***sunSurgeAutomata* (1986/1987)**

Scaletti composed *sunSurgeAutomata* using the Platypus Multiprocessor.[135] A fixed media piece, *sunSurgeAutomata* sonically explores a Cellular Automata (CA) algorithm. Scaletti's primary goal "was to create a computer-generated piece that was not based on a model of 'instruments' playing 'notes'; rather, the structure arises from the self-organizing patterns that emerge when the simple (local) cellular automata rules are applied to pulses or as a signal processing algorithm."[136] Composer Kristin Grace Erickson refers to this kind of approach to algorithmic music as "sonification;" (not to be confused with data sonification), meaning that the composer constructs an audible representation of an algorithmic process, in this case the result of running a CA.[137]

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[135] Scaletti and Hebel merged the Platypus hardware and Kyma software to create the Kyma system shortly after the composition of this piece.
[136] Scaletti, "sunSurgeAutomata," program note, carlascaletti.com, accessed November 25, 2018.
[137] Kristin Grace Erickson, "Performing Algorithms," in *The Oxford Handbook of Algorithmic Music*, edited by Alex McClean and Roger T. Dean (Oxford: Oxford University Press, 2018), 335.

CA are models of self-regulating, self-similar systems. A CA consists of cells with a value of 0 or 1, on or off. The value of each cell is determined—in discrete time steps (states)—by rules involving its nearest neighbor. Over time, after moving through many generations, self-similar and fractal patterns can emerge.[138] According to mathematician Stephen Wolfram, CAs challenge the second law of thermodynamics, demonstrating that rather than moving towards ever increasing entropy and disorder, "dissipative" systems, which interact with their environments can evolve to ordered, stable states. *sunSurgeAutomata* opens with shifting rhythmic clicks that translate the CA's make-up from state to state making the self-similar patterns audible. The clicks are digital, created by an audio signal that abruptly increases to 1 and then immediately decreases back to 0. These clicks are heard throughout the piece, providing the most accessible audible representation of the CA.

Although Scaletti employed Wolfram's Rule 90 to construct the CA for *sunSurgeAutomata*, in the program notes, she mentions John Conway's "Game of Life," (1970), likely the most famous CA. Conway's "Game of Life" models population growth and decay. It is made up of four rules, which determine whether or not a cell lives (becomes a 0 or a 1) based on the number of its neighbors that are alive or dead:

1. Any live cell with fewer than two live neighbors dies, as if by under population.
2. Any live cell with two or three live neighbors lives on to the next generation.
3. Any live cell with more than three live neighbors dies, as if by overpopulation.

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[138] Stephen Wolfram, "Statistical Mechanics of Cellular Automata," in *Cellular Automata and Complexity: Collected Papers* (Reading, MA: Addison-Wesley Publishing Company, 1994).

4. Any dead cell with exactly three live neighbors becomes a live cell, as if by reproduction.

"Game of Life" is an example of the potential for CAs as simple yet powerful models of complex behavior. As biologist Jamie A Davies explains: "Different starting conditions result in different behaviors of the system. Some initial patterns die out, some settle down quickly into stability, while others keep changing…"[139] CA illustrate the phenomena of emergence, where a simple process yields complex results.

Conway's "Game of Life" is a two-dimensional CA, whereas Wolfram's Rule 90 is a one-dimensional CA. Additionally, Conway's CA was designed to model a metaphor of population growth and decay, and Rule 90 is the enumeration of a rule set of all possible cellular automata rules. With Rule 90, a cell's value is determined by adding the values of its two neighboring cells from the previous time step. However, since the cell's value cannot exceed two, the rule uses modulo two arithmetic to wrap the value to be between 0 and 1. Rule 90 was ideal for Scaletti since she had to employ binary machine language to program the Platypus multiprocessor. When represented visually Rule 90 produces a pyramid-like fractal image called the Sierpiński triangle.[140]

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[139] Jamie A. Davies, *Mechanisms of Morphogenesis* (Boston: Elsevier Academic Press, 2013), 9.
[140] Described in 1915 by Waclaw Sierpinski. Eric W. Weisstein, "Rule 90." *MathWorld*—A Wolfram Web Resource. http://mathworld.wolfram.com/Rule90.html, accessed December 13, 2018.

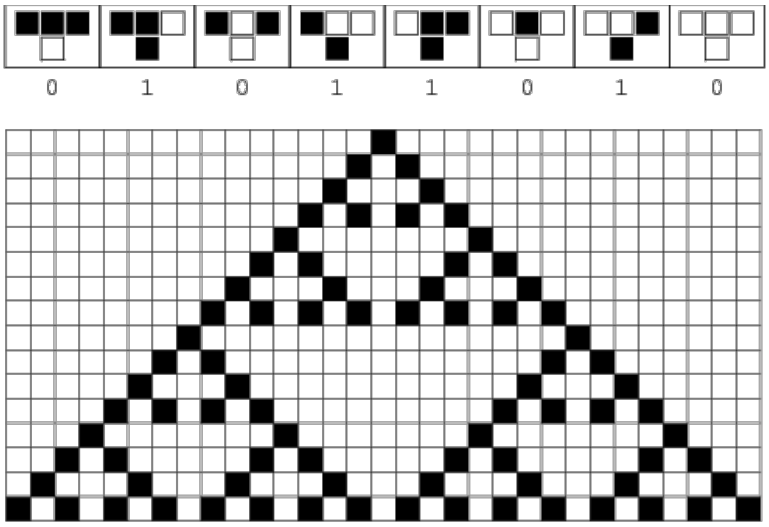

Figure 2.2: The Sierpiński triangle associated with Wolfram's Rule 90[141]

Scaletti applied the CA to three different sonic processes: to arranges clicks into self-similar rhythmic patterns; to gates on a recording of herself reading a quote from Thomas's *Lives of a Cell* about the relationship between musical creativity and the thermodynamic process; and a Karplus-Strong-type resonator. Scaletti wrote separate microcode programs for each of the processes. Each had to be loaded one at a time into Platypus. She then recorded output of the Platypus's DAC, and ran the output through an ADC and finally stored the piece on a SCSS disk, a sound conversion and storage system created by Hebel.

For Scaletti's first use of the CA, to arrange clicks, the audio moves through cells quickly. Cells considered "on," sound a click and sites that are "off" do not. This creates the self-similar rhythmic patterns. Similarly with the second process, a cell considered on will trigger a gate to open on the recording of Scaletti's voice. For the Karplus-Strong-type resonator, Scaletti applied CA rules to a stream of samples, "by taking an input stream of samples and forming each output sample as a function of

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[141] Ibid.

the previous and next samples in a buffer."[142] The Karplus-Strong resonator models plucked string instruments; it is most often associated with synthesized guitar tones. As part of her DMA thesis, Scaletti created her own plucked string synthesis algorithm to model harp tones that extends the Karplus-Strong and the work of David Jaffe and Julius Smith.[143] Her use of a Karplus-Strong-type resonator demonstrates her ongoing interest in harp-like timbres. In the piece the resonator creates long tones that would be impossible on an actual plucked string instrument.

In *sunSurgeAutomata*, Scaletti also sonically considers the idea that life emerged through a thermodynamic process, and that the creation of music simply mirrors this initial creative burst. Scaletti recites a quote from a chapter in *Lives of a Cell* called "Music of the Spheres," in which Thomas discusses bioacoustics and the tendency for animals and insects to make sound, or in his words "music." Musing about the origins of musical creativity, Thomas begins by postulating: "If the urge to make a kind of music is as much a characteristic of biology as our other fundamental functions, there ought to be an explanation for it. Having none at hand, I am free to make one up." His theory is that in making sound, humans, animals, and insects are recalling an "earliest memory," conflating the potential impetus of musical creativity with a thermodynamic theory of the origin of life on earth. In *sunSurgeAutomata*, the CA is applied to gates on a recording of Scaletti reciting from the following passage:

> …a transformation of inanimate, random matter in chaos to the improbably ordered dance of living forms. Morowitz has presented the case in

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[142] Scaletti, "sunSurgeAutomata," program note, carlascaletti.com, accessed November 25, 2018.
[143] David Jaffe and Julius Smith, "Extensions of the Karplus Strong Plucked-String Algorithm," *Computer Music Journal* 7:2 (Summer 1983): 56–69; Scaletti, personal notes, Champaign, IL, January 6, 2018.

> thermodynamic terms, for the hypothesis that a steady flow of energy from the inexhaustible source of the sun to the unfillable sink of outer space, by way of the earth, it mathematically destined to cause the organization of matter into an increasing ordered state…In such system, the outcome is a chancy kind of order, always on the verge of descending into chaos, held taut against probability by the unremitting, content surge of energy from the sun.[144]

Thomas's quote inspired the "sunSurge" in the work's title. Scaletti also represented the origin of life and creativity through the Karplus-strong type resonator. Scaletti employs an effect that sounds like a Shepard tone with a slowly and continually rising tone, which increasingly gets louder and finally bursts into a resonant full spectrum chord at the end of the piece.

According to composer and historian Elizabeth Hinkle-Turner, Scaletti's use of clicks in *sunSurgeAutomata* was inspired by the soundscape of the Sandia Mountains near Scaletti's hometown Albuquerque, New Mexico. In particular, Scaletti was struck by the "short clicks, chirps, or impulses" made by local birds, insects, and plants.[145] In an email, Scaletti explained that this experience inspired also "the idea that simple, localized rules being 'executed' by simple organisms can result in the complex patterns we observe all around us."[146] Scaletti commonly draws inspiration from her local environs as will be discussed with *Frog Pool Farm*, and *Cyclonic*.

sunSurgeAutomata was the first piece Scaletti created using the Platypus multiprocessor, which eventually became the first dedicated DSP hardware for the Kyma system. Scaletti believes that creating this piece led her to fully recognize the

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[144] Thomas, *Lives of a Cell*, 24–25.
[145] Elizabeth Hinkle-Turner, *Women Composers and Music Technology in the United States: Crossing the Line* (Burlington: Ashgate Publishing Company, 2006), 155.
[146] Scaletti, email to Heying, February 18, 2019.

need to create Kyma, because, she states: "With *sunSurgeAutomata* I finally had access to the virtually infinite flexibility of software synthesis and could hear the results in real time. Instead of using a specific machine, I could create any virtual machine."[147] The Platypus and an SCSS storage disk Scaletti employed also imposed constraints on the piece forcing her to limit the amount of material included.[148] *sunSurgeAutomata* is straightforward and effective. The evolution of the CA is clearly audible and Scaletti's use of signal processing and compositional techniques evoke the idea of life or creativity emerging out of a burst of solar energy.

***Frog Pool Farm* (2002)**

Frog Pool Farm is a piece for live Kyma system with quadraphonic or octophonic playback. *Frog Pool Farm* emerged out of a collection of field recordings Scaletti and Hebel made near Champaign, Illinois. The recordings are of what Scaletti referred to as a "frog orgy" that she and Hebel sought out in a farm turned office park south of Champaign. According to Scaletti, the frogs could be heard for miles almost every night during the summer. When Scaletti and Hebel initially heard the sound, they thought crickets, or some other insects made it. However, once on site, the ground swarmed with frogs in a manner that suggested an ancient plague. This gave Scaletti the impression the frogs were emerging out of the mud, trying to reach up to the moon, which served as the inspiration for much of the piece. She stated: "I just kind of identified with them…you know? These poor guys are just singing their

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[147] Scaletti, "Looking Back, Looking Forward," 15.
[148] Scaletti could only fit five minutes of audio on the SCSS disk Hebel created. Scaletti, "Looking Back, Looking Forward," 15.

hearts out trying to mate… they looked like they were crawling up out of the mud, trying to get to the moon, everyone that's alive is kind of like 'here I am' and striving for something."[149] Scaletti's statement demonstrates her ongoing fascination with morphogenesis, or how things emerge and take shape. The anthropomorphism with the frogs also indicates Scaletti's tendency to connect animal, plant, and insect behavior to human characteristics.

Frog Pool Farm is one of the first pieces Scaletti composed using the Kyma Timeline. As discussed in Chapter One, like a standard Digital Audio Workstation (DAW), the timeline consists of a horizontal grid, however instead of placing a media item such as a sample, one places Kyma Sounds in the grid. When a Sound is played, it triggers computation of an algorithm, playback of a sample, live DSP, or a generative process. The Timeline enables easy scheduling and seamless playback of Kyma Sounds. In *Frog Pool Farm* and future pieces, the Timeline facilitated the precise layering of sampled sound and live Kyma processing.

In *Frog Pool Farm*, Scaletti explicitly explores the relationship between recorded and synthesized sound. Throughout the piece she progressively introduces more and more synthesized sound. Scaletti has a particular approach to using field recording in her compositions. She explains:

> When I've used field recordings, it's been more of a jumping off point for transitioning into the surreal. I enjoy playing tricks by synthesizing sounds to sound as if they were field recordings, then changing the parameters to make it clear that they were synthetic all along. Or conversely, processing the recordings to sound as if they were synthetic. So it can be useful to have 'anchors' or 'pivot points' in the form of familiar sounds that then veer off into fantasy.[150]

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[149] Scaletti, interview with Heying, Urbana-Champaign, Illinois, January 7, 2018.
[150] Scaletti, email to Heying, February 4, 2017.

She also described her approach to using field recordings as "composing with" or "shaping" natural sound.[151]

With few exceptions, the musical material for *Frog Pool Farm*, even when significantly processed, utilizes or references Scaletti and Hebel's field recordings. They made a variety of recordings, some of the entire chorus of frogs, some of the frogs from a distance, a single frog "chirp" in close range, and smaller groups of frogs. Scaletti also made recordings of herself whistling, breathing, and saying, "I'm here."[152] These recordings are processed and used throughout *Frog Pool Farm*. Scaletti most frequently employed the single frog chirp, which appears throughout the piece in various altered and unaltered forms.

Frog Pool Farm begins with a "morph" between a human whistle and the frog's chirp, which is then transposed and layered. "Morph" is the Kyma term for a convolution-like technique that enables a seamless cross-fade between two audio signals.[153] The chirp-whistles are also processed through a Sound called FrogReverb, a pitched reverb that consists of harmonic resonators at each of the pitches Scaletti heard in the recording of the frog. Scaletti includes field recordings of the frog chorus and splashing sounds, which gives the impression of being present at the recording site in Champaign. Scaletti then layers the chirp-whistles, subtly altering them by synthetically lengthening or changing their envelopes and character over time so that the chirps start to sound uncanny.

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[151] Scaletti, interview with Heying, Champaign, Illinois, January 7, 2018.
[152] Scaletti, personal notes, Urbana-Champaign, Illinois, accessed January 6, 2018.
[153] In other words, the morph interpolates between the spectrums of two audio signals.

The morph and other alterations are based on spectral analysis. This chirp attracted Scaletti because the waveform looked like repeated impulse responses. Scaletti performed the morph using a Kyma Sound called SumofSines. The morph multiplies the results of spectral analyses on two signals, Scaletti describes it as a "crossfading" the amplitude envelopes and frequency envelopes of the two signals.[154] According to Scaletti, the morph between the chirp and human whistle symbolizes her identification with the frogs, their basic need of recognition, and way of proclaiming, "Here I am!" After the morphs are heard, the piece transitions to a quiet section with water droplets emulating rain and ambient noise. New sounds, both synthesized and altered frog recordings are also introduced.

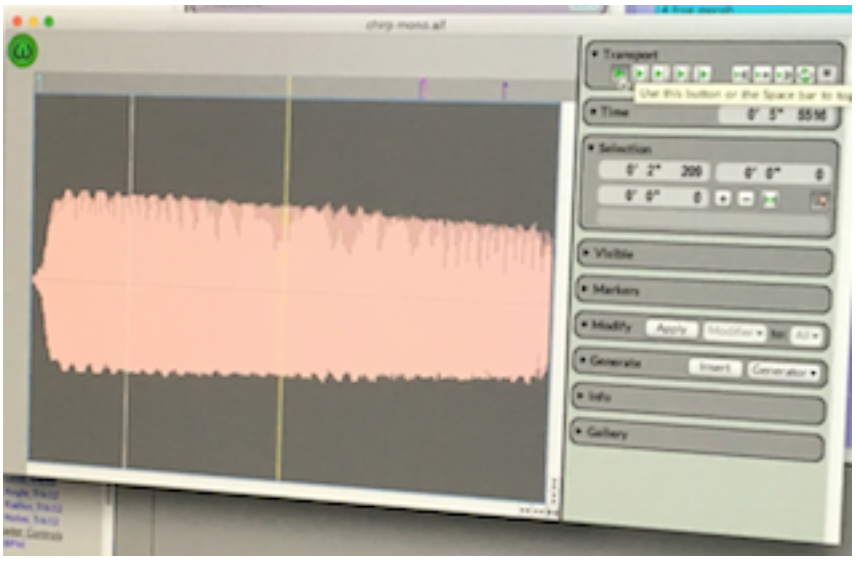

Figure 2.3: Screenshot of the frog chirp waveform (X is time and Y is amplitude)

[154] According to Scaletti, the Morph is "a spectral analysis of the whistling and spectral analysis of the frogs…if you cross-fade the amplitude envelopes with the frequency envelopes than you do kind of a morph because you control the same bank of oscillators." Scaletti, interview with Heying, Urbana-Champaign, Illinois, January 7, 2018.

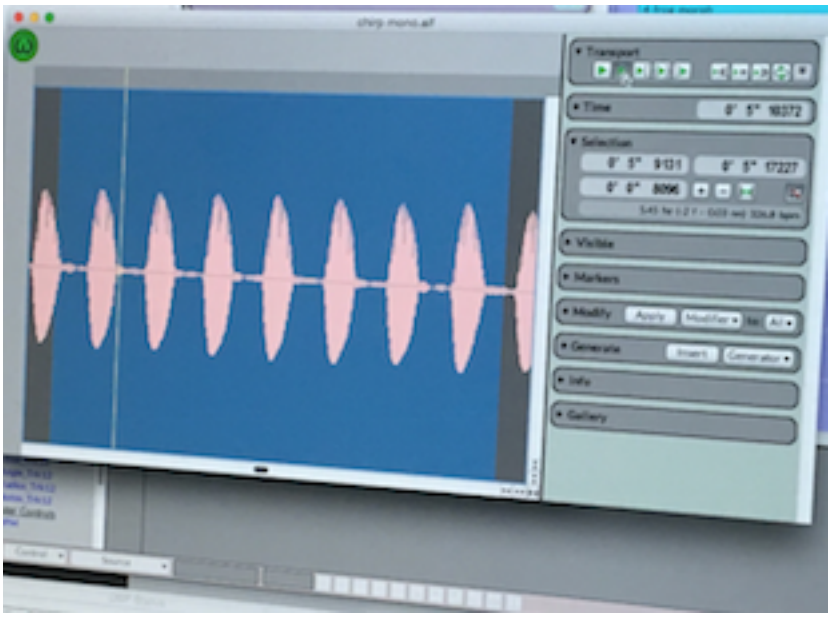

Figure 2.4: Screen Shot of the frog chirp zoomed in

Scaletti applied several other effects to the chirp throughout the piece. One is a Shepard tone-like effect that changes the rate in which the chirp repeats giving the impression that it also continually rises in pitch. Scaletti also used a panning technique with the Shepard chirp, which makes it sound like wind rushing around the room in cycles, providing an immersive quality. Additionally, Scaletti used a FrequencyScalar on the chirp, which allowed her to slow down or speed up the frog chirp sample without altering its frequency, creating a rhythmic clicking effect. As she explains, with the FrequencyScalar: "I'm lying to it by telling what the frequency is, normally you would do frequency tracking with it, but I'm lying to it so I'm really sure I'm just going to get individual impulses of the frog."[155] This allowed Scaletti to alter the rate of impulses, without changing the frequency, so she can slow down or speed up chirps while they retain their timbral character.

[155] Ibid.

Another inspiration for *Frog Pool Farm* was Scaletti's interest in the similarities between the frog sounds and granular synthesis.[156] For the Kyma Sound Splash, Scaletti used the pitches in the frog recordings to control another Kyma Sound called GrainCloud, which is a Kyma Sound that performs a type of granular synthesis.[157] As the title of the sound suggests, it produces water-like sounds. Throughout the piece, Scaletti created what she calls "self-similar" or "fractal" melodies made using both sampled and synthesized frog sounds. Scaletti applied a granular pitch shifter to the recording of the frog's chirp to create the basic material for the self-similar melodies. Scaletti explains:

> The pitch shifter identifies grains and then shifts the pitch by repeating the same impulse response, but stretched further apart, or crushed together and overlapping. In this case, I'm just telling it what the frequency is so that I'll get exactly one chirp, and then [I] can re-pitch the frog's chirp.[158]

Scaletti created the melodies by writing a block in Smalltalk that defines a function to which she supplies values for frequency and duration of notes as well as the number of recursions. The melody acts like a Koch curve, or in Scaletti's words a "fractal flake." As the number of iterations increases, more pitches are added, making the melody sound faster and faster.

In *Frog Pool Farm* Scaletti builds to a middle section that is made up almost entirely of synthesized sound. The Sounds' titles include SyntheticWarps, RanaAirSweeps, which suggest something about the loud, noisy, synthetic sounds Scaletti sends around the space using panning techniques.[159] One of the Sounds

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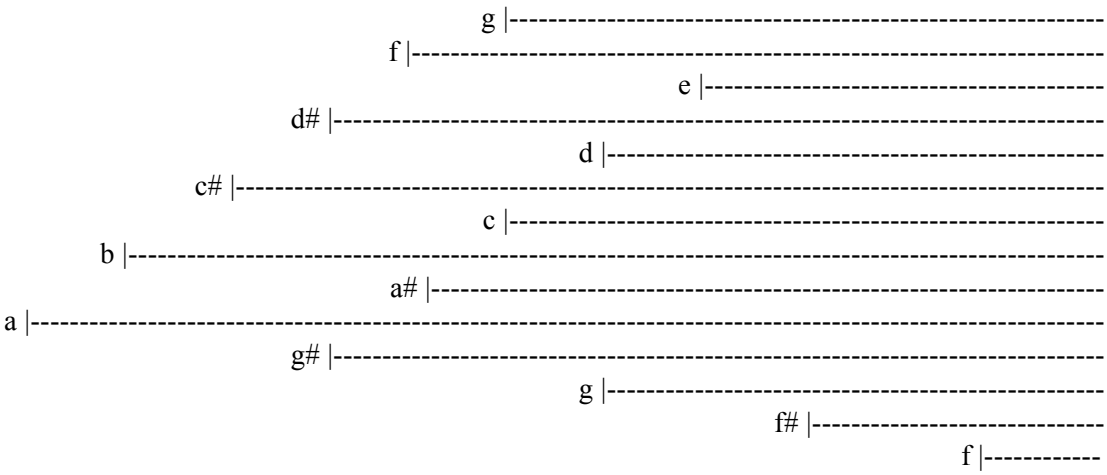
[156] Hinkle-Turner, *Women Composers and Music Technology*, 158.
[157] Scaletti, interview with Heying, Urbana-Champaign, IL, January 7, 2018.
[158] Ibid.
[159] Scaletti, personal notes, Urbana-Champaign, IL, accessed January 6, 2018.

present is called PigBank. For this Sound Scaletti analyzed the spectrum of a recording of a squealing pig, which is then used to control a CloudBank (another type of granular synthesis). This produces a stretched out, noisy whirling wind sound. Slowly, Scaletti introduces more recorded, recognizable sounds in with the synthesized sounds, transitioning to the next section distinguishable by the self-similar frog-chirp melodies.

After the middle section, and a section that heavily features the self-similar melodies, the piece becomes quiet, with low frequency ambient noise and the sounds of the frog chorus at a distance. Out of this low rumble, frequencies processed with a harmonic resonator begin to emerge one at a time. The pitches were identified from the frog chorus. The chart below shows the scheme in which she introduced new pitches[160]:



Ever interested in symmetry and cycles, *Frog Pool Farm* ends subtly after this section with a mirror image of the beginning in which the frog chirp is morphed back into the recording of the human whistle.

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[160] Based on a chart found in Scaletti's personal notes. Ibid.

***Conductus* (2014)**

Composed for Kyma System, organ, three singers in tap shoes, and reverberation, *Conductus* premiered in 2014 at the Jakobikirche in Lübeck, Germany during the 2014 Kyma International Sound Symposium.[161] Scaletti composed *Conductus* specifically to be performed in the Jakobkirche and the piece contains many layers of meaning and symbolism that make reference to St. Jakobi's history and exploits its acoustic properties. The singers circumnavigate the church and tap a pulse while singing an arrangement of "Congaudeant Catholici" from the *Codex Calixtinus* (12th century) accompanied by the organ.

Kyma produces sound by processing microphone input through a model of a gene transcription regulation network of an E. coli cell that is mapped to various sound parameters. The network models biochemical reactions, leading Scaletti to consider how the diffusion of chemicals in a cell resembles the diffusion of sound in a room, or the diffusion and evolution of a musical practice, such as singing *organum,* across space and time. In the program note for *Conductus*, Scaletti connects the seemingly disparate elements of the piece, and addresses the KISS theme, "organic sound":

> In organic life forms, it's rare for new growth to completely supplant what already exists; usually, growth occurs as new layers are added to older ones, similar to the way polyphonic music or 'organum' evolved as new layers and new intervals were added to the original monophonic chants. Reverberation functions in a similar manner, allowing you to add new layers as the older layers are still ringing in the air.[162]

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[161] Performed by Franz Danksagmüller, organ; Theresa Szorek, Birte Prüfert, Iga Osowska, voice; Scaletti, Kyma.
[162] Scaletti, "Conductus," program note, carlascaletti.com, accessed December 19, 2017.

Scaletti refers to the reverberation in St. Jakobi as the "fifth element" in *Conductus*, and even lists it as a performer. She described it as "ancient reverb," inspired by the idea that there may still be some sounds echoing in the walls of the church. As she explains:

> By exciting the reverberation in St Jakobi, the hope was that we might be able to hear, not just this piece, but faint echoes and traces of all the music and words that have ever been spoken or played here over the years. And that we could add our own new layer of computer-processed sound to join those echoes.[163]

Throughout the piece she gives the reverb "solos" in which the singers and organ abruptly stop, allowing reverb to ring. Scaletti's conception of ancient reverb touches on the idea of *transcendence*—the notion that one is a part of something on a grander scale than one person could achieve alone—that is present throughout her work. Although this theme was present in her work prior to reading Johnson, she explained in an interview that Johnson emphasizes the importance of experiencing transcendence for a human's sense of being.[164] For Johnson the attraction of science and art is the result of providing people with experiences of transcendence.

The vocalists sing an arrangement of "Congaudeant Catholici," a chant found in the *Codex Calixtinus*, a medieval tourist's guidebook for pilgrimages to Santiago de Compostela. Scaletti selected this chant because St. Jakobi was a stop along the St. Jakobsweg, or Way of St. James, the trail that led through Europe to Santiago de Compostela.[165] Along with polyphonic compositions, the *Codex* also included travel

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[163] Ibid.
[164] Scaletti in interview with Heying, Champaign, IL, January 6, 2018.
[165] Likely compiled in France around 1170, also called *Liber sancti Jacobi* or "Book of St. James." Richard Taruskin, *Oxford History of Western Music*, Volume 1 (New York: Oxford University Press, 2010), 162–168.

advice regarding roads, towns, peoples, and rivers along the way, as well as information about Santiago de Compostela, tales of saints and miracles experienced by pilgrims, liturgical texts, and sermons.[166] The particular chant employed by Scaletti, "Congaudeant Catholici" was one of the first pieces of three-part polyphony ever written down.[167] Conductus typically consisted of rhymed poems in Latin on a sacred topic, and were used for processionals during liturgical services.[168] Scaletti wanted to use a conductus due to its role as a processional to mirror the trek made by pilgrims from St. Jakobi. She explains: "So the music itself is a kind of echo or reverberation from medieval times and the processional is an echo of all the pilgrimages associated with St Jakobi."[169] As Scaletti's earlier statement indicates, she relates the emergence of organum and the development of polyphony to the evolution of biological life forms.

Scaletti had each of the singers wear a scallop shell during the performance. The scallop shell is associated with pilgrimages to Santiago de Compostela, and images, engravings, and references to scallop shells feature prominently throughout

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[166] Alison Stones and Jeanne Krochalis, *The Pilgrim's Guide: A Critical Edition*, Volume 1 (London: Harvey Miller Publishers, 1998), 52. More specifically, chapters included: "Roads," "Days' Journeys," "Names of Towns," "Three Hospices," "Names of Road Repairers," "Good and Bad Rivers," "Lands and Peoples," "Bodies of Saints," "City and Basilica of St. James," "Number of Canons," "Two Santiago Pilgrim Miracles," "Explicit," "Colophon," and "St. James Matamoro."

[167] Taruskin, *Oxford History of Western Music*, Volume 1, 162–168. The notation was a record of an oral transmission practice, and Taruskin highlights that the notation might not always accurate. The third voice in this chant was added later, probably by a different person. It was meant to harmonize the cantus firmus alone, rather then the existing two musical lines, leading to a great deal of dissonance when the three parts are sung together.

[168] The rhyme scheme, metrical, strophic setting is typical of a conductus. J. Peter Burkholder, Donald Jay Grout, and Claude V. Palisca, *Norton Anthology of Western Music*, 5th Edition (New York: W.W. Norton & Company, 2006), 96–97.

[169] Scaletti, "Conductus," program notes, http://carlascaletti.com/sounds/sound-art/conductus/, accessed December 19, 2017.

St. Jakobi. Scaletti saw the shell as a symbol of femininity, as a poem written in the margins of her notes suggests: "Scallop shells/feminine symbol, end of the earth/ exciting the resonances / echoes of all music, voices, instruments."[170]

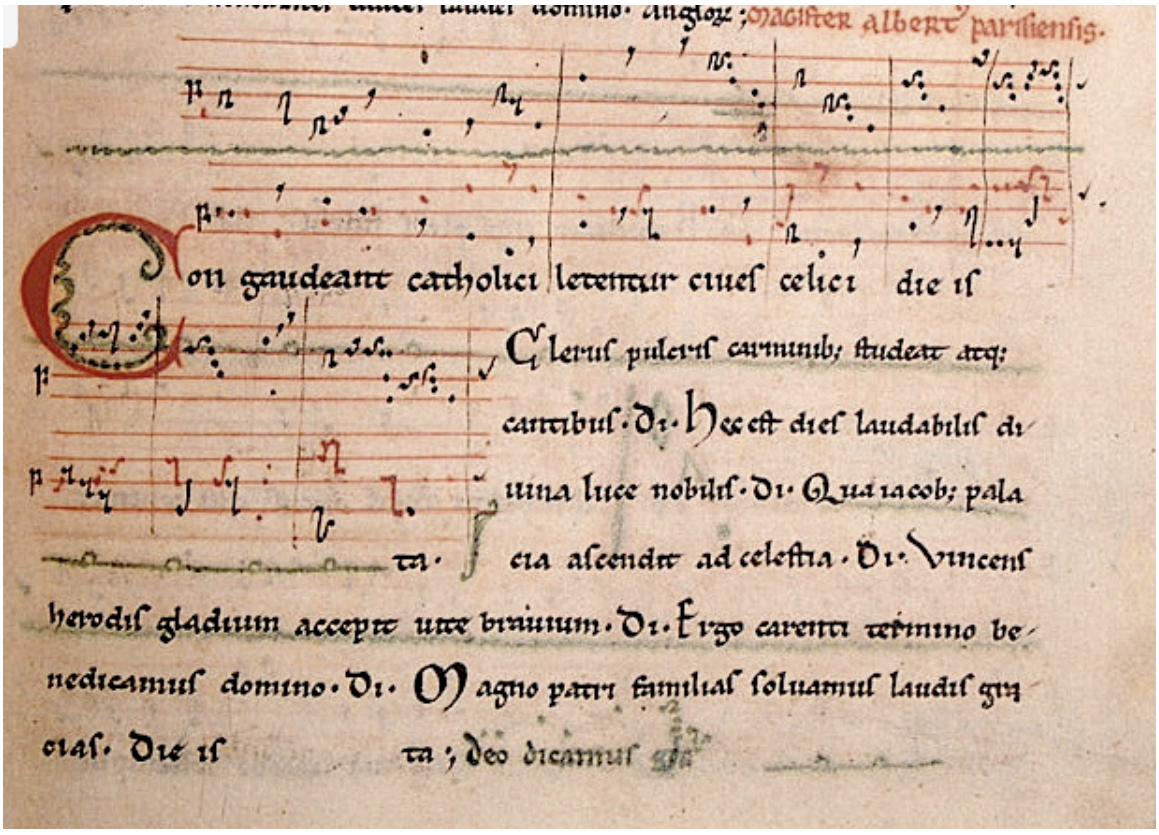

Figure 2.5: Congaudeant catholici in the Codex Calixtinus[171]

Scaletti did not use the chant verbatim. She changed the order of the lines of text, added text, and altered the music. *Congaudeant catholici* original text:

[170] Scaletti, personal notes, Champaign, Illinois, accessed January 5, 2018.
[171] Annie Stones and Jeanne Krochalis, *The Pilgrim's Guide to Santiago De Compostela: A Critical Edition*, Volume 1 (London: Harvey Miller Publishers, 1998), 52.

Congaudeant catholici,	Let the whole church rejoice,
Letentur cives celici die ista.	Let the heavenly host be glad this day.
Clerus pulcris carminibus	Let the clergy diligently sing
Studeat atque cantibus die ista.	Lovely tunes and songs this day.
Hec est dies laudabilis,	This is a praiseworthy day,
Divina luce nobilis die ista.	Made glorious by divine light this day.
Vincens Herodis gladium,	Overcoming the sword of Herod,
Accepit vite bravium die ista.	He received the crown of life this day.
Qua Iacobus palatial,	When James went up
Ascendit ad celestia die ista.	To the heavenly palace this day.
Ergo carenti termino	Therefore without ceasing
Benedicamus domino	Let us bless the Lord this day.
Magno patri gamilias	To the great Father of us all let us send forth
Solvamus laudis gratias die ista.	Let us send forth our thanks and praise this day.

Scaletti's *Conductus* text:

Qua Iacobus palatia,	When Jacob went up
Ascendit ad celestia die ista.	To the heavenly palace this day
Clerus pulcris carminibus	Let the clergy diligently sing
Studeat atque cantibus die ista.	Lovely tunes and songs this day.
Hec est dies laudabilis,	This is a praiseworthy day,
Divina luce nobilis die ista.	Made glorious by divine light this day.

Instead of using the original text in the last verse, Scaletti borrowed lines from Ovid's

Metamorphoses:

> Est via sublimis caelo manifesta sereno
> Lactea nomen habet, candore notablilis ipso.
> Caelo manifesta sereno lacte nomen habit
> Canodre notabilis ipso lacte nomen habit.[172]

Translation:

> There is a high track, seen when the sky is clear, called the
> Milky Way, and known for its brightness.[173]

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[172] Ovid, Metamorphosis, Book 1 lines 168–176.
[173] "Metamorphosis by Ovid" http://www.mythology.us/ovid_metamorphoses_book_1.htm, accessed December 19, 2018.

Scaletti selected this text because it references the Milky Way, which was also thought to help guide pilgrims along the St. Jakobsweg. Scaletti projected an image of the Milky Way onto the ceiling of St. Jakobi during the premiere of *Conductus*.[174]

Scaletti also added the following lines from the Apocryphal scripture the *Wisdom of Solomon* to "honor" the female singers:

> Clara est et quae numquam marcescat sapientia
> et facile videtur ab his qui diligent eam
> et invenietur ab his qui quaerunt ilam.

Translation:

> Wisdom is radiant and unfading,
> And she is easily discerned by those
> who love her,
> And is found by those who seek her.[175]

In this text, wisdom is personified as a woman. Furthermore, Scaletti was inspired by theories that the Holy Spirit may have been associated with the feminine divine wisdom, *hagia Sophia*, making the Trinity a family with a father, mother, and son.[176]

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[174] Scaletti, email to Heying, November 16, 2018. According to Scaletti's research, St. Jacobsweg may also have been a Roman Road, and to lead to *Finisterra* or the "end of the earth," a town on sea cliffs in Galicia, Spain.
[175] Wisdom 6:12 (The New Oxford Annotated Bible).
[176] Scaletti, email to Heying, November 16, 2018.

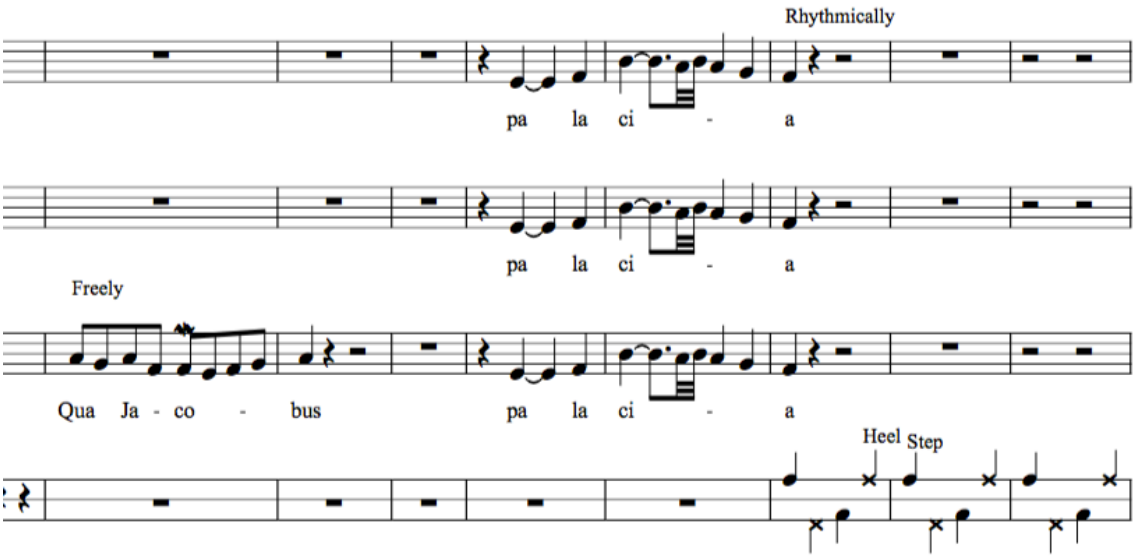

Figure 2.6: *Conductus*, MM 25–30, first vocal entrance

Musically, the piece begins with a close paraphrase of the original chant and progressively becomes more complex, straying further from the original with each verse.[177] The first verse mirrors the original's use of note-against-note discant, and Scaletti adopts the original's use of melismatic writing on the words "die ista" meaning "this day," which occurs at the end of each statement in the original chant. After an initial staggered entrance, the first verse is homorhythmic, and the organ provides sparse accompaniment of a drone, or joins in the chant melody in the bass register with the singers. In the second verse, the top singing voice is treated as a soloist with the two lower voices accompanying. The singer's step pattern is more rhythmically varied than the regular eighth-note pattern in the first verse. The organ part builds and now includes bass, treble, and pedal parts. It initially mirrors the

[177] The notation of the chant is open to interpretation. As previously noted, the chant as notated in the *Codex Calixtinus* served as a written record of an oral tradition, and as such some practices were assumed and not recorded. Although a translation of the notes to contemporary Western notation is straightforward, there is no clear translation of the rhythm, so Scaletti used simple 8th-note rhythmic patterns in the first iteration of the chant. As she varies the original notes, she also provides more rhythmic complexity.

bottom two voices, however by the middle of second verse the organ part gains more independence and plays full harmonies. Verse three begins with a brilliant polyphonic organ passage. There is also more independence among the vocal parts, which are now more rhythmically varied. The vocalists hold more long notes drawing attention to the organ. The fourth verse is the passage from Ovid. Scaletti highlights the shift in text by giving the music a wholly new character. It begins with long notes arranged homorhythmically, which gives the effect of changing meters. The parts suddenly break out into polyphony with staggered entrances. In the final verse, based on the passage from the Apocryphal book Wisdom, the top voice sings solo while the bottom two voices and organ sound longer notes providing harmonic accompaniment. *Conductus* ends with a duet in which the organist improvises on pitches sounded by Kyma. At the premiere, Dansagmüller improvised a triumphant, fanfare-esque ending.

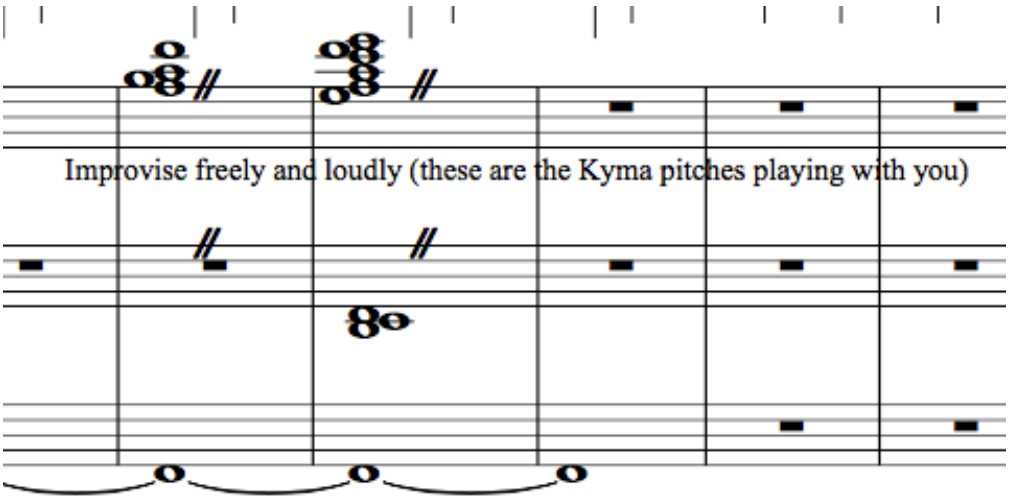

Figure 2.7: *Conductus*, MM 188–193, Finale organ improvisation with Kyma accompaniment

The singers circumnavigate St. Jakobi as they tap an 8th note pulse or other rhythmic patterns with tap-shoe clad feet. The audible steps are yet another reference

to the associations of St. Jakobi and the *Codex Calixtinus* with medieval religious pilgrimages. In Scaletti's notes, she wrote: "Carrying the text to where it would be read, call/response pg. 1 walk pg. 2"[178] The idea of "carrying the text to where it would be read" connects the role of the conductus in medieval church services with a the journey of a pilgrim. Scaletti's notes regarding the singer's steps include diagrams and written out step patterns, which indicate that refining the rhythm and tempo of the singer's steps was not a trivial decision.[179] Scaletti originally alternated between sections of singing or stepping, and employed different rhythmic patterns in different sections, however she eventually made the steps more continuous and steady at the request of Dangsagmüller, the organist, because it helped him keep track of the beat when he could no longer hear the singers.[180]

In Kyma, Scaletti mapped frequency to the genetic information of E.Coli gene transcription regulation networks. She learned about the networks from the work of physicist Uri Alon, who, inspired by a biology class he took, noticed the modularity of gene transcription networks and modeled them as analog circuits. In his book, *An Introduction to Systems Biology: Design Principles of Biological Circuits*, Alon analyzes transcription networks. In such networks a cell receive signals that indicate which chemical elements are in an environment, these signals are translated into transcription factors which access a specific gene to make a protein in response to new elements. These gene transcription regulation networks evolve quickly, and according to Alon, they can *tune* to their environment. He explains: "Laboratory

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[178] Scaletti, personal notes, Champaign, IL, accessed January 5, 2018.
[179] "Step-shuffle, speed (full 8th, then quarter?), change verse by verse? (triple or no steps?)," ibid.
[180] Scaletti, email to Heying, November 16, 2018.

evolution experiments show that when placed in a new environment, bacteria can accurately tune to these [new conditions] within several hundred generations to reach optimal expression levels."[181] When some chemicals are produced, others are suppressed, indicating that the value of each chemical is less important than the rate in which the chemicals change. In part because of this characteristic, Alon explains that the transcription networks are dynamical systems:

> After an input signal arrives, transcription factor activities change, leading to changes in the production rate of proteins. Some of the proteins are transcription factors that activate additional genes, and so on. The rest of the proteins are not transcription factors, but rather carry out the diverse functions of the living cells, such as building structures and catalyzing reactions.[182]

Scaletti's fascination in the E.Coli gene transcription networks likely stemmed from these indirect relationships.

Scaletti modeled the gene transcription networks in Kyma associating pitches present in the written score with different chemicals that influence the network. Scaletti's model is a feedback network that takes in live input and responds in real-time with live output. A Kyma Sound reads in a script with network information from Alon's *An Introduction to Systems Biology*, and Kyma algorithmically generates "circuits" from that information. In the virtual circuits, amplitude followers on live input from microphones placed around St. Jakobi track and respond to certain frequencies present in the written music. Each of these frequencies represents different chemicals in the network, which correspond to sound generators that reproduce the same frequency back into the room, mimicking the complex positive

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[181] Uri Alon, *An Introduction to Systems Biology: Design Principles of Biological Circuits* (London: Chapman & Hall/CRC, 2007), 15.
[182] Alon, *Introduction to Systems Biology*, 8–9.

and negative feedback of the gene transcription networks. Scaletti explains: "So Kyma played tones at those frequencies into the church, which in combination with the organ and modes excited by the tap shoes of the singers, changed the levels of the spectrum of the reverberation in the church, which in turn acted as fresh input to the audio circuits."[183] Scaletti used a lossy integrator, which sets the production time (start time) and decay time of each frequency to account for the rates of change of the frequencies representing the chemicals present. Although Scaletti designed her program so that she could change aspects of the system in real time, it runs automatically, and evolves and tunes to the space and sounds present on its own.

The various elements in *Conductus* result in the subtle interplay between the live performers, the acoustics of St. Jakobi, and Kyma's processed output. The Kyma processing is extremely delicate, capturing and extending the beauty of the singer's voices and organ in the space. It is often difficult to tell if any synthesized sound is being made at all since it seems to reinforce the live performers.

II. Models of Physical Systems and Phenomena

Scaletti is interested in modeling chaotic and dynamical systems. Scaletti belonged to a generation in which the study of chaos and dynamical systems flourished and seeped into popular culture. Earlier work by scientists like Lorenz and Mandelbrot was built upon or elucidated by popular authors such as James Gleick with *Chaos: Making a New Science* (1987) and physicist Steven Strogatz with *Nonlinear Dynamics and Chaos* (1994). Scaletti's interest in dynamical systems

[183] Scaletti, email to Heying November 16, 2018.

began during her time at UIUC. The mathematics of chaos and dynamical systems provided Scaletti with a tool to model complex systems with emergent behavior and seemingly disordered systems with deep underlying structure. This fits with her larger goal to make universal patterns audible.

According to Strogatz, a chaotic system is one "in which a deterministic system exhibits aperiodic behavior that depends sensitively on the initial conditions, thereby rendering long-term prediction impossible."[184] Or put more poetically by musicologist Kenneth McLeod: "Chaos…subsumes both order and randomness. It is a state in which the outcomes appear to be random at a local or microscopic level of detail, but also simultaneously ordered at a macroscopic level."[185] Weather is one of the most recognizable examples of a chaotic system. Chaotic systems are a class of dynamical systems. A dynamical system is a system that evolves over time. Since sound is time-based, it lends itself to exploring how dynamical and chaotic systems evolve, and to observe emergent behavior such as reaching states of stability.

The following pieces each explore chaotic or dynamical systems. Scaletti evokes a chaotic weather system in *Cyclonic* through the creation of an immersive soundscape. In *Double-well* and *Autocatalysis*, Scaletti models dynamical systems. Both works are also "audience participation" pieces that rely on input from the audience to control aspects of her models.

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[184] Steven Strogatz, *Nonlinear Dynamics and Choas*, Second Edition (Bolder: Westview Press, 2015), 3.
[185] Kenneth McLeod, "Interpreting Chaos: The Paradigm of Chaotics and New Critical Theory," *College Music Symposium* 45 (2005), 43.

***Cyclonic* (2008)**

Cyclonic is a piece for live synthesis by the Kyma system. It was commissioned for and premiered at the 50th Anniversary of the Experimental Music Studio at the University of Illinois, Urbana-Champaign. In *Cyclonic*, Scaletti sonically examines cyclic patterns present in weather, in this case, extreme weather such as tornadoes and severe storms. Scaletti modeled the mechanisms of natural processes as well as the mechanisms of communication technology, which are combined with field recordings to create an immersive sonic environment. *Cyclonic* is deeply rooted in human experience and perception: Scaletti not only emulates a storm, but how someone in Champaign, Illinois might experience such a storm. Additionally, Scaletti relates the cyclic patterns present in storms to cycle patterns in human cognition.

In *Cyclonic,* Scaletti emulates a storm by creating a soundscape of field recordings and synthesized sounds. The synthesized sounds are seen as imitations and extensions of the field recordings of rain, thunder, and wind made by Scaletti in downtown Champaign.[186] Like *Frog Pool Farm* or *Conductus*, *Cyclonic* is emblematic of Scaletti's approach to using recorded and synthesized sound as extensions of each other with many possibilities for creating auditory tricks or illusions. The piece uses quadraphonic speaker playback to surround listeners and move sound in space, which provides an immersive quality that is crucial to experiencing Scaletti's sonic storm.

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[186] Scaletti, "*Cyclonic*," program note, carlascaletti.com, accessed December 3, 2017.

Scaletti's use of cycle metaphors was particularly influenced by Johnson's work on embodied meaning and image schemas, or patterns in behavior that shape human cognition. Johnson shaped Scaletti's belief that "the way we experience music is very closely related to the way we experience thought. We experience it directly, without translation into and out of symbols."[187] Several of the cycle metaphors employed by Scaletti extend the idea of a Shepard tone—the auditory illusion of endlessly rising pitch—to other musical parameters. In Kyma, Scaletti created a Shepard pan, a model of a Shepard tone that is mapped to panning, where "the rate of panning speeds up and when it reaches double the speed, a slower pan starts up in parallel and so on..."[188] This gives the impression of an endlessly accelerating pan around the space. Scaletti also created ShepardWind, which uses a bank of band pass filters and Doppler effects to emulate cycles of wind.

In *Cyclonic*, Scaletti explores the conflation of music and thought by representing events as recorded, lived, remembered, or imagined. This conflation mirrors how sound, thought, and memory often work: when one hears a tornado siren, it might simultaneously trigger memories of a past storm, fear for future destruction, and the mixed emotions and environmental circumstances of one's embodied present. In *Cyclonic,* the music unfolds as an accumulation of cycles and patterns that shift in and out of focus only to reemerge slightly altered. This is achieved by subjecting each cycle metaphor to a series of transformations: Scaletti applied a different filter or shifted the pitch each time a siren or Shepard effect is heard. Additionally, Scaletti

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[187] Scaletti, "Sonification ≠ Music." In *Oxford Handbook of Algorithmic Music*, edited by Roger T. Dean (Oxford, Oxford University Press, 2018), 375.
[188] Ibid.

intentionally blurs the distinction between recorded and synthesized weather sounds, emulating the often-hazy workings of memory or imagination.

The form of *Cyclonic* is also a cycle. It begins and ends with a recreation of the National Weather Service alert, as it would be heard on the National Oceanic and Atmospheric Administration (NOAA) Weather radio station. This signal encodes information about an incoming storm; it contains two frequencies: 1562.5 Hz and 2083.3 hz, the message is repeated three time and then followed by a third tone at 1050 hz. *All* of the pitch material in *Cyclonic* is derived from these three frequencies. Scaletti encoded this alert signal in Kyma, which is synthesized live in performance. Throughout the piece computer-generated voices—processed through radio simulation—provide updates about the status of the storm; what they are saying is often indiscernible, but the rhythm and impression of a news update is unmistakable.

In addition to modeling the National Weather Service alert, Scaletti also modeled a manual tornado siren in which air passes through a spinning perforated disc. The siren contains two frequencies in a 5/6 ratio, which Scaletti referred to as a "mournful sounding minor third."[189] She used a formant setting in Kyma and two triangle waves to make a duty cycle, creating the effect of the flat surface between the holes on the disc. Scaletti used the impulse response of downtown Champaign, and the CrossFilter (Kyma's version of circular convolution) to make the Tornado siren sound as if it were going off in Champaign. Recreating the siren (rather than simply recording one) gave Scaletti great control over the frequency and other parameters of the siren allowing her to create more Shepard effects with it and use it in ways not

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[189] Scaletti, "Dissecting Cyclonic," lecture presented at *Future Music Oregon*, University of Oregon, Eugene, Oregon, 2008.

physically possible with an actual siren. Scaletti is as interested in these alert signals as she is in the storm: by beginning and ending with the Weather Service alert, and including references to sirens, Scaletti frames weather phenomenon as experienced through the mechanisms of human communication and perception.

Since *Cyclonic* was commissioned for the 50th Anniversary of the Experimental Music Studio at the University of Illinois, Urbana-Champaign, it was important to Scaletti that it "be about" Champaign—her home for the last three decades.[190] Musicologists Denise Von Glahn and Sabine Feisst have examined how musical evocations of place are linked to a composer or listener's sense of place, which can be deeply connected to individual and collective identity, experience, and memory.[191] In *Cyclonic*, Scaletti makes several explicit references to Champaign, first in the opening storm-warning announcement. In another section, the names of nearby counties are used as source material that is process and filtered. Scaletti also uses field recordings taken during storms around Champaign. Lastly, she filtered the tornado siren with the impulse response of a thunderclap in downtown Champaign to simulate how such a siren would sound in that space. Each of these techniques provides *Cyclonic* with a sense of place, rooting the piece in the collective identity and memory of Scaletti's local community.

Scaletti's *Cyclonic* bears many connections to John Cage's *Lecture on the Weather* (1975). Both are immersive multi-channel evocations of storms; however,

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[190] Scaletti claimed that the first image that came to her mind was of a powerful tornado violently ripping apart the UIUC School of Music, leaving behind nothing but rubble.
[191] Denise Von Glahn, *The Sounds of Place: Music and the American Cultural Landscape* (Boston: Northeastern University Press, 2003); Sabine Feisst, "The American Southwest as Muse: Maggi Payne's Sonic Desertscapes," *Contemporary Music Review* 35:3 (2016): 318–335.

each piece offers different kinds of embodied experience: *Cyclonic* is more presentational where Cage's *Lecture*, with Maryanne Amacher's recordings of storms, is mimetic. Like Scaletti, Cage includes human voices, but as part of the chaotic texture of the storm; he was preoccupied with how meaning could arise out of the abundance of this kind of sonic environment. Composer-scholar Christopher Shultis sheds light on Cage's intent: "If there was an order in the universe, if there were patterns behind the chaos, Cage's focus was away from pattern, away from the large view, and toward the chaotic particularity of experiences and of things experienced 'as they are,' in other words, as we directly experience them rather than how we mediate between experience and our conceptual shaping of it."[192] In Scaletti's quest for understanding weather and cycle patterns in *Cyclonic*, she explores both how people directly experience storms *and* how they are mediated by our perception: she wants to explore how thought and experience are embodied.

Presenting things experienced "as they are" allowed Cage to appear neutral. Borrowing Donna Haraway's term, musicologist Ben Piekut labels Cage "sound's modest witness," because of this claim to objectivity or neutrality. Piekut explains that modesty in this sense is a virtue that is associated with modern masculinity and it bestows on its subject the air of authenticity and authority. According to Haraway:

> [Modesty] guarantees that the modest witness is the legitimate and authorized ventriloquist for the object world, adding nothing from his mere opinions, from his biasing embodiment. And so he is endowed with the remarkable power to establish the facts. He bears witness: he is objective; he guarantees the clarity and purity of objects. His subjectivity is his objectivity.[193]

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[192] Christopher Shultis, "Cage and Chaos," *American Studies* 45:1 (2000): 93.
[193] Donna Haraway cited in Piekut, "Sound's Modest Witness: Notes on Cage and Modernism," *Contemporary Music Review* 31:1 (2012): 15.

Piekut and others have pointed out the contradictions in Cage's removal of his intentions from the act of composition. Cage's work established a dominant experimental aesthetic, one that is largely removed from the body and the voice of the composer. As electronic music scholar Tara Rodgers highlights in the introduction to *Pink Noises*, the negation of identity that results from the Cagean "removal" of a composer's intentions from the compositional process "may not be a universally desirable aesthetic for artists of historically marginalized groups who have suffered the effects of imposed forms of silencing and erasure."[194] Scaletti makes no pretense about being neutral—her compositional intentions are central as she sonically guides the listener through her understanding of embodied thought and experience. This lack of neutrality in no way diminishes Scaletti's precise and careful modeling of physical or biological systems, or what these sonic models can communicate to an audience. Rather, it demonstrates a transparency about her role in shaping how these phenomena are presented to the audience.

***Autocatalysis* (2010)**

Autocatalysis is a piece for audience participation and Kyma system. It premiered at the 2010 Kyma International Sound Symposium in Vienna, and is dedicated to Scaletti's father. The piece consists of "auditory autocatalytic reactions." An autocatalytic chemical reaction is one in which the product of the reaction is also the catalyst for the reaction. Scaletti's interest in autocatalytic reactions stems from their nonlinearity and the tendency for a kind of order or equilibrium—such as

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[194] Tara Rodgers, *Pink Noises: Women on Electronic Music and Sound* (Durham: Duke University Press), 10.

patterns in spatial or temporal arrangements—to spontaneously emerge out of a seemingly disordered state.[195] Intrigued by the possibility of modeling chemical diffusion as sound, Scaletti created auditory autocatalytic reactions by building a Brusselator model in Kyma. A Brusselator model is a hypothetical model of an autocatalytic reaction; it is also a chemical oscillator.[196] There are four steps to the Brusselator reaction and six molecules: A, B, C, D, X, and Y. A and B are reactants. C and D are products. And X and Y are intermediates. This equation represents the reaction:

$$A \rightarrow X$$
$$B + X \rightarrow C + Y$$
$$2X + Y \rightarrow 3X$$
$$X \rightarrow D$$

In Scaletti's Brusselator model, the products of the reaction (C and D) are sonically represented as audio feedback, more specifically dynamically-damped audio feedback, with decay models that indicate the "using up" of reactants. The audience controls the levels of the chemicals A and B by sounding plastic clickers, which then corresponds to the level of feedback heard. Scaletti designed the model to produce sonic spatial patterns, and loud, dense feedback predominates.

Scaletti's *Autocatalysis* consists of two Brusselator models. The density of the audience's clicks increases or decreases the levels of A and B reactants in the models. Scaletti explains: "The amounts of the different chemicals are used to control

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[195] Scaletti, "Autocatalysis," http://carlascaletti.com/sounds/sound-art/autocatalysis/, accessed December 3, 2017.

[196] It was first proposed by Ilya Prigogine and René Lefever in 1968. They worked for the University of Brussels, hence the name "Brusselator." Phillip Ball, *Self-Made Tapestry: Pattern Formation in Nature* (Oxford: Oxford University Press, 1999), 183; Steven Strogatz, *Nonlinear Dynamics and Chaos* (Cambridge, MA: Perseus Books Publishing, 1994), 290.

different parameters of the sounds and the filters in the feedback path."[197] Scaletti employs SoundToGlobalController Sounds to detect changes in the levels of X or Y and use these changes as triggers. The audience indirectly influences the system with their clicks, triggering a series of changes in other sonic parameters.

Autocatalytic reactions are self-oscillating. The catalyst speeds up the reaction, which uses up the catalyst, inhibiting the continuation of the reaction and causing it to oscillate. The oscillations in the reaction produce the patterns in space over time. In creating the sounds for *Autocatalysis*, Scaletti found inspiration in other natural oscillators, or what she calls "oscillators of life." She explains:

> You can also hear sounds reminiscent of breathing and heartbeats controlled by the Brusselator. Not sure whether you can tell from the video but it is quite disturbing to hear it in person. Part of the piece is a reflection on complex systems, life, death, and how the 'oscillators of life' like breathing and heart rate show features of chaos as a system approaches death.[198]

Scaletti wrote *Autocatalysis* the year her father died and the piece is dedicated to him. It is likely that this conflation of human life cycles with the life cycles of a chemical reaction served as a reflection on her father's passing. The Brussselator models are used to control these natural oscillators, one controls the breath, and the other controls the heartbeat.

Using audience input required precise testing of audio equipment and the room prior to performance. The microphones are placed in a triangle with two in the front and one in the back of the room. Prior to performance, Scaletti tests microphone inputs and Kyma output, and enters the number of feet between three microphones

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[197] Scaletti, "Dissecting *Autocatalysis,*" notes for a presentation given at KISS2010, Vienna Austria, September 26, 2010.
[198] Scaletti, email to Heying, December 13, 2017.

into Kyma. Scaletti also analyzed the clicker sound, which tends to fall around 7350 Hz, and last 93 ms with a 10 ms attack.[199] A high pass filter is used to detect the clicks and weed-out unwanted sound, and Kyma is only triggered when all three microphones receive the click signal.

The first click made by an audience member is crucial for the piece because it triggers the start of the reactions and other compositional processes. Therefore, Scaletti placed a Kyma Sound called WaitUntil at the beginning of her Kyma Timeline so that the piece automatically starts after the first click is detected. Once triggered, Scaletti explains: "The first click is reflected in an acoustic mirror, played back slowed down and reversed from all speakers."[200] The clicks then cycle through the speakers: "A click played into the first microphone is played back by the second speaker in reverse, then reversed again in speaker 4, and so on around the room until it is picked up by Microphone 1 again."[201] This process mimics the self-oscillating character of autocatalytic reactions.

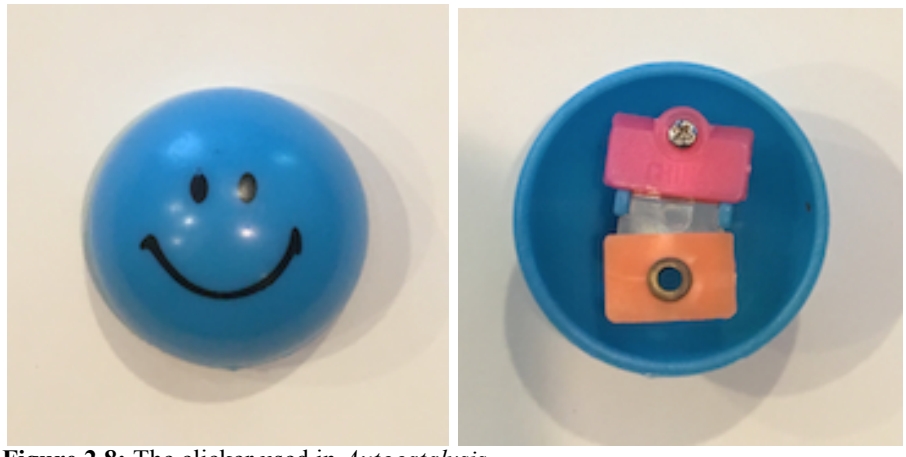

Figure 2.8: The clicker used in *Autocatalysis*

[199] Scaletti, personal notes, Champaign, IL, accessed January 6, 2018.
[200] Scaletti, "Dissecting Autocatalysis."
[201] Ibid.

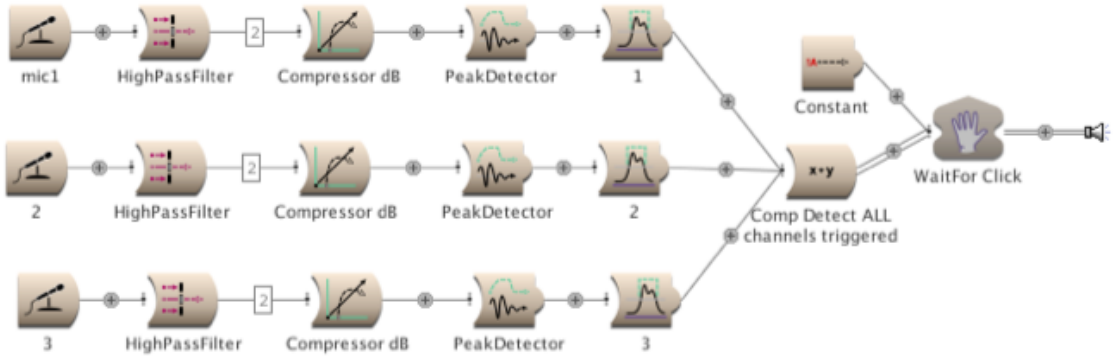

Figure 2.9: Kyma Sound WaitUntil, waiting for the first click[202]

Scaletti created a Virtual Control Surface (VCS) (Figure 2.10) in Kyma that is projected on stage so the audience could see their impact on the reactions in the Brusselator models. In addition to showing the output of the model, the VCS also shows the other parameters controlled by the audience's clicks. Most prominent are the sliders showing the concentration of the A and B reactants, and a graph illustrating diffusion. The chemicals can leak into each other, which is demonstrated through this diffusion graph.[203]

[202] Ibid.
[203] Ibid.

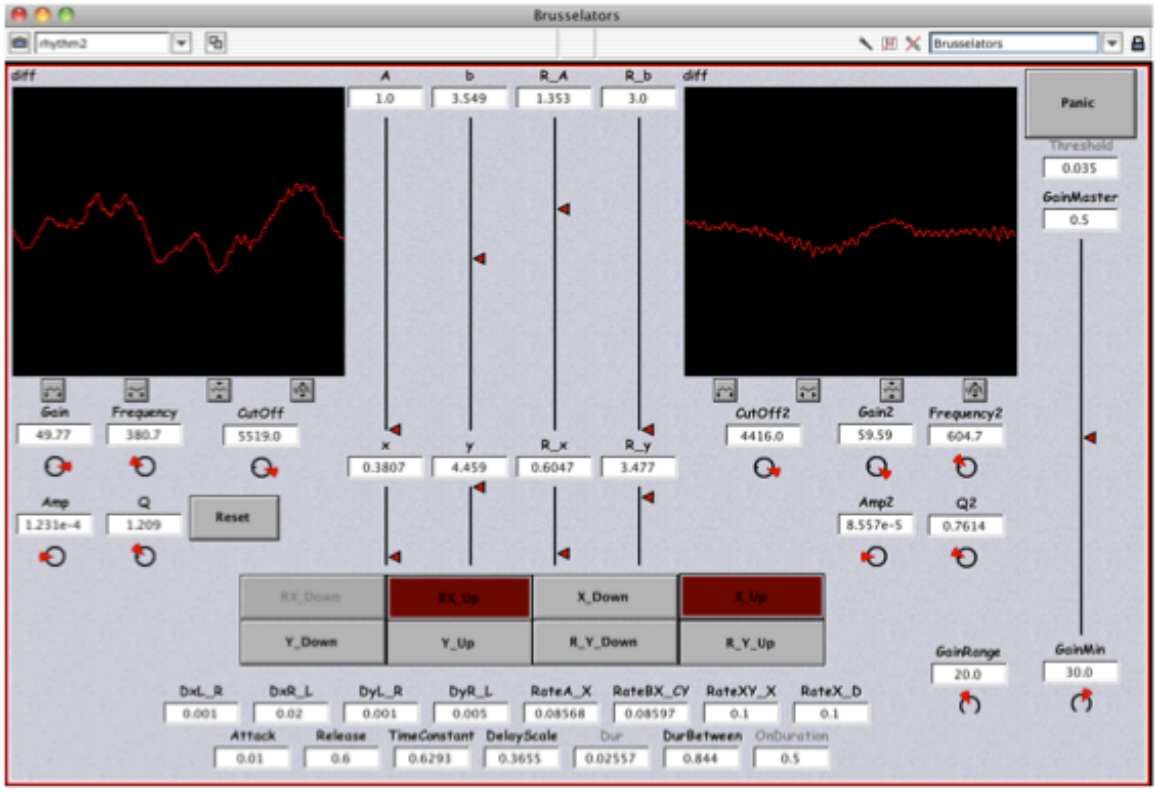

Figure 2.10: The Virtual Control Surface (VCS) projected for the audience. Show diagrams for both Brusselator reaction models.[204]

Scaletti added other effects to the clicks. For instance, when Kyma detects a click it is sent trough a delay line that is either shortened or lengthened and the output is sent around the space creating a Doppler shift effect, "compressing or stretching out the waveform as it flies by."[205] This also creates something of a steady pulse. The click position is also used as a trigger; the position is triangulated by measuring the difference in the time it takes to reach each of the three microphones. The position in the room is then used to determine which sample from a bank will be triggered. In one section, sound from the audience is written into Kyma's memory, copies of the sample sound are then played back at different rates. Before being sent to the speakers, these samples go through high and low pass filters, and finally an all pass

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[204] Ibid.
[205] Ibid.

filter with frequency sweeps to interfere with the feedback to keep it under control. Scaletti included several other "safety mechanisms" to constrain the levels of feedback such as filters, peak detectors, and Kyma Sounds to carefully control the amplitude on the signals as they are played back.

Figure 2.11: Kyma Sound to detect click position[206]

Another safety mechanism is a Kyma Sound called AdaptiveFIR, a filter that changes to match the waveform of an incoming signal. However, instead of building a filter to match the input, Scaletti outputs the difference between the input and sustained frequencies present in the room, effectively cancelling out the sustained frequencies and keeping the room's feedback in check. The amplitude of the input signal controls the AdaptiveFIR, so the audience influences this process through how loud they click. The last section contains heavy rhythmic pulses that Scaletti produced by processing the sound of the room through a CrossFilter, which uses a convolution technique to filter the sound with a pulse train.[207]

In the program notes and lectures about *Autocatalysis*, Scaletti metaphorically connects an autocatalytic reaction to the blending of ideas and creativity. Scaletti

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[206] Ibid.
[207] Ibid.

stated: "Sometimes when you collaborate with other people, the result can become a catalyst for even more creative activity."[208] *Autocatalysis* is one example of works throughout Scaletti's career including *Lysogeny*, *Double-well*, and *Frog Pool Farm* that share the theme of comparing a biological or chemical process to the ways in which humans connect with each other and share ideas.

Scaletti's desire to make *Autocatalysis* a participatory piece was partially motivated by an experience she had at a concert for acousmatic music at a club in Athens, Greece. As the music played through speakers, rather than listen quietly as they might do in a concert hall, the audience began chatting and socializing with one another. Disappointed by this experience, Scaletti declared: "I decided I wanted to try to make a kind of music that people couldn't ignore, that wouldn't fade into the background, because the music depended entirely on *them*—because they were part *of* the music."[209] Beyond the desire for the music in a space to be an audience's primary point of attention, Scaletti wanted to provide an audience with a meaningful musical experience, where the audience "cooperatively controlled" the outcome of the piece, also demonstrating emergence.[210] Scaletti's hope is for the audience to be actively listening and engaged.

With a few exceptions, Scaletti's compositions include some live performance element, highlighting the body's importance to the work. Although Scaletti created two pieces with audience participation earlier in her career—*X* bar (1986), *Public Organ* (1995)—*Autocatalysis* was the first in a series of later audience participation

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[208] Ibid.
[209] Scaletti, email to Heying, December 13, 2017.
[210] Ibid.

pieces. After this attempt, Scaletti admitted that the systems is so complex it is difficult for the audience to hear the cause and effect of their actions, and in later pieces she honed involving the audience. For example, the audience input in *Autocatalysis*—of clicking or not when instructed—is more passive than *Double-well*, which encourages more "active listening" by having participants respond to other audience members.

***Double-well* (2016)**

Double-well, written for Kyma system, is an audience interactive piece. It premiered at the Fiftieth Anniversary of the E.A.T (Experiments in Art and Technology) concerts at Stony Brook University in 2016.[211] Like *Quantum*, Scaletti's *Double-well* was inspired by the behavior of the Higgs Boson particle. She states:

> This piece was inspired by the story of how, when the universe was young, the Higgs lived in a double-well potential and there was symmetry between the weak and electro-magnetic forces. But, as the universe cooled down, the Higgs settled into just one of the wells and broke that symmetry, resulting in the universe in which we find ourselves today.[212]

Scaletti learned about this history of the Higgs Boson at a weeklong workshop in Geneva, Switzerland lead by choreographer Gilles Jobin called GVA Sessions 2015. Jobin's choreography was influenced by particle physic research, in particular the behavior of the Higgs Boson. At the workshop, dancers, scientists, composers,

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[211] E.A.T. (Experiments in Art and Technology) was a collaborative founded in 1966 by artists Robert Rauchenberg and Robert Witman with Bell Telephone Laboratory engineers Billy Klüver and Fred Waldhauer. The 50th Anniversary at Stony Brook also featured Miller Puckette, the creator of Max and PureData. Janell Rodgers, "F_E.A.T.: Fifty Years of Experiments in Art and Technology Celebration," http://scgp.stonybrook.edu/archives/20214, accessed January 30, 2019.

[212] Scaletti, "Double-well," program note, carlascaletti.com, accessed October 22, 2017.

filmmakers, and journalists participated in dance classes and physics lessons. The workshop culminated in a public performance at the Cinema Sputnik Theater.

During the workshop, particle physicist Nicholas Chanon drew a picture illustrating how a particle behaves in a *double-well potential*. This diagram showed a double-well potential shaped like a W with soft edges, plotted on X/Y coordinates. Inside the double-well, a particle remains in one well or oscillates between the two wells depending on the particle's velocity and the position in which it enters the double-well. A double-well potential is an example of a dynamical system. Scaletti was fascinated by how the double-well potential illustrated "tipping points"—how a minute perturbation may cause a particle to enter a well from which it is (almost) impossible to escape.

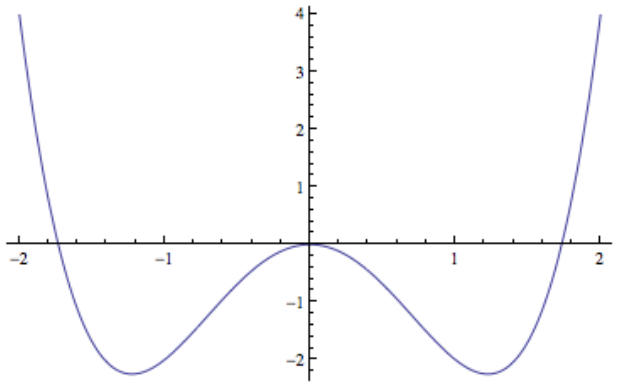

Figure 2.12: Graph of a double-well potential[213]

Scaletti wrote and premiered *Double-well* in the lead-up to the 2016 presidential election in the United States. The piece can be heard or understood as a reflection on democratic process and the United States' two-party system. "Part of the goal for this piece was an experience of how, working together, we can effect change

[213] Photo from "Dissecting *Double-well*," a lecture presented by Scaletti at the University or Oregon in 2017.

(since the piece is clearly influenced by what the audience does)."[214] For Scaletti, the concept of a double-well is also a metaphor for the way that people make decisions when presented with two options, or how one decision can tip someone into a single well, having unexpectedly important ramifications. The double-well potential also describes how *groups* make decisions, and how a minute action or shift can force the "particle" or decision into a single well and change the course of history. Scaletti gave the example of James Comey's letter to Congress regarding Hillary Clinton's private email server one week before the election.

The social metaphors in *Double-well* reflect Scaletti's interest in time. By storing recorded sounds in memory, processing them and playing back later, Scaletti is interested in how past decisions influence the future. In a piece like *Cyclonic*, Scaletti explored this idea with the use of pre-recorded sounds, however in this case she employs "on the fly" processing to represent the human capacity for memory and how humans experience time and thought.

[214] Scaletti, email to Heying, October 23, 2017.

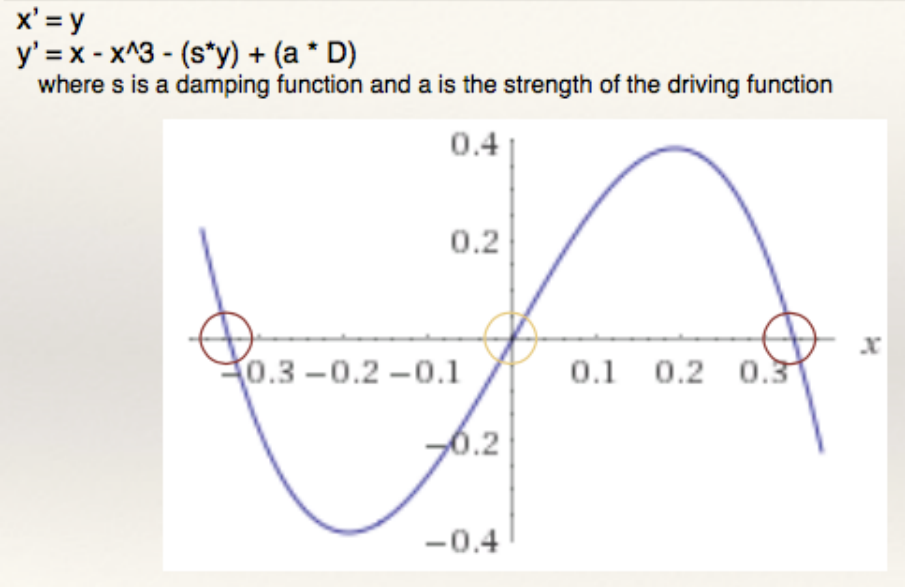

Figure 2.13: Scaletti's two-dimensional double-well model[215]

Scaletti modeled a two-dimensional double-well system as a Kyma Sound object called DoubleWellPotential. This model controls both audio signals and other control parameters. The components of the Sound include: a Damping function, which represents friction enabling the oscillators to slow down and stop over time; TimeConstant controls how quickly the system is updated; GenerateEventValues X, Y is used to create variables for the system; there is a Live Override in case the user wants to enter X and Y in by hand or with live input; and a Reset button to refresh the system. The X and Y are the crucial variables. X represents the position of the particle in the system, and Y represents the particle's velocity. When going through the DoubleWellPotential Sound, X and Y are generated by Scaletti's double-well algorithm.

Scaletti used the double-well model output in two ways, either as control signals for DSP and other audio processing or as live audio signals. In one instance,

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[215] Scaletti, "Dissecting *Double-well*."

the particle in the DoubleWellPotential is driven by an oscillator. In another, Scaletti creates a double-well ring modulator by multiplying the X and Y signals by each other. Scaletti also employs the double-well model to control a pan function, sending the audio around the four channels. The result is replicated six times creating six different particles with different positions going through the double-well. The X and Y signals were also used to control morphs between two samples.

The audience input drives or controls aspects of the system, in other words it influences or replaces the X and Y variables, changing how the particle moves through the system. Each audience member plays a small toy plastic flute. Many of the Kyma Sounds are controlled by audience input via four microphones placed around the performance space. Scaletti projects a "score" that indicates in real-time when each microphone detects a sound. The score gives the audience specific instructions for how to play their flutes. Throughout the piece they are instructed to play:

- the same pitch;
- a pitch different from their neighbor;
- trills;
- at various dynamics;
- "lightning blasts" (short, forceful blows on their flutes).

The performance of *Double-well* begins with a "rehearsal" in which the audience is instructed to play their flutes in unison pulses with all five fingers down, and then with just one finger down. This allows Scaletti to check the levels and to give the audience a chance to get used to playing the flutes. Throughout the piece, the flute sounds are stored to be used later; analyzed, processed and played back in real-time; or used in real-time to control a double-well potential system. High pass filters are

used to suppress extraneous audience sounds, so that only the high frequencies of the flutes will influence the double-well. The score is a VCS (Kyma Virtual Control Surface), so audience input also affects the projected animated "score."

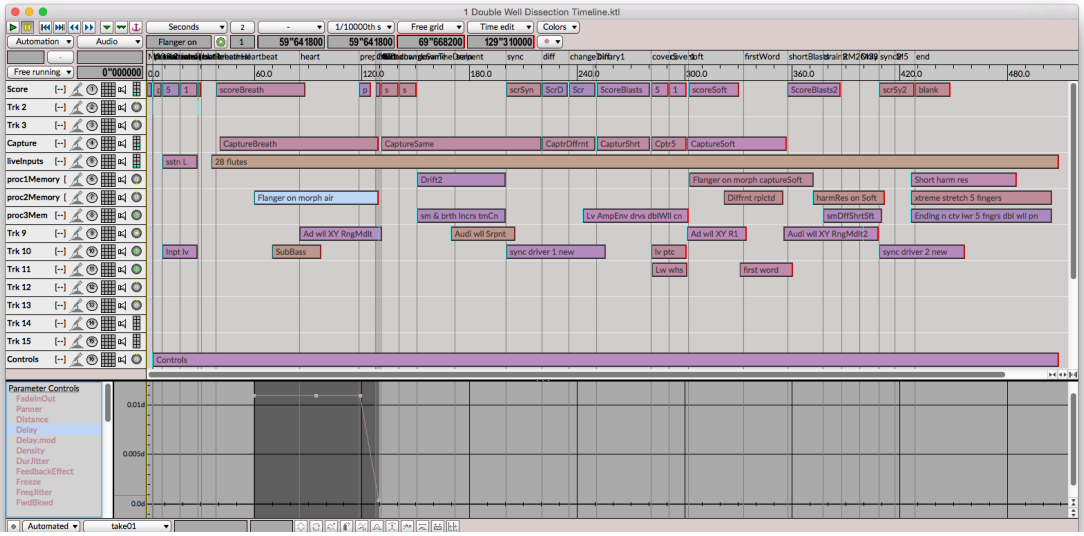

Figure 2.14: Kyma Timeline for *Double-well*

The flute sounds are rarely processed in a straightforward manner. In one instance the flute sounds themselves control their own processing. This complex Kyma Sound contains multiple steps of DSP and it involves processing the live audience input and flute sounds that were stored to Kyma's memory. The first part of the Sound contains two SampleClouds (granular synthesis on designated samples). The input for the first consists of flute sounds stored to memory from earlier in the piece when the audience is instructed to play different pitches than their neighbor. The input for the second is a recording of a heating duct. The output of the two SampleClouds is then cross-filtered with each other, seamlessly merging the spectra of the two Sounds. The result is then sent through two modulated delays, one after the other, which creates a flanging effect. The signal is then sent through a final delay that models a Doppler shift. This Doppler shift is being controlled by the ongoing

DoubleWellPotential Sound, which is being driven by the audience's live input. In this last part of the process, the audience input controls the level and angle of the Doppler process. The amplitude envelope of the audience input drives the double well and modulates the TimeConstant, controlling how fast the particle goes through the double-well, in effect changing its frequency.[216] This is one example of the complex Kyma Sounds that incorporate control of the double-well and other audio processing simultaneously throughout the piece.

Scaletti created a Kyma Sound to do live spectral analysis on flutes playing in unison, which is then resynthesized four octaves lower. The resynthesized flutes are used to drive a double-well. The live flutes are also stored in memory to be played back later, while all of these sounds are also mixed together and played live. Throughout the piece the audience also controls the stereo panning via a bi-directional amplitude-following algorithm, changing direction based on amplitude fluctuations.

In composing *Double-well*, Scaletti was partially motivated by her interest in spontaneous synchronization as indicative of emergent behavior and group decision-making. She wanted to explore how to get people to breath together, arrive at the same pitch or beat, and how they accelerate or decelerate together, without direct verbal instructions.[217] In one section of *Double-well* the audience's ability to synchronize their flute playing determines whether or not the double-well's "particle" will stay in one well or be pushed into the other. The audience is instructed to synchronize "rhythmic blasts" on their flutes. A Kyma Sound called

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[216] Scaletti, "Dissecting Double-Well."
[217] Scaletti, email to Heying, November 14, 2017.

EnergyAtFrequency measures the amount of energy around 5kHz. The audio is also converted into a square wave with sharp "on/off" edges, which enables Kyma to tell if the audiences "blasts" are synchronized. If the audience does manage to sync, they push the particle from the left well to the right well. If they do not, the pulses cancel each other out, and the particle unpredictably bounces around the left well. According to Scaletti:

> The most interesting part is not so much whether sync is achieved but what it sounds like as people approach it together. Also, I had read that when people synchronize their breathing, other biological oscillators also start to synchronize (including neurons) which is why the piece opens with the breath.[218]

Scaletti recognizes that failure is one possible outcome of an attempt to synchronize. Her statement demonstrates a loosening of her control over the outcome of the piece and acceptance of what the audience is capable of producing.

With *Double-well*, Scaletti refined her approach to employing audience participation in her compositions. According to Scaletti, it is about *agency*, providing the audience with a new way of experiencing music and sound by actually participating in the piece. As with *Autocatalysis*, Scaletti's experience at the club in Athens stuck with her as the impetus to create *Double-well* as did the desire to used participation so the piece cannot be ignored. She explains:

> I was trying to come up with a kind of music that could not become background sound because it required the active participation of the audience. I am also interested in how one of these participation pieces might change the way the audience experiences the other pieces on the same program—that it might cause them to go into a more active listening state.[219]

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[218] Scaletti, email to Heying, November 13, 2017.
[219] Scaletti, email to Heying, October 23, 2017.

Scaletti's statement also demonstrates how she thinks about programming her music as part of a concert, and that she values different kinds of active listening experiences throughout.

Scaletti's interest in active listening in *Double-well* recalls Pauline Oliveros's *Sonic Meditations* and *deep listening* practices. This is particularly true of passages in which Scaletti instructs the audience to focus on breathing, or to listen to their neighbors and either match their pitch or play a different pitch. *Double-well* encourages a kind of listening and awareness of one's sonic environments akin to that experienced in Oliveros's work such as the *Tuning Meditation* (1971).[220] Oliveros's meditations are more open-ended and process oriented, whereas Scaletti's *Double-well* is more regimented and structured over time by giving precise instructions to the audience throughout the piece. Promoting "active listening" in audience members might also be motivated by Scaletti's desire to be *heard*, for people to pay attention to her music.

Although Scaletti values and promotes audience agency with her participatory pieces, she wants the audience to participate on her terms, and she wants the piece to "sound good."[221] As Scaletti's statements about synchronization indicate, in *Double-well*, she has a fairly broad understanding of what "sounding good" means, and the idea of "sounding bad" seems to refer to uncontrollable, loud feedback. As in *Autocatalysis*, Scaletti includes "protectors," safety mechanisms such as high-pass filters to block unwanted sound (sound outside the range of the toy flutes), and turns off the microphones when she does not want audience input. Although these

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[220] Pauline Oliveros, *Deep Listening Pieces* (Kensignton: Deep Listening Publications, 1990).
[221] Scaletti, email to Heying, October 30, 2017.

protectors might limit audience participation, they are a practicality; performing *Double-well* creates a situation that could produce uncontrollable feedback. Scaletti's use of "protectors" is quite like Gordon Mumma's inclusion of a knob to control the gain on the French horn input on his cybersonic console for *Hornpipe* as "a safety feature."[222]

III. Data Sonification and Data-Driven Music

Scaletti's practice of data sonification has been an important part of her work. She has made significant contributions to the literature about the practice, including something of a unique approach in which she distinguishes data sonification, mapping data to sound for scientific research, from data-driven music, and a musical composition that employs the methods of sonification. The following section includes a brief history of the use of the term data sonification and the practices of mapping data to sound in order to provide a context for Scaletti's approach and data-driven pieces *QUANTUM* (2013) and *H→gg* (2017).

Broadly defined, data sonification is the mapping of data to sound. The use of the term dates back to the early 1990s, when scientists began to formalize approaches to data sonification as "auditory display," or an aural representation of scientific data. The forming and first meeting of the International Community for Auditory Display (ICAD) in 1992 marks this movement. Scaletti was a part of this codification and formalization of approaches to data sonification. Today, many definitions of data sonification can be traced back to Scaletti's early work. In "An Introduction to Data

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[222] Gordon Mumma, "The Computer as a Performing Instrument," Massachusetts Institute of Technology A. I. Laboratory Memo No. 213 (February 1970), 6.

Sonification," David Worrall surveys existing definitions of data sonification and claims the term's contemporary use dates back to its implementation by Sara Bly and Scaletti at the ICAD conference in 1994. In the conference proceedings, Bly defined data sonification as "audio representation of multivariate data," and Scaletti defined it as "a mapping of numerically represented relations in some domain under study to relations in an acoustic domain for the purposes of interpreting, understanding, or communication relations in the domain under study."[223] The most commonly cited definition of data sonification is scientist and composer Gregory Kramer's: "The use of non-speech audio to convey information. More specifically, sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation."[224] These definitions suggest how data sonification should be employed in a scientific context.

Today, the use of the term data sonification is somewhat confused and contested, as it has become common in both the arts and scientific disciplines. Although members of ICAD and practitioners such as Bly and Kramer advocate for the use of data sonification as a research tool, in scientific disciplines data sonification still lacks acceptance as a legitimate method for representing and interpreting data.[225] Conversely, in the fields of music and sound art, in the push to

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[223] Susan Bly and Scaletti, in "Introduction to Data Sonification," by David Worrall, in *The Oxford Handbook of Computer Music*, edited by Roger T. Dean (Oxford, Oxford University Press, 2009), 312–313.
[224] Gregory Kramer, in "Introduction to Data Sonification," by David Worrall, in *The Oxford Handbook of Computer Music*, edited by Roger T. Dean (Oxford, Oxford University Press, 2009), 313.
[225] "This popularity is in stark contrast with the contested status of sonification in the sciences, where a small interdisciplinary community is still struggling for scientific acceptance." Alexandra Supper, "Sublime Frequencies: The Construction of Sublime

integrate the arts and sciences dating back to the early 2000s, "data sonification" gained popularity as a blanket term for musical or sound-based art works that employ the mapping of data to sound.[226] According to sociologist Alexandra Supper, public fascination with data sonification stems from its promise of "auditory sublime" experiences—basically novel experiences of science that claim to provide access to otherwise inaccessible information.[227]

Sonifying data has also become more common due to accessibility of digital technology and the nature of digital audio. Digital audio simply consists of a stream of numbers that represent sonic information. This is true whether the sound was converted from an acoustic signal like a microphone input or generated digitally by an algorithm. One of the most common methods of data sonification is to replace the stream of numbers that represents an audio signal with a string of numbers from scientific data.[228] Scaletti gives the example of replacing microphone input in a digital synthesis algorithm (which goes through and ADC and is represented as a string of numbers in the computer), with a string of numbers (data) collected from a science experiment or mathematical model.[229] It is not the only method of mapping data to sound, but it is easy and accessible to people with little technical or scientific knowledge.

Listening Experiences in the Sonification of Scientific Data," *Social Studies of Science* 44:1 (2014): 49.

[226] Supper, "Sublime Frequencies: The Construction of Sublime Listening Experiences in the Sonification of Scientific Data." *Social Studies of Science* 44:1 (2014): 36.

[227] Ibid., 51. Sociologist Alexandra Supper studies both the public interest and scientific practices of data sonification. I would also like to suggest that mapping data to sound has also become popular because of the centrality of "data" in contemporary culture.

[228] Kramer labels this kind of sonification as "parameter mapping," and representing a string of linear data as an audio signal is considered a 0^{th} order mapping of data to sound. Kramer, "Introduction to Data Sonification," 322.

[229] Scaletti, "Sonification ≠ Music," 363–385.

The mapping of scientific data to sound as the basis for a musical work, with the aid of digital technology can be traced to Charles Dodge's *Earth's Magnetic Field* (1970). For this piece, several geophysicists from the NASA Goddard Institute at Columbia University mapped numerical data that documented changes in the sun's radiation on the earth's magnetic field to music notation.[230] Since the data were already mapped to pitch, Dodge's primary contribution consisted of designing timbre and rhythm to represent the data and convey a sense of the sun's "radiance."[231] Dodge did not call his composition "data sonification" at the time, however the term has commonly been applied to his piece in retrospect.[232] More recently artists including John Luther Adams and Andrea Polli have employed the term to describe their work. For Adams's *The Place Where You Go to Listen* (2006), he mapped his compositional language onto the seismic and meteorological data of Fairbanks, Alaska as part of a sound and light installation. In *Heat and the Heartbeat of the City* (2004), and *N.* (2005), Polli mapped climate and weather data to sound, and created multi-channel installations in order to evoke an emotional connection and reaction to the impacts of climate change.[233]

Scaletti is deeply invested in the use and mapping of data to sound for both scientific and artistic means. She is undoubtedly part of the artistic lineage of Dodge,

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[230] Bartel's Musical Diagram. Charles Dodge, liner notes to *Earth's Magnetic Field*, Nonsuch, LP, 1970.
[231] Ibid.
[232] Laurie Spiegel also employed a pre-existing mapping for her piece *Harmonices Mundi* (1977); she used Johannes Kepler's 1619 mapping of planetary data to frequency. Jazz musician Willie Ruff also realized Kepler's mapping using a synthesizer in 1979.
[233] Andrea Polli, "Sonifications of Global Scientific Data," in *Environmental Sound Artists: In Their Own Words*, edited by Frederick Bianchi and V.J. Manzo (Oxford, Oxford University Press, 2016), 1–7.

however, she employs the term data sonification in the scientific manner, as a tool for scientific research, as opposed to what she calls "data-driven music," musical works that use the methods of sonification.

Data Sonification ≠ Data-Driven Music

Throughout the last three decades Scaletti refined a set of sophisticated tools and best practices for mapping data to sound. In 1991, Scaletti and National Center for Supercomputing Applications (NCSA) scientist Alan B. Craig published "Using Sound to Extract Meaning from Complex Data"—one of the first studies that defined data sonification and its methodologies.[234] In their article they made a clear distinction between the terms data sonification and data-driven music.[235] In 1994, Scaletti extended this work in "Sound Synthesis Algorithms for Auditory Data Representations," from which Worrall cited Scaletti's definition of data sonification: "a mapping of numerically represented relations in some domain under study to relations in an acoustic domain for the purposes of interpreting, understanding, or communication relations in the domain under study."[236] In this article she focuses on methods of mapping scientific data to sound using tools in the Kyma system. Scaletti's 2018 essay, "Sonification ≠ Music" further defines and explores the distinction between data sonification and data-driven music as well as her evolving

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[234] Alan Craig's specialty is data visualization. Craig also worked at CERL from 1983–1986, where he developed interactive ear-training and music pedagogy software. Craig and Scaletti became acquainted after he left CERL and began working at NCSA through Lippold Haken.
[235] Craig and Scaletti also demonstrate that pairing visual and aural representations of data is a more effective method for interpretation of data than the sole use of a visual or aural representation.
[236] Bly and Scaletti, in "Introduction to Data Sonification," 312–313.

methodologies and approaches to both.[237] Scaletti describes a sonification as an "interface" to the data, and like a well-designed interface, she explains:

> In data sonification, the goal is to understand or interpret the underlying source of the data. In a sense, you'd like the data sonification to 'disappear' and for the researcher to just hear the structure of the underlying model and forget that [data are] being conveyed by sound at all.[238]

Scaletti sees data as a "trace" left by a dynamic process. Data do not capture a process in its entirety; they only suggest order, relationships, or patterns that may be present. Yet, studying data enable a greater understanding of the processes being examined.

Scaletti commonly refers to sonification as "cross-domain inference preserving mapping," a phrase borrowed from Johnson and Lakoff.[239] It suggests that the most important part of mapping data from one domain to another is preserving the salient features and relationships present in the data. She states: "A well-designed data sonification is a map or morphism that preserves the most important elements, connections, and relations such that sequences of actions and chains of reasoning in the target domain also make sense in the source (and vice-versa)."[240] Scaletti's focus on preserving relationships suggests her belief that the benefit of representing data using sound is that it is an excellent medium for communicating these relationships and patterns. She asserts that a listener can hear relationships and make intuitive connections that one might not be able to see in a visual representation of data.

In both her 1994 and 2018 papers, Scaletti based her definition of data sonification and the distinction between data sonification and data-driven music on

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[237] Scaletti, "Sonification ≠ Music," 363–385.
[238] Scaletti, email to Heying, February 9, 2017.
[239] Scaletti, "Sonification ≠ Music," 364.
[240] Scaletti, "Sonification ≠ Music," 375.

intent. With data sonification the intent of the creator is to craft a tool to aid in understanding and interpreting the results of an experiment, a natural phenomena, or a model. Whereas with data-driven music, the goal is not necessarily to accurately or transparently represent data, the goal is to make a sonically interesting, meaningful piece of music. Although Scaletti maintains that a data sonification is not music, music can be thought of as sonification. Scaletti considers music a sonic index or sonification of thought and experience: "When we create music, we're creating a sonification of what it's like to be inside our heads, to feel time passing, to move through space, and be alive."[241] As a sonic index or sonification of thought and experience, music captures and communicates aspects of the human experience that are impossible to convey with language alone.

For Scaletti, the need for the distinction also stems from the way people tend to listen to music in the West; rather than actively and analytically listening, most people go into what she calls a "trance" state when listening to music, or they just leave music on as background to create a certain ambiance. As with her audience participation pieces, Scaletti hopes that the distinction will encourage active listening to both data sonification and a piece of data-driven music. With data sonification in particular, she hopes that researchers will be able to move away from the expectation that when listening to a sonification they will hear music, and instead expect to hear an interface to the data, where they can hear the structures, patterns, and relationships present in the data.

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[241] Scaletti, "Sonification ≠ Music," 378.

Lastly, the distinction between data sonification and data-driven music is also important to Scaletti because in any instance of cross-domain mapping, whether it is from data to a visual or sonic representation, it is impossible to be neutral. Scaletti borrows from geographers John Krygier and Denis Wood when she states: "A map is a proposition. It reflects the worldview of the maker."[242] When data are mapped to sound, the mapping necessarily adds new information that shapes the interpretation.[243] Additionally, musical compositions are often thought of as autonomous and presented with little or no contextual materials, e.g. on a radio broadcast, a concert with little or no program notes, or as the soundtrack to a film or TV show. However, the representations of scientific data are typically presented as part of an article or lecture where the methodologies and goals of the experiment that produced the data are explained in detail, providing a framework for the data's interpretation. Scaletti believes that "a sonification is meaningless when pulled out of its context, when it is not presented as part of a cascade of text, equations, tables, graphs, captions, legends, and citation of previous work."[244] She writes detailed program notes that indicate how she used data in composing a piece and provides a context for understanding the data as part of a musical composition rather than of as an accurate representation of an experiment or scientific model.

Since the experience of a musical work is subjective and based on one's previous experiences and cultural context, Scaletti asserts that through the simple act

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[242] Scaletti, "Mu-Psi: Making the Invisible Audible," *Prisms Contemporary Music Festival*, Arizona State University, Tempe, Arizona, November 9, 2017.
[243] Even the collection and documentation of data in the first place is loaded, inflected with the values of the collector and methodologies used.
[244] Scaletti, "Sonification ≠ Music," 377.

of using the label "data-driven music," composers are liberated from certain expectations that their data-based piece should illustrate something concrete and specific about science or the underlying data. In addition, "it avoids the implication that music is the handmaiden of the great and almighty god of Science."[245] When writing a piece of data-driven music, Scaletti feels free to use her previous sonifications of data sets as the source material for the composition, to make changes to the mappings, add new sounds, repeat sections or phrases, all to create a dynamic and engaging piece of music.

Lastly, Scaletti always collaborates with specialists and scientists when employing data sonification; the scientists shed light on how parameters function and which are most important; and Scaletti carefully crafts synthesized sounds and procedures in Kyma to represent the data. Kyma has been integral to Scaletti's practice: as a sound design and programming environment it is particularly well suited for data-sonification. With Kyma, Scaletti can craft unique synthesized sounds that avoid conventional musical references to more accurately convey data.

QUANTUM (2013) and *H→gg* (2017)

Scaletti's *QUANTUM*, for the Kyma system, is the data-driven soundtrack for Swiss choreographer Gilles Jobin's dance of the same name, which also features kinetic lighting by German artist Julius von Bismarck. *QUANTUM* premiered in 2013 on a platform 300 feet above the Large Hadron Collider at CERN in Geneva,

[245] Scaletti, "Sonification ≠ Music," 379.

Switzerland.[246] The music for Jobin's *QUANTUM* is based on a data sonification project Scaletti undertook with particle physicist Lily Asquith that began in 2011.[247] Asquith was a member of the ATLAS experiment at CERN, one of four teams of researchers that used the Large Hadron Collider (LHC) to detect the Higgs Boson particle. The LHC is a particle accelerator; sub-atomic particles are sent through its miles-long rings at the speed of light and then crashed into each other, which produces new particles such as the Higgs Boson. Asquith founded the LHC Sound project with the goal of using data sonification as a tool for her LHC research.

Since the data were confidential at the time, Scaletti and Asquith were restricted to using Monte Carlo simulations of ATLAS Experiment data. They were particularly interested in discerning if a collision that resulted in a Higgs Boson particle "sounded different" than collisions that did not. Their mappings reflected this goal and the nature of the ATLAS Experiment. In Scaletti's words: "The data sets are collection of vectors [positions in space], where each vector represents measured and computed characteristics of a single collision in the LHC at CERN."[248] This is not a mapping in which parameters change over time; instead, each sonic event corresponds to a single multi-dimensional collision event. They made hundreds of different mappings of the data to sound, and often paired the audio with visual representations for optimal results.

Scaletti's collaboration with Asquith led to her work on *QUANTUM*, Jobin's algorithmic choreography based on the interaction of sub-atomic particle. Jobin's

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[246] LHC actually crosses the border between Switzerland and France.
[247] Their collaboration took place entirely over email. Scaletti, email to Heying, February 9, 2017.
[248] Scaletti, *Sonification ≠ Music*, 368.

choreography resulted from an artist's residency called Collide@CERN, where he worked with particle physicists to develop movement derived from the behavior of the Higgs Boson and other particles.[249] Jobin actually introduced Scaletti to Asquith in 2011, sparking their collaboration. Scaletti and Jobin met in 2010 at one of Jobin's GVA Sessions workshops in Geneva. As a result of this meeting, Jobin asked Scaletti and composer Christian Vogel to collaborate on the soundtrack for his upcoming project, a dance called *Spider Galaxies*. Scaletti contribute data-driven music, which primarily consisted of sounds adapted from the LHC data sonifications she created with Asquith.[250] As with the soundtrack for *Spider Galaxies*, Jobin felt that incorporating Scaletti's sonification of LHC data into the soundtrack for *Quantum* would be the perfect compliment to his particle-physics-inspired generative choreography.

By the time Jobin brought Scaletti on to compose the music for QUANTUM, she had a massive collection of hundreds of different mappings of LHC data from her work with Asquith. However, for *QUANTUM*, Scaletti had access to *real* data from the LHC ATLAS experiment, which she used as the source data for the mappings she devised with Asquith. When Scaletti began composing *QUANTUM* she claimed:

> I took off my sonification hat and put on a composer's hat, treating the data-driven sounds as if I had no idea where they had come from. From that moment, the sounds ceased to be a tool for explaining or interpreting data and became the raw materials to be manipulated, transformed, layered, reversed,

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[249] Von Bismarck's kinetic light installation, called *Versuch Unter Kreisen,* was also the product of the Collide@CERN residency. He and Jobin were the first artists awarded the residency.
[250] Scaletti, email to Heying, February 9, 2017.

> modified and composed into a flow of experience intended to transport the listener to an alternate universe.[251]

Scaletti's description is crucial for understanding her approach to and distinction between data sonification and data-driven composition. While making the music for the data-driven piece *QUANTUM,* she felt free to make changes to the original mappings, add filters and other processing, and repeat sections she heard as musical phrases, sometimes changing the frequency or timbre each time. As Scaletti says, she composed "the 'energy' or 'feel' of a section, the data controlled the pitches, relative durations, spatial locations, etc."[252] She also set out to evoke the experiences she and Jobin had at CERN, and the excitement they felt by being surrounded by scientists on the brink of discovery.

Revisiting Scaletti's compositional "philosophy" and how it is embedded in Kyma is useful in this context. In many ways *QUANTUM* is like a piece of musique concréte. However, instead of fixed bits of pre-recorded sound, each *object sonore* is a Kyma Sound object, a generative process or synthesis technique that runs in real-time. In this case, each object encapsulates a different mapping of ATLAS experimental data or other synthesized sounds that are layered and manipulated to create a full texture of clicks, "data melodies" or "musical" lines that arise out of the data sonification. Scaletti also adds additional Sounds, typically longer sounds including drones and other more atmospheric effects since many of the data-driven Sounds consist of short pops, crackling clicks, and bell tones. Since each sound is connected to a collision event, there are many sequences of shorter sounds in the

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[251] Scaletti, "QUANTUM," Program Note, http://carlascaletti.com/sounds/sound-art/quantum/, accessed February 9, 2017.
[252] Scaletti, email to Heying, November 13, 2017.

piece. Scaletti designed sounds that are onomatopoetic, such as crackles, clicks, and bell tones, sounds that suggest the movement of something small so that it might be easy to connect these sounds to the idea of sub-atomic particles.

Scaletti made many compositional decisions by watching the dancers. She chose previous mappings and altered the way the data were mapped so that the music corresponded with the dancers' movements. And at times, she claims she tried to "move the dance forward" with the music she created. According to Scaletti: "The actual source of the data was less important than the way it was mapped (because I could map the same data to something that was melodic and slow or something quick and rhythmic, or textural/choral, or something extremely short and crackly)."[253] For example, in one of the opening sections of *QUANTUM* subtitled 'Vibration,' the dancers shake their entire bodies (it looks as if they are being electrocuted). For the music, Scaletti used several sonifications that "were textural, clicky, and quasi random to create the same kind of energy in sound."[254] In the beginning of Vibration, Scaletti plays a recording of a previous sonification processed with tuned and "space-giving" reverb, and then slowly adds other processed sounds and new live-processed data mappings to emulate the idea of "heat rising" as a result of the dancer's vibrations.[255] Some examples include a ShepardSampleCloud*,* which uses samples of low piano tones, as well as Shepard tone effects created using samples of a needle

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[253] Ibid.
[254] Ibid.
[255] Scaletti, interview with Heying, Champaign, IL, January 8, 2018. Scaletti explained that in this section Jobin was inspired by knowledge he learned from the physicists at CERN that everything is vibrating, which causes constant fluctuations in heat.

scratching on the surface of a vinyl record. In this way Scaletti aimed to create sonic schemata that mirrored the patterns of dancers movements.

As the previous example demonstrates, Scaletti used ATLAS experiment data in two ways: pre-recorded sound from her previous work with Asquith or processed live (but the mappings were still based on her work with Asquith). When processed live, Scaletti created uniform scripts that could be read into Kyma. Kyma normalized the text files and created SoundEvents such as start time, duration, frequency, and other sonic parameters. In a section titled "Elusive" the data sets are mapped to a sonic spectrum. The data had three variables. Scaletti mapped one to the time of a frame, one to the amplitude of a partial, and one to the frequency of the partial in the frame. Scaletti then resynthesized the sound using either an OscillatorBank (a filterbank), or a GrainCloud. Since the data was processed one frame at a time at a regular rate, the effect is of a high frequency, rhythmic melody.[256] In a section called "Danse," Scaletti created a mapping that produced a tinkling melody over a drone. Scaletti used the delR of the data, which represent the angle between two gamma particles when they hit LHC's detector. She processed the delR through eight harmonic resonators that are also given Shepard tone treatment so that the frequencies seem to continually rise.

In performance, the music is synchronized to the dancers. Scaletti employed WaitUntils at the start of each section so that the music was not fixed in time. The Kyma Sounds in a given section would continue to generate new sound until the person running Kyma at a performance could trigger the WaitUntil and start the next

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[256] Ibid.

section. Scaletti believed that Jobin had a love-hate relationship between music and the dance, "Gilles will insist that the music and the dance are separate pieces, just played at the same time. Clearly he's influenced by Cunningham & Cage in that idea. But what he says and what he really wants from the music are not always the same. I think he really does want the energy of the music to fit that of the dance. And the dancers definitely prefer it that way."[257] The dancers appreciated the cues and relation of their movements to the music, even though Jobin resisted some of Scaletti's more literal sonic gestures.

In addition to mimicking or emphasizing aspects of the dance with sound, Scaletti also uses sound to mirror the movements of von Bismarck's light sculpture. Von Bismarck's sculpture consists of several large bell-shaped lamps that are suspended from the ceiling and swing in choreographed movements. Scaletti collected measurements of the lengths of the light's cords so that she could create periodic sounds that parallel the light's pendulum-esque swinging. The length of the light's cords changed throughout the tour to fit into spaces with different ceiling heights, however according to Scaletti, audiences were still struck by the apparent synchronization of the sound, lights, and dancers. For example, in a section of "Danse," where the dancer's movements bear no relation to particle physics, in addition to the mapping using eight harmonic resonators, Scaletti tuned the rate of an LFO to the length of Bismarck's lamps. She made four copies, one for each light. The LFOs then generate a pan function and a time function sending their sound cascading around the room slightly out of phase with each other.

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[257] Scaletti, email to Heying, November 13, 2017.

Spatialization of sound for a quadraphonic speaker system is a crucial and dynamic element in *QUANTUM*. Sounds constantly shift in and out of one speaker to the next, in subtle and surprising ways. According to mechanical engineer Ed Childs and acoustician Ville Pulkki: "The physical location of data to be sonified is frequently as important as the value of the data itself."[258] Childs and Pulkki also assert that it is easier to detect "spectrally rich sounds in space."[259] In *QUANTUM*, the panning and spatialization are primarily controlled by data variables. Scaletti explains: "there are sections where the perpendicularity of the gamma particle to the thrust of the beam was mapped to deviation from a straight-ahead pan position. So the more perpendicular, the more the sound event moved to the back of the room."[260] Like *Cyclonic* and *Double-well*, in *QUANTUM,* Scaletti set out to create Johnson's cycle schema, and employs simple effects such as the Shepard pan. The use of Doppler effects and Shepard pan emulates the circular motion of particles around the rings of the Large Hadron Collider. The effect is that the audience feels fully engulfed in a dynamic sonic environment with a foreground of sound particles swirling around them at a seemingly ever-increasing rate.

Spatialization is also used to reinforce aspects of the choreography. For instance in a section called "Jauge 1," there is a "Symmetry Dance," where a pair of dancers closely mirror each other's movements without touching. Scaletti also created symmetry in the sound in with "mirror images" in the speakers. She explains:

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[258] Ed Childs and Ville Pulkki, "Using Multi-channel Spatialization in Sonification: A Case Study with Meteorological Data," *Proceedings of the 2003 International Conference on Auditory Display*, Boston, 192.
[259] Ibid.
[260] Scaletti, email to Heying, November 17, 2017.

> Gilles had created some beautiful, highly abstract interlocking movement patterns that I tried to mirror in the sound to help the audience notice the pattern. In the section subtitled "symmetry" there is a long section of interlocking movements that is then repeated in a mirror image. It's hard to notice it the first time you see it, so I tried to underline it by using one of the pitch-based mappings (that produced a melodic line) in the front channels. And then, when they perform the mirror image, playing the same melodic line but inverted and in the back channels.[261]

During the first part of "Jauge 1," Scaletti processes samples of struck metal by offsetting their attacks and uses panning to send the result around the room, giving the effect of being surrounded by someone running their fingers along a bell tree. This also mimics the swinging of the lights.

H→gg is a 15-minute version of *Quantum*. The title refers to the symbol used to represent a Higgs Boson particle that has decayed into two gamma particles. At CERN, scientists discovered Higgs Boson particles indirectly through the detection of an excess of gamma particles. Scaletti relates this phenomenon to indirect knowledge acquisition in humans. She claims: "So many aspects of our knowledge are acquired indirectly, by observing the effects or the traces of the actual process rather than by observing the process itself: like hearing the results of modulation, rather than hearing the modulator directly, or seeing a spiral pattern in the seeds of a sunflower even without being able to directly see the growth process that resulted in the pattern formation."[262]

In both *H→gg* and *QUANTUM*, with all this modification to the original data sonification, how does the underlying data actually contribute to the resulting music and listening experience? On one level, the LHC data function like a programmatic

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[261] Ibid.
[262] Scaletti, "H→gg," carlascaletti.com, accessed October 24, 2017.

title; it suggests the relationship between the LHC project and the music. With *H→gg*, the program is so crucial to the experience of the piece that Scaletti projects it on stage so the audience can read it before the piece starts. On another level, some of the patterns in the data can still be heard quite clearly. According to Scaletti, with data-driven music one can "feel the structure as a field of vibrations…people can experience a structure in a visceral way."[263] For Scaletti this experience can be more meaningful than a fully cognizant appreciation of structures in the data. Supper's assertion that experiencing pieces based on data sonification like Scaletti's *QUANTUM* provides listeners with an experience of the auditory sublime provides insight into the power of the piece. Scaletti's use of LHC data as the source material for *QUANTUM* makes elusive, invisible concepts such as the existence and behavior of a Higgs Boson particle more concrete and accessible to a general audience. The sense of the auditory sublime is aided by the sense of immersion that is facilitated by Scaletti's use of spatialization to engulf the listeners in moving sounds, as well as the multi-sensory elements of the movement of the dancers and the darkness of the space in contrast to von Bismarck's moving lights.

Lastly, Scaletti compares her use of data to other composers looking to stochastic or randomly generated processes as a means of breaking composerly habits and providing new patterns or organizing principles in music. Scaletti finds patterns from the natural world more meaningful, as potentially possessing some fundamental truth, rather than other musical systems composers devise. With each piece Scaletti hones in on capturing our current understanding of the order present in the universe.

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[263] Scaletti, email to Heying February 9, 2017.

Conclusion

Mapping data to sound and modeling complex systems with sound are two methods of sonically engaging with the non-human world. Scaletti's hope is that "mappings like sonification (and art) can be our microscopes and telescopes to help us perceive [patterns at different] timescales and different size-scales. To actually *experience* them, not just read about them, which is never quite the same as actually feeling them in real time with our bodies and experiencing them with our senses."[264] Bodies are at the center of Scaletti's compositions. Each piece centers on Scaletti performing on stage, audiences participating in creating sound, or as the center of an immersive experience. Scaletti is keenly aware of how sound moves bodies in particular ways, and uses sound to communicate non-verbal forms of meaning. Data-driven music is a way to sonically explore patterns found in the physical world, and to have an embodied understanding and meaningful musical experience based on those patterns. In Scaletti's compositions, these embodied experiences of universal patterns—of phenomena that occur on scales so large or so small that we could never fully appreciate them otherwise—instill a sense of wonder in the listener.

Scaletti's compositions move beyond exploring patterns in the world as it is. In framing her music as Mu-psi, and experimenting with connections between music and science fiction, with her compositions she also imagines how the world could be. Thus, Scaletti creates sonic cyborg worlds that bring together science, humans, technology, and the environment imaginatively extended to suggest alternative bio-political formations and possible solutions to the world's current problems. The layers

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[264] Scaletti in email to Heying, February 5, 2017.

of meaning, symbolism, and musical processes present in her work also reinforce the hybrid or mutant character of the cyborg. *Double-well* illustrates the cyborg in Scaletti's work: it was inspired in part by the 2016 election and served as a way for her to explore the ramifications of the two-party system. Therefore, rather than performing herself, she has the audience contribute audio input; moreover, a significant portion of their participation requires that they listen to the people around them, suggesting that deeply listening to each other may bring some resolution to the current political crisis. In addition to these layers of social and political meaning, Scaletti is simply interested in exploring the physical phenomenon of the double-well potential through sound. Haraway's hybrid cyborg figure provides a framework to understand Scaletti's work, which is interested how humans are connected to each other, technology, and their environments. By exploring these themes through the creation of self-contained "sonic worlds" that operate according to rules and principles Scaletti imposes based on her values and interests, she in effect creates cyborg worlds that challenge current norms and dominant ways of seeing the world.

Scaletti's approach to composition and the design and evolution of Kyma are profoundly intertwined. As discussions of Scaletti's compositions before and after the creation of Kyma make evident, Kyma enabled more sophisticated layering of generative musical processes and DSP as encapsulated in Sound objects. Scaletti's compositions demonstrate how she often thinks in terms of scientific metaphors, which are also instilled in Kyma. For instance, the notion of recombinance from genetics plays an important role in how Scaletti arranges musical material, which influenced how she conceived of the modularity of Sound objects in Kyma. With

each new piece, Scaletti also pushes the boundaries of possibility in Kyma, necessitating the creation of new Kyma Sounds, which are eventually integrated into the language for Kyma users to employ.

Chapter Three
The Coding of Community

> What if freedom consisted of being an equal part of an activity, of being integrated into a community, of being a valued member of the process? What if freedom began not with the design of the machine or the outcome of its use, but within the social networks it enabled? And for that matter, how might media machines be used to generate chains of human-machine interaction that boost the agency of individuals involved? –Fred Turner[265]

Introduction

In a 2002 article titled "Computer Music Languages, Kyma, and the Future," Scaletti stated that a successful computer music programming language "must serve a community of users."[266] A strong user community has been crucial to the success of Kyma. For Scaletti and Hebel, forming and fostering a community of users was a primary consideration from an early stage in Kyma's development. In this chapter, I study the community of Kyma users. I examine how and why people use Kyma, the values that contribute to how Kyma is used, how Scaletti and Hebel have shaped users' values and the community as a whole and conversely how users have influenced the development of Kyma. Traditional ethnographies of music communities tend to focus on how a community forms through the act of making or listening to music, yet in this chapter, I examine how the community formed around Kyma, a technological object. In this regard, the Kyma community is unique yet it is

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[265] Fred Turner, "The World Outside and the Pictures in Our Networks," in *Media Technologies: Essays on Communication, Materiality, and Society*, edited by Tarleton Gillespie, Pablo J Boczkowski, and Kristin A. Foot (Cambridge, The MIT Press, 2014), 256.
[266] Scaletti, "Computer Music Languages, Kyma, and the Future," *Computer Music Journal* 26:4 (Winter 2002): 71.

also emblematic of a shift that occurred in the late 1980s and early 1990s as the advent and accessibility of personal computers and the internet allowed experimental electronic music-making to evolve outside of the studio, lab, or university and into people's homes.

This study of the Kyma community also suggests trends regarding the role of technology in community formation and the changing character of human relationships in the twenty-first century.[267] The Kyma user community exists because of a network of factors that includes online resources such as forums, email, newsletters, and social media platforms as well as annual meet-ups like the Kyma International Sound Symposium, which facilitate the creation of relationships among users and strengthened the bonds of participants around the object of Kyma. The development of the Kyma user community is also the result of strategic cultivation and promotion by Scaletti and Hebel who drew from their experiences at CERL as a model of a collaborative group that created a thriving environment for the development of technology. To promote a sense of connection with and amongst users, Scaletti and Hebel actively sought out cutting-edge communications technology and implemented it in the infrastructure of Kyma. These tools allowed users to share their experiences with Kyma and assist each other in learning the language. Scaletti and Hebel's pursuit and use of new technology is remarkable and it is easy to take for granted today because email and other internet resources such as websites are so ubiquitous.

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[267] The Kyma user community shares characteristics in common with other user groups that use music technology and/or formed through the use of online communication platforms.

The formation of the Kyma community is an ongoing, ever-evolving process, one that has taken place over the last three decades as users became acquainted with the Kyma system and each other. The community has also transformed through changes in technology that influence how users interact, and in the development of the Kyma system itself. An essential element in the survival of the Kyma community has been the presence of both off and online resources that give depth to the relationships in the Kyma community and reinforce user's connections with each other across space and time.

As outlined in the introduction to this dissertation, this chapter is based on participant-observation ethnography conducted since 2015 at three Kyma International Sound Symposiums, through interviews with over twenty-five Kyma users, and online including analysis of years of data on Kyma forums, the Kyma Q & A, and Facebook pages. Since the Kyma user community is not the sole focus of this dissertation and considering that the community has existed for thirty years, this chapter only scratches the surface of inner workings of this complex community and how it has evolved.

Background

As discussed in Chapter One, the early development of the Kyma system took place while Scaletti and Hebel were graduate students at UIUC, where they also worked as research assistants at Computer-based Education Research Laboratory (CERL). In the music school, engineering school, and CERL, they saw models of how people used and created technology and the consequences of working in

isolation versus collaborative groups. Scaletti in particular witnessed the effect working in isolation or competing factions had on the development of technology in the music department. She felt it limited the musical products and created a divisive, contentious atmosphere. For Scaletti, the toxic climate of the music department stood in stark contrast to the sense of camaraderie and collaboration at CERL, which encouraged prolific exploration and creation of new technologies. Students at CERL recognized that they could develop more innovative tools by working together in interdisciplinary groups. Working in such groups did not preclude institutional politics, a sense of competition, or differences of opinions that come with working in a team, but such difficulties were accepted as part of the process. Collaboration between Scaletti and Hebel was integral to the creation of Kyma, with Scaletti designing software, and Hebel the hardware.

For Scaletti and Hebel establishing a strong community of users was a priority from an early stage in Kyma's development and the founding of their business Symbolic Sound Corporation (SSC). Beyond creating a dedicated client base, they believed a strong user community would produce a superior user experience. SSC's active cultivation of the Kyma community likely stems from Scaletti and Hebel's idealistic desire to create a community that they wanted to be a part of: a community that was inclusive, where people were kind and encouraged each other in learning Kyma as well as the creative projects they made using it.

In the 1980s and 1990s advances in communication technology enabled the formation of a heterogeneous international community. By the early 1990s, personal computers were fast and relatively affordable. These personal computers contained

more abstraction than their predecessors, meaning they required little to no computer coding experience to use.[268] Thus, PCs became accessible to the middle-class outside of academia or industry, and they became a fixture in people's homes around the world. Aided by this development of affordable user-friendly PCs, the Kyma's user base is international, and has been since the beginning of SSC. An Italian psycho-acoustician, Francesco Guerra, purchased the first Kyma system.

The development and accessibility of high speed internet also enabled the creation of international communities and user-bases. In 1991, the US federal government passed the High Performance Computing Act. Spearheaded by then-senator Al Gore, the bill allotted $600 million to the creation "the Information Superhighway," infrastructure that supported networks of computer-mediated communication now known as the internet.[269] By 1996, the High Performance Computing Act made the internet and online resources much more accessible to people outside of academia and industry, ushering in the era of high-speed at home internet commonly referred to as Web 2.0. Along with advancements in PC technology, this bill brought the digital age into people's homes and everyday lives. It supported the development of internet-based communication technology including email, forums and bulletin boards, and later social media, all tools that are crucial to the establishment and growth of online communities like the Kyma community.

Scaletti and Hebel's recognition of the value of new communication technology likely stemmed from their time at CERL. As detailed in Chapter One,

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[268] Janet Abbate. *Inventing the Internet* (Cambridge: MIT Press, 1999).
[269] Howard Rheingold, *Virtual Communities: Homesteading on the Electronic Frontier* (Cambridge: The MIT Press, 1993), 79–80.

CERL was established in the 1960s to support PLATO, a network of computers designed primarily for educational and research purposes. It allowed scholars and students at one university to share resources and information with one another. To facilitate this sharing, the PLATO system contained early forms of instant messaging, email, and screen-sharing. Although PLATO was originally established for research, students and professors were most enthusiastic about the social aspect of the system facilitated by direct messaging. In many ways PLATO pre-empted contemporary use of computers, smart devices, and the prevalence of internet communication technology. Sociologist Howard Rheingold, who coined the term "virtual community," identifies PLATO as the *first* virtual community and emphasizes that its "most enduring legacy is the online community spawned by its communication features."[270] By working with the PLATO system at CERL, Scaletti and Hebel had first-hand experience working with an internet-like system and the power of virtual communities years before most people in the United States had home computers or access to the World Wide Web.

Review of Literature

Existing literature on technology and musical communities has primarily focused on how technology mediates the participatory experiences of either listening to or making music; the key here is that the act of making music is examined as having a generative role in forming a community. Studies of this nature include Thomas Turino's *Music and Social Life* (2008), René Lysloff and Leslie Gay Jr.'s

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[270] Rheingold, *Virtual Communities*, 111.

Music and Technoculture (2003), Mark Katz's *Capturing Sound* (2004), Timothy Taylor's *Strange Sounds* (2001), and Kiri Miller's *Playing Along* (2011). There is no doubt that the act of making music and making music together has played a role in sustaining and maintaining the Kyma user community. However, those acts of making music are not at the root of Kyma's community formation. Rather the Kyma system, a technological object is the point around which the community converges.

Ethnographies of musical collectivities have also tended to focus on groups that form in fixed geographic locations, in diasporas among people with a shared ethnic background or cultural heritage, or affinity groups that form around a particular genre and group music-making. None of that exists with Kyma. The Kyma community formed around a technological object. It is an international group; there is no shared cultural understanding amongst participants, no common genre of music making or method of using Kyma. With this project I seek to answer the question: how does a community form around a music-making technology without these geographic, cultural, or musical bonds?

Although the aforementioned research on the role of music and technology in the formation and maintenance of community has not provided a complete framework for discerning Kyma's role in this collective, it has been integral to my understanding of musical communities and my interpretation of ethnographic data. In particular, my notion of community has been shaped by ethnomusicologist Kay Shelemay's definition:

> A musical community is whatever its location in time or space, a collectivity constructed through and sustained by musical processes and/or performances… A musical community is a social entity, an outcome of a

> combination of social and musical processes, rendering those who participate in making or listening to music aware of a connection among themselves.[271]

As Shelemay indicates, recognizing the shared connections among themselves is a key factor in the establishment of the Kyma community. This awareness is the result of a process that continues over time as people come into contact through music and technology.

Early scholarship about online communities tended to operate within a dichotomy where people's entire social existence operated solely online or off-line. However, now that social media and the internet are deeply entrenched in people's daily lives through smart phones, tablets, and laptops, it is clear that that is a false dichotomy. The Kyma community is an excellent example that this strict separation between virtual and in person community has never quite been accurate. In 2001, sociologist Barry Wellman asserted that online socializing is integrated into a larger network of the ways people communicate: "the internet usually supplants solitary activities, like watching TV, rather than other forms of social life."[272] Further, Wellman disclosed: "The internet has burrowed into my life, but it is not separate from the rest of it."[273] His claims lay to rest assumptions about the separation of virtual and the actual.

Throughout the history of the Kyma community, in-person interactions have been foundational to the establishment and growth of the community. However, these relationships are sustained through interactions online; both on and offline

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[271] Kay Kaufman Shelemay, "Musical Communities: Rethinking the Collective in Music," *Journal of the American Musicological Society* 64:2 (2011): 364–365.
[272] Barry Wellman, "Connecting Communities: On and Offline." *Contexts* 3:4 (2004): 22.
[273] Ibid., 23.

interactions reinforce each other to maintain and strengthen the ties among community members. Online resources enable users to make "real human connections" while gaining information to aid their use of the Kyma system.[274] In *Social Computing and Virtual Communities*, media scholars Panayiotis Zaphiris and Chee Siang Ang claim: "One of the most important characteristics of the Internet is the opportunities it offers for human-human communication through computer networks."[275] Zaphiris and Ang assert: "In general what brings people together in an online community is common interests such as hobbies, ethnicity, education, and beliefs."[276] The Kyma community formed around user's shared interest in Kyma, creating a community around the problems and triumphs of using a complex programming language to create sound.

The Kyma Community

For this study, I consider the Kyma user community to include two groups that intersect: one consists of users that posts on online community pages and forums, and the other group includes of Kyma users that regularly attend the annual Kyma International Sound Symposium (KISS). There are approximately 200–300 in the Kyma user community as considered in this dissertation, which is about one quarter of the total user base. The Kyma community is characterized by users who are extremely dedicated and passionate about Kyma to the extent that numerous Kyma users affectionately describe themselves as a "cult" of "Kyma believers."

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[274] Rheingold, *Virtual Community*, 41–45.
[275] Panayiotis Zaphiris and Chee Siang Ang, *Social Computing and Virtual Communities* (Boca Raton: Chapman & Hall/CRC, 2010), v.
[276] Ibid., vi.

One of the most striking features of the group is the diversity of users' musical output. This variety became evident within a year or two after Kyma was made available to the public. Today, Kyma is used to make algorithmic and procedural compositions, to emulate or prototype analog synthesizers or other hardware; it is used for interactive improvisation, club music, rock, drone, processing for vocals, sound design, and foley. One of the most recognizable uses of Kyma was for the voices of Wall-e and Eva, as well as other sound effects in Pixar's animated film *Wall-e* (2008). As this list might suggest, the musical values of users vary starkly, often along the lines of age, nationality, and educational background. The heterogeneity of the community is partially due to the structure of the language; Scaletti designed Kyma to be ideologically and aesthetically inclusive so that it does not impose a single compositional paradigm on its users. It is remarkable that in spite of this multiplicity of backgrounds and values that there is a strong and sincere sense of camaraderie among users.

Where or how people hear about Kyma influences the make up of the community. During the 1990s and early 2000s, some Kyma users—particularly from the film and music industry—learned about Kyma through print articles and advertisements in magazines like *Electronic Musician* or at demonstrations at tradeshows like the *Audio Engineering Society* meetings. Others learned about Kyma through Scaletti's academic articles, published in *Computer Music Journal* and *Perspectives of New Music,* as well as SSC's presentations and demonstrations at academic conferences such as *International Computer Music Conference*, and *Object-Oriented Programming, Systems, Languages & Applications* (OOPSLA). Today,

younger Kyma users learn about Kyma while in a music composition program at a university or are exposed to Kyma online through websites, blogs, and forums, often around the topic of famous sound designers like Ben Burtt or electronic music producers like Aphix Twin, Amin Tobin, or Autechre.

Kyma users are predominately from the United States, the United Kingdom, and Europe in general (Italy, Germany, France, Austria, Spain, Norway, Netherlands, Belgium, Denmark, Greece), however there are also significant contingents from Canada, South Korea, China, and Taiwan, and smaller user bases in Mexico, Ecuador, Australia, and Israel. The majority of Kyma users work as composers or musicians either in industry or academia. This includes professors, as well as professional orchestral, ensemble, or session musicians as well as sound designers, foley artists, engineers, producers, and composers in the game, music, film, or TV industries. Some Kyma users are visual and/or installation artists, and they either work with Kyma on the side or for sound design for their installation or visual art practice. Kyma users who do not have a background in music tend to have experience with programming and computer science, many are also in academia in fields including Mathematics, Computer Science and Engineering, Physics, Psycho-acoustics, Speech Research, and Psychology.

Another striking aspect of the Kyma community is the age range of participants. Although the majority of Kyma users are over the age of forty, with a good portion of that majority over sixty, there is a significant contingent of users under forty. At KISS2016, participants from twenty-five to thirty-five made up the

single largest age demographic present.[277] Along with age, there is also a large range of length of time people have been using Kyma. Some active users have been using Kyma since 1991 or 1992 when it first became available to the public, and many more have been using it for over two decades. There are also significant differences in education among Kyma users. Some users have a high school degree, while others have undergraduate degrees, and many have graduate degrees. Kyma is a complicated programming environment, however, the technical fluency of users on online resources including forums, social media, and email varies significantly. For example, some users bypass all online resources preferring instead to call SSC on the telephone; some still phone daily or weekly with technical support questions. In terms of gender approximately 25% of Kyma users identify as women, 70% as men, and 5% queer/non-binary.[278] While there is some subtle discrimination and prejudice among users, in general Kyma users are an inclusive group.

With all of users different cultural and musical backgrounds, what do they have in common? One common thread is a desire for professional sound tools. When asked why they use Kyma, almost all users cited the "excellent sound quality" as the primary reason they use Kyma and its "powerful" ability to compute and process algorithmically generated sound. This has some aesthetic bearing on their music and suggests their musical values; Kyma is not commonly associated with a DIY or a lo-fi aesthetic, although some users do make "noise" music or incorporate Kyma with handmade electronics. Rather Kyma users tend to value the ability to create

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[277] Heying, Kyma User Survey, 2016.
[278] Numbers based on surveys taken at KISS, data from SSC, and from online forums for Kyma. Demographic information from three KISSs is included in Appendix III.

algorithmic music with polished professional sound processing. Most Kyma users are financially secure or get access to Kyma as a student at a university or through their industry job.

The importance of the community for many Kyma users is that it is made up of their "peers" in the sense that other Kyma users are most likely to understand and appreciate their work with Kyma. Since Kyma is not as widely used as other computer music programs and languages, the community resources online and in-person meetings provide a sympathetic and supportive environment where users can have meaningful interactions grounded in their shared experience with Kyma. For some users, the community is the biggest incentive to use Kyma:

> The number one reason is the community. Which is a bit unexpected really—as the system is so proprietary and in some aspects secretive. I find the community musically (if not demographically) diverse, supportive and one where I make real connections with people.[279]

The Kyma community is not necessarily a user's sole musical community, however it is an important creative network for the development of their work. Additionally, users often find it personally enriching as they develop friendships with other users. Considering how heterogeneous the community is, especially in terms of musical output, approaches to music-making, and cultural background, it is remarkable that users are kind, accepting, and supportive of one another.

SSC's autonomy from the institutions associated with computer music such as universities, studios, and research centers, distinguishes Kyma from other music programming languages created in the 1980s that had institutional support, either financially or with other resources such as lab space, equipment, and research

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[279] Alan Jackson, Kyma User Survey, Sept. 13, 2018.

personnel. This support tended to fix the communities that sustained these languages to a geographic location. Examples include FORMES, CHANT, and MAX at IRCAM, HMSL at Mills College, and SAWDUST at UIUC. As a result Scaletti and Hebel often felt like "outsiders" in the computer music community. This outsider status seems to have imbued Kyma with a sense of independence that is attractive to many Kyma users who want to distance themselves from the aesthetic rigidity and bureaucracy of many of the institutions associated with computer music.[280] Bruno Liberda, a Viennese composer explained during my fieldwork:

> I never was keen to go to IRCAM, I never was keen to join one of these institutions, I always was a solitude worker and I always dreamt to have a studio of my own, I just couldn't afford it! And then Kyma came along and I was very lucky because I had everything I wanted in a studio. Kyma afforded me a kind of independence as a composer that was not possible before.[281]

Liberda's testimony suggests that Kyma attracts users that consider themselves "outsiders" in the academic or computer music world. These users tend to avoid ascribing to a single compositional school or particular aesthetic. Although it is common for people to have a personal composition or production station today, that was not the case in the late 1980s and 1990s. With Kyma, users had the utility of a music studio, coupled with developments in personal computers and communication technology, which enabled them to establish personal music production studios, often in their own home. Composer and electronic music historian Margaret Schedel explains: "The advantages of having a home studio are numerous: primarily, it

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[280] As discussed in Chapter One, composer and electronic music historian Margaret Schedel refers to the aesthetic identity of certain studios as "operational characteristics." Schedel, "Electronic Music and the Studio," in *The Cambridge Companion to Electronic Music*, edited by Nick Collins and Julio d'Escriván (Cambridge: Cambridge University Press, 2007), 152.
[281] Bruno Liberda, interview with Heying, Skype, October 30, 2016.

liberates the composer, promoting flexibility and freedom of self-expression."[282] This sense of flexibility and freedom is of the utmost importance to many Kyma users.

Beyond the practicality of Kyma as a utility, Kyma is a unique programming experience that is quite different from other programming paradigms. Kyma imposes a certain cognitive independence on its users—they way one thinks through programming or composing with Kyma is likely slightly different than how one might approach such processes in a different language. Composer Ryan Page explains how thinking in terms of Kyma's Sound objects alters his creative process:

> From a user's perspective, Kyma is oriented almost entirely towards the production of sound. In other programming languages, including graphical languages such as Max and Pure Data, you are allowed to construct patches that exist for the sole purpose of manipulating logic gates, or generating text, for example. In Kyma you are forced, due to the way that each "sound" is handled in the interface, to always create complete patches that will function right away. [It]…reminds me of modular synthesizers or other patchable electronic systems in which the user is oriented toward making changes derived from heuristic processes, rather than silently devising logical systems.[283]

Kyma imposes a unique compositional paradigm on its users. Page describes heuristic processes that allow users to listen to their creations as they program and compose. A user cannot simply copy and paste code from a different language or easily adapt pseudocode. Users often have to develop a new workflow and way of thinking about sound and digital signal process in order to assimilate to Kyma. This is common when using any programming language to some degree, but many music-programming languages share a common ancestry or framework that minimize the differences from language to language, which makes Kyma stand in stark contrast.

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[282] Schedel, *Cambridge Companion to Electronic Music,* 32.
[283] Ryan Page, email to Madison Heying, August 8, 2018.

When discussing Kyma with computer musicians and scholars, the question of Kyma's accessibility commonly arises. Kyma's design and resources are accessible in some ways and yet inaccessible in others. Kyma's inaccessibility stems from the proprietary nature of the system. Design and component information about Kyma's software and hardware are not public. There is a point in the language's architecture beyond which users cannot go: for instance users cannot make their own SoundAtoms or new classes in Smalltalk. Users also forfeit their warranty if they want to "hack" or alter the system's hardware.[284] For some users this is not an issue and there are tools in Kyma that allow them to make a program similar to a Sound Atom. Another issue related to accessibility is that Kyma has a relatively steep learning curve that often necessitates previous knowledge of either programming or music; it is relatively easy for users to make sound immediately, however moving past using stock Sounds can be a slow process.

Another barrier to entry is that Kyma is expensive. The current system sells for $2,970–$6,828.[285] The low end consists of the Kyma software sold with the Paca, a "Basic Sound Computer," whereas the most popular system of the software and Pacarana "Pro Sound Computer" sells for $4,402. The high end and least purchased system includes the Kyma software and the Wormhole "Ultimate Sound Computer."

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[284] One Kyma user explained to me that it was worth the risk of loss of warranty to alter the Kyma hardware because it is part of their aesthetic approach to sound and their work is based on a DIY approach to making and manipulating hardware. September 14, 2016, Leicester, UK.

[285] Symbolic Sound Corporation Website, "Which Kyma System is Best for You?," 2019, accessed June 9, 2019. The Kyma system is considered expensive compared to other music programming languages and software including Max/MSP 8, which sells for $399 and Ableton software, which ranges from $99–$1,549, or free software such as SuperCollider and PureData.

The differences between the Paca, Pacarana, and Wormhole include the number of processors (two, four, or six) and the amount of RAM, which is upgradable.

Although Kyma has several barriers to entry, Scaletti, Hebel, and other Kyma users are active in making it more accessible and there is a strong culture of sharing among users. SSC wants to limit the obstacles people face when using digital music technology, particularly in the way information is conveyed. Online, in manuals, and at in-person talks, Scaletti and Hebel explain complicated aspects of Kyma such as coding scripts in Capytalk or constructing digital-signal-processing algorithms simply and clearly so that people with all levels of programming experience or technical knowledge can understand it. If users have questions or problems they take care to explain solutions in such a way as to avoid indicating ineptitude on the part of the user, yet they make sure even a beginner could understand their answers. Hebel described Scaletti's manual, *Kyma X Revealed* as an "invitation" into the world of Kyma. It is warm, full of humor and insights into the world of computer music, and detailed, sophisticated examples that assume little prior knowledge or experience using music programming languages. This is just one example of the benevolent ethos throughout Kyma, from the descriptions in Kyma Sounds, to information on their website and how they run KISS, SSC tries to minimize as many barriers to entry as possible.

Although Kyma is not open source like its peers PureData and SuperCollider, there is a strong culture of sharing among Kyma users. Online resources provided by SSC including the Kyma Q & A forum, along with user-initiated platforms such as

the Unofficial Symbolic Sound Kyma Facebook Page enable this sharing culture, as Jon Bellona attests:

> I go to the Q&A when I have a problem or question I am trying to resolve. The Q&A is really helpful. Carla and others (Gustav and Christian are two examples) respond quickly and with insightful answers. Often, I get a code example that helps me learn even if I don't solve my problem. I have found super interesting Sounds in the Community Library, such that I began posting some of my work here too. I think it's good policy to be open source in a Community like Kyma. You learn more by sharing, and we grow as a group.[286]

As Bellona's statement demonstrates, the Kyma community shares traits with communities of proprietary languages and the ethos of open source languages. Users share resources with each other and Scaletti and Hebel incorporate user feedback by making regular updates to Kyma, posting new Sounds online, and notably, they commonly respond to user emails and forum posts with custom Kyma Sounds to suite the user's particular needs.

The Kyma community has something of a top-down structure due to several factors including the small size of SSC, and Scaletti and Hebel's active involvement in technical support and encouraging the growth of the user community. As a result, in my study Scaletti and Hebel take a central role as an active force in the formation of the community. In this chapter I hope to show that the active participation and leadership of Kyma users played just as important a function in this process as Scaletti and Hebel's dominant role. The community's hierarchy, with Scaletti and Hebel on top, was especially apparent in the early years of Kyma's development, yet over time this structure evolved as the user community developed more autonomy. The Kyma user base is rather egalitarian, however there is also some differentiation

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[286] Jon Bellona, Kyma User Survey, September 16, 2018.

among users due to several factors including: how long they have used Kyma; how active they are on online forums; and their active role in KISS or other in-person gatherings. Kyma users gain notoriety and recognition by actively answering people's questions and engaging online, or by creating their own Kyma resources such as NeverEngine Labs packages of pre-made Kyma Sounds, the Delora Software KymaConnect app, or Timothy McGuinness's Youtube tutorials.

Shelemay and ethnomusicologist Thomas Turino cite the presence of a charismatic leader as a significant element in the formation of community. This is a factor that cannot be underestimated in the formation of the Kyma community. Scaletti can be characterized according to Turino's statement: "charismatic individuals have the ability to make the people they interact with feel special about themselves and feel an intimate connection."[287] Scaletti and Hebel are commonly a user's first point of contact and they make themselves highly available to users. Longtime Kyma user Pete Johnson explained, that when corresponding with SSC, "Carla always made you feel like you were [SSC's] only customer."[288] This kind of sentiment developed during the close communication that is often necessary to get a Kyma system functioning and through continuing customer support over the phone or email. User correspondence with SSC often strays from topics strictly related to Kyma or music; some users divulge very personal information, including the status of personal relationships or updates about work and family. Throughout my research I experienced this first hand, Scaletti in particular is skilled at putting people at ease,

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[287] Thomas Turino, *Music as Social Life: The Politics of Participation* (Chicago: The University of Chicago Press, 2008), 64
[288] Pete Johnston, Facebook Message to Heying, July 31, 2018.

she asks thoughtful questions that sometimes delve into the personal, and always responds in a caring manner. Many users form close bonds and friendships with Scaletti and Hebel through this kind of correspondence. This closeness is not without complications. Users sometimes feel their divulgences are one sided and not reciprocated by Scaletti and Hebel.

The Kyma Community Online

For Scaletti and Hebel, fostering the Kyma community is inherently connected to technical support and pedagogy. Beyond the belief in the benefits of collaboration for developing new technology, Scaletti and Hebel also believed that working in groups could be a vital resource in learning said technology. Scaletti and Hebel actively sought out new communication technology to help users foster connections among themselves in the process of learning or trouble-shooting in Kyma. By the late 1980s, they recognized that the internet would become a part of people's everyday lives and they began employing online communication technology to support Kyma users and grow the user community.

Scaletti and Hebel started SSC on the cusp of Web 2.0, when the internet and smart technology began entering people daily lives. At the outset, most of SSC's technical support occurred over the telephone. They had an 800 number for fielding phone calls regarding sales and technical support. They also had a fax machine that enabled SSC and users to fax visuals and handwritten notes over the telephone lines. SSC kept meticulous hand-written call logs in spiral notebooks, where they recorded the caller, date, time, caller's phone number, subject of the call, and follow-up

actions. As was mentioned previously, some Kyma users called every day or multiple times a week, and for some the telephone is still their primary mode of communication with SSC.

Scaletti and Hebel's use of new technology was a classic scenario of trial and error. In many cases it was difficult for the new mode of communication to catch, on as Scaletti detailed in an email:

> We already had a community called the CERL Sound Group. We knew from our experiences with PLATO what an online community could be. We bought disk space from CERL and started a Kyma Notes file and tried to get people to dial in to Champaign. Not a single person took us up on that. Next we tried a "new thing" called Apple Mail. The only person who took us up on that was John Paul Jones. But you had to pay by the email, so that was a little inhibiting. Concurrent with that we tried the PAN network. That was another experiment at making a music list/bulletin board kind of thing. The culture of that one was not quite right. There was someone on there from Blue Oyster Cult that everyone was fawning over all the time. So again it never took off for Kyma users. So in a way, I felt like we kept trying to get people to realize how useful a Kyma community could be. And technology and culture finally caught up to that idea.[289]

This statement demonstrates that the adoption of new technology and formation of a community was not a seamless process, one that it is still ongoing as means of communication and technology continue to change. Scaletti's statement also suggests how various internet platforms provide certain affordances yet also come with some limitations.[290] According to sociologists Panayiotis Zaphiris and Chee Siang Ang:

> An affordance of a thing refers not only to the properties of the thing that allow it to be used in certain ways, but also to perceived properties of a thing….Telecommunication technologies afford synchronous and asynchronous interaction among multiple users. Computer conferencing and the internet afford the design of social computing environments that support

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[289] Scaletti, email to Heying, October 21, 2016.
[290] Zaphiris and Ang, *Social Computing and Virtual Communities*, 8–9.

> the development of communities of inquiry, collaboration, negotiation and problem solving within authentic contexts."[291]

For Kyma users to adopt an online platform, they had to find it beneficial through the ways it afforded new means of technical support and connection with other users.

In the following section, I discuss various Computer-mediated Communication (CMC) platforms employed by Kyma users. The Kyma community only briefly used some CMCs, so the focus is on the platforms that were used for long periods of time, once "technology and culture caught up" to each other. The most interactive are bulletin board-style (BBS) platforms including forums and social media applications such as Facebook and Twitter. I also discuss the Kyma community's use of email, Symbolic Sound's website, and SSC's blog and online newsletter, both called the *Eight Nerve*.

Forums and Bulletin Boards

The Bulletin Board System (BBS) and forum format were central platforms on ARPAnet and the early internet from the 1950s through the early 1990s. The influence of BBSs is clear on sites like Facebook, Youtube, StackOverfow, Tumblr, and other more sophisticated public platforms where users post information for other users to see, comment on, and repost.[292] For decades, forums and BBSs have been the site of community formation as well as online ethnography. Even today most online ethnographies still utilize forums as a primary field site.[293] Forums often become a

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[291] Ibid., 8.
[292] A BBS consists of topic pages where users post about said topic and engage in discussions through commenting and message threading functions.
[293] Examples include Kelty, Rheingold, Pinch, Lysloff, and Wellman.

"third space," where users go off topic to share friendly greetings and digress into personal conversations.[294] On all of the BBS-style platforms, whether a discussion thrives or not is often the result of several key users who set the tone and keep the conversation going. As will become clear, Scaletti and Hebel moderate all of SSC's official BBS platforms, however, in order for community to flourish, Kyma users needed to take up the leadership mantle by facilitating discussions, answering user queries, and welcoming new users. This process often happened rather organically and the same users tend to function in this leadership role across platforms.

In this study I highlight the moments of connection and interaction that indicate when a given platform becomes a "third space," demonstrating how interactions in online platforms contribute to a sense of community. In 2015, SSC launched a new website. Although the resources and forums on their old website are still available, users were encouraged to use the forums available through the updated website. Comparing user data from the old and newer forums provides a case study in how the format and design of a platform has a significant influence on how people communicate. More importantly, however, it suggests how patterns in use and interaction have changed over time.

The following study of the Kyma community online is based on analysis of user communication on the Kyma.5 forum (2000–2019), The Kyma 7 Forum (2015–present), the Kyma Q & A (2015–present), official and unofficial Kyma Facebook groups, and Kyma Community Sound Libraries (1997–present). I compared numerical and textual data within each platform as well as across platforms to

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[294] Term coined by Ray Oldenburg. Rheingold, *Virtual Community*, 10.

understand the mechanisms and patterns of communication at work. I performed textual analysis on over 1000 posts and qualitative analysis on small samples (approximately fifty posts) from each platform to assess the amount of user-to-user communication. Additionally, I used these online platforms myself to engage with users and understand how each platform works. Appendix Two contains statistics about user activity on the online Kyma platforms.

SSC and Early BBS Platforms

In 1991, as SSC began to sell and market Kyma, they established a BBS-style page on NovaNet, a networked education service that existed in various guises from 1960–2016. CERL employees including Lippold Haken contributed to NovaNet's development using the PLATO computer system. SSC made NovaNet available to registered Kyma users, who were able to access it for free for one year. Once CERL closed and SSC became more independent, they moved beyond the Champaign-Urbana community for their online resources. As Scaletti mentioned in the quote above, in 1994, SSC set up a Bulletin Board on the PAN (Performing Arts Network), a network with online services specifically for people in the music industry. PAN included BBS-style platforms where Kyma users could upload and download Sound files and post on discussion pages, however it also offered other services including e-mail, fax service, file sharing, and online storage. PAN was available internationally, although it did require a service fee—$3.60/hour and $15/month—that was common

of BBS platforms at the time.[295] As Scaletti mentioned above, this service was not offered for long because Kyma users did not find it suited their needs, and many of these resources were incorporated into SSC's website within a few years. In this case, the expense to access the network likely played a major role in its lack of acceptance by Kyma users. By the early 2000s, when SSC created the Kyma.5 forum, there was much broader cultural acceptance and understanding of CMCs and their usefulness as a tool for technical support and online socializing.

Kyma Q & A

In 2019, the Kyma Q & A is by far most popular BBS-style platform for Kyma users. The Q & A is accessed through the Kyma Help menu or SSC's website. The style of the Q & A is similar to Stack Overflow. User questions are displayed with three columns to the left, labeled: "votes," "answers," and "views." This lets users quickly assess how popular the question is. The more votes a question gets the higher it moves to the top of the page. Below each question is a subject category tag that indicates such topics as "coding," "interfaces," "general" issues, or "sound design." There are also searchable keyword tabs under each question, which further facilitate users' ability to explore existing questions and answers. In part because of the ability to search the Q & A, in addition to the storage of all previous posts, it is not uncommon for users to comment or ask a follow up question on a post months after the original post date. Some conversations can last for months or even years. The Kyma Q & A is password-protected. The general public can read questions,

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[295] Scaletti and Kurt Hebel, "sound files on PAN," *The Eighth Nerve: The Official Organ of the Symbolic Sound Corporation.* 3:1 (Winter 1994): 1.

answers and comments, but only registered Kyma users can add content to the site. According to Scaletti, this prevents trolling and prioritizes the needs of Kyma users.

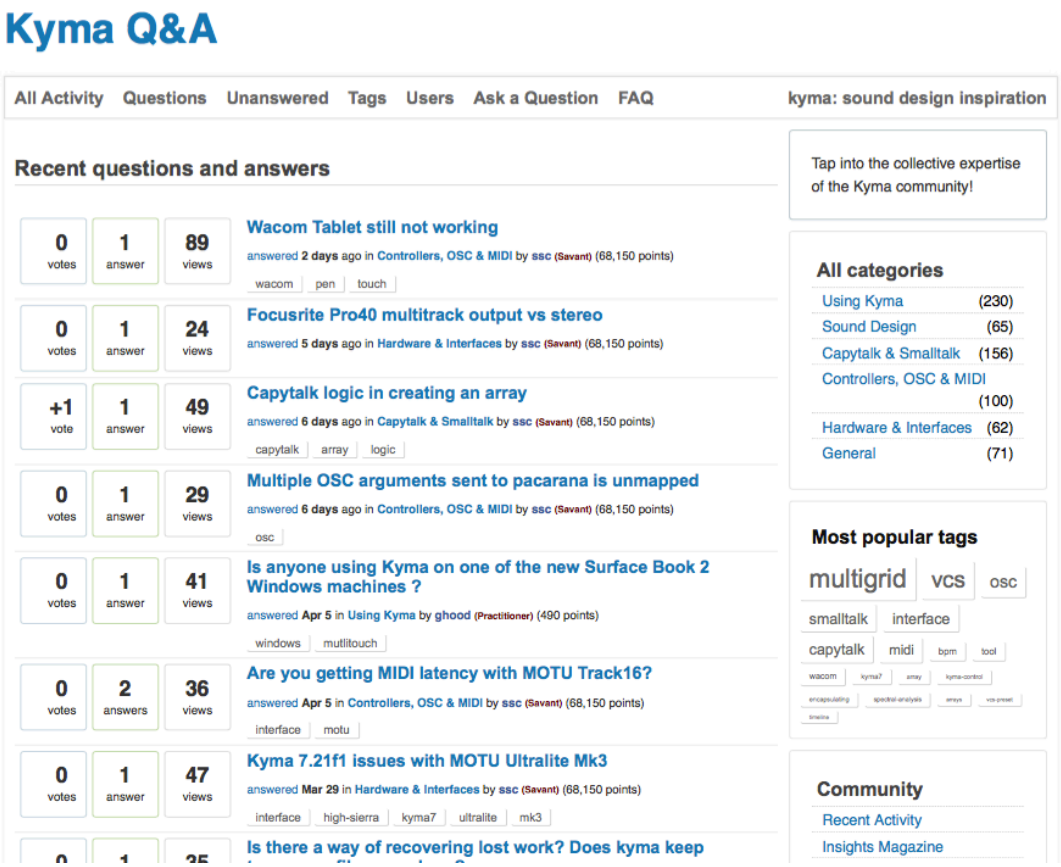

Figure 3.1: Screenshot of Kyma Q & A, April 13, 2018

The average user on the Kyma Q & A posts an occasional question, approximately once every few months or more frequently in bursts as they are working on a project. They also make occasional comments on posts relevant to their work, or to add a friendly greeting or joke to a comment thread. Key users, who tend to set the tone for the platform, actively answer and comment on users posts and tend to post many questions of their own. Key users also help establish the norms on a platform, which include direct user-to-user contact, and avoiding negative and critical language about Kyma in favor of more constructive comments. Norms also include

addressing posts directly to SSC or "The Kyma Community," formatting posts like a letter, using emojis and emoticons to avoid misreading of sarcastic or playful text. Key users often include Kyma Sounds and screenshots when answering questions, which can be invaluable for troubleshooting and solving issues. They are also agents of group bonding. They tend to be friendly and make people feel welcome, and through their regular contributions give each platform an air of familiarity. Some key users include Roland Kuit, Alan Jackson, Christian Schloesser, Delora Software, Charlie Norton, Christian Vogel, Gustav Scholda, and Anne La Berge. Jackson, who began using Kyma several years ago, made the conscious decision to post as many questions as possible to the Kyma Q & A to contribute to its content and help make the Q & A a valuable resource for other users. Most key users are extremely active across *all* Kyma platforms. SSC also plays a leadership role: they post an answer or comment on virtually every question on the Q & A. For reference, SSC posts about seven times more than the *most* active Kyma user.

Although the key users play a crucial role in perpetuating online activity, all levels of use, including the occasional poster, are necessary to make Q & A and other platforms function. It is also important to note that in the case of several of the top posters they may have ulterior motives beyond the benevolence of helping other users; they run businesses that sell Kyma Sounds or apps to use with Kyma. However, this personal benefit does not diminish their contributions to the Kyma community. They are knowledgeable and other users value their work and enjoy conversing with them online and in person. Their business activities can be considered as part of the Kyma ecosystem.

The most popular Q & A topic is "Using Kyma," where questions are typically about how a specific Kyma Sound works or how to accomplish a specific task. For example, user Anne La Berge asked:

> I have made a drone with 35 presets. Each time I trigger the drone to turn on I would like it to choose one of the 35 presets. I would also like to set the range of which presets to select 1-15-35, for example. Where shall I put this random choice control for the presets in my sound?[296]

Here La Berge seeks advice about where in her Sound's signal flow to insert an automated control. She included a hyperlink so users or SSC could download her Sound to assess the issue—this also serves the dual purpose that another user could download her Sound to use in the future. Due to the specificity of the question, La Berge received a very detailed and specific answer from SSC.

In addition to questions about Kyma Sounds, users also ask questions about sequencers and Sound control interfaces including the Virtual Control Service (VCS), the Multigrid, and the Timeline. Below is an example of an entire Q&A about the Multigrid from user Paul:

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[296] Anne La Berge, "Next Random Preset," *Kyma Q & A*, posted May 6, 2017, accessed July 16, 2018.

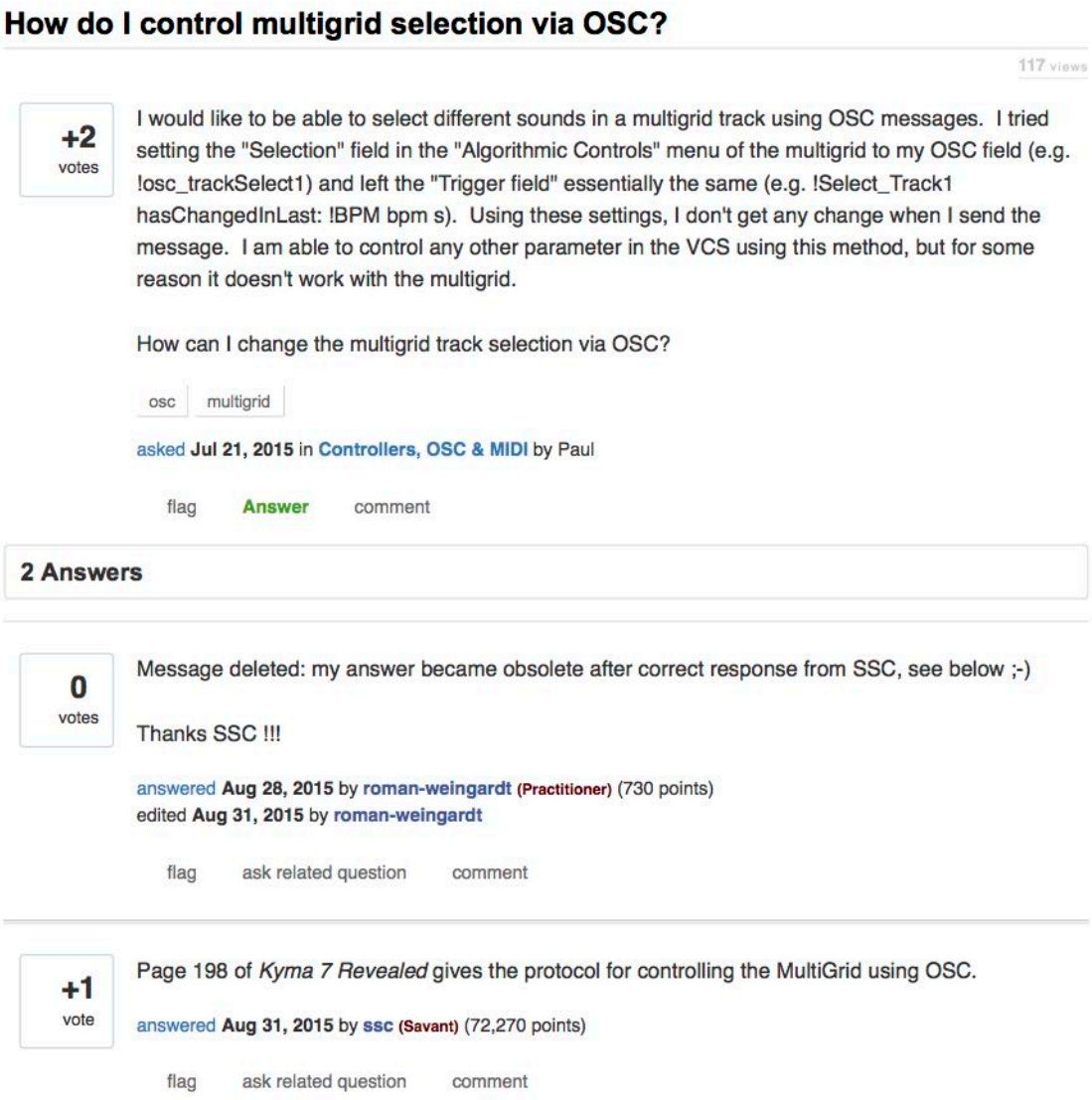

Figure 3.2: Screenshot, "How do I control multigrid selection," *Kyma Q & A*[297]

This exchange demonstrates a common interaction between users and SSC where a user provides an answer that is amended or gently corrected by SSC. In this case and numerous others, when a user answers the question they post it as a "comment" rather than an "answer," which suggests a perceived lack of authority or modesty. Users sometimes start their answer with a response along the lines of Alan Jackson's:

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[297] Paul, roman-weingardt, and SSC, "How do I control multigrid selection via OSC?," *Kyma Q & A,* posts made from July 21–August 31, 2015, accessed July 16, 2018.

"SCC's answer is probably the best way of doing what I was trying to do. But I still wanted to know [if this would work]."[298] Responses like Jackson's function to both recognize SSC's authoritative role and to motivate other users to answer questions in spite of any feelings of inexpertness. Most users appear to appreciate SSC's input (and input from other users as well) as is demonstrated with positive and encouraging comments upon receipt of advice or suggestions. Common examples include simply saying, "Thanks!," "Thanks for the example!," "That works great!" This positive feedback along with the large volume of user-provided solutions (even in the form of a comment) suggest that many users are not deterred from contributing to the discussions that emerge. Further, the plethora of comments, multiple answers with different solutions to a user's issue demonstrates that in Kyma there are often several possible solutions to a problem.

Questions and answers posted on the Kyma Q&A become a part of a voting and points system designed to promote answers that are "accurate and useful."[299] Users accumulate points each time they post content on the site, which encourages friendly competition. They move through different ranks as they gain more points from practitioner to adept, master, and finally savant. SSC has tens of thousands more points than the highest scoring user, which subtly defeats the purpose of the point system (at least in terms of community, but not in terms of technical support). Rating answers also potentially curtails informal or conversational interactions on the Q &

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[298] alan-jackson, "Is it possible to add increment and decrement buttons to a fader?," *Capytalk & Smalltalk*, *Kyma Q & A*, posted July 5, 2016, accessed July 16, 2018.
[299] Symbolic Sound Corporation, "Q & A FAQ," https://kyma.symbolicsound.com/qa/faq, accessed July 16, 2018.

A. In spite of any interference, users tend to get around the platforms organization by starting conversations in threads of comments.

Kyma.5 Forum

The Kyma.5 Forum was the primary BBS platform for Kyma users from 2000–2015. It is still active, however most users have migrated to using the Kyma Q & A or the Kyma 7 Forum. The Kyma.5 Forum is similar to Q&A, however it has a looser structure that allows for many different kinds of posts beyond questions or answers. On the Kyma.5 Forum, topics for discussion include “Announcements,” “Upcomming Events,” “Tips & Techniques,” “Kyma Sound Exchange,” “Kyma Support,” and “Confabulation.” Users post sub-topics for discussion under each of these main subjects.

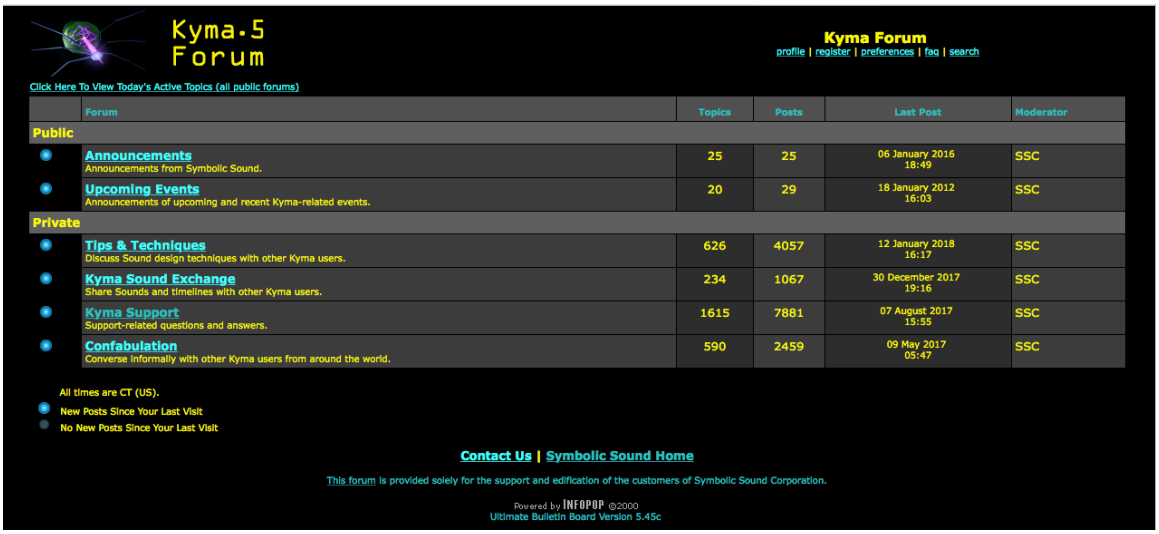

Figure 3.3: Screenshot of Kyma.5 Forum, "Main Page," April 30, 2018

The closest topics to the Q & A are “Tips and Techniques” and “Kyma Support,” which are also the most popular topic on the Kyma.5 forum. User behavior varies between the two topics. The Tips and Techniques page is characterized by more user-to-user interaction, whereas on the Kyma Support page, most users are in

direct contact with SSC. Compared with Q & A, on the Forums there is more interaction in general, both among users and between users and SSC.

As the title of the page suggests, Kyma Support operates as a platform for technical support and customer service. Conversations between users and SSC often emerge with other users chiming in. Like the Q&A, one of the benefits of using the Kyma.5 Forum for technical support is that it is searchable. When other users encounter an issue with Kyma, they can check the forum to see if someone else has posted about a similar issue and fix it on their own. The ability to comment on old posts also contributes to discussion threads that last months and even years as users add comments about their experiences to other user's original posts. It is also common for users to post issues that are specific to their particular system; in such instances SSC often encourages them to go off the forum to handle the problem directly over email. For instance, user Francois Vacherot, posted on the Kyma Support (Kyma.5 forum) on January 16, 2016 complaining that the noise from the fans on his Pacarana were getting louder and to ask if he could exchange them. SSC responded several hours later, explaining that newer models of the Pacarana have quieter fans, and suggested that he contact SSC by email to figure out the cost of repair or replacement.[300] Another reason for this direct contact is that sometimes the issues are the result of a bug in the software that only SSC can fix; this is especially true after a software update.

On Tips & Techniques user interactions are quite different than on the Q & A and the Kyma Support page. There is much more direct user-to-user contact. This was

[300] Francois Vacherot and SSC on Kyma Support, Kyma.5 forum, accessed April 30, 2018.

the case from establishment of the Forum in 2000. On Kyma Support, SSC was the dominant poster from the outset, while on Tips & Techniques, Pete Johnston and other key users took an active role right away. On Tips & Techniques it is much more common for users to actively comment on each other's posts. SSC comments, but much less frequently than on the Kyma Support page.

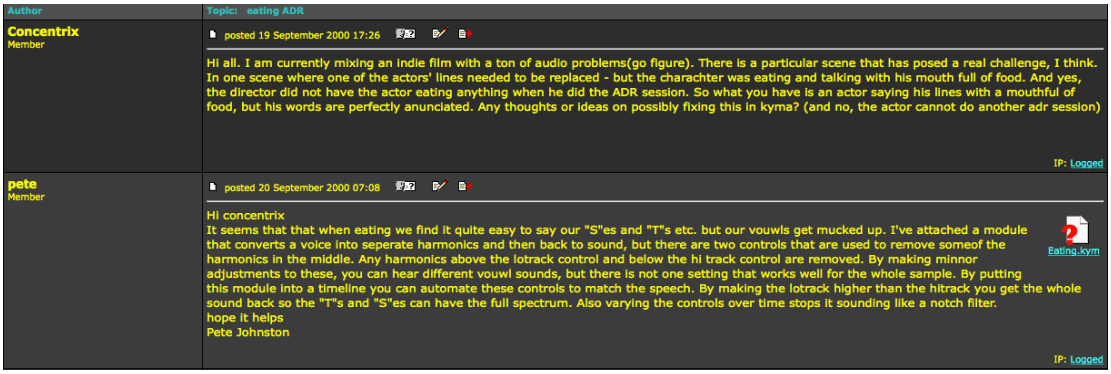

Figure 3.4: Kyma.5 Forum, "Tips & Techniques," September 2000, accessed April 30, 2018

As on the other forums and Q & A, active commenting often diverges into informal more personal forms of conversations, however it is much more frequent on Tips & Techniques than on other topics and platforms. The above thread continues:

> You have my sympathies
> I have also suffered at the hands of directors who plainly don't have a *** clue about the difficulties of post production - what a prat!
>
> Garreth[301]

By commiserating over the shared experience of doing sound design under a difficult director, Gareth makes Concentrix feel welcome and opens the conversation for other users to share advice about working in the film industry, a topic unrelated to Kyma use. Concentrix continues the conversation:

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[301] Garreth Whitock, on Tips & Techniques, Kyma.5 Forum, posted September 20, 2000, Accessed July 15, 2018.

> Not to change the subject too much, but I was wondering if anyone else has experienced working with a director that - when you call him to ask a simple yes/no question - he takes about 45 minutes to an hour explaining the yes or no answer...while you could have been working on his film. Sheesh[302]

This conversation is a great example of the kind of pivots and tangents that occur on the forums and also demonstrate the kinds of informal greetings and jokes that are common.

The following example demonstrates how seasoned users tend to welcome newcomers to a platform:

> Hello Polypx
> Welcome to the Kyma Community!
>
> Do not worry if the questions you encounter seem too obvious, always post them as it serves a great purpose: I had not encountered the MultitoMultiChannel prototype before!! There are also sometimes a few techniques to achieve the same ends, it is great to read about the various implementations people conjure up. If you find workflow areas you think can be improved, such as the interleaved file formats, login and browse/edit the wish! http://www.symbolicsound.com/cgi-bin/bin/view/Wish/WebHome
>
> Have fun,
>
> Charlie[303]

Throughout forums and Q & A Charlie Norton in particular wrote notes like this to welcome new users, demonstrating importance of "key" users in the development of the forums as a "third space."

As on the Q & A, users regularly address posts and questions directly to SSC, and to a lesser extent, the Kyma Community. A post might start with the phrase: "Hi I have already emailed SSC about this but I would still like some user feedback on

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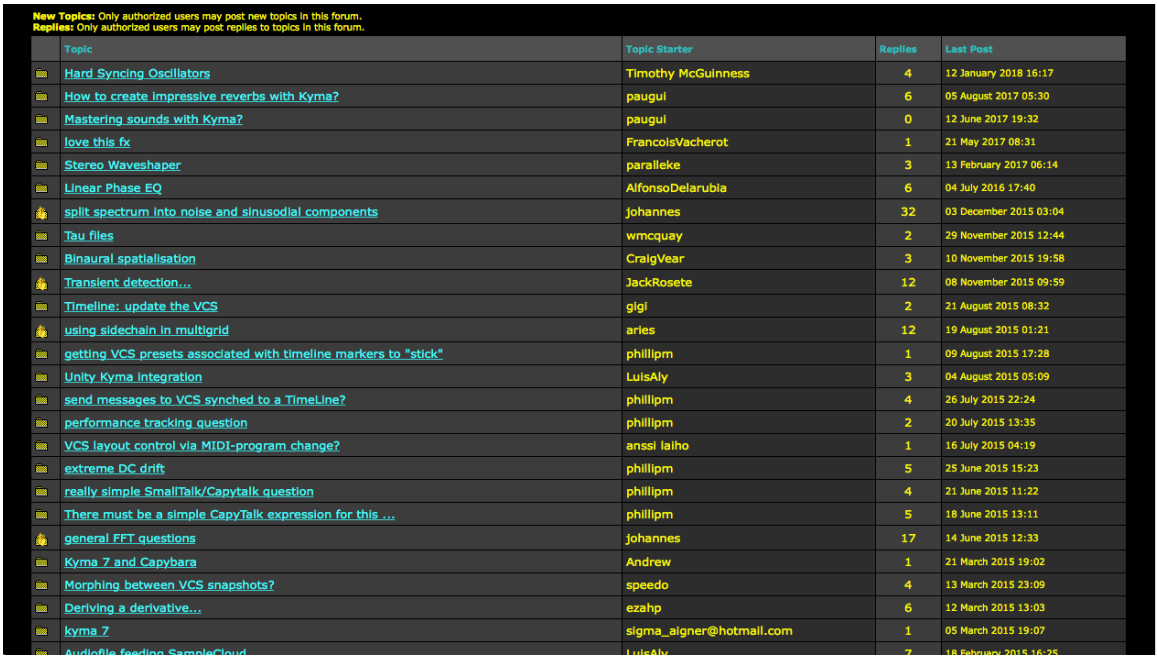
[302] Concentrix, on Tips & Techniques, Kyma.5 Forum, posted September 20, 2000, Accessed July 15, 2018.
[303] Charlie Norton, Kyma Support on Kyma.5 Forum. April 14, 2014.

in."[304] Norton's post demonstrates the cordiality many users employ on Kyma forums. User conversations are typically characterized by empathy and understanding mixed with a sense of play and humor. These friendly moments indicate community, where the conversation goes beyond users sharing information as a utility to the building blocks of more meaningful relationships.



New Topics: Only authorized users may post new topics in this forum.
Replies: Only authorized users may post replies to topics in this forum.

Topic	Topic Starter	Replies	Last Post
Hard Syncing Oscillators	Timothy McGuinness	4	12 January 2018 16:17
How to create impressive reverbs with Kyma?	paugui	6	05 August 2017 05:30
Mastering sounds with Kyma?	paugui	0	12 June 2017 19:32
love this fx	FrancoisVacherot	1	21 May 2017 08:31
Stereo Waveshaper	paralleke	3	13 February 2017 06:14
Linear Phase EQ	AlfonsoDelarubia	6	04 July 2016 17:40
split spectrum into noise and sinusodial components	johannes	32	03 December 2015 03:04
Tau files	wmcquay	2	29 November 2015 12:44
Binaural spatialisation	CraigVear	3	10 November 2015 19:58
Transient detection...	JackRosete	12	08 November 2015 09:59
Timeline: update the VCS	gigi	2	21 August 2015 08:32
using sidechain in multigrid	aries	12	19 August 2015 01:21
getting VCS presets associated with timeline markers to "stick"	phillipm	1	09 August 2015 17:28
Unity Kyma integration	LuisAly	3	04 August 2015 05:09
send messages to VCS synched to a TimeLine?	phillipm	4	26 July 2015 22:24
performance tracking question	phillipm	2	20 July 2015 13:35
VCS layout control via MIDI-program change?	anssi laiho	1	16 July 2015 04:19
extreme DC drift	phillipm	5	25 June 2015 15:23
really simple SmallTalk/Capytalk question	phillipm	4	21 June 2015 11:22
There must be a simple CapyTalk expression for this ...	phillipm	5	18 June 2015 13:11
general FFT questions	johannes	17	14 June 2015 12:33
Kyma 7 and Capybara	Andrew	1	21 March 2015 19:02
Morphing between VCS snapshots?	speedo	4	13 March 2015 23:09
Deriving a derivative...	ezahp	6	12 March 2015 13:03
kyma 7	sigma_aigner@hotmail.com	1	05 March 2015 19:07
Audiofile feeding SampleCloud	LuisAly	7	18 February 2015 16:25

Figure 3.5: Screenshot of Kyma.5 Forum, "Tips & Techniques," April 30, 2018

One key difference between the Kyma.5 Forum and Q & A is that this forum is not set up for questions and answers. On a given forum, many different kinds of posts appear next to each other, ranging from posting an elegant formulation of a specific synthesis technique, asking for a solution to a problem, to opinions about new updates, or tricks for how to achieve certain kinds of sounds. On the Q & A, providing an answer to another users question might be intimidating, whereas on the Kyma.5 forum data suggests that users were less reticent to comment, offering a

[304] Tazio Schiesari, "Saffire Pro not showing up," Kyma Support on Kyma.5 Forum, 1.21.2015.

partial insight, affirming the value of such a question or problem, or brainstorming a potential solution. Another reason might be that interacting on the Kyma.5 Forum allowed users to display their knowledge and virtuosity with the system in a different way.

Kyma 7 Forum

On SSC's current website, the Kyma 7 Forum continues where the Kyma.5 forum ended in 2015. The Kyma 7 Forum includes similar main topics: "Announcements," "Tips & Techniques," and "Confabulation," however there is no Kyma Support page since users are encouraged to use the Kyma Q & A for technical support. Like the other BBS platforms, the public can read the Kyma 7 Forum, but one must be logged in to join the discussion or post a topic. In general, it is more informal, and off-topic discussions happen on the Kyma 7 forum more often than on the Kyma Q & A or the Kyma.5 Forum.

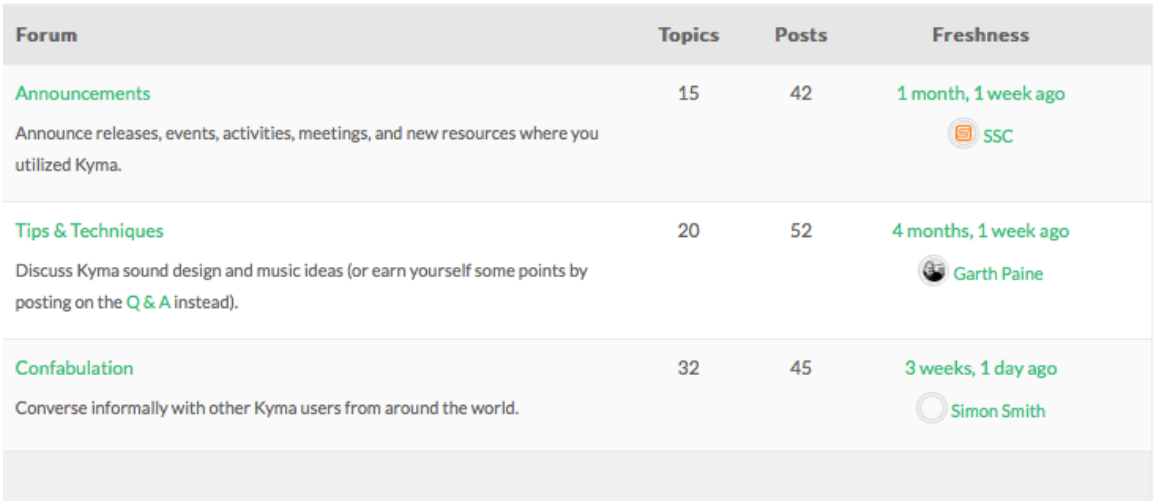


Figure 3.6: Screenshot of Kyma 7 Forum main page, April 30, 2018

An example of a post from the "Tips & Techniques" by user Jeffery Hinton: "Anyone doing ambisonic work with Kyma?"[305] Here Hinton sees the community as a resource to get advice regarding using Kyma with a recent development in recording and spatializing audio. Since the Kyma community is made up of people in the industry and academia, asking this kind of question is bound to get insightful feedback from audio experts or interested hobbyists that pertain to a variety of circumstances in which someone might want to pursue the use of ambisonics or some other specialized technique.

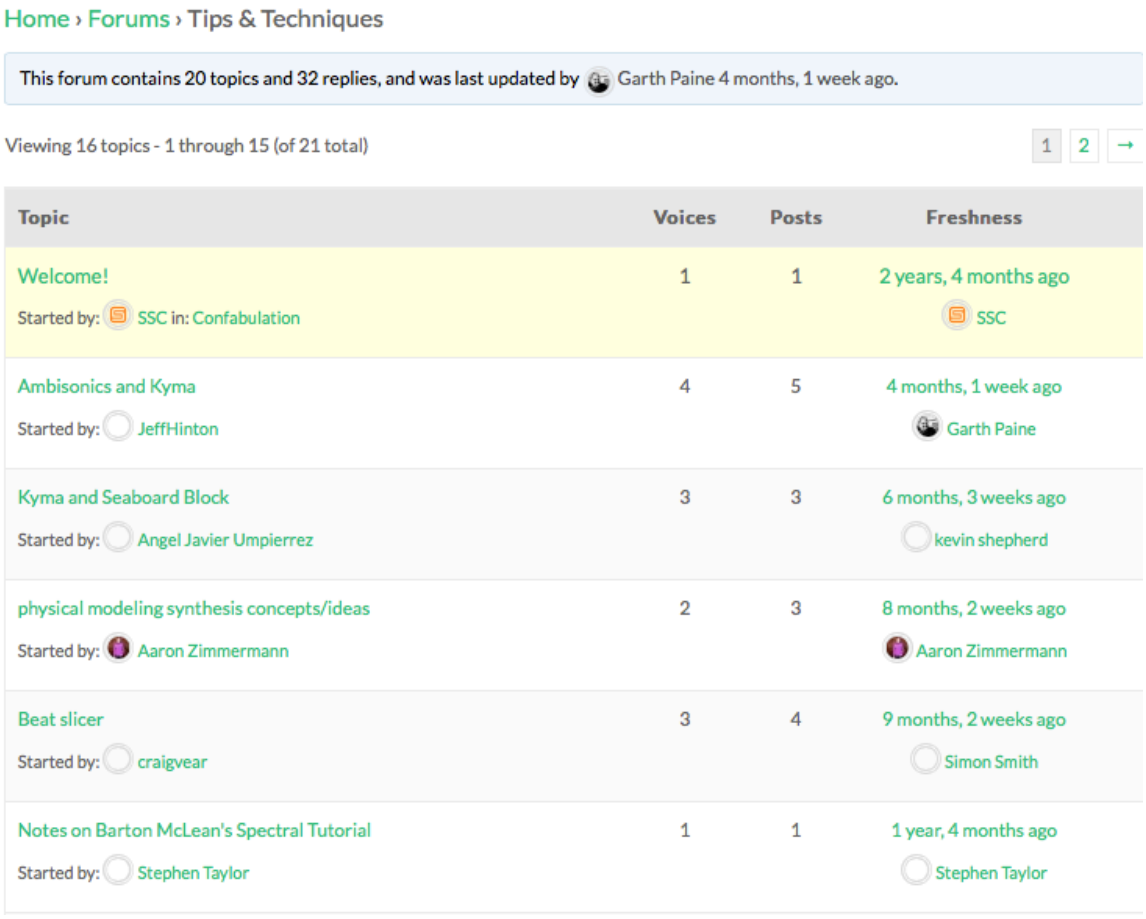


Figure 3.7: Screenshot of Kyma 7 Forum, "Tips & Techniques," April 30, 2018

[305] Jeff Hinton, "Ambisonics and Kyma" in Tips and Techniques, March 9, 2017.

An example of forum posts of a more personal nature include this one from Robert Efroymson after he received news of an explosion in Leicester, UK, the site of the previous year's KISS. He writes: "I saw on the news that there had been a major explosion in Leicester, and I wanted to send prayers to all of the fine people from there who helped out at Kiss 2016. It was a terrific conference, and I hope everyone is safe."[306] Efroymson's post demonstrates how users move beyond using the forums strictly for technical support to maintain their personal connections to the community and its members.

Kyma Community Sound Library

The Kyma Community Sound Library is a code repository where users can upload their custom-made sounds for other users to view and download. The Sound Library is accessed through SSC's website and it contains hundreds of Kyma Sounds. Each is labeled with descriptions of what they do, download format, a rating (1–5 stars) given by other users, and information regarding who posted the sound, when, and how many times it has been downloaded. Users can also share control frameworks like the Multigrid, as well as sample and sound analysis files. Like the older Kyma forums versus the new Kyma Q & A, there are new and old versions of the Sound Library that correspond to the old and updated SSC websites. On SSC's current website the Kyma Community Sound Library contains 81 sounds. However, users can still access the Sound library on SSC's older website, which contains hundreds of Kyma Sounds.

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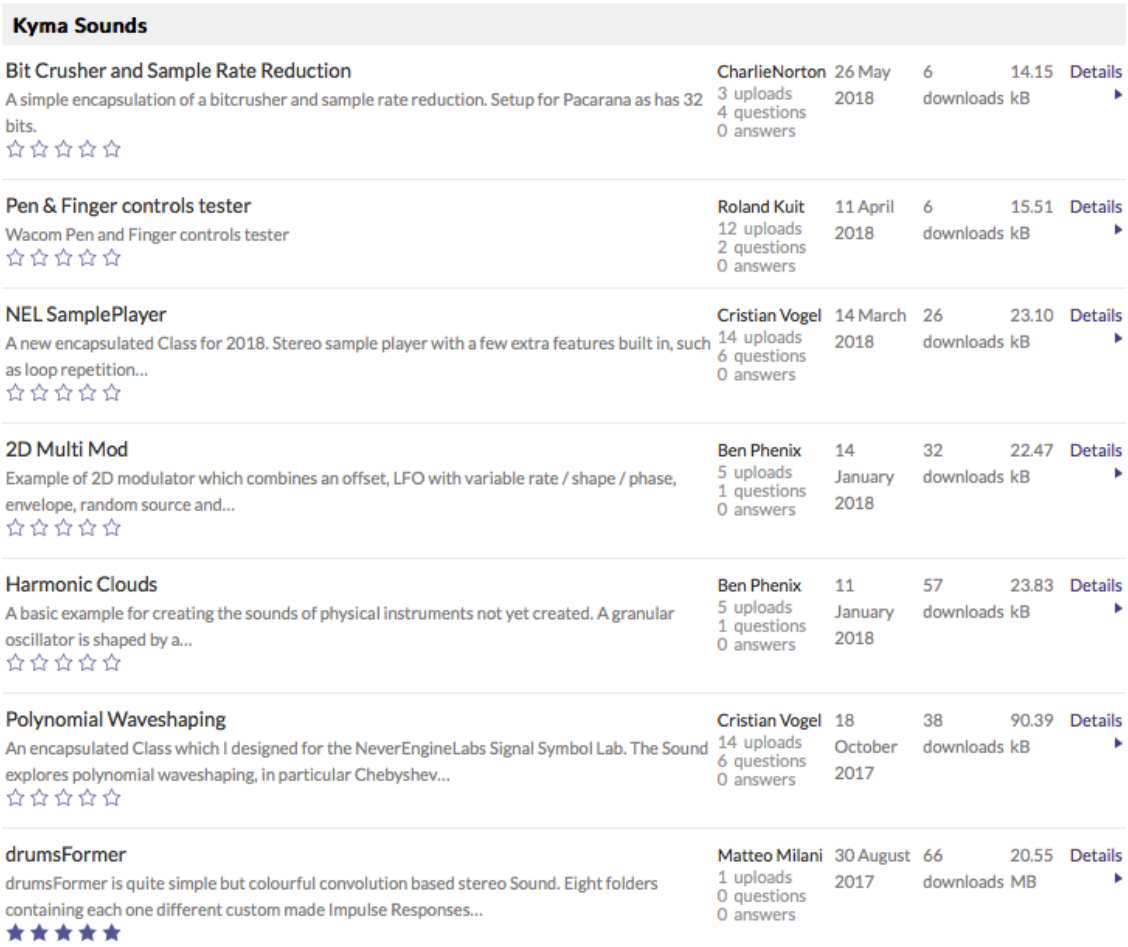
[306] Robert Efroymson, "Hope everyone is ok in Leicester" in Confabulation, February 25, 2018.

Kyma Community Sound Library is one indicator of the culture of sharing amongst Kyma users. They are rarely territorial about the algorithms and Sounds they develop in Kyma, rather the tendency seems to be just the opposite: Kyma users want to share the advancements and tools they make in Kyma with other users. By sharing Sounds that result from the progress they make in Kyma, many users recognize that they benefit from looking at and adapting other user's Sounds, and that they can help others along in the process of learning Kyma in return.



Kyma Sounds

Bit Crusher and Sample Rate Reduction A simple encapsulation of a bitcrusher and sample rate reduction. Setup for Pacarana as has 32 bits. ☆☆☆☆☆	CharlieNorton 3 uploads 4 questions 0 answers	26 May 2018	6 downloads	14.15 kB	Details
Pen & Finger controls tester Wacom Pen and Finger controls tester ☆☆☆☆☆	Roland Kuit 12 uploads 2 questions 0 answers	11 April 2018	6 downloads	15.51 kB	Details
NEL SamplePlayer A new encapsulated Class for 2018. Stereo sample player with a few extra features built in, such as loop repetition... ☆☆☆☆☆	Cristian Vogel 14 uploads 6 questions 0 answers	14 March 2018	26 downloads	23.10 kB	Details
2D Multi Mod Example of 2D modulator which combines an offset, LFO with variable rate / shape / phase, envelope, random source and... ☆☆☆☆☆	Ben Phenix 5 uploads 1 questions 0 answers	14 January 2018	32 downloads	22.47 kB	Details
Harmonic Clouds A basic example for creating the sounds of physical instruments not yet created. A granular oscillator is shaped by a... ☆☆☆☆☆	Ben Phenix 5 uploads 1 questions 0 answers	11 January 2018	57 downloads	23.83 kB	Details
Polynomial Waveshaping An encapsulated Class which I designed for the NeverEngineLabs Signal Symbol Lab. The Sound explores polynomial waveshaping, in particular Chebyshev... ☆☆☆☆☆	Cristian Vogel 14 uploads 6 questions 0 answers	18 October 2017	38 downloads	90.39 kB	Details
drumsFormer drumsFormer is quite simple but colourful convolution based stereo Sound. Eight folders containing each one different custom made Impulse Responses... ★★★★★	Matteo Milani 1 uploads 0 questions 0 answers	30 August 2017	66 downloads	20.55 MB	Details

Figure 3.8: Screenshot of Kyma Community Sound Library, "Kyma Sounds," July 9, 2018

Social Media - Facebook

The Facebook platform is basically an expansion of earlier BBS-style forums with more content and the opportunity for more interaction. Kyma users access three Kyma-related pages on Facebook: Kyma Sound Design Language, Kyma International Sound Symposium, and the Symbolic Sound Kyma (unofficial) group. As these titles suggest, the first two are the "official" pages run by SSC, while Kyma users run the unofficial group. The SSC pages are public and anyone on Facebook can assess them by "liking" or following the page, but Symbolic Sound Kyma (unofficial) is a group that is private and requires permission from one of the group's administrators to join.[307] In the unofficial group there is a lot more user-user interaction, whereas on the Kyma Sound Design Language page, the posts are predominantly made by SSC, often with updates about the software or Kyma users. Users frequently "like" SSC's posts and one or two users may comment or start discussions, but this is not as common as in the unofficial group.

Content on the SSC page includes updates about uses, announcements about software updates, tips about a particular synthesis technique, job listings, scientific articles, videos and pictures of capybaras. In many ways it is an extension of the *Eighth Nerve* newsletter. The content on the Symbolic Sound Kyma (unofficial) page includes questions about software or hardware, pictures and updates about user's pieces and other projects, notifications about selling or seeking hardware, jokes, and other more personal, trivial, fun posts such as Malcolm Braff's photo of his leather

[307] The unofficial page is run by the at least one of the people that own NeverEngine Labs, promotion for their business may be one of the motives for supporting the group.

Pacarana case, a photo of user Roland Kuit's quote on the Pacarana, or a gripe about someone's Pacarana in the shop.[308]

Conclusions regarding the Online Kyma Forums

The Q & A is now the dominant BBS-style platform provided by SSC. This change has occurred gradually since 2015, which interestingly coincided with the start of my research. When I first accessed the Q & A, it was useful, but significantly fewer users posted there compared to in 2019. The change occurred as users became more comfortable with the new platform and began using the Q & A after the soft closing of the Kyma.5 forums. Some users who were very active on the Kyma.5 Forum, like Brian Belet, are not active on the Kyma 7 Forum or the Q & A. Reasons for this may include disinterest in the newer platform, but it more likely has to do with their increased fluency with Kyma: they do not need as much help, so they are not as actively involved online. Mark Phillips's experience may also shed light on this phenomenon:

> I do use the Kyma 7 site and I used the Tweaky site, too…But I was probably more active on the *old* Kyma Forum. That may partially be because of the nature of the community, but also because I was *such* a novice in those days and needed a lot more help on an ongoing basis. Also, I tend to use Kyma in spurts of intense deadline-driven work and then lay off it entirely until the next project that involves electronic music.[309]

However, some longtime and even new users take on a mentoring or teaching role on the Q & A by answering many questions or adding insightful comment and encouraging comments on other user's posts. These users also tend to post questions

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[308] When Kyma starts up or shuts down it displays a quote, often by famous intellectuals, musicians, computer scientists, but also occasionally from Scaletti, Hebel, or a user.
[309] Mark Phillips, Kyma User Survey, September 16, 2018.

when the have them, which is useful because it demonstrates that no matter one's fluency or mastery of Kyma, there is always more to learn.

When comparing the forums and the Kyma Q & A, the forum fostered more user-user interaction, which is not necessarily to say that the forums were more egalitarian, but users had fewer restrictions and there was less of a distinction between kinds of posts. The difference in use suggests how each platform has certain affordances and limitations that impact how users interact on them.[310] Some key users do not use the Q & A, because "it doesn't have the simple, conversational, linear 'written on the back of a fag packet' type of feel."[311] Instead these users opt to engage more on discussion-based platforms like the Unofficial Kyma Facebook group. Now that the Kyma Q & A is more established, it is more common for discussion threads to occur on posts.

One of the striking features of these closed resources is the lack of trolling or bullying behavior, which is not often the case on more public platforms. For example, according to composer Kristin Erickson, the people on forums for other music programming languages such as Max/MSP were ruthless, competitive, and rude.[312] There was a competitive atmosphere of one-up-manship, and if someone asked a simple or beginner's question they were mocked and made to feel stupid. Electronic music historian Tara Rodgers suggests that Erickson's experience was not unique: "Online forums for knowledge-sharing in music production are routinely hostile places for women and queer participants, with cheap misogynistic comments a

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[311] Pete Johnston to Heying, Facebook Messager, July 31, 2018.
[312] Erickson specifically referred to her experiences in the early 2000s and explained that the atmosphere on Max/MSP forums has become much more cordial over the last few years.

predictable dimension of their discourse."[313] For Erickson, using the online platforms for Kyma users felt shockingly different.[314] On the Kyma forums, users are generous with each other in response to questions or comments; it is uncommon to witness outright condescension, let alone bullying. The friendly atmosphere on the online forums suggests something of the ethos of the community that developed over time by keeping online platforms closed to the public. As a relatively small community, many Kyma users are close in ways that are not possible in larger communities. When accessing online Kyma platforms, the other users one interacts with are likely to be other someone they have had a meaningful in-person or online interaction with in the past. Users do engage in friendly competition and occasionally exchanges contain a bit of tension over differences of opinion, yet even on the Unofficial Facebook page where there is more banter and joking there is no bullying or trolling.

The tone and norms on the forums were not established quickly. Particularly in the early years, norms were constructed through careful planning and implementation by SSC as well as thoughtful interactions by key users. Most of the online platforms are password protected in order to prevent "trolling" behavior. As discussed earlier, some are viewable to the public, but a username registered to a specific Kyma system and password is required to post. This insures that the content posted on platforms is relevant to Kyma users and prevents unaffiliated people from bullying users for sport. In the following statement Scaletti explains the decision to

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[313] Tara Rodgers, "Tinkering with Cultural Memory: Gender and the Politics of Synthesizer Historiography," *Feminist Media Histories*, Vol. 1 No. 4, (Fall 2015): 8.
[314] Kristin Erickson, interview with Heying, October 12, 2018.

make online platforms private and how they encouraged a respectful tone among users:

> On Kyma forums (and at KISS), we have tried to cultivate a professional, factual, and constructive atmosphere. In other words, we want those online resources to be useful sources of information and help… We had already had our fill of flame wars and the kind of berating or belittling answers people feel so free to make when they are anonymous. We had already experienced that and tried to discourage it in our online communities.[315]

SSC's "rule of thumb" no matter how personal or negative a user's post, is to "answer in a civil, factual manner and in a way that both acknowledges their frustration and tries to offer a reasonable way to address or solve the problem."[316] Scaletti and Hebel attempt to remove emotional or defensive content from their messages, which, in their experience diffuses the situation and puts the poster in the position to have a productive discussion and solve the problem.

When SSC first implemented the forums, they explained that some users were quite negative and mean. Scaletti also explained that a Kyma user stepped in and helped discourage the negative culture that began to develop:

> Unexpectedly, it was Pete [Johnston] who played a major role in turning that attitude around. When people saw it wasn't just SSC who was answering, but one of their peers [who] was patient enough to answer their questions and defend some of the decisions in Kyma, the overall tone of the forum started to improve. That's where Pete's signature phrase 'Hope this makes sense' first started appearing (some people still quote him on that). It's a shame he no longer participates in the forum, but the positive atmosphere has carried over into the Kyma 7 Q & A and Forum.[317]

The overall positive attitude of early user posts set the tone for how users continue to engage online and in person. When asked about the tone employed on the forums,

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[315] Scaletti, email to Heying, October 21, 2016.
[316] Scaletti, email to Heying, October 23, 2016
[317] Ibid.

Pete Johnston countered that he did not do much: "The helpful tone was already there as Carla and Kurt had already established it, and it was up to us to keep it that way." Johnston explained further that he valued and felt protective of the close, direct relationship SSC had with its customers:

> I was aware that Carla and Kurt were putting themselves on the line in talking directly to the customers and not being protected by layers of support personnel, product specialists and the like. I don't know any other company where you are allowed to talk to the creators and are actively encouraged to do so. In return for this privilege it was the user's job to not allow people who had a bad day to unjustifiably take their frustrations out on SSC and if we did have requests for desirable additions to Kyma we would do it in what I hoped was a positive way.[318]

Johnston's statement indicates the loyalty many Kyma users feel toward Kyma and SSC. Users feel responsible for maintaining the helpful and cordial atmosphere on online platforms and their contributions and self-monitoring are important mechanisms in the preservation of platform etiquette.

Website, Newsletter, and Blog

SSC was one of the first businesses to have a website, which they established in 1995 using a local information network called PrairieNet. It took several years for people to access the website and employ the resources provided on it. In fact, Scaletti joked that after they first published the website, SSC got many complaints: users were frustrated because they did not realize they had to click on icons to take them to the informative sub-pages of the site. In 2019, SSC's website is the primary platform for business as well as a hub for user support. On the website, people can purchase a Kyma systems, watch tutorials, and access forums.

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[318] Johnston, Facebook Message to Heying, July 31, 2018.

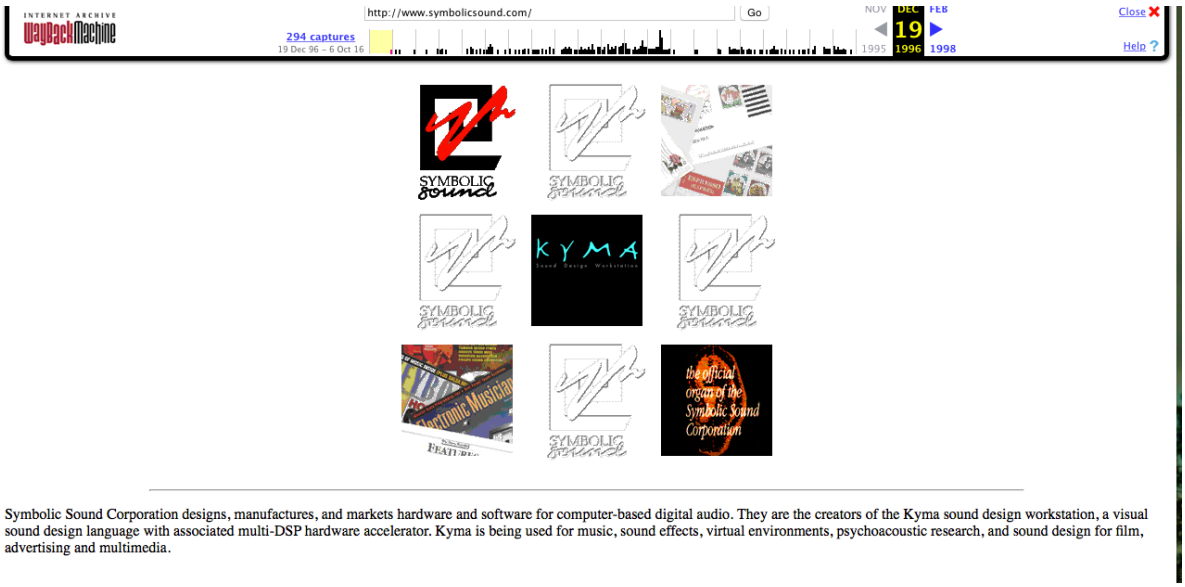


Figure 3.9: Screenshot of Symbolic Sound's Original Website , October 29, 2016

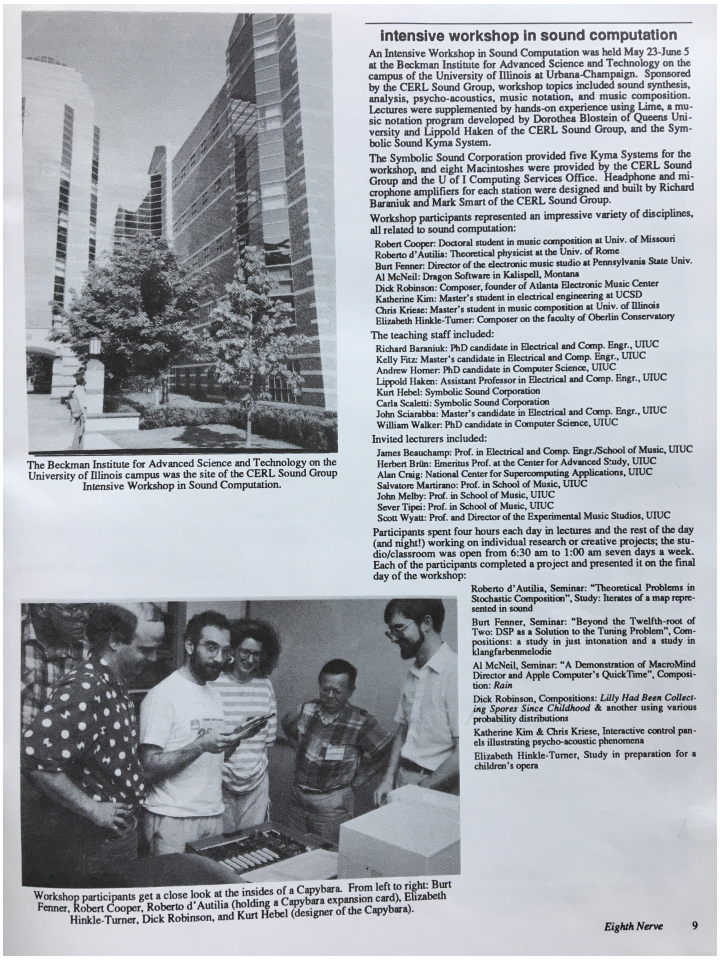
The Eighth Nerve

The *Eighth Nerve* is a newsletter, started by SSC in 1990. The first several years of issues were distributed annually in print. SSC initially intended to publish the *Eighth Nerve* quarterly, however they released it somewhat irregularly at first: vol.1 no. 1 Fall 1990, vol.1. no. 2 Summer 1991, then Spring 1992, Spring 1993, Winter 1994. By 1996 they released the newsletter online. While *The Eighth Nerve* was in print it functioned like SSC's current website, forums, and blog combined. Each edition of the *Eighth Nerve* contained announcements and updates about the system and users.[319] One element of the *Eighth Nerve* that promoted the sense of community among Kyma users was the inclusion of photos. SSC included photos of the Intensive courses and workshops they offered, and Kyma users they profiled. These photos

[319] For example, Volume one included sections titled: Welcome, Symbolic Sound, Kyma System, Music-N & Kyma, q & a, User profile, tutorials, products, feedback.

enabled users to visualize themselves as part of a group, which proved a powerful tool for the building and strengthening of the community as a whole.

The inclusion of user profiles and interviews also enabled Kyma users to envision themselves as part of a community by getting a sense of how other people used Kyma and their personal character. The first issue of the *Eighth Nerve*, which was released several months before Kyma became available to the public, contained a user profile of composer Mark Lentczner. SSC lent him a system so that he could write a review. The profile includes a photograph of Lentczner and an interview in which Scaletti, asked him about his interests, occupation, and the projects he was working on in Kyma. He was working on several projects including a live performance, a realization of Steve Reich's *Music for Pieces of Wood*, and a novel algorithm developed at CCRMA. They also asked him about how Kyma works with rest of his computer music workstation. In many ways this was simply smart marketing to assuage user trepidation about investing in a new music programming environment, but it also gave people a sense of the other members of their community and where they might fit in.



The Beckman Institute for Advanced Science and Technology on the University of Illinois campus was the site of the CERL Sound Group Intensive Workshop in Sound Computation.

intensive workshop in sound computation

An Intensive Workshop in Sound Computation was held May 23-June 5 at the Beckman Institute for Advanced Science and Technology on the campus of the University of Illinois at Urbana-Champaign. Sponsored by the CERL Sound Group, workshop topics included sound synthesis, analysis, psycho-acoustics, music notation, and music composition. Lectures were supplemented by hands-on experience using Lime, a music notation program developed by Dorothea Blostein of Queens University and Lippold Haken of the CERL Sound Group, and the Symbolic Sound Kyma System.

The Symbolic Sound Corporation provided five Kyma Systems for the workshop, and eight Macintoshes were provided by the CERL Sound Group and the U of I Computing Services Office. Headphone and microphone amplifiers for each station were designed and built by Richard Baraniuk and Mark Smart of the CERL Sound Group.

Workshop participants represented an impressive variety of disciplines, all related to sound computation:

Robert Cooper: Doctoral student in music composition at Univ. of Missouri
Roberto d'Autilia: Theoretical physicist at the Univ. of Rome
Burt Fenner: Director of the electronic music studio at Pennsylvania State Univ.
Al McNeil: Dragon Software in Kalispell, Montana
Dick Robinson: Composer, founder of Atlanta Electronic Music Center
Katherine Kim: Master's student in electrical engineering at UCSD
Chris Kriese: Master's student in music composition at Univ. of Illinois
Elizabeth Hinkle-Turner: Composer on the faculty of Oberlin Conservatory

The teaching staff included:

Richard Baraniuk: PhD candidate in Electrical and Comp. Engr., UIUC
Kelly Fitz: Master's candidate in Electrical and Comp. Engr., UIUC
Andrew Horner: PhD candidate in Computer Science, UIUC
Lippold Haken: Assistant Professor in Electrical and Comp. Engr., UIUC
Kurt Hebel: Symbolic Sound Corporation
Carla Scaletti: Symbolic Sound Corporation
John Sciarabba: Master's candidate in Electrical and Comp. Engr., UIUC
William Walker: PhD candidate in Computer Science, UIUC

Invited lecturers included:

James Beauchamp: Prof. in Electrical and Comp. Engr./School of Music, UIUC
Herbert Brün: Emeritus Prof. at the Center for Advanced Study, UIUC
Alan Craig: National Center for Supercomputing Applications, UIUC
Salvatore Martirano: Prof. in School of Music, UIUC
John Melby: Prof. in School of Music, UIUC
Sever Tipei: Prof. in School of Music, UIUC
Scott Wyatt: Prof. and Director of the Experimental Music Studios, UIUC

Participants spent four hours each day in lectures and the rest of the day (and night!) working on individual research or creative projects; the studio/classroom was open from 6:30 am to 1:00 am seven days a week. Each of the participants completed a project and presented it on the final day of the workshop:

Roberto d'Autilia, Seminar: "Theoretical Problems in Stochastic Composition", Study: Iterates of a map represented in sound

Burt Fenner, Seminar: "Beyond the Twelfth-root of Two: DSP as a Solution to the Tuning Problem", Compositions: a study in just intonation and a study in klangfarbenmelodie

Al McNeil, Seminar: "A Demonstration of MacroMind Director and Apple Computer's QuickTime", Composition: *Rain*

Dick Robinson, Compositions: *Lilly Had Been Collecting Spores Since Childhood* & another using various probability distributions

Katherine Kim & Chris Kriese, Interactive control panels illustrating psycho-acoustic phenomena

Elizabeth Hinkle-Turner, Study in preparation for a children's opera

Workshop participants get a close look at the insides of a Capybara. From left to right: Burt Fenner, Robert Cooper, Roberto d'Autilia (holding a Capybara expansion card), Elizabeth Hinkle-Turner, Dick Robinson, and Kurt Hebel (designer of the Capybara).

Figure 3.10: "Intensive Workshop in Sound Computation," Eighth Nerve, Vol. 1 no. 2 (1991)

In 2018, *The Eighth Nerve* exists in two forms: an emailed newsletter that is sent out about once a month and a blog linked to SSC's website. Kyma users are the primary focus of the newsletter. The email consists of a detailed list of user updates and upcoming events with an occasional note about a Kyma software update or a message about the upcoming KISS symposium. The blog is essentially an expanded version of the content in the emailed newsletter. Each blog post typically focuses on a single topic: a Kyma user and their current project, an upcoming concert, the call for proposals for KISS, or in depth information about recent software updates. The posts contain images, videos, audio, and screenshots of Kyma Sounds or code.

Virtual Community Conclusions

In Shelemay's words, these online resources enable Kyma users to recognize the "shared connections among themselves."[320] Discovering a shared interest through a blog post or forum, a friendly discussion in the comments section, seeing image of themselves with other users at a workshop, all serve as mechanisms that connect users to each other and see themselves as part of a collective. Online platforms also make it possible for users who are geographically dispersed to maintain correspondence and connections, allowing for the creation of a heterogeneous international community of Kyma users. Users with varying levels of participation, from users that only read online content, to occasional posters, and up to key users are all necessary for the formation of a virtual community. Although SSC tends to dominate, regular and key users are crucial for keeping the tone of a particular platform, and for sustaining and maintaining the interpersonal connections established online.

The Kyma Community Face-To-Face

Since the founding of SSC, Scaletti and Hebel created and encouraged opportunities for Kyma users to meet in person. From her time at CERL, Scaletti recognized that written manuals and online resources were often inadequate for learning programming languages. Early on, Scaletti was struck by:

> …the impact it had on people to be able to watch over someone's shoulder as they were using Kyma. It made me realize how inadequate a traditional, written "handbook" or manual was when it came to computer software...One could see what was going on immediately, things that would take several pages of awkward prose to try to describe with text.[321]

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[320] Shelemay, "Musical Communities: Rethinking the Collective in Music," 364–365.
[321] Scaletti, email to Madison Heying, October 18, 2016.

SSC has something of an "open office" policy. If a Kyma user happens to be in Champaign or make a special trip, they are commonly encouraged to visit the office where they can trouble-shoot issues they have with Kyma in person. Since the late 1980s, SSC has also offered workshops, courses, and in-person demonstrations. These courses and workshops are a valuable mechanism for users to gain knowledge about Kyma and to socialize with each other. Users bond over their shared experience of learning Kyma. At in-person meetings and online forums users commiserate over their struggles with the language, share tricks and resources to make it easier, and share in their accomplishments and mastery of aspects of Kyma.

Two-week Intensive Workshops in Sound Computation

Starting in the summer of 1991, SSC co-organized three annual two-week "Intensive Workshops in Sound Computation" hosted by the CERL Sound Group at the Beckman Institute at the UIUC. As the title of the course suggests, the focus was on using computers to engage with sound synthesis, digital signal processing, and audio analysis, not just learning Kyma. SSC provided Kyma systems to participants as their primary tool for doing sound computation throughout the workshop. They also used music notation software called Lime, developed by CERL Sound Group member Lippold Haken (who co-developed the Platypus multiprocessor with Kurt Hebel). Over the two weeks, participants heard lectures on computer music, digital sound synthesis and signal processing, as well on sessions to "speed-learn" Kyma so

that they could finish a composition employing these techniques by the end of the workshop.

In the first year, the staff of teachers included eight graduate students and recent graduates from UIUC from the Music, Computer Science, Electrical, and Computer Engineering programs, and almost all were a part of the CERL Sound Group. The Two-Week Intensive Workshops also featured guest lectures from UIUC professors including James Beauchamp, Herbert Brün, Salvatore Martirano, John Melby, Sever Tipei, and Scott Wyatt. Each day participants spent four hours in lectures and the rest of their time working on individual research and creative projects, which they presented to the group at the end of the workshop. The participants came from a range of disciplines, including music composition, theoretical physics, computer science, and electrical engineering. Many were in academia as graduate students or faculty, and several came from industry. Several of the participants already used Kyma, and it is clear that SSC marketed the workshop as a way for users to improve their dexterity in Kyma. .

Kyma Immersion Weekends

In 1994, CERL closed and SSC no longer had access to its resources. From 1994 to the early 2000s, SSC held over a dozen Kyma Immersion Weekends and short workshops in which Scaletti and Hebel offered tutorials and lectures about using Kyma. Unlike the two-week Intensive Courses these workshops focused entirely on Kyma, and they were produced solely by SSC. The workshops were more flexible and varied in format. Many were held in Champaign at SSC's offices, however some

were held in various studios and universities throughout the United States and Europe. The content and format changed depending on the locale and user group, their experience with Kyma, and their resources. Scaletti referred to the workshops as "intensive training sessions" rather than as a symposium-style gathering. She also suggested that the three-day intensives were preferable to two days, because there was "more time for people to do presentations and share their work."[322] Kyma users found these weekend-length workshops so valuable they commonly attended more than one.

In print and online, SSC marketed the Two-Week Intensives and Immersion Weekends as resources for Kyma users. They included write-ups on the workshops in the *Eighth Nerve* newsletter and SSC's website with pictures and descriptions of the users and their presentations, one year they also included user's answers to a questionnaire. As previously mentioned, this gave the community images of itself, which enabled people to visualize themselves as part of the group, and shaped their perceptions of the community's character. These write ups also demonstrated that Scaletti and Hebel believed that a strong user community could attract new users and the role customer service and technical support in the formation and maintenance of the Kyma community.

Although SSC stopped offering Immersion Weekends in the early 2000s they had a lasting impact not only on the users that attended but on the user-base more broadly because Scaletti adapted the materials she developed for the workshops into the Kyma manual, *Kyma X Revealed*. For most Kyma users, *Kyma X Revealed* was

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[322] Scaletti, email to Heying, October 17, 2016.

the first substantial introduction they received to Kyma. It also influenced the community because it gave users a shared context and language for describing their work in Kyma.

Kyma International Sound Symposiums

After SSC stopped offering Immersion weekends, Kyma users started to seek out in-person interactions with other users themselves. In 2009, volunteers from the Kyma community, along with Scaletti and Hebel, began hosting annual Kyma International Sound Symposiums (KISS). Christian Vogel, a Kyma user, initiated and spearheaded the first KISS in Barcelona, Spain. This established the model of collaboration between a member of the community and SSC to produce KISS each year. The first KISS was small, less than ten people including Scaletti and Hebel; in many ways it was more like the earlier Immersion Weekends. By the second year, in Vienna, KISS was much larger, more than double the participants than the first year. KISS continues to grow; at KISS 2018 there were over eighty participants.

These four-day symposiums are an essential element in the growth and maintenance of the Kyma community. KISS is more user-oriented than the immersion weekends: users give presentations and demonstrations of their work and concerts allow Kyma users to share their music. In order to present their work, users submit a proposal for a composition, talk, or workshop. Every year there is a theme and participants are encouraged to submit pieces and talks that are related to that theme. Nearly everyone who submits a proposal is accepted as long as the host institution can facilitate their technical needs.

The organization and planning of KISS is usually a collaboration between a Kyma user and their host institution and SSC. The Kyma user facilitates local arrangements including venues, technological requirements for performances and presentations, food, lodging, some promotion and marketing, and they manage volunteers and technical staff. SSC helps with the scheduling, the copy and press releases, and correspondence with users. All parties collaborate on budgets and selecting participants based on their proposals. Each year KISS has a slightly different flavor based on the location and resources of the host institution. For example, whether it is held at a university or not, whether meals included or not, whether it is held in Europe or the United States, and how many concerts are included.

KISS participants pay a registration fee to attend that covers the cost of running the symposium. The fee varies from year-to-year, typically ranging from about $90–$250; symposiums with higher fees provide meals for participants. The fees also cover administrative costs, venue rentals (which often includes payments to venue staff), other rentals such as tables and chairs, and snacks and coffee. Students and faculty at the host institution often volunteer their time organizing or working at KISS. SSC does not make a profit on KISS, and the host institution typically handles funds.

At KISS there are no parallel sessions, which is an important factor that encourages closeness and camaraderie among participants. SSC deliberately designed KISS this way, since the first several years were small, parallel sessions were not needed. But even as KISS has grown to over eighty participants, SSC prioritizes

keeping the group together. As Scaletti explained in an email, they want participants to have common, shared experiences:

> We kind of try to find, because there are these different, not factions, but different directions and one of the things we consciously try to do with KISS is to give all the people the *same* experience, so that there is some common ground for them to talk about. Because at a lot of conferences there are parallel sessions and everyone is on their own for meals so it is easy to separate out into different cliques and factions, but we try to at least give people some common experience.[323]

Participants hear music and talks from people of many different nationalities who use Kyma in very different ways, yet going through the conference together provides participants with some common ground. This facilitates easy conversation during the many break periods throughout the day. Exposure to new ideas also makes KISS exciting for many users and they tend to be sociable to each other in spite of their differences. For example, Scaletti explains: "I even overheard Robert Efroymson saying: 'Well, even though I strongly disagreed with some of the people, I still found it stimulating!' It was like he was surprised almost."[324] Efroymson's is a common sentiment among KISS attendees.

The concerts highlight the variety of approaches to making music and using Kyma found among Kyma users. At KISS there are commonly two concerts a day: one in the afternoon and one in the evening. At a given concert, one might hear an electro-acoustic piece with an acoustic instrument accompanied by and/or controlling sound in Kyma; or an interactive improvisation with a live performer and Kyma; dance club beats synthesized and mixed live in Kyma; a data-driven piece where scientific data such as brainwaves or climate data direct Kyma synthesis; a minimalist

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[323] Scaletti, interview with Heying, September 24, 2018.
[324] Ibid.

drone work where Kyma processes vocals; a video game with a generative Kyma soundtrack; the use of a gestural controller such as a Wi-mote or Wacom tablet; or a set in which Kyma interacts with analog electronics.[325] One striking commonality is that most participants at KISS are composer-performers who perform their own pieces, even when working with another musician or performer. The large numbers of composer-performers in the Kyma community is made possible by the high degree of control and self-sufficiency afforded by Kyma as well as other contemporary music software.

The concerts also draw attention to the similarities in Kyma user's music. Although Kyma is flexible and can accommodate many compositional styles, it does have something of a signature sound, not unlike a Moog, Buchla, or ARP synthesizer. Some pieces share timbral qualities because users employ the same stock Kyma Sounds and controls such as GrainClouds, Drone, OscillatorBank, SoundtoGlobalController, or the CrossFilter. Kyma also lends itself to the creation of generative structures that are often perceived as repeating patterns. Subgroups in the community also tend to share aesthetics, for example almost all of the users associated with the University of Oregon use gestural controllers, incorporate voices, and employ a similar form.

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[325] Some of the piece that stood out to me over the last several years includes: a remake of Cage + Duchamp's *Reunion* called *Reunion2012* by Anders Tveit and Ulf A. Holbrook; Andrea Young's vocal drone pieces; narrative or poetic readings with sound by Ming-Ling Lee; Olga Oseth's use of novel gestural controllers including home-made jam jars electronics or Play Station Kinnect; *En Garde* by Gabriel Montufar and Nelson Garcia featured a real-time fencing match and choir in which the fencer's movements triggered sound synthesis in Kyma and reactions from the choir.

For many users the concerts at KISS are an opportunity to collaborate with each other. Collaborations tend to happen organically, however for several years SSC played an active role in facilitating cooperative pieces. At KISS2015 on the CFP participants could opt to do an "arranged marriage" in which the proposal committee paired users to collaborate on a piece. And at KISS2016, SSC arranged for John Mantegna, an American professor of music who is interested in generative algorithms and Franz Danksagmüller, a Viennese Organist that uses Kyma to synthesize sound and process his organ, to work on a piece together. At KISS 2016, Robert Jarvis, a long-time Kyma user initiated a large group improvisation at one of the concerts featuring eight other Kyma users: Anne La Berge, Brian Belet, Sarth Calhoun, Paul Connolly, Robert Efroymson, İlker Işıkyakar, Silvia Matheus and Mark Phillips. The theme that year was Emergence, thus the ensemble called itself "The Emergent Ensemble." The program note explained: "The Emergent Ensemble was formed not only for KISS2016, but during KISS2016. It has been assembled by Robert Jarvis, trombonist and improviser with the London Improvisers Orchestra (and other ensembles)."[326] KISS2016 also included a collaboration between Marinos Giannoukakis, a Greek DMA student living in Leicester, England, Gustav Scholda, a sound designer living in Vienna, Austria, and Alex Retsis a Greek electronic musician; their piece involved modeling physical systems and mapping sound parameters to the parameters of the systems. KISS2017 included several examples of user-initiated collaborations: on instance was between Anne La Berge and Craig Vear who co-wrote a piece called *Postcards*, which they developed after meeting at

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[326] Robert Jarvis, "The Emergent Ensemble," KISS2016 website. http://kiss2016.symbolicsound.com/program/, accessed July 21, 2018.

KISS2016. Since participants are geographically dispersed, these collaborations are typically made possible by internet applications like Skype, FaceTime, SMS messages, and email.

The majority of KISS attendees participate by performing in a concert, giving a presentation, or a demonstration. Of this majority most perform a piece in addition to a talk or demonstration, however a small percentage opt to just give a talk. For example, long-time Kyma use Pete Johnston is not a composer or performer, rather he tends to give talks about spectral analysis techniques or the DSP processes he develops. Another small percentage of attendees come to observe. For some, they are interested in purchasing a Kyma system and want to learn more about it, and for others, they already use Kyma but chose not present a piece or a talk.

The following statement by Marinos Giannoukakis captures many of the reasons why Kyma users attend KISS:

> First, cause every year they get better: performances, talks and organization. It's a great opportunity to see Carla up-close; I feel like she is one of the dearest people in my life and a great mentor and I always get inspired by her. Same goes for many other participants, which by now I consider dear friends. I love to see their work evolve and learn from their approach to Kyma. New participants almost always bring something new 'to the table'. They come from diverse disciplines and bring new aura and inspiration. Everyone shares their work and usually this is my most productive and rewarding time of the year. In general KISS evolves and gets better and I benefit greatly by keeping tuned with its evolution.[327]

Participants overwhelmingly cite the community as the main reason they attend KISS. Olga Oseth exclaimed: "Oh man the community is so supportive, welcoming, genuine. I learn so much, feel comfortable to present; I love interaction with other

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[327] Marinos Giannoukakis, Kyma User Survey, September 2016.

Kyma users. Its a warm atmosphere unlike other conferences that feel cut throat competitive."[328] Kyma users are also drawn to the "warm" and "welcoming" atmosphere Oseth described. When asked why he attends KISS, Alan Jackson responded:

> The community. It's an intriguing bunch of people. The set of people that are interested in Kyma and come to KISS is quite an eclectic mix. Music, performance art and installation art all get blurred. The community is very accepting and supportive. It's as if we've all gone through this trial by fire of learning kyma so now we all share a common bond like soldiers... or the masons or something. I find KISS inspiring. It challenges my own definition and experience of music and I come away feeling capable. I have conversations that have a big influence on me. Before KISS, I think I'm going to learn more about how to use Kyma. It doesn't seem to work out that way. Instead I get more inspired to use Kyma and more certain that it is somehow possible(!) to use it as I've seen other people doing it. I'm still holding out hope that I will pick up more direct technical skills from the next KISS.[329]

Users overwhelmingly share this sentiment, summing up their reasoning for attending KISS by stating that it is "inspiring," and the opportunity to spend time with "kindred spirits," which refers both to other users and Scaletti and Hebel. Marianne Bickett stated: "This is my third KISS but the first time I attended as a participant...big difference! I really felt accepted and acknowledged, which made a huge difference to me."[330] Kyma community members genuinely value each other, their work with Kyma, the insights they provide about the system, but most importantly they value each other as people and friends. Jon Bellona stated:

> [KISS]isn't a conference focused on one field, but rather a diverse community interested in sound and music and its relationship to our world. People are honest in their listening and sounding. I am blown away by the type of work and ideas other Kyma users are doing/making. At the same time, I feel humbled when someone tells me they used a Sound I posted on the

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[328] Olga Oseth, Kyma User Survey, September 16, 2018.
[329] Alan Jackson, Kyma User Survey, September 13, 2016.
[330] Marianne Bickett, Kyma User Survey, September 18, 2018.

> Community Library or found an article I wrote helpful in their exploration of Kyma. There's a lot of positive vibrations and geeking out on sound problems at KISS. Each year, my list of ideas, books, Sounds, and concepts to explore is several pages long. My creative batteries are recharged by coming to KISS.[331]

This is partly demonstrated by the amount of time participants spend together after the day's events are over. For example at KISS2018, after dinner each night the majority of participants met at a bar in town to continue socializing.

The comparatively congenial atmosphere of Kyma community events does not mean that it is flawless: it is not without cliques and users are not without prejudices and preferences. Although community members tend to be very accepting, many still make assumptions around gender in particular. For example, I experienced this first hand while attending KISS2015. Kristin Erickson Galvin and I composed an operetta with our partners Matthew Galvin and David Kant. Kristin and I did all the programming and composing with Kyma and Matthew and David helped with the libretto, video, lights, and supplemental sounds. We did not perform until the last night, and during the first several days at KISS, most people we met assumed that our partners David and Matthew were the Kyma users. It is not uncommon for partners to perform together with the man operating Kyma and the woman performing or running visuals. For example Ilker Isikayakar and E. Zoe Schutzman, Rich O'Donnell and Anna Lum, and Kiyoung Lee and Ha-Young Park. However, there are as many examples of the reverse where women operate Kyma and while a man performs, runs visuals or non-Kyma sound, including Helge Sten with various performance partners, Mei-ling Lee and Jefferson Goolsby, and Anne La Berge and David Dramm. Mei-ling Lee also attested to experiencing this stereotype. There are also numerous examples

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[331] Jon Bellona, Kyma User, September 16, 2018.

of women using Kyma who perform on their own, including, most notably Scaletti. Women typically make up at least one-third of KISS participants.

A Feedback Loop

The developments in digital computing technology that made Kyma, DSP, and computer music possible also enabled the growth of a close-knit international community of Kyma users. In many ways the Kyma community is a case study demonstrating the influence of the internet and CMC technology in the formation of community in the late twentieth and twenty-first century. Through the creation and utilization of technical support platforms online, users developed meaningful relationships with each other and bonded over their shared use of Kyma, and these bonds were further reinforced at in-person workshops and symposiums (or vice-versa). The importance of both online resources and face-to-face interaction affirms Wellman's notion that virtual encounters do not replace in-person ones, rather both can be integrated as part of a web of one's social life.

The close contact between SSC and Kyma users at KISS and through online resources is an important feedback mechanism that allows them to change Kyma to better suit user's needs. As Scaletti explains**:** "I learn a great deal by talking with Kyma users, and, by inference, from watching them work, studying the sounds they create, and analyzing the questions they ask or new features they request. That knowledge becomes incorporated into Kyma."[332] As discussed in Chapter One, Scaletti and Hebel also exert influence on users through the design of Kyma and how

[332] Scaletti, "Computer Music Languages, Kyma, and the Future," 79.

that shapes how they can composer or make sound. In her book *Playing Along*, Kiri Miller suggests that the experience of technology is always collaborative, the result of an ongoing process that builds relationships among engineers, commercial interests, designers, and users.[333] Many Kyma users recognize their status as collaborators and stress this feeling of cooperation as one of the reasons that they continue to use Kyma; it gives them a sense of ownership over and investment in the technology.

An indicator of how user's needs are acknowledged and are eventually addressed in Kyma is the phrase: "Looking into how that might be made possible in the future," which occurs frequently in some variation across online Kyma platforms, from forum in early 2000 to Q & A in 2019. The kinds of user contributions vary, from Alpha and Beta testers, to users that post often on forums or Q & A, or that send frequent emails to SSC, to people who are less engaged or not engaged at all. Alpha and Beta testers can have a significant impact on subsequent releases: they use updated versions of Kyma software at various stages of completeness before they are released in order to identify bugs or other issues. One example of the substantial influence users can have in this stage is Helge Sten and John Paul Jones who provided considerable input for the Multigrid, a control interface, which was released in 2015 as part of Kyma 7. They were involved from the initial design of the Multigrid to the testing of various iterations, and their feedback shaped the final design.

User contributions through the process of technical support and as Alpha and Beta testers points to the social construction of technology as forwarded by Bijker,

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[333] Kiri Miller, *Playing Along: Digital Games, YouTube, and Virtual Performance* (Oxford: Oxford University Press 2012).

Pinch, and Hughes and indicates how users actively shape the development of Kyma. These authors explain that through technical support and "problem solving" a given technology can reach a state of "closure" that stabilizes the technology for a period of time: "When the social groups involved in designing and using technology decide that the problem is solved, they stabilize the technology."[334] Bijker, Pinch, and Hughes continue to explain that it is up to users to conclude when closure is achieved: "Various groups will decide differently not only about the definition of the problem but also about the achievement of closure and stabilization."[335] With Kyma, the cycles of change, closure, and stabilization can be seen around software updates. In addition to advances in technology, updates are often dictated by user needs. Users further influence an update's development by contributing as alpha and beta testers, bringing the software closer to a state of closure. Finally once the update is released, it goes through more cycles of change and stabilization as people utilize the new software and come across bugs or limitations, which often lead to further changes. This process ultimately leads to a period of stabilization in the Kyma software.

In a few cases, Kyma users have developed new Kyma Sounds (SoundAtoms) in collaboration with Scaletti and Hebel. Pete Johnston worked closely to develop the CrossFilter Sound, which is based on his design of a technique to "morph" or convolve two signals together. For years the CrossFilter has been one of the most popular Sounds in Kyma. Other Sound objects created by users are also commonly featured as one of the "Sounds of the Day," a section in the Sound Browser that is updated daily with new Sounds for users to explore.

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[334] Bijker, Huges, and Pinch, eds, *The Social Construction of Technological Systems*," 12.
[335] Ibid.,13.

Kyma users have a relationship with Scaletti and Hebel that is more unique than most people have with their software developers and these close bonds are part of what makes using Kyma special and contributes to people using Kyma for many years. Although establishing close bonds with the people who created the software one uses can be meaningful and freeing in some ways, tensions can arise from such relationships. Looking at Kyma users overall, this kind of sentiment is limited, because many people are not as personally connected to SSC. However, with the core community who are very active online and at KISS and are very personally invested in using Kyma, this is more common. For these users, Kyma is deeply tied to their identity as a musician, composer, and/or artist, they know how to use the system extremely well and have been involved—often for decades—beyond active contribution online. SSC might also feel that a user overstepped their boundaries, or was not respectful and understanding of what they do and their design of Kyma. In many ways the Kyma community is like a family, where little resentments build up (toward SSC or others in the community), but people are still very endeared toward each other, and care deeply about the community as a whole.

Conclusions

The Kyma community really came into existence once "it took on a life of its own."[336] This happened when Scaletti and Hebel were no longer the sole point of contact for users and the group began operating autonomously. Users began to seek each other out and create their own networks of communication and support. In the

[336] Scaletti, email to Heying, October 17, 2016.

process several subgroups emerged in the form of local and virtual learning groups and around universities that teach Kyma. For instance after KISS2016 in Leicester, UK, several new user groups were formed in London, Berlin, and Oslo. Another example is that two Kyma users started the NeverEngineLabs, an independent online resource for Kyma tutorials and pre-made Kyma sounds and programs. Kyma users have also created training tools and modules including Jeffrey Stolet's book *Kyma and the SumofSines Disco Club*, Delora Software's Kyma Connect, and Timothy McGuiness's Youtube tutorials. This autonomy is where user agency comes into play. Scaletti and Hebel initially facilitated user connections by making modes of communication available, but users had to want to connect and find the method of communication that suited their needs.

In a time when ever-increasing aspects of our lives are dictated and directed by algorithms—algorithms that most of us do not understand, written by people we will likely never meet, embedded with values from the maker, the corporation that employs them, the advertisers that fund them, etc.—the relationships Kyma users have with Scaletti and Hebel are important, unique, and often empowering. Even when members of the community feel frustrated by an aspect of Kyma, they know Scaletti and Hebel and their dedication to Kyma's development. Moreover, they have a direct line to email or call SSC to address their concerns, giving them a mechanism for agency over their Kyma system and feedback to SSC. All of this is obscured when we interact with digital technology in our phones, computers, tablets, cars, homes (Alexa, Google), in the growing "internet of things." In a discussion about online communications platforms, media theorist Fred Turner explains how some

technologies provide users with "freedom from" limitations of other media, some provide users with "freedom to" engage in certain activities, yet he posits that the most personally fulfilling technologies are those that provide "freedom with," by serving an integrative function within a larger social fabric. He posits:

> What if freedom consisted of being an equal part of an activity, of being integrated into a community, of being a valued member of the process? What if freedom began not with the design of the machine or the outcome of its use, but within the social networks it enabled? And for that matter, how might media machines be used to generate chains of human-machine interaction that boost the agency of individuals involved?[337]

Along with the connections between Scaletti and Hebel and community members, Kyma provides many users "freedom with" music-technology, enabling them to feel accepted and acknowledged as an integral mechanism in the development of Kyma.

[337] Fred Turner, "The World Outside and the Pictures in Our Networks," 256.

Conclusion

Each chapter in this dissertation shed light on different aspects of Kyma, its history and development, and its role in fostering a community of users. Chapter One laid a foundation with a brief history of Kyma, a discussion of Scaletti's early influences, and some of the core features of Kyma. Studying Scaletti's compositions in Chapter Two not only provided insight into her unique approach to composition, it also provided insight into what is possible to do in Kyma, how Scaletti uses Kyma, and why it might have been necessary for her compositional practice. The analyses of Scaletti's musical works indicate the centrality of Sound objects to her compositional philosophy and how Kyma lends itself to the creation of generative processes and DSP she tends to employ. Chapter Three focused on the formation and make up of the Kyma user community, which took on some of its characteristics as the result of Scaletti and Hebel's strategic cultivation. In 2019, a time in which social media companies grapple with issues of free speech and how to maintain civil discourse on their platforms, Scaletti and Hebel's proactive role in the formation of the community stands out. Doing so allowed SSC to establish norms encouraging respectful and thoughtful interactions among community members. This not only made the process of online technical support more pleasant and beneficial for users, it also facilitated and strengthened close bonds among users. Through a discussion of technical support and the other ways Kyma users contribute to Kyma's development, this chapter also illustrates the substantial influence the Kyma community has on the evolution of Kyma.

Scaletti is also the focus of this dissertation. The first chapter established how her particular personal, technical, and educational experiences contributed to the creation of Kyma. Each subsequent chapter further explored Scaletti's unique approaches to composition and music programming, which she has been able to maintain by working outside established institutions of computer music. Although Scaletti's outsider status restricted access to resources associated with the academic institutions that support the creation of computer music, especially early on, this independence has provided Scaletti with aesthetic, technical, and social freedom, allowing her ideas and work to flourish.

Methodology

Scaletti, Kyma, and the Kyma user community offer a compelling example of the benefits of the ethnography-based methodology employed in this dissertation. Situating the creation, development, and use of Kyma within cultural, historically, and technological contexts demonstrates how the evolution of a technology is shaped by many factors and interactions among people and technologies. This framework also enables the understanding of creative practices and the development of technology as highly collaborative. Ultimately, this interdisciplinary methodology is a fruitful way to study music technologies, composers, or music-making communities.

Further Research

This dissertation only scratched the surface of what there is to know about Scaletti, Kyma, and the Kyma user community. These are rich, multifaceted topics

and a great deal of work remains to be done. In particular, the study of Kyma would benefit from a scholar with more technical expertise than I possess. Other methodological approaches to these topics might also yield new information and new conclusions about Kyma, Scaletti, or the Kyma community.

In the future I plan to incorporate the work of quantum physicist and feminist theorist Karen Barad into my methodology. The move is inspired by taking Barad's class Feminism and Science at UC, Santa Cruz in the Spring of 2019, along with the work of musicologists Ezra Teboul and Ted Gordon, who apply Barad's ideas to the research and analysis of technical systems and their entanglements in cultural, scientific, and political systems. Barad's work provides a methodology that moves beyond ANT and SCOT to uncover how a phenomenon—in this case a technological object—is not a reflection of its immediate cultural context, but part of a large web of entanglements that can be traced to expose the people, intuitions, movements, regimes of power and issues like gender, class, and politics that work to co-constitute said phenomenon. Incorporating Barad's framework will enable me to broaden the scope of my study beyond Scaletti's immediate contexts.

To this end I also plan to undertake a comparative study of music programming languages and their user communities. A comparative analysis will allow me to understand and articulate the important differences and particularities of each design, the forces that contributed to each languages creation, and how these differences have played out in the interplay between creator(s), technology, and users. A comparative study will also shed light on shared contexts among different music programming languages, such as how advances in online communication

technologies facilitated the growth of international user communities more broadly. The study of Kyma and other music programming languages would also benefit from an in-depth study about the arguments around open source and free software, and proprietary languages. This study would investigate the values embedded in both sides of these arguments, where the arguments come from, and the infrastructure that supports such arguments. Such a study would contribute to understanding issues of access, and the perception of access around Kyma and other music programming languages. Lastly, I plan to extend this dissertation by collaborating with a computer scientist or expert in computer music to undertake a more in-depth analysis of Kyma. I will also study user's compositions and programs made using Kyma in addition to continuing my ethnographic work at KISS and the online Kyma forums.

Appendix I: Carla Scaletti: List of Compositions

Motet (1977)
For mezzo soprano, bass clarinet, harp, and narrator
Text: "Dr. Potatohead Talks to Mother" by Judith Johnson Shermin

Yes (1981)
For mezzo soprano and Buchla-generated tape

Blood Wedding (1982)
Instrumental Ensemble and actor/singers
Score to a Lorca play. Scaletti wrote all the music including songs, incidental music, and other accompaniment.

Lysogeny (1983)
For harp and Music 360-generated tape

X Bar (1986)
For Interactive Music System (CERL) // audience input
Recording Lost. No score, only some diagrams and print outs of IMS and Plato programs

Levulose (1986)
For double-bass and Interactive Music System

sunSurgeAutomata (1986–1987)
Platypus Multiprocessor

Trinity (1989)
For Kyma-processed narrator

Mitochondria (1994)
For Kyma

Public Organ (1995)
For Kyma, WWW, CU-SeeMe, audience input

Tangled Timelines (1999)
For Celtic harp and Kyma System

Lament (1999)
For Kyma-processed narrator

Frog Pool Farm (2002)
For Kyma

Sound Source: Field recordings of frogs near Champaign, IL.

Slipstick (2008)
For Continuum fingerboard and Kyma System
Also adapted to WACOM tablet

Cyclonic (2008)
For Kyma
Sound Source: Field recorded sound in Champaing, IL.

Autocatalysis (2010)
Audience processed through Kyma System

…odd kind of sympathy (2011)
Audience processed through Kyma System

Spider Gaalaxies (2011)
Co-composed with Christian Vogel
Data-driven music, using mock ATLAS Experiment data and sonification tests co-developed with Lily Asquith

QUANTUM (2013)
For Kyma
Accompaniment to choreography by Gilles Jobin.
Data-driven music based on data from the ATLAS Experiment at CERN

Conductus (2014)
For pipe organ, three singers in tap shoes, and Kyma System

Double-well (2016)
For Kyma System and Audience input

Bubble and Squeak (2017)
For Kyma, and balloon sounds

h→gg (2017)
15-minute concert version of *QUANTUM*

VR_I (2017)
Kyma
Sound design and Score for VR environment with dancers choreographed by Gilles Jobin

Appendix II: Online Kyma Forums[338]

1. The Kyma.5 Forum

Topic	Number of Sub-Topics	Number of Posts
Announcements*	25	25
Upcoming Events*	20	29
Tips & Techniques	627	4059
Kyma Sound Exchange	235	1068
Kyma Support	1615	7883
Confabulation	590	2459

* Public Forums

2. The Kyma 7 Forum

Topic	Number of Sub-Topics	Number of Posts
Announcements	20	68
Tips & Techniques	21	55
Confabulation	32	51

3. The Kyma Q & A

Total Users: 182
Number of Questions: 898
Number of Answers: 988
Number of Comments: 2,123

Topic	Number of Questions
Using Kyma	304
Capytalk & Smalltalk	209
Controllers, OSC & MIDI	120
Sound Design	99

[338] Based on data collected March 22, 2019.

General	88
Hardware & Interfaces	78

Appendix III: KISS Demographics[339]

KISS 2016: Leicester, England

UK	28
USA	26
Norway	3
Netherlands	3
Austria	3
China	3
Germany	3
Greece	2
South Korea	2
Canada	1
Denmark	1
Switzerland	1
Sweden	1
Italy	1
France	1
Total	79

Male	76%
Female	24%
Kyma owner	71%
Non-Kyma owner	29%
Academic	56%
Non-academic	44%

KISS 2017: Oslo, Norway

USA	24
UK	13
Switzerland	2
Poland	2
Norway	12
Netherlands	6
Korea	4
Italy	3

[339] Based on data collected by Scaletti and Hebel.

Greece	2
Germany	1
Denmark	3
Belgium	1
Austria	3
Total	76

Female	18%
Male	82%
Kyma Owner	72%
Non-Kyma Owner	28%
Academic	39%
Non-academic	61%

KISS 2018: Santa Cruz, California

USA	75 (Includes international students attending US universities)
UK	5
Netherlands	1 (Registered, did not attend)
Korea	2
Italy	2
India	1
Greece	1 (Registered, did not attend)
Ecuador	2
Canada	1
Belgium	2
Total	92

Female	24%
Male	76%
Kyma Owner	70%
Non-Kyma Owner	30%
Academic	47%
Non-academic	53%

Bibliography

Abbate, Carolyn. "Sound Object Lessons." *Journal of the American Musicological Society* 69:3 (Fall 2016): 793–829.

Abbate, Janet. *Inventing the Internet*. Cambridge: MIT Press, 1999.

_____. *Recoding Gender: Women's Changing Participation in Computing.* Cambridge: MIT Press, 2012.

Abtan, Freida. "Where is She? Finding the Women in Electronic Music Culture." *Contemporary Music Review* 35:1 (2016): 53–60.

Alon, Uri. *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Boca Raton: Chapman & Hall/CRC, 2007.

Ames, Charles. "Automated Composition in Retrospect: 1956–1986." *Leonardo* 20:2 (1987): 169–185.

Amirkhanian, Charles. Liner Notes. *New Music for Electronic And Recorded Media: Women In Electronic Music 1977*. New World Records, 2006. CD.

Anderson, Benedict. *Imagined Communities*. New York: Verso Books, 1983.

Andrejevic, Mark. *iSpy: Surveillance and Power in the Interactive Era*. Lawrence: University Press of Kansas, 2007.

Appleton, Jon, and Ronald Perera. Eds. *The Development and Practice of Electronic Music*. Englewood Cliffs: Prentice-Hall, 1975.

Ashley, Robert. *Outside of Time: Ideas about Music*. Köln: Editions Musiktexte, 2009.

Attali, Jacques. 1985. *Noise: The Political Economy of Music*. Minneapolis: University of
Minnesota Press.

Ball, Phillip. *Self-Made Tapestry: Pattern Formation in Nature*. Oxford: Oxford University Press, 1999.

Balsamo, Anne. *Technology of the Gendered Body: Reading Cyborg Women*. Durham: Duke University Press, 1996.

Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham: Duke University Press, 2007.

Barkin, Elaine, and Lydia Hamessley. Eds. *Audible Traces: Gender, Identity, and Music.* Zurich: Carciofoli Verlagshaus, 1999.

Baron, Robert and Lee Higbie. *Computer Architecture: Case Studies*. Reading, MA: Addison-Wesley Publishing Company, 1992.

Barz, Gregory, and Timothy J. Cooley. *Shadows in the Field: New Perspectives for Fieldwork in Ethnomusicology.* Oxford: Oxford University Press, 2008.

Bateson, Gregory. *Steps to an Ecology of Mind*: *Collected Essays in Anthropology, Psychiatry, Evolution and Epistemology*. London: Granada Publishing, 1973.

_____. *Mind and Nature: a Necessary Unity.* New York: Bantam: 1980.

Berman, Marshall. *All That is Solid Melts Into Air: The Experience of Modernity.* New York: Penguin Books, 1982.

Bianchi, Frederick, and V.J. Manzo. Eds. *Environmental Sound Artists*: *In Their Own Words*. Oxford: Oxford University Press, 2016.

Bijker, Wiebe E., Thomas Parke Hughes, and T. J. Pinch. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge: MIT Press, 1987.

Borchert, Gavin. "American Women in Electronic Music, 1984–1994." *Contemporary Music Review* 16:1–2 (1997): 89–97.

Born, Georgina. *Rationalizing Culture: IRCAM, Boulez, and the Institutionalization of the Musical Avant-Garde*. Berkeley: University of California Press, 1995.

_____. "On Musical Mediation: Ontology, Technology and Creativity." *Twentieth-Century Music* 2:1 (March 2005): 7–36.

Bosma, Hannah. "Bodies of Evidence, Singing Cyborgs and other Gender Issues in Electrovocal Music." *Organized Sound* 8:1 (April 2003): 5–17.

Burkholder, J. Peter, Donald J. Grout, and Claude V. Palisca. *Norton Anthology of Western Music*, 5th Edition. New York: W.W. Norton & Company, 2006.

Byte Magazine: Smalltalk. August, 1981.

Cage, John. *Silence*. Middletown: Wesleyan University Press, 1961.

Cage, John, Lejaren Hiller, Antoinette Vischer, Neely Bruce, David Tudor, and Ben Johnston. Liner Notes. *HPSCHD: For Harpsichords & Computer-Generated Sound Tapes*. Nonesuch, 1969. LP.

Casti, John, and Anders Karlqvist. Editors. *Art and Complexity.* Amsterdam: Elsevier, 2003.

Chadabe, Joel. "Some Reflections of the Nature of the Landscape within Which Computer Music Systems are Designed." *Computer Music Journal* 1:3 (June 1977): 5–11.

_____. *Electric Sound: The Past and Promise of Electronic Music.* Englewood Cliffs: Prentice Hall, 1997.

Ed Childs and Ville Pulkki, "Using Multi-channel Spatialization in Sonification: A Case Study with Meterological Data," *Proceedings of the 2003 International Conference on Auditory Display*, Boston.

Collins, Nick, Schedel, Margaret, and Wilson, Scott. *Cambridge Introduction to Electronic Music.* New York: Cambridge University Press, 2013.

Demers, Joanna. *Listening Through the Noise: The Aesthetics of Experimental Electronic Music*. New York: Oxford University Press, 2010.

Dewar, Andrew. *Handmade Sounds: The Sonic Arts Union and American Technoculture*. PhD Dissertation. Wesleyan University, 2009.

Dodge, Charles and Thomas A. Jerse. *Computer Music: Synthesis, Composition, and Performance.* New York: Shirmer Books, 1985.

Evens, Aden. "Concerning the Digital." *differences: A Journal of Feminist Cultural Studies* 14:2 (Summer 2003): 49–77.

_____. "Object-Oriented Ontology, or Programming's Creative Fold." *Angelaki* 11:1 (2010): 89–97.

_____. "Programming the Fold." Paper presented at *Digital Arts and Culture*. Irvine, California, December 12–15, 2009.

_____. *Logic of the Digital*. New York: Bloomsbury, 2015.

Galloway, Alexander. *Protocol: How Control Exists After Decentralization*. Cambridge, MA: MIT Press, 2004.

_____. *The Interface Effect.* Malden: Polity Press, 2012.

Galloway, Patricia. "Personal Computers, Microhistory, and Shared Authority: Documenting the Inventor-Early Adopter Dialectic." *IEEE Annals of the History of Computing* 33:2 (April-June 2011): 60–74.

Gillespie, Tarleton, and Pablo J. Boczkowski, Kirstin A. Foot. Eds. *Media Technologies: Essays on Communication, Materiality, and Society*. Cambridge, MA: MIT Press, 2014.

Gardner, Robert Owen. "The Portable Community: Mobility and Modernization in Bluegrass Festival Life." *Symbolic Interaction* 27:2 (Spring 2004): 155–178.

Goldberg, Adele. *Smalltalk-80: The Interactive Programming Environment*. Menlo Park: Addison-Wesley Publishing Company, 1984.

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

Haraway, Donna. *Simians, Cyborgs, and Women*. London: Free Association Books, 1991.

Heying, Madison. "A Room of One's Own: The Independent Studios of Women Making Electronic and Computer Music," paper presented at the annual meeting of the *American Musicological Society*, San Antonio, Texas, November 1–4, 2018.

Hiller, Lejaren, and Leonard Isaacson. *Experimental Music: Composition with an Electronic Computer.* New York: McGraw-Hill Book Company, Inc., 1959.

Hine, Christine. "Internet Research and the Sociology of Cyber-Social-Scientific Knowledge." *The Information Society* 21:4 (2005): 239–248.

Hinkle-Turner, Elizabeth. *Women Composers and Music Technology in the United States: Crossing the Line.* Burlington: Ashgate Publishing Company, 2006.

Holmes, Thomas. *Electronic and Experimental Music.* New York: Charles Scribner's Sons, 1985.

Hyland, Stanley. Ed. *Community Building in the Twenty-First Century*. Santa Fe: School Of American Research Press, 2005.

Jaffe, David A. and Julius O. Smith. "Extensions of the Karplus-Strong Plucked-String Algorithm." *Computer Music Journal* 7:2 (Summer 1983): 56–69.

Johnson, Mark. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. Chicago: University of Chicago Press, 1987.

_____. *The Meaning of the Body: Aesthetics of Human Understanding*. Chicago: University of Chicago Press, 2007.

Jones, Steve. "Music and the Internet." *Popular Music* 19:2 (April 2000): 217–230.

Jordan, Tim. *Internet, Society and Culture: Communicative Practices Before and After the Internet*. New York: Bloomsbury, 2013.

Katz, Mark. *Capturing Sound: How Technology Has Changed Music*. Berkeley: University of California Press, 2010.

Keislar, Douglas. "A Historical View of Computer Music Technology." In *The Oxford Handbook of Computer Music.* Edited by Roger T. Dean. Oxford: Oxford University Press, 2009.

Kelty, Christopher. *Two Bits: The Cultural Significance of Free Software*. Durham: Duke University Press, 2008.

Kibby, Marjorie D., "Home on the Page: A Virtual Place of Music Community." *Popular Music* 19:1 (January 2000): 91–100.

Latour, Bruno. *ARAMIS or The Love of Technology*. Cambridge, MA: Harvard University Press, 1996.

_____. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press, 2005.

Lewis, George. "Too Many Notes: Computers, Complexity and Culture in *Voyager*." *Leonardo Music Journal* 10(2000): 33–39.

Lochhead, Judy. "'How Does it Work?': Challenges to Analytic Explanation." *Music Theory Spectrum* 28:2 (Fall 2006): 233–254.

Loy, Gareth. "Composing with Computers—a Survey of Some Compositional Formalisms and Music Programming Languages." In *Current Directions in Computer Music Research*. Editors, Max V. Mathews an John R. Pierce. Cambridge, MIT Press, 1989.

Lysoff, René, and Leslie Gay Jr., eds. *Music and Technoculture.* Middletown, Wesleyan University Press, 2003.

Lysoff, René. "Musical Community on the Internet: An On-Line Ethnography." *Cultural Anthropology* 18: 2 (May 2003): 233–263.

Manning, Peter. *Electronic and Computer Music.* Oxford: Oxford University Press, 2004.

McCartney, James. "Rethinking the Computer Music Language." *Computer Music Journal* 26:4 (Winder, 2002): 61–68.

McClary, Susan. *Feminine Endings: Music, Gender, and Sexuality*. Minnesota: University of Minnesota Press, 1991.

McClean, Alex, and Roger T. Dean. *The Oxford Handbook of Algorithmic Music*. Oxford: Oxford University Press, 2018.

McLeod, Kenneth. "Interpreting Chaos: The Paradigm of Chaotics and New Critical Theory." *College Music Symposium* 45 (2005): 42–56.

Miller, Kiri. *Playing Along: Digital Games, YouTube, and Virtual Performance*. Oxford: Oxford University Press, 2012.

Mindell. David. *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*. Baltimore: Johns Hopkins University Press, 2002.

Nwana, Hyacinth. "Software Agents: An Overview." *Knowledge Engineering Review* 11:3 (October/November 1996): 205–244.

Olaveson, Tim. "Collective Effervescence and Communitas: Processual Models of Ritual and Society in Emile Durkheim and Victor Turner." *Dialectical Anthropology* 26:2 (2001): 89–124.

Ostertag, Bob. "Human Bodies, Computer Music." *Leonardo Music Journal* 12 (2002): 11–14.

Perkis, Tim, and John Bischoff. Liner Notes. *The League of Automatic Composers 1978–1983*. New World Records, 2007. CD.

Piekut, Benjamin. *Experimentalism Otherwise: The New York Avant-Garde and Its Limits*. Berkeley: University of California Press, 2011.

_____. "Sound's Modest Witness: Notes on Cage and Modernism." *Contemporary Music Review* 31:1 (2012): 3–18.

_____. "Actor-Networks in Music History: Clarifications and Critiques." *Twentieth-Century Music* 11:2 (September 2014): 191–215.

Polansky, Larry. "Live Interactive Computer Music in HMSL, 1984–1992." *Computer Music Journal* 18:2 (Summer 1994): 59–77.

Polli, Andrea. "'Atmospheric/Weather Works': A Spatialized Meterological Data Sonification Project." *Leonardo Music Journal* 38:1 (2005): 31–36.

Pope, Steven, ed. *The Well-Tempered Object*. Cambridge: MIT Press, 1991.

Puwar, Nirmal. *Space Invaders: Race, Gender, and Bodies out of Place*. Oxford: Berg, 2004.

Ralston, Geoff. "Object-Oriented Programming (OOP)." In *Encyclopedia of Computer Science*. Ralston, Geoff, and Edwin Riley, and David Hemmendinger, eds. Fourth Edition. Oxford: Nature Publishing Group, 2000.

Rheingold, Howard. *Virtual Communities: Homesteading on the Electronic Frontier*. Cambridge: The MIT Press, 1993.

Rodgers, Tara. *Pink Noises: Women on Electronic Music and Sound*. Durham: Duke University Press, 2010.

_____. "Tinkering with Cultural Memory: Gender and the Politics of Synthesizer Historiography." *Feminist Media Histories* 1:4 (Fall 2015): 5–30.

Scaletti, Carla. "The CERL Music Project at the University of Illinois." *Computer Music Journal* 9:1 (Spring 1985): 45–58.

_____. "Kyma: an Object-oriented Language for Music Composition." Apple/InterUniversity Consortium for Educational Computing Fellowship Proposal, University of Illinois, Urbana-Champaign, October 26, 1987.

_____. "The Kyma/Platypus Computer Music Workstation." *Computer Music Journal* 13:2 (Summer 1989): 23–38.

_____. "Composing Sound Objects in Kyma." *Perspectives of New Music* 27:1 (Winter 1989): 42–69.

_____. "Sound Synthesis Algorithms for Auditory Display." In *Auditory Display: Sonification, Audification, and Auditory Interfaces*. Edited by Gregory Kramer. Addison-Wesley Publishing Company: Reading, MA, 1994.

_____. "Computer Music Languages, Kyma, and the Future." *Computer Music Journal* 26:4 (Winter 2002): 69–82.

_____. Interviewed by Matteo Milani. July 2004. http://www.symbolicsound.com/cgi-bin/bin/view/Connect/KymaInPrint.

_____. "Sonification of the World." *Ear to the Earth* (web chadabe). https://eartotheearth.org/2015/01/sonification-of-the-world/, January 12, 2015.

_____. *Carla Scaletti*. Copyright, 2014. http://www.carlascaletti.com.

_____. "Looking Back, Looking Forward: A Keynote Address for the 2015 International Computer Music Conference." *Computer Music Journal* 40:1 (Spring 2016): 10–24.

Scaletti, Carla, and Alan B. Craig. "Using Sound to Extract Meaning from Complex Data." Proc. SPIE 1459, Extracting Meaning from Complex Data: Processing, Display, Interaction II, 207 (June 1, 1991)

Scaletti, Carla, and Kurt J. Hebel. "The Software Architecture of the Kyma System." *Proceedings of the International Computer Music Conference*, Tokyo, Japan, 1993, 164–167.

_____. "An Object-based Representation for Digital Audio Signals." In *Representations of Musical Signals*. Edited by Giovanni De Poli, Aldo Piccialli, and Curtis Roads. Cambridge: MIT Press, 1991.

Schedel, Margaret. "Electronic Music and the Studio." In *The Cambridge Companion to Electronic Music*. Edited by Nick Collins and Julio d'Escriván. Cambridge: Cambridge University Press, 2007.

Shelemay, Kay Kaufman. "Musical Communities: Rethinking the Collective in Music." *Journal of the American Musicological Society* 64:2 (Summer 2011): 349–390.

Shultis, Christopher. "Cage and Chaos." *American Studies* 45:1 (2000): 91–100.

Sterne, Jonathan. *The Audible Past: Cultural Origins of Sound Reproduction*. Durham: Duke University Press, 2003.

Sterne, Jonathan, and Tara Rodgers. "The Poetics of Signal Processing." *differences: A Journal of Feminist Cultural Studies* 22:2&3 (2011): 31–53.

Sterne, Jonathan. Ed. *The Sound Studies Reader*. Oxon: Routledge, 2012.

Stones, Annie, and Jeanne Krochalis. *The Pilgrim's Guide to Santiago De Compostela: A Critical Edition*, Volumes 1–2. London: Harvey Miller Publishers, 1998.

Strogatz, Steven. *Nonlinear Dynamics and Chaos*. Cambridge, MA: Perseus Books Publishing, 1994.

_____. *Sync: How Order Emerges From Chaos in the Universe, Nature, and Daily Life*. New York: Hachette, 2003.

Supper, Alexandra. “Sublime Frequencies: The Construction of Sublime Listening Experiences in the Sonification of Scientific Data.” *Social Studies of Science* 44:1 (2014): 34–58.

Taylor, Timothy. *Strange Sounds: Music, Technology & Culture.* New York: Routledge, 2001.

Théberge, Paul. *Any Sound You Can Imagine*. Middletown: Wesleyan University Press, 1997.

Thomas, Lewis. *The Lives of a Cell: Notes of a Biological Watcher*. New York: The Viking Press, 1974.

Turino, Thomas. *Music as Social Life: The Politics of Participation.* Chicago: University of Chicago Press, 2008.

Turner, Fred. *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*. Chicago: University of Chicago Press, 2006.

Von Foerster, Heinz, and James Beauchamp. Eds. *Music By Computers*. New York: John Wiley and Sons, Inc., 1969.

Von Glahn, Denise. *The Sounds of Place: Music and the American Cultural Landscape.* Boston: Northeastern University Press, 2003.

_____. *Music and the Skillful Listener: American Women Compose the Natural World*. Bloomington: Indiana University Press, 2013.

Wellman, Barry, et. al. “Computer Networks as Social Networks: Collaborative Work, Telework, and Virtual Community.” *Annual Review of Sociology* 22 (1996): 213–238.

_____. “Connecting Communities: On and Offline.” *Contexts* 3:4 (2004): 22–28.

Williams, Robin, and David Edge. “The Social Shaping of Technology.” *Research Policy* 25 (1996): 865–899.

Wolfram, Stephen. *Cellular Automata and Complexity: Collected Papers*. Reading, MA: Addison-Wesley Publishing Company, 1994.

Wooley, Nick. “PLATO: The Emergence of Online Community,” 1994. http://just.thinkofit.com/plato-the-emergence-of-online-community.

Worrall, David. “An Introduction to Data Sonification.” In *The Oxford Handbook of Computer Music*. Edited by Roger T. Dean. Oxford: Oxford University Press, 2009.

Zaiment, Judith Lang. *The Musical Woman: An International Perspective.* Westport: Greenwood Press, 1984.

Zaphiris, Panayiotis and Chee Siang Ang. Editors. *Social Computing and Virtual Communities*, Boca Raton: Chapman & Hall/CRC, 2010.