The Path to *Half-life*

Curtis Roads

A composer does not often pause to explain a musical path. When that path is a personal breakthrough, however, it may be worthwhile to reflect on it, especially when it connects to more general trends in today's musical scene.

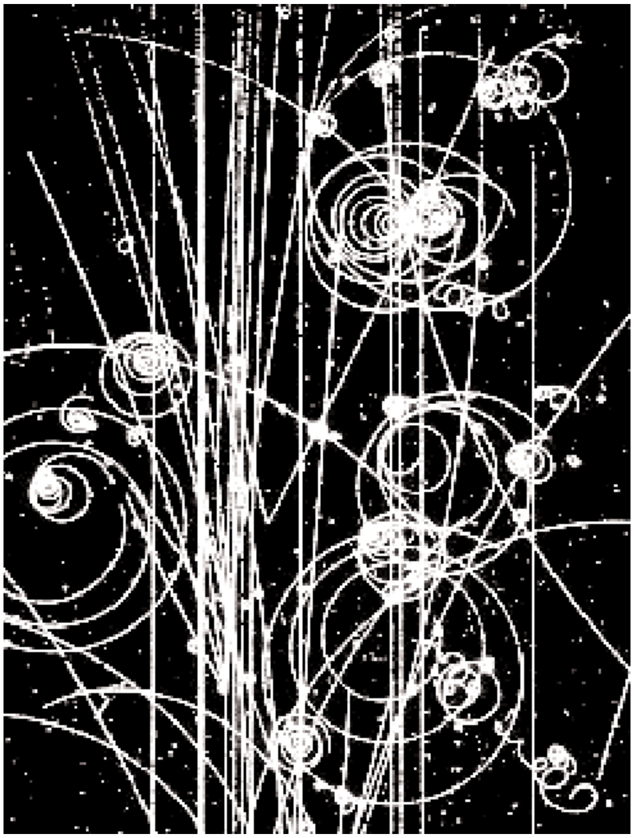

Figure 1. Bubble chamber image (© CERN, Geneva).

My electronic music composition *Half-life* portrays a virtual world in which sounds are born and die in an instant or emerge in slow motion. As emerging sounds unfold, they remain stable or mutate before expiring. Interactions between different sounds suggest causalities, as if one sound spawned, triggered, crashed into, bonded with, or dissolved into another sound. Thus the introduction of every new sound contributes to the unfolding of a musical narrative.

Most of the sound material of *Half-life* was produced by the synthesis of brief acoustic sound particles or grains. The interactions of acoustical particles can be likened to photographs of bubble chamber experiments, which were designed to visualize atomic interactions. These strikingly beautiful images portray intricate causalities as particles enter a chamber at high speed, leading to collisions in which some particles break apart or veer off in strange directions, indicating the presence of hidden forces (figure 1).

Composed years ago, in 1998 and 1999, *Half-life* is not my newest composition, nor does it incorporate my most recent techniques. The equipment and software used to make it was (with exception of some custom programs) quite standard. Nonetheless this piece is deeply significant to me as a turning point in a long path of composition.

EARLY EXPERIMENTS IN GRANULAR SYNTHESIS

The notion of sound particles or grains can be traced back to antiquity, but the modern concept derives from experiments of the physicist Dennis Gabor and the composer Iannis Xenakis (Gabor 1946, 1947; Xenakis 1960, 1971; Roads 2002). I first heard about the theory of granular synthesis at Xenakis's 1972 course at Indiana University. I then studied electronic music and computer programming at California Institute of the Arts but I did not have access to a computer that could produce sound. In pursuit of such a facility, I enrolled at the University of California, San Diego and obtained research grants in order to use the campus mainframe computer. The purpose of this research was to test Xenakis's theory of granular synthesis, which had never before been programmed. Beginning in the autumn of 1974 I realized nine technical studies in digital synthesis. Each study involved multiple steps: programming on paper, typing punched cards, waiting for calculation, transferring the calculated data to different media, and finally audio conversion and recording. After some preliminary tests, I synthesized a 30-second study with 766 sound grains. The culmination of my efforts was an eight-minute study based on granular synthesis (Roads 1975). I called it *Prototype* to indicate its experimental nature. *Prototype* was an interesting technical experiment, but it was not compelling music. I sensed that granular synthesis had promise, but it was obvious that much more research would be needed to explore its true musical potential. I published a brief article in *Computer Music Journal* about my initial experiments (Roads 1978). As I had other compositional interests, I put aside this research for a time.

It was not until I arrived as a researcher at the MIT Experimental Music Studio (EMS) in 1980 that I had the opportunity to continue experiments with sound particles.

I used granular textures in my compositions *nscor* (1980) and *Field* (1981), but only at isolated moments when they were deployed for an explosive crescendo. Granular synthesis seemed like a specialized effect. Could it be taken further? With this question in mind, I began late-night experiments with a new technique: the granulation of sampled sounds. To granulate means to decompose an existing sound into thousands of particles while reassembling them in a new order and microrhythm. I granulated sounds such as alto saxophone tones (played by Earl Howard) as well as snare drum and cymbal strokes. At the same time, I developed spatialization algorithms for scattering the grains to the four Klipschorn loudspeakers in the corners of the studio. These experiments showed me once again how granular techniques could be a powerful resource. I began to dream about musical processes in new ways.

For various reasons, however, the technical conditions at MIT EMS were not ideally suited to this approach. Added to this, I had heavy work responsibilities, including my role as Editor of the quarterly *Computer Music Journal.* This left little time for personal research. The combination of these factors did not favor open-ended experimentation. I still thought of granular synthesis as a fascinating phenomenon with untapped potential. But I did not yet have a vision of how to compose interesting music with granular materials.

In the mid-1980s, the Canadian composer Barry Truax took an interest in granular synthesis. He programmed a specialized device that could realize multiple streams of granular synthesis in real time (Truax 1986, 1987, 1988). This meant that he could quickly explore a much broader range of variations than I had. His explorations opened up a realm of new musical possibilities, specifically in the play between synchronous and asynchronous grain sequences and manipulations of grain duration.

By the late 1980s, technology greatly improved. Personal computers and high quality sound cards opened up fresh possibilities for the synthesis and transformation of microsound outside of university laboratories. By 1988 I developed new implementations of granular synthesis and granulation at home on my Apple Macintosh II computer.

In 1991, I developed another particle synthesis technique called *pulsar synthesis* (Roads 1997, 2001), which appears in parts of *Clang-tint* (1994). I later employed this technique in *Half-life.* (I explain more about pulsar synthesis later.)

In 1995, working in Paris at what is now the Centre de Création Musicale «Iannis Xenakis» or CCMIX, John Alexander and I wrote Cloud Generator, a program for granular synthesis and granulation of sampled sounds. Cloud Generator provided a graphical interface for my granular synthesis and granulation algorithms. It offered a "design-then-render" type of interaction, in which the rendering of a sound cloud could take several seconds.

By the time of my arrival at the University of California, Santa Barbara in 1996, the use of granular techniques around the world was becoming widespread. I was beginning to write the book *Microsound* (Roads 2002), which was leading me to much reflection on the aesthetic implications of particulate materials and processes.

In 1997, Stephen Pope and I developed a new implementation of pulsar synthesis. Around the same time I wrote a program for granulation of sound files in which each grain passes through a unique bandpass filter. (This is also described in more detail later.) Both programs operated in real time, which let me quickly explore a large space of possibilities. These programs were instrumental to making *Half-life*.

Composition, however, requires inspiration as well as technique. Two pieces piqued my interest. I knew that Horacio Vaggione's *Schall* (1994) was a landmark when I first heard it at the electroacoustic music festival in Bourges, France. *Schall* is composed completely out of sound particles derived from a piano that are projected on various time scales. In 1997, Ken Fields, a UCSB graduate student, played me his *Life in the Universe,* an intriguing mixture of granulated voice with distant sinusoidal textures. It became clear that I could combine techniques of phrase construction developed in *Clang-tint* (which already used pulsar synthesis) with granulation processes. 24 years after my initial experiments, I finally had a clear idea of how to proceed.

SOUND MATERIALS AND TRANSFORMATION

The composition of *Half-life* began in January 1998 with the creation of a 14-second sound file produced by pulsar synthesis. Pulsar synthesis generates a train of sound particles. Each pulsar particle repeats at a fundamental frequency with a formant peak in the spectrum above the fundamental. Depending on the fundamental frequency, one can produce either rhythms or tones. I controlled the fundamental and formant frequencies by separate time-varying envelopes that I drew on the screen.

The 1997 pulsar synthesis instrument used to make *Half-life* was simple compared to the PulsarGenerator program that Alberto de Campo and I later made (Roads 2001). The 1997 pulsar synthesis instrument was controlled by five graphically-drawn envelopes:

1. fundamental frequency over the duration of a pulsar train
2. formant frequency over the duration of a pulsar train
3. amplitude envelope over the duration of a pulsar train.
4. stereo spatial position over the duration of a pulsar train
5. waveform of each pulsaret (a pulsar = pulsaret + silence),
which was fixed over the entire trian

The next aesthetic decision was central to the compositional process: I granulated the pulsar train. This is significant, as it differentiated my approach from that of Vaggione, whose particulated sound world derives consistently from the acoustic orchestral instruments. (Despite this aesthetic difference, I greatly admire Vaggione's work; see Roads 2003.) The decision to granulate synthetic particles was a conscious effort to make music purely out of electronic materials. I wanted to demonstrate that the medium of electronic music had reached a point of self-sufficiency. In particular, I was tired of the dogma, repeated by traditional composers, that electronic sound was somehow lacking in comparison with acoustic instruments. I strongly disagree.

Granulation can spawn a vast amount of output sound material from a tiny amount of input. A given sound can be time-stretched by a factor of 100 or more. Simultaneous with this telescoping effect, other processes may also be occurring, such as pitch-shifting, filtering, and spatial scattering. By shrinking the grain duration one can cause the sound to dissolve into broadband noise, and by varying the grain density one can play with the sound's transparency and mass. When the grains are synchronized (aligned in time) this leads to pulsation and pitch formation, while asynchronous grains generate turbulence in the granular cloud. The product of all of these transformations is a very large space of mutations from one state to another.

I also created sound particles directly by *transient wave writing* (Roads 2002). In this method one draws individual particle waves in the window of a sound editor and sculpts them with various software implements (narrow-band filtering, envelope reshaping, and so on). The last important sound source in *Sonal atoms* was a three-second recording of steam.

SONAL ATOMS

Based on the original pulsar train, I produced enough material for four movements. (I eventually discarded two of these.) In the end, *Half-life* was organized in two distinct parts: *Sonal atoms* and *Granules.*

In *Sonal atoms,* I wanted to shift the musical discourse away from continuous, stationary, and homogenous signals (such as pitched tones) to intermittent, nonstationary and heterogeneous emissions (pulses, grains, and noise bands). Thus the sound universe of *Sonal atoms* is a concentrate of punctiform transients, fluttering tones, and broadband noise textures (figure 2). Only a few stable pitches appear, the result of unusually regular particle repetitions in the middle of the audio frequency range.

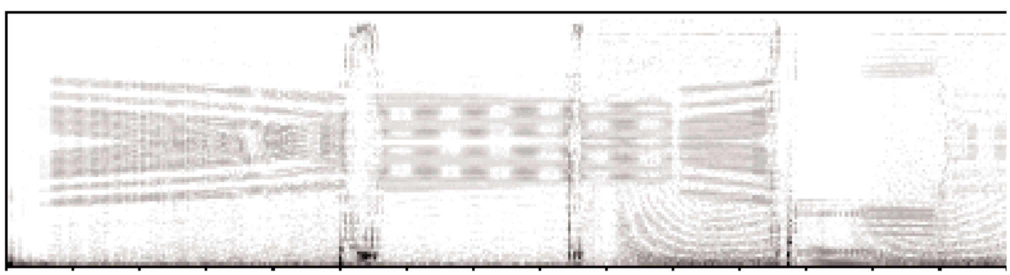

Figure 2. Sonogram of the first 15 seconds of *Sonal atoms.*

Increased heterogeneity in musical material leads to a proliferation of singularities–events that appear only once. For example, one can start with a single particle, and from it breed a family of different sounds by means of various signal processing operations.

On a macro time scale, the work unfolds without formal repetition of subsections. However the work is full of iterations on the micro time scale. Pitched tones are, by definition, repetitious in their internal structure. Each pitched tone that appears in *Sonal atoms* was constructed by replication of a single particle (figure 3). For example, when the time interval between successive iterations of a particle is less than 25 ms (corresponding to the wavelength of a low-frequency tone at 40 Hz) a 20-times replication forms a pitched tone. A replication interval between 25 and 50 ms generates ambiguous sounds, where pitch meets pulsation. When the time interval between successive iterations is greater than 50 ms (corresponding to the wavelength of a vibration at 20 Hz) the replication generates a repeating pulsation, which can be sculpted into a dramatic introductory sweep or a fading echo, depending on its amplitude envelope.

Another place where internal repetition appeared was in the pseudo-reverberant tails of certain pulse clusters. Rather than use generic global reverberation, I staggered multiple copies of a sound with diminishing amplitudes to create an impression of increasing distance. In this way I could exactly match the color of the pseudo-reverberant tail to the initial excitation particle.

As is obvious in the first few seconds of the piece, spatial movement is fundamental to the structure of *Half-life*. I applied a battery of techniques to position sounds on multiple time scales, from particles to large phrases. At the lowest level, my granulation algorithm assigned a unique spatial position to each grain that it emitted. This essential condition contributes to a three-dimensional spatial quality of the resulting textures. Other strategies included balancing (amplifying one channel over another), motion panning between channels, layering of a slightly delayed copy in one channel, panning with Doppler shift to enhance the sense of motion, binaural filtering (for simulating the effect of sounds emanating overhead), and phase manipulations. Phase manipulations alter the spatial image of a sound: narrowing, widening, or shifting the apparent source location. For example, by phase inverting one channel of a stereo pair, a sound's image shifts, projected in relief, as it were. In other cases I extracted the pure monaural part of a stereo signal and then phase inverted it to control the width of the stereo image. (Such manipulations mean that *Half-life* is not monaural compatible. This means that if it is broadcast with both channels mixed to one, both its spatial and spectral character will be strongly effected.)

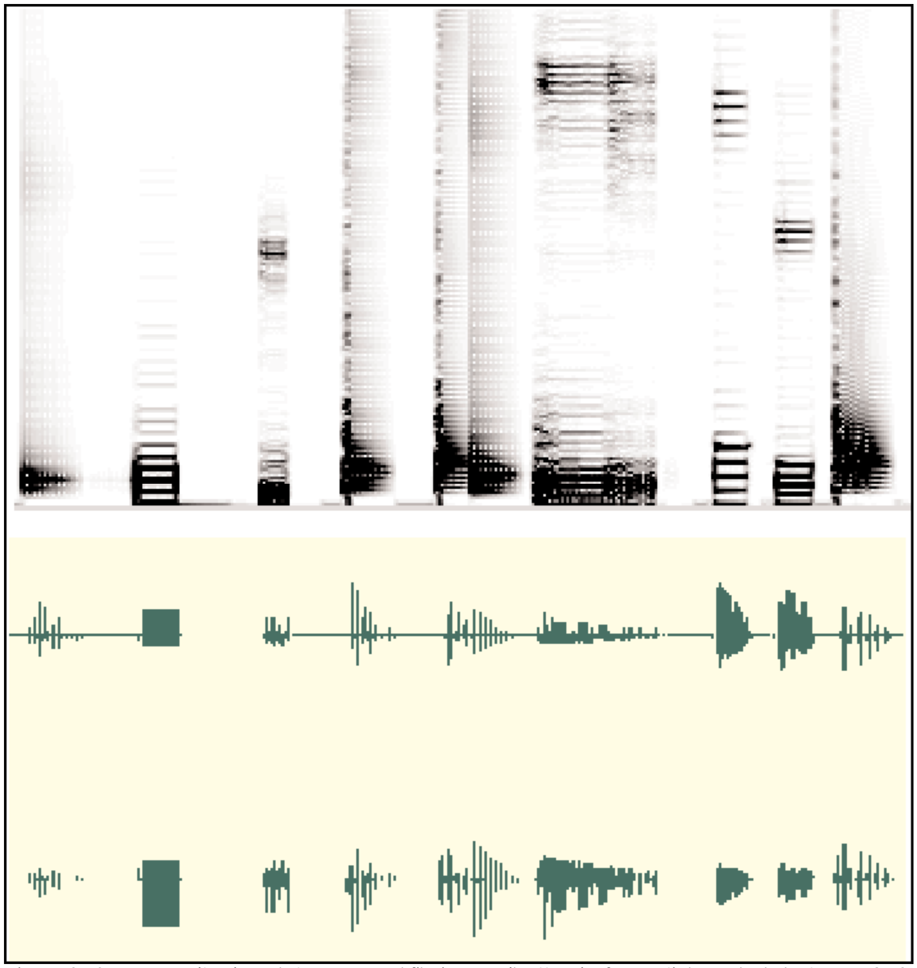

Figure 3. Sonogram (top) and stereo sound file image (bottom) of a particle melody between 2:19 and 2:22 in *Sonal atoms.*

Although the piece was composed in two channels, it was also designed to be performed over multiple loudspeakers. Indeed, for the first performance I played it over 28 loudspeakers scattered around a large auditorium (1998, Australian National Conservatory, Melbourne). For me, projecting a work such as *Half-life* in space is an opportunity to perform, since each hall and every sound system requires a unique adaptation.

GRANULES

For the second part of *Half-life, Granules,* I elaborated the original pulsar material by granulation, turning it into flowing streams and clouds. One of the key factors in granulation is the density of grains per second. When the density is high, the source material is reiterated, with numerous grains superimposed in time. When the density is low, the source material is cavitated–pocked with holes.

As mentioned previously, the granulation instrument applied a bandpass filter to every grain. This filter had a "constant-Q" characteristic. The term "Q" refers to the ratio between the center frequency of the filter and its bandwidth, a musical interval. "Constant-Q" means that this musical interval is preserved regardless of the center frequency. For example, given a Q factor of 2, the bandwidth of a filter centered at 100 Hz is 50 Hz, with a low frequency boundary of 75 Hz, and a high frequency boundary of 125 Hz. If, in the contrary, the center frequency is 1000 Hz, then the bandwidth is 500 Hz, that is, between 750 Hz and 1250 Hz. Since frequency perception is logarithmic, the two filters correspond to the same musical interval: 1.666... or a Major sixth.

In *Granules,* the center frequency of each grain's filter was selected by a random choice between two limits that I set. At high grain densities, this produced a texture in which up to several hundred independent filters were operating at any given second, leading to highly animated microtextures.

The core of *Granules* is a long flowing granulation gesture that I call the Grand Descent (figure 4). The Grand Descent involved a continuous downward pitch-shifting that uncovered layer upon layer of sound microstructure. The particle flow in *Granules* is very different from that in *Sonal atoms,* in that the entire structure is a slow release of energy, bubbling down to the depths, proceeding inexorably to a sputtering end.

MULTISCALE PLANNING

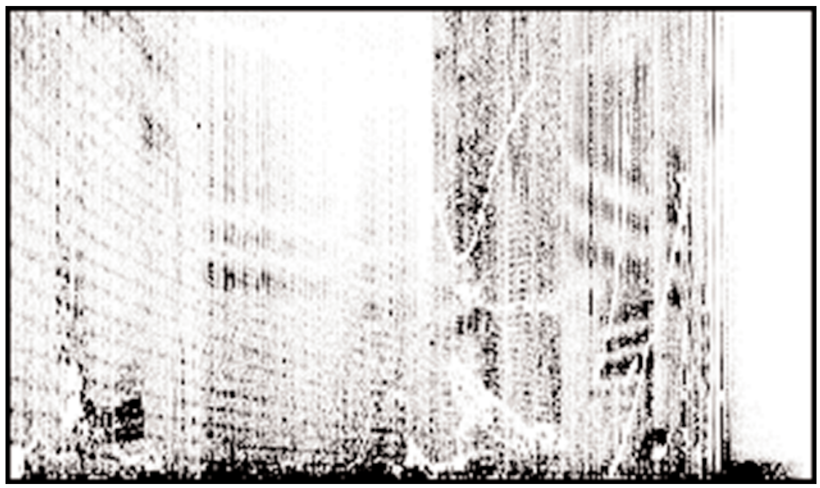
Figure 4. Sonogram of the Grand Descent, from *Granules.*

How did I arrive at the macroform of *Half-life*? There was no preset design. Rather, the strategy was to generate the sounds, to study and classify the sounds, to pick, choose, and transform the sounds, and finally to connect and layer the sounds.

Rather than strictly top-down or bottom-up preplanning, I followed a strategy of *multiscale planning* in the presence of sound. By multiscale planning I mean that I was not limited by either the original sound material or a grand macro design. I began by organizing phrase structures from the sequencing and layering of individual sound objects (a bottom-up strategy). When I sensed the possibility of a large-scale gesture emerging, I would change direction (working from the top down) in order to assemble it. When I found myself in a situation where I had several large chunks of a piece, but nothing to connect them, I would change strategy again and synthesize new connective tissue. At any point in the work I might sprinkle newly-generated particles, like salt and pepper to spice up a sauce.

For example, midway into *Sonal atoms,* I set up several *zones of attraction.* Sounds gravitate around zones of attraction. In *Sonal atoms,* up to 80 sounds converge within brief zones of attraction (1:41-1:48, 2:39-2:43, 3:21-3:26). I often found it useful to listen at half-speed in order to make fine adjustments in the microrhythm. The final stages of editing involved an accumulation of details. For example, a transition that had originally been a simple crossfade between two stereo sound files became a zone of attraction by inserting dozens of individually-tuned particles across a two-second transition.

Multiscale planning is essentially an intuitive process, and is certainly not predictable because it is based on a trial-and-error methodology. In this approach, there are no shortcuts; it is usually quite time-consuming. Dead-end experiments are an inevitable part of this process. As previously mentioned, I composed four movements of *Half-life* before I decided to discard two of them. Nonetheless, for me this is the only way to tackle the medium of studio-based electronic music. A sound-oriented multiscale approach is one of the major differences between this medium and that of traditional instrumental composition, where the palette of sound is preformed and symbolically coded on paper.

STUDIO TECHNOLOGY

The technology of *Half-life* was modest. I used two computers. The first was an ageing Apple Macintosh Quadra 700 computer (40 MHz, purchased in 1992). This was connected to the Studer Dyaxis, a multitrack audio mixing device consisting of a signal processing card (for filtering) and a box that performed signal mixing as well as digital-to-audio and audio-to-digital conversion. (I bought the Dyaxis in 1988; it is no longer commercially available.) The second computer was a 1997 Apple Power Macintosh 8600 (200 MHz) with a Digidesign Audiomedia III sound card. My pulsar synthesis and granulation programs ran on the 8600. Both were written in James McCartney's SuperCollider 1 language (www.audiosynth.com). The sound monitoring system consisted of a Mackie 1202 mixer, Threshold S/500 II amplifier, and B&W 803 Matrix loudspeakers.

I used several graphical sound editors in constructing the piece: BIAS Peak, Passport Designs Alchemy, and Alberto Ricci's Soundmaker. I should also cite Arboretum's Hyperprism, whose graphical approach to time-varying continuous sound transformation I consider to be a model. Thanks to these programs, *Half-life* was honed in microscopic detail, on a particle-by-particle basis. This led to great diversity in the sonic material, even though it was derived from just a handful of source sounds.

I assembled *Half-life* with Adrian Freed's MacMix, a graphical mixing program for the Dyaxis. Work with MacMix involved building up mesostructures from individual sounds. When a given section reached a certain level of complexity, I would mix it down from multiple tracks into a stereo version. Then I would import this stereo version as a new foundation for further layering. I commonly used dozens of tracks, not to create thick layers, but to design intricate filigrees. Technology marches on, however, and *Half-life* is the final piece that I realized with the Dyaxis/MacMix combination.

HAPPY ENDING

In the time since I composed *Half-life,* I have realized a number of pieces using essentially the same aesthetic and technical approach. In this collection, called *POINT LINE CLOUD,* the sensations of point, pulse (series of points), line (tone), and cloud (texture) emerge as the density of particles increases. Sparse emissions produce rhythmic figures. By cloning particles in rapid succession, one can induce an illusion of tone continuity or pitch. As the particles meander in time and in frequency, they flow into streams and rivulets. Dense agglomerations of particles form clouds of sound whose shapes evolve over time.

The compositions in *POINT LINE CLOUD* are meticulously organized, but this does not mean that they were planned in advance. To the contrary, they are the result of intense encounters with sound. One might say that they are highly organized in the same sense as a stone sculpture, which embodies thousands of decisions and subsequent gestures on multiple scales.

POINT LINE CLOUD is the product of certain technical developments but also an aesthetic vision. This article documents how technology and my aesthetic viewpoint evolved over a long period of time. In hindsight, it may seem obvious where this research was leading, but it was not obvious to me. Nor is it obvious where it will lead in the future. Together with some bright graduate student researchers, I am exploring several threads of inquiry. Please stay tuned.

PRODUCTION NOTES

Sonal atoms appeared on the double CD album *CCMIX: New Electroacoustic from Paris* on the Mode label (New York). This anthology won the "HEARTBEAT" award (the French GRAMMY) from the Charles Cros Academy, France and was named FIVE BEST OF 2001 by *THE WIRE* magazine, London. *POINT LINE CLOUD* will be released on the Asphodel label (www.asphodel.com) in the CD + DVD boxed set.

ACKNOWLEDGMENTS

Half-life is dedicated in memorium to my friend, the composer Ivan Tcherepnin, who passed away in 1998 after a courageous struggle with cancer. Among other things, Ivan was Director of the Electronic Music Studio at Harvard University, where I first taught electronic music composition. I would like to thank Brian O'Reilly, Woon Seung Yeo, and James Ingram for their fine visual renderings of *Half-life* and also John Thompson for his thoughtful analysis of the piece. I also thank Brigitte Robindoré for her excellent comments on drafts of this text.

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APPENDIX: PERFORMANCES OF *HALF-LIFE: 1998-2004*

May 1998, Next Wave Festival, Australian National Conservatory, Melbourne, Australia, with sound projection over 28 loudspeakers.

November 1998, CREATE concert, University of California, Santa Barbara

November 1998, DAFX 98 conference, Univeritat Pompeu Fabra, Barcelona

June 2000, Synthèse Festival, Bourges

September 2000, Swiss Center for Computer Music, Zurich

February 2001, Engine 27, New York City

May 2001, El Rey Theater, Los Angeles (concert with Autechre and Russell Haswell)

September 2001, Olhares de Outono Festival, Porto

April 2002, L'Espace Jean Renaudy, Paris

September 2002, Ars Electronica, Brucknerhaus, Linz

September 2002, Rhiz, Vienna

October 2002, Conservatory of Music "Benedetto Marcello," Venice

November 2002, Centre ADAC, Paris

April 2003, All Tomorrow's Parties UK, Camber Sands

November 2003, Paris Planetarium, Cité des Sciences, Paris

November 2003, Instanbul Technical University, Istanbul

April 2004, Cut and Splice Festival, BBC and Sonic Arts Network, Belfast

September 2004, Traiettorie Festival, Teatro Farnese, Parma

October 2004, Museum of Science, Naples

October 2004, Royal Conservatory of Music, Stockholm

FIGURE CAPTIONS

Figure 1. Bubble chamber image (© CERN, Geneva). A bubble chamber is a type of subatomic particle detector that was used during the initial years of high-energy physics (1955-1975). The device consists of a vessel filled with a transparent fluid that is on the verge of boiling, that is, under a pressure and a temperature for which it is on the liquid-gas boundary. For hydrogen this is only a few degrees above absolute zero, -273 Celsius. When an ionizing particle passes through a bubble chamber, it initiates a string of bubbles—due to boiling—along its path, which can then be photographed and analyzed.

Figure 2. Sonogram of the first 15 seconds of *Sonal atoms*. The vertical scale represents frequency, plotted linearly from 0 to 22 kHz. Notice the broad noise bands that are interrupted by vertical clicks and pops.

Figure 3. Sonogram (top) and stereo sound file image (bottom) of a particle melody between 2:19 and 2:22 in *Sonal atoms*. These pitched tones were produced by replicating individual particles. The frequency range of the sonogram is between 10 Hz and 6 kHz.

Figure 4. Sonogram of the Grand Descent, from *Granules*. The plotted excerpt begins at 83 seconds into the piece and lasts 81 seconds.