Of the close to 150 compositions that Iannis Xenakis created, only a handful involve electroacoustics (sounds directly produced by electronic, digital, or other studio means). Those works, however, are influential beyond their number. Any history of electronic music must place Xenakis as a central figure, both for his innovations and for the impact his music has had on successive generations. His involvement in the creation of multimedia “spectacles” brought him wide exposure, although his uncompromising aesthetic vision precluded fame and fortune on a popular scale.

Nonetheless, through his work, Xenakis (see Figure 1) presented a bold, charismatic persona: he was a revolutionary, both in politics and in art. The restive students of the 1960s, in particular, were drawn to him, to his peculiar mixture of forward-reaching modernism and noisy, pounding primitivism. There are many parallels between Xenakis’s work and experimental elements of popular music, particularly in the embracing of technology and high-density/high-amplitude sound set off by disorienting, hallucinatory light-shows. The electroacoustic music of Xenakis, Concret PH in particular, provided a link between the “academic” components of the 2000 International Computer Music Conference in Berlin and the club-oriented “off-ICMC” celebration, held concurrently. Additionally, a new Asphodel release of his massive electroacoustic work, Persepolis, is accompanied by “re-mixes” by, among others, Japanese techno artists.

It is my aim to present here a brief overview of Xenakis’s electroacoustic music in the manner of a tutorial. Certain aspects or selected works from this area of his compositional output have been examined in some detail (Di Scipio 1998, 2001; Hoffmann 2000a; Solomos 1993), and a more detailed study of these works within the context of the rest of his output is found in Harley (forthcoming). While there is a strong unity of aesthetic and compositional technique running through his entire oeuvre, five stages in the trajectory of his studio output can be distinguished (see Table 1). In each, the technical means change somewhat, as do the aesthetic concerns. There are connections to the instrumental music he was writing around the same time, and there are also connections to the electroacoustic music being written by others (though surprisingly few). Throughout his life, as clearly exemplified in his electroacoustic works, Xenakis sought to “extend the limits of musical thought” (Robindoré 1996).

Stage One: Musique Concrète

Xenakis arrived in Paris as a 25-year-old refugee in November 1947. He decided, having barely escaped Greece (as a condemned insurgent) with his life, to devote himself to music, a dream he had guarded within himself but which had been sidelined by turmoil, both political and personal (see Matossian 1986 for fuller details of Xenakis’s early life). As a trained civil engineer, Xenakis found himself working in the architectural studio of Le Corbusier, where he was able to earn a living while pursuing music in his spare time. He would have known virtually nothing of contemporary music, but the milieu he worked in was certainly cultured (Le Corbusier was acquainted with Edgard Varèse, for example), and he would no doubt have heard various broadcasts on Radio-France. He very likely listened to the early broadcasts of Pierre Schaeffer, who, in 1948, presented his first experiments in musique concrète on the radio and in concert.

Xenakis met Olivier Messiaen in 1951 and began attending his classes that year, a habit he would continue more or less regularly for the next two years. Messiaen was a central figure in the Parisian new music world; Pierre Henry, who began working closely with Schaeffer in 1949, had been his student between 1944 and 1948 (Boivin 1995). During this period (1951–1952), Messiaen himself visited Schaeffer’s studio, producing a short piece, Timbres-durées. Karlheinz Stockhausen, who sat with Xenakis in Messiaen’s class during 1951–1952, also created a tape study during that time.
<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Medium</th>
<th>Duration</th>
<th>Studio</th>
<th>Recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>Diamorphoses</td>
<td>Tape</td>
<td>6:53</td>
<td>GRM</td>
<td>EMF CD 003</td>
</tr>
<tr>
<td>1958</td>
<td>Concet PH</td>
<td>Tape, multimedia</td>
<td>2:42</td>
<td>Philips/GRM</td>
<td>EMF CD 003, Caipirinha CAL.2027.2, Bvhaast CD 06/0701</td>
</tr>
<tr>
<td>1959</td>
<td>Analogique B</td>
<td>Tape</td>
<td>1:30</td>
<td>Gravesano/GRM</td>
<td>Vandenburg VAN 003</td>
</tr>
<tr>
<td>1960</td>
<td>Orient-Occident</td>
<td>Tape (soundtrack)</td>
<td>10:56</td>
<td>GRM</td>
<td>EMF CD 003</td>
</tr>
<tr>
<td>1960</td>
<td>Vasarely</td>
<td>Soundtrack</td>
<td>GRM</td>
<td>Withdrawn</td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>Formes rouges</td>
<td>Soundtrack</td>
<td>GRM</td>
<td>Withdrawn</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>Bohor</td>
<td>Tape (8-channel)</td>
<td>21:36</td>
<td>GRM</td>
<td>EMF CD 003</td>
</tr>
<tr>
<td>1967</td>
<td>Polytape de Montréal</td>
<td>Orchestra (pre-recorded)</td>
<td>c. 6 min</td>
<td>Radio-France</td>
<td>LP</td>
</tr>
<tr>
<td>1969</td>
<td>Kraanerg</td>
<td>Orchestra and tape (4-channel)</td>
<td>75:00</td>
<td>Radio-France</td>
<td>Ecteetera KTC 1075, Asphodel 0975</td>
</tr>
<tr>
<td>1970</td>
<td>Hibiki-Hana-Ma</td>
<td>Tape (12-channel)</td>
<td>17:39</td>
<td>NHK Tokyo</td>
<td>EMF CD 003</td>
</tr>
<tr>
<td>1971</td>
<td>Persepolis</td>
<td>Tape (8-channel), multimedia</td>
<td>55:06</td>
<td>FractalOX, Asphodel forthcoming Mode 98/99</td>
<td></td>
</tr>
<tr>
<td>1972</td>
<td>Polytape de Cluny</td>
<td>Tape (7-channel), multimedia</td>
<td>c. 25 min</td>
<td>CEMAMu</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>La Légende d’Eer (Le Diatope)</td>
<td>Tape (7-channel), multimedia</td>
<td>46:00</td>
<td>WDR Cologne/CEMAMu</td>
<td>Montaigne MO 782058</td>
</tr>
<tr>
<td>1978</td>
<td>Mycenae Alpha (Polytapes de Mycéne)</td>
<td>Tape (2-channel), multimedia</td>
<td>9:36</td>
<td>CEMAMu</td>
<td>Neuma Records 450-74, Mode 98/99</td>
</tr>
<tr>
<td>1981</td>
<td>Pour la Paix</td>
<td>Voices and tape, radiophonic multimedia</td>
<td>c. 27 min</td>
<td>CEMAMu/Radio-France</td>
<td>none</td>
</tr>
<tr>
<td>1987</td>
<td>Tauriphanie</td>
<td>Tape (2-channel), multimedia</td>
<td>10:46</td>
<td>CEMAMu</td>
<td>Neuma Records 450-86</td>
</tr>
<tr>
<td>1989</td>
<td>Voyage Absolu des Unari vers Andromède</td>
<td>Tape (2-channel)</td>
<td>15:25</td>
<td>CEMAMu</td>
<td>Perspectives of New Music PNM 28</td>
</tr>
<tr>
<td>1997</td>
<td>Erod</td>
<td>Tape (2-channel)</td>
<td>c. 5 min</td>
<td>Ateliers UPIC</td>
<td>Withdrawn</td>
</tr>
<tr>
<td>1991</td>
<td>GENDY301</td>
<td>Tape (2-channel)</td>
<td>14:15</td>
<td>CEMAMu</td>
<td>Withdrawn</td>
</tr>
<tr>
<td>1991</td>
<td>GENDY3</td>
<td>Tape (2-channel)</td>
<td>18:45</td>
<td>CEMAMu</td>
<td>Neuma Records 450-86</td>
</tr>
<tr>
<td>1994</td>
<td>S.709</td>
<td>Tape (2-channel)</td>
<td>7:03</td>
<td>CEMAMu</td>
<td>EMF CD 003</td>
</tr>
</tbody>
</table>
It was a few years later, in 1954, that Xenakis was accepted as one of the first members of the Groupe de recherches de musique concrète [renamed Groupe de recherches musicales in 1958, now commonly called GRM]. His assimilation of the concerns of contemporary musical culture had proceeded rapidly. That same year, he completed his first major orchestral score, Metastaseis, a work that explores novel sonorities built from complex configurations of string glissandi [see Figure 2]; it provoked a major scandal at its premiere in Donaueschingen the following year. Drawn to the new possibilities of the studio, Xenakis expressed his intention to “study the evolution of timbres, dynamics, and register . . . to make chromosomes of attacks” [Matossian 1986].

Diamorphoses

Xenakis completed his first electroacoustic composition in 1957. Diamorphoses (Greek for “continuity—discontinuity,” “two aspects of being”) is a relatively brief work, but sonically intense and quite unlike other music being produced at GRM at that time (such as Orphée, the opera by Schaeffer and Henry, or even Déserts, by Varèse). There was a strong concern among many of the composers working in the studio to create sounds from relatively discrete instrumental or real-world sounds. Xenakis, on the other hand, sought to create dense, noisy textures that bore little direct resemblance to the world around him. Instead, his sounds derived from the same imagination that was creating complex clouds and masses in the orchestra—an imagination, it should also be pointed out, strongly affected by the chaotic, traumatic sounds of war. [One might also speculate that the hearing loss, particularly in the higher frequencies, Xenakis suffered from his injuries during that time would have shaped, to some extent, his attraction to “noisy” sounds and to high-decibel playback levels.]

Indicative of the dichotomy described by the title, Diamorphoses combines noisy, primarily low-frequency sounds—derived from an earthquake, a jet engine, and a train—with more sharply defined, high-register bell sounds. The natural glissando effect of the jet engine winding up is combined with glissandi of other sounds, produced in the studio by means of tape manipulations. Often, the composite sonority produces something quite new, the sources being submerged.

The formal organization is quite clear: the two outer sections of more-or-less sustained sounds (layered noises, glissandi) are contrasted with a central, more discontinuous passage, filled with many shifts of sonority (starting with the bell sounds, then adding others). Xenakis worked in particular to create shifts and continuities of density through layered variations of sound objects [Delalande 1997]. For the discrete sonorities, he used probabilities to calculate attack points, layering the tracks in the studio to achieve a perceivable range or scale of activity.

Concret PH

Xenakis carried these concerns to his next electroacoustic piece, Concret PH, produced in 1958. [According to Delalande, it was revised in 1961 to Harle
create a stereo version, then re-mixed in 1969 onto four channels.) This 2-min miniature was produced as an introduction to the Poème électronique of Le Corbusier and Varèse for the Philips Pavilion in Brussels. Xenakis had been heavily involved in the design and construction of the Pavilion (see Figure 3), often standing in for Le Corbusier who was also working on a major project in India (Treib 1996). His music was intended to fill the gap between presentations of the 8-min performances of the main multimedia work, which occurred at 10-min intervals. In other words, it was intended to fill in the time as the audience filed into and out of the pavilion. Nonetheless, for a young, relatively unknown composer, the opportunity to create a work for presentation at a major international exposition that would be heard by many thousands of people would have been enticing. In addition, the facilities that Philips had developed in order to project sound, light, and images were among the most advanced in the world.

Unfortunately, Le Corbusier, who was operating under enormous pressure and seriously behind schedule, would not grant Xenakis leave to work at the Philips studio in Eindhoven, Holland. He needed him to supervise the construction of the pavilion, and seemed to consider the composition of the little interlude of secondary importance. Varèse, on the other hand, was able to take advantage of Philips’s technology, including special equipment for the projection of sounds over multiple loudspeakers. (The pavilion ended up housing over
400 loudspeakers.] Xenakis, in his spare time, was instead forced to work in the rather primitive facilities of the Philips offices in Paris. He produced a monophonic version there, and then completely re- composed the piece later at GRM. (Xenakis produced multiple versions of all his tape pieces, up to *La Légende d’Eer*, mixing for different numbers of channels, accounting for different playback situations, and so forth.)

The only sound source used in *Concret PH* is the crackling and hissing of burning charcoal. The study of density and the application of stochastic functions to the calculation of articulation points for each layer of sound were the main concerns. The crackling texture evolves in a continuous fashion, much like the central portion of *Pithoprakta*, his second orchestral score, completed in 1956. The sense of spatial movement as the music moved along the trajectories through the loudspeakers of the pavilion in Brussels would have been particularly effective using these primarily mid- to high-register grains of sound. Certainly, it was utterly unlike any other electroacoustic music of the time, and remains a gem of the tape music idiom.

**Analogique B**

Xenakis first met the renowned Swiss conductor and researcher Hermann Scherchen in 1954. The elder musician became something of a mentor to the fledgling composer, encouraging him in particular to work out his ideas of combining mathematics and music so that they could be expressed cogently. Scherchen held a “retreat” every year at his estate in Gravesano, to which he invited leading thinkers of the time to discuss a range of topics. (Guests included Werner Meyer-Eppler, Lejaren Hiller, Max Mathews, and others.) The proceedings were published in the *Gravesaner Blätter*.

Scherchen’s interests ranged to acoustics and new technology, and he had actually developed a rudimentary studio for carrying out experiments and producing electroacoustic music.

By 1958, Xenakis had become interested in the theory of acoustical quanta [Gabor 1947], the precursorn to granular synthesis [Roads, 2002]. He had developed a proposition for composing on the basis of “screens,” a representation of clouds of quanta for each “slice of time” (Xenakis 1992). The progression from one screen to the next is governed by Markov chains, whereby the settings for one screen exert an influence on the calculations for the next, building a form of “memory” into the temporal organization of the music.

That year, Xenakis composed *Analogique A*, a short work for strings in which there are nothing but discrete notes (no held pitches, glissandi, tremoli, etc.). The music proceeds as a succession of changing densities, registers, ranges, and intensities (along with timbral changes from plucked notes to struck or short bowed ones). In the summer of 1959, during his stay with Scherchen in Gravesano, Xenakis produced a complementary composition, *Analogique B*, for discrete electronic sounds, produced in this case by oscillators. The procedure was the same, though the particular parametrical constraints are of course different. The composer worked out an interlocking scheme whereby the two pieces can be performed as a unit, the strings alternating with the pre-recorded electronic sounds, with some moments of simultaneity.

*Analogique A + B* was premiered in Paris in 1960 along with the first French performance of *Pithoprakta*, conducted by Scherchen. From that point, Xenakis’s music began to receive more dedicated attention in his adopted land. A final break with Le Corbusier provided him with the opportunity to
quit his day job (for the most part) and devote himself at last professionally to music.

**Orient-Occident**

One of the first commissions Xenakis received through his association with GRM was for a soundtrack to a documentary film by Enrico Fulchignoni for UNESCO. The film, *Orient-Occident* [1960], tried to express by visual and sonic means the relations and resonances of artistic relics from various ancient cultures. The film was based upon an exhibition at the Cernuschi Museum in Paris, where the director spent three months shooting. Xenakis was not brought into the project until that phase was complete. Mr. Fulchignoni intentionally gave no instructions or “interpretation” to the composer, preferring to allow him the liberty of working from his own reactions and analyses [Fulchignoni 1981]. The film links disparate eras and cultures primarily through visual resemblances rather than any sort of chronological or cultural narrative. In effect, this more abstract approach enabled Xenakis to construct his own “narrative” to underscore the images.

The original 22-min soundtrack is not well known. What is available is the concert work of half that length extracted from it. A 4-channel version was apparently produced at GRM in 1969 [Delaude 1997], and available recordings show some slight discrepancies of detail. (For example, the version released on a compact disc from the Electronic Music Foundation stops 16 sec before the version that had been released on vinyl by Nonesuch.)

Compared to *Diamorphoses* or *Bokor*, the sounds of *Orient-Occident are much clearer (i.e., less noisy). A bow drawn over various objects is the source of many of the sustained sonorities. The percussive sounds are often presented as regular pulsations or perceptible patterns rather than statistical “clouds.” The music is dramatic, with the more reflective sounds being surprised by sharp attacks or “ethnic” drumming-like patterns. There are some silences, unusual in Xenakis’s electroacoustic output, but also grating metallic sounds that resemble sonorities from other pieces. The granular texture of burning charcoal from *Concret PH* makes an appearance in the latter part of the work, this time mixed with water droplets and other sounds.

The formal outline of *Orient-Occident is less sharply defined than is usually the case in Xenakis’s music, no doubt due to its original conception as a soundtrack. The music proceeds from one section to another by shifts of sonority, effected at times by gradual transition and at other times by sharp divisions. The liner notes of the Nonesuch LP state that “Xenakis looks upon this work as a solution to the problem of finding many different means of transition from one kind of material to another” [Brody 1970]. In drawing upon a relatively wide range of sonorities, none recognizably linked to any particular culture but related to each other by various means of transition or juxtaposition, Xenakis enables the listeners (and presumably the viewers, originally) to create their own associations between the sounds and images from ancient cultures.

**Vasarely and Formes rouges**

In the period 1960–1961, Xenakis produced two more soundtracks in addition to *Orient-Occident*. Never again would he work in this domain. (Hollywood decidedly did not beckon!) *Vasarely* [1960] was a similar project to the previous, more well-known piece, a short film by Peter Kassovitz and E. Szabo based on an exhibition of Op Art paintings by Victor Vasarely (see Figure 4). The composer was quite taken with this artist, and he ended up working with him a few years later on his ballet, *Kraanerg*.

*Formes rouges* [1961] was a short animated film by Piotr Kamler. Little is known of the music for these films, as they were both quickly withdrawn from the composer’s catalog. Produced at GRM, which is the reason for noting them here, these pieces were primarily instrumental rather than electroacoustic, apparently. Regardless, the sounds would have been assembled in the studio.

During this same period, however, Xenakis was becoming more and more drawn into completing a
stochastic algorithm for composing music using computers. These mathematical, abstract concerns conflicted both with the dictates of producing music for film and with the general aesthetic direction of the GRM studio as directed by Pierre Schaeffer.

**Bohor**

In 1962, Xenakis completed his most ambitious electroacoustic work to date, and subsequently withdrew from being an associate of GRM. Bohor was one of the first 8-channel works created at GRM [John Cage and Earle Brown had created 8-channel works back in 1952/1953]. The piece constitutes a radical exposition of the issues of density and transition that Xenakis had been concerned with throughout this period. It is conceived as a single, slowly evolving gesture lasting close to 22 min. The composer describes it as being “monistic with internal plurality, converging and contracting finally into the piercing angle of the end” [Brody 1970].

There are two basic textures in Bohor: one, a concentrated, teeming sonority, constantly in motion, ranging in timbre from bell-like sounds [filtered to muffle the resonance] to metallic rattlings, finer-grained metallic sounds closely resembling the charcoal crackles of Concret PH, and noisy, clashing and crashing sounds; the other is a low,
sustained sonority adapted from a Laotian mouth organ, the characteristic crescendo-decrescendo and breaking off for breath being preserved. The low sounds are heard twice, primarily, beginning at the 5'30" mark, and lasting about 8 min, and reappearing after the 17'00" mark and lasting 1-2 min. The other texture continues throughout, adding layers to itself one by one until there are several going on at the same time. On the 8-channel version, these would be distributed around the different channels. Each layer builds and subsides independently, producing an opaque, constantly-evolving texture that at the same time seems to have no clear linear trajectory. When the low sustained sound drops out the first time, there is a noticeable loss of intensity and tension, but the metallic sounds build up again, leading at the end to a sublimation of all of the other layers by the noisiest, crashing sonority, which sharply boosts its mass and dynamic level over the final three minutes. [As with Orient-Occident, the version presented on the Electronic Music Foundation compact disc stops 20 sec sooner than the Nonesuch LP recording. This is regrettable, as this last segment consists of a greatly heightened culmination of the crescendo of dynamics and density—the “piercing angle” Xenakis mentions.]

Bohor is, perhaps ironically, dedicated to Pierre Schaeffer. The elder director, who had in fact been quite supportive of Xenakis throughout his seven years of “apprenticeship” at GRM, was horrified by the piece. Part of his reaction was to the extreme level of amplification at the Radio-France premiere, intensified by the distribution of loudspeakers surrounding the audience. As he put it, “this was no longer tiny embers, each with its own allure, this was an enormous burst of explosions, an offensive accumulation of lancet jabs to the ear at maximum volume level” (Schaeffer 1981). Xenakis’s “war” aesthetic was obviously still present, but also paramount was the formal concern for sustaining tension for a long period of time through the layering and variation of density and other sonic parameters. Later electroacoustic pieces would carry this approach much further.

Xenakis left GRM, but he did not cut himself off from the studio definitively, nor did Schaeffer demand it. His works continued to be performed there and issued on recordings, and he visited a number of times in subsequent years to produce new mixes of his pieces and to make other uses of the facilities (Delalande 1997).

One of the sources of conflict was Xenakis’s growing conviction that digital technology was vital to the future of music. His growing stature as a composer added weight to his argument that GRM should be the first French institution to equip itself for carrying out research in computer music. This orientation was anathema to Schaeffer, and Xenakis realized that he would be better off working to establish such a facility elsewhere.

A rift had also developed between Xenakis and some of the other GRM composer-associates. A “collective concert” had been planned for 1962 involving nine composers, the others being Claude Ballif, François Bayle, Edgardo Cantor, Luc Ferrari, François-Bernard Mâché, Ivo Malec, Bernard Parmegiani, and Michel Philippot. Xenakis took charge of organizing the event, and put forward the idea that the succession of electroacoustic fragments be determined according to a probability matrix. His proposal was rejected by the others, who preferred to work more intuitively. Xenakis withdrew from the project, and there was evidently a certain amount of ill feeling (Schaeffer 1981).

**Stage Two: Mixed**

Having made the decision to distance himself from GRM, Xenakis became preoccupied with other concerns. He wrote music for the stage (Hiketides, Oresteia, Medea), began lecturing, finished writing his book Musiques Formelles, composed various instrumental and vocal pieces, did a residency in Berlin, and, in 1967, took up a position at Indiana University.

One of his concerns through this period (and throughout his career) was the spatialized presentation of his music. He had worked with Philips on the elaborate sound projection system for the Philips Pavilion in 1958, and had produced Bohor with the 8-channel “surround” diffusion in mind. Xenakis extended this thinking into his instrumental
and stage music as well. *Eonta* (1963), for brass quintet and piano, requires the brass players to move around the stage, point the bells of their instruments in different directions, and so forth. In *Oresteia* (1966), the chorus members are asked to create “clouds” of stochastic sounds by playing small percussion instruments and sirens while moving around the stage. *Terretetkorch* (1966), for orchestra, distributes the individual musicians among the audience, so that each listener has a unique experience of the piece.

**Polytope de Montréal**

In 1966, Xenakis received a prestigious commission: to create a multimedia work for the French Pavilion at the 1967 Montréal World Expo. He would have preferred to design the pavilion itself, but that job was awarded to architect Jean Faugeron (who won the Grand Prix de Rome for this work). In fact, the pavilion is still standing, presently housing the Casino de Montréal.

For the large central space of the pavilion, which rises through several floors and is accessible from all of them, Xenakis constructed five networks of intersecting steel cables, each outlining curved geometrical shapes (see Figure 5). Onto these cables were attached 1,200 flash bulbs (800 white, 400 colored), which were triggered by a control system involving a perforated tape and photosensitive cells. This *Poème de lumière* comprised a succession of visual configurations, the aim being to “create a luminous flow analogous to that of music” (Fleuret 1988). Xenakis used interconnected techniques to compose the music and the “poem of lights,” but for him, “the link is not between them but beyond or behind them” (Varga 1996).

The music for *Polytope de Montréal* is scored for four identical instrumental ensembles, each to be

*Harley*
placed along one of the four cardinal directions with the audience placed in the intervening quadrants. The score, however, has apparently never been performed live. It was recorded at Radio-France prior to the presentations in Montreal, and the music was played by means of loudspeakers. The use of a recording, even broadcast from four spaced loudspeakers, would obviously not be the same as performing the music live, but Xenakis designed the piece very much in terms of layers of sonorities, much as he had composed Bohor. Thus, while not strictly electroacoustic, *Polytope de Montréal* exhibits similar concerns.

Instrumental sonorities produced by similar instruments in each ensemble are fused primarily through register, and dynamic swelling effects are used throughout to produce the sensation of movement as the aural spotlight shifts from one ensemble (or channel) to another. The layers are treated independently, so that the overall spatialization is quite complex.

The architecture of the music, though, is clear, being constructed from three contrasting sections, each containing a number of distinct sonic elements. While the music is intense, concentrating on registral extremes and being filled with dynamic gestures, it does seem to leave perceptual space for the visual elements that were intended to occur alongside. There are no programmatic links between the design of the cables, the succession of flash bulbs, and the music. But, as Xenakis stated, “We are capable of speaking two languages at the same time. One is addressed to the eyes, the other to the ears. The content of the communication is different but sometimes there’s a link between the two” [Varga 1996].

*Kraanerg*

The *Polytope de Montréal* made quite an impact in Montreal during its run there in 1967. So, it was perhaps not surprising that Xenakis’s name came up a year later when officials at the National Ballet of Canada were seeking to commission a new, modernist dance work for the gala inauguration of the National Arts Centre in Ottawa, the nation’s capital [Harley and Harley 1997].

The choreographer was Roland Petit, from France. Xenakis was given complete freedom by the choreographer and the commissioners to create his music, aside from the proviso that it be at least 75 min in length, and that it incorporate, if possible, an electronic element, along with the chamber orchestra, to highlight the sophisticated playback system installed in the new facility (with loudspeakers all around the hall). It was the composer who recommended that Victor Vasarely be engaged to create the set [see Figure 6].

*Kraanerg* (Greek for “to perfect, accomplish, [cerebral] energy”) is concerned, according to the composer, with “the overwhelming fight of man’s brain and the [un]ending obstacles that exist or that he himself creates” [Xenakis 1969]. Xenakis was also thinking, apparently, of the student demonstrations going on in Paris and elsewhere through the period he was working on this piece, extending those social conflicts to global concerns:

In barely three generations, the population of the globe will have passed 24 billion. 80% will be aged under 25. The result will be fantastic transformations in every domain. A biological struggle between generations unfurling all over the planet, destroying existing political, social, urban, scientific, artistic and ideological frameworks on a scale never before attempted by humanity and unforeseeable. This extraordinary multiplication of conflict is prefigured by the current youth movements throughout the world. [quoted in Toop 1989]

The music of *Kraanerg* is primarily instrumental in conception, similar in its textures to the orchestral score, *Nomos gamma*, completed that same year. The tape part, originally conceived in four channels, is built from processed instrumental sounds, apparently based on recordings done with the same 23-member chamber orchestra as the live parts. The music needed to be written, produced, and recorded within about six months, in time to be ready for the rehearsals with the dancers. It seems likely that the orchestra parts were recorded and then sections of that used to create the electroacoustic part.

The piece is built from blocks of material alter-
nating between tape and live ensemble. The obvi-
ous reference is Edgard Varèse's *Déserts* [1954], but
*Kraanerg* is much more elaborate in the structuring
of the mosaic-like form. The tape often overlaps
the live parts, to create more of a sense of continu-
ity than is found in *Déserts*. The overlapping may
be slight or may be more extended. The continuity
is enhanced by the similarity of material between
the recorded sounds and the instrumental ensem-
bles. There is never any confusing them, though, as
the produced sounds are always processed, some-
times quite heavily (primarily through filtering, of-
ten to obtain degrees of distortion). Silence is also
treated as an important structural element, and
there are 21 such passages of stillness, ranging in
duration from 2 sec to 28 sec. These occur primar-
ily in the middle portion of the work, so are not in-
tended to delineate large-scale formal divisions.
The proportional relationship between tape and en-
semble does shift at certain points, and thse
changes create a tripartite form. The first section
presents the two entities with more or less equal
attention (eight blocks each); the second, beginning
at 23'00'', shifts the focus to the live ensemble; the
third, beginning at 52'00'', settles on the tape, pri-
arily. The final 6 min, for example, are entirely
for tape.

Within these blocks of sound, Xenakis plays off
the orchestral groups [woodwinds, brass, and strings] one against another, sometimes layering, sometimes juxtaposing them. The music is often built from global sonorities, or textures, but there are also moments of solo melodies and exposed chamber-like combinations of instruments.

The ballet as choreographed by Mr. Petit was less than successful, though the National Ballet of Canada did present the work numerous times on tour in Europe and North America over the next few years. Although there were a few concert performances, no other company took up Kraner until Graeme Murphy, of the Sydney Dance Company, created a new choreography in 1988. The music, though, was praised from the beginning, and became known through the LP recording that was issued from the original recording produced at Radio-France for the rehearsals in Ottawa.

**Hibiki-Hana-Ma**

By 1970, 10 years into his career as a professional composer, Xenakis was known around the world. For the Osaka World Exposition that year, he was invited to the studio facilities of NHK (Nippon Hoso Kyokai) in Tokyo to compose a tape work to be presented in the Japanese Steelworkers Federation Pavilion. No doubt one of the great attractions of this commission was that the music was to be projected through a sound system of 800 loudspeakers grouped in 250 locations.

*Hibiki-Hana-Ma* ("reverberation-flower-interval"), originally conceived for 12 channels, was later mixed down to eight for concert diffusion (and then to two for the issuance of the recording). At the radio studio in Japan, Xenakis had access to an orchestra, and, like Kraner, much of the material comes from orchestral sonorities. In this case, the sources were "typical" textures from existing scores with emphasis on the strings, particularly featuring glissandi and natural harmonics. To this the composer added the biwa, a Japanese lute-like instrument, and some additional percussion sounds.

There are varying degrees of studio manipulation of these instrumental sounds, from virtually none to so much that the original sources are unrecognizable. There is a much wider range of sounds presented in *Hibiki-Hana-Ma* than in Kraner, which is understandable considering that the electro-acoustic element must stand on its own. The possibility of deploying up to 12 channels enabled Xenakis to build up layers and complex superpositions of sonorities. The music is put together from blocks of material spliced into the different channels, in a similar process to the ballet piece, though extended from three or four layers to 12. There are many sudden shifts of sonority, density, and intensity, and various layers are brusquely cut in or out.

Major articulation points serve to loosely divide the piece into four sections. The first section, lasting to 3'00", is built from a low, booming, undulatory sonority over which orchestral glissandi string sounds are layered. A sweep up to a sustained high-register cluster signals the start of the second section, which introduces a layer of tinkling bells, stochastic clouds of whips and pizzicati, and much else. A sudden drop in dynamic level and in the number of layers at 6'32" signals the third section, resembling the previous one in featuring successions of a wide range of sonorities, most of which have been heard already. Here, though, the orchestral winds are introduced, playing both sustained sonorities and glissando textures reminiscent of similar passages in *Nomos gamma* and Kraner. At 11'07", another sudden drop in intensity/density signals the shift to the final, most substantial, section. Through this passage, various noise-based sonorities are introduced, of both sliding and fixed-band types. This material carries on to the end, layered with previously introduced sounds.

The impact of hearing such a wide range of produced sonorities based on acoustic sources, both sustained and percussive, as they were projected through the pavilion's large sound system must have been powerful. What made a strong impression on the composer, though, were the dynamic light sculptures and laser projections presented in that same pavilion by Japanese artist Keiji Usami. Xenakis was particularly interested in the new technology used to control the lasers and to synchronize the lights with the sound. In this, he was preparing to take on a series of large multimedia
Figure 7. Archeological site of Persepolis, Iran.

projects for which he alone, finally, would be responsible.

**Stage Three: Multimedia**

In 1969, Xenakis had traveled to the ancient site of Persepolis, Iran, for the premiere of his ambitious work for six percussionists, *Persephassa*. The Shiraz Festival was organized under the patronage of the Empress of Iran, and Xenakis and his music created quite a sensation (Matossian 1986). He was apparently engaged on the spot to create an even more ambitious work for the 1971 festival. This time, the composer was to create a multimedia event, with all the resources of Iranian Radio and Television placed at his disposal.

**Persepolis**

The one limitation Xenakis was faced with in planning his first real “polytope” was that the location within the ruins of such an important historical site necessitated a ban on construction or renovation (see Figure 7). All loudspeakers (59), lights (92 spotlights), and lasers (2) needed to be installed in an non-invasive a way as possible (see Figure 8).

The lasers and spotlights were ranged throughout the site and projected to create “luminous patterns evoking the Zoroastrian symbolism of light as eternal life” (M. A. Harley 1998). From the central portion of the site, where the 59 loudspeakers projected the eight channels of sound throughout the audience area, the lights swept upward and out toward the hillside tombs of Darius and Artaxerxes. There, in the distance, bonfires were burning, and parades of children carrying lighted torches wended their way up the hillsides, creating ever-changing linear patterns.

The music, with its noisy sonorities and overlapping waves of intensity, looks back to *Bohor. Persepolis*, though, is 55 minutes in length, a very long span for a continuously evolving form. According to his sketches, Xenakis constructed the tape from 11 sonic entities distributed among the eight channels (see Figure 9). The sketch shown gives precise timings for the first reel of the origi-
nal tape, which ends at 31'30". The performance would have required two 8-track machines so that the piece could be performed with no breaks. Multiple layers of similar material create overall textural "zones" which serve to delineate the form, though the shifts from one to another are rarely easy to distinguish.

The sonic entities range from clarinet multiphonics (3, as numbered in the sketch), to complex, high sustained sounds derived from string harmonics (2), to low, sliding distortions of timpani rolls (9), to gongs (7) and ceramic wind-chimes (11). Others are harder to identify, but one is derived from recordings of cardboard being handled (6), and another sounds as if a strong, buffeting wind had been fed through a distortion module (8). The remaining entities can be identified as metallic, noisy sonorities. Entities 1 and 4 are not used at all in the first part, occurring only in the final moments of the piece.

None of these entities are simple or "pure" sonorities, by any means, and the sonic intensity often seems overwhelming. All of the material is developed rather than just being repeated, so that the music evolves, while remaining unified, over the course of its journey through this violent, shrouded soundscape. Hearing the music in the setting for which it was intended, the dark ruins of Persepolis within the desolate beauty of the Iranian desert, with spotlights sweeping the sky and fires burning in the distance, would have been an awesome experience.

**Polytope de Cluny**

*Polytope de Cluny* (1972), Xenakis's next multimedia creation, followed fast on the heels of *Persepolis*. It was commissioned for the Festival d'Automne in Paris, and was set in the historic Roman Baths of Cluny, just off the Boulevard Saint-Germain-des-Prés. It premiered in October 1972, and ran for 16 months, four times daily, with the cumulative audience reaching over 200,000. The experience was popular among young people, who, in their radical political and social orientation, sought "music that transcended the limits of tradition and nationalism" and rejected the "formal apparel and conventions" of the concert ritual. Underground in Cluny, they "sat on the floor, surrounded by strange sonorities and subjecting themselves to perceptual and aesthetic experimentation" (M. A. Harley 1998).

The T-shaped chambers of Cluny were, like the historic site in Iran, not to be altered, so Xenakis's installation was erected within the walls by means
of scaffolding and cables. Along with the flash bulbs reminiscent of *Polytope de Montréal* [600 in number] were three lasers [colored red, green, and blue] projected along pathways determined by 400 adjustable mirrors. Xenakis was able to control the operations of the lights, lasers, and mirrors through digital means. All of the calculations were programmed on a computer, and the output data was then converted to electromagnetic signals.

This implementation of digital technology brought to fruition one of Xenakis's long-held dreams. In 1966, he had established an organization, EMAMu [l'Équipe de mathématique et automatique musicales], which in 1972 became CEMAMu [Centre d'Études de mathématique et automatique musicales], with the goal of pursuing computer music and related research. He had apparently attempted to set up a parallel operation at Indiana University during his tenure there, but he was unsuccessful, and he resigned his position in 1972, the same year of *Polytope de Cluny* and the consolidation of CEMAMu. One of his interests was the refutation of Fourier analysis as the basis for sound synthesis. As he put it in his chapter on "New Proposals in Microsound Structure:"

[S]pectral analysis of even the simplest orchestral sounds ... presents variations of spectral...
lines in frequency as well as in amplitude... These tiny variations... would certainly require new theories of approach, using another functional basis and a harmonic analysis on a higher level, e.g., stochastic processes, Markov chains, correlated or autocorrelated relations, or theses of pattern and form recognition. [Xenakis 1992]

The electroacoustic music for the Cluny installation was produced on seven channels of the 8-channel tape, with the last track reserved for electromagnetic control signals for the lights, lasers, and mirrors. Timing between the various elements, including the music, could thus be precisely controlled—although, as before, Xenakis sought parallels rather than unions. “I wanted to establish a contrast: the lights are a multitude of points, with stops, starts, etc., and the music is continuous, for although the sound changes it does not stop” (Fleuret 1972).

The music was presented through 12 loudspeakers distributed around the site. The event, which ran some 25 min, falls in between the 6-min duration of the Polytope de Montréal and the hour-long length of Persepolis. The music bears some resemblance to the Iranian piece, even borrowing sonic material. There is much that is new, as well, including a wild, brassy sound that is treated extensively throughout. There is a greater prominence given to textures of percussive sounds, such as ceramic wind-chimes from the previous piece, but others as well, including a plucked African thumb-piano. There is a striking moment at the end, when the focus suddenly turns to the thumb-piano, an exposed single note being plucked slowly and evenly, the ear zooming in on the rich, rattling, resonances of this distinctive sound.

As one would expect, the various sounds are generally layered and distributed across the seven channels, though the density is not as high as the earlier pieces, possibly in deference to the vaulted, reverberant performance space. Particularly notable in Polytope de Cluny are the synthesized sounds, created using stochastic algorithms. Xenakis was proud to have been the first in France to produce computer-generated sounds, even if he lagged behind Bell Labs, where digital synthesis had been launched by Max Mathews in 1957.

**Le Diatope; La Légende d’Eer**

At first glance, *Le Diatope* (the title of the installation) would appear to be a variation of *Polytope de Cluny*. The electroacoustic music is recorded on seven channels, with the final channel reserved for control signals. The multimedia performance involves 1,680 flash bulb lights, 4 colored lasers, and 400 programmable mirrors. This was a far more ambitious project, however. It was commissioned for the inauguration of the acclaimed Centre Georges Pompidou in Paris, and it also included an original architectural component. At long last, Xenakis was able to design the free-standing shell within which the spectacle would take place (see Figure 10). It was also, at 46 min, about twice the length, an ambitious duration for lighting effects that required updating 25 times per second.

In addition, the music was commissioned separately, and was clearly conceived to stand as an independent piece. WestDeutscher Rundfunk (WDR) invited Xenakis to produce the piece using the facilities in Cologne, and it was in fact premiered there in February 1978, months prior to the opening of *Le Diatope* outside of the Centre Pompidou in Paris. Its North American premiere took place at the 1978 International Computer Music Conference in Evanston, Illinois (to much acclaim, and some controversy).

Xenakis, almost uniquely in his entire output, expended much effort on the program notes for *Le Diatope*, presenting his own thoughts and gathering inspirational texts which, while not forming a narrative, resonate in multiple ways with the cosmic, apocalyptic scope of the sounds and lights. The title of the music, *La Légende d’Eer*, is taken from the concluding passage of Plato’s *Republic*, in which a soldier is killed in battle then brought back to life full of images of the afterlife, including the famous “music of the spheres.” The medieval era is represented by Hermes Trismegistus, an alchemist, who, in a similar way, is given a vision of the boundless darkness and light of immortality.

Computer Music Journal
The passage from Blaise Pascal’s *Pensées* contemplates the insignificant place of humanity within the infinity of nature, and Jean-Paul Richter carries the vision further, writing of the terror of being alone in the universe. The final text is a scientific description of a supernova, presenting its awesome size and energy with detached precision. It is always easier to interpret words than music, and clearly, these texts all share a vision of the vastness of the universe, with different images of light and life within that infinity. The composer, in discussing *Le Diatope* and his other polytopes, confessed: “I want to bring the stars down and move them around. Don’t you have this kind of dream?” (Matossian 1981).

Even if less protracted in duration than *Persepolis*, *La Légende d’Eer* is vast in scope, with a more concentrated, directed formal outline. The overall trajectory, which proceeds without break, is one of a gradual descent, returning at the end to the high whistling sounds of the opening. The multichannel projection of the sounds aids perception of the different, often overlapping, entities, and also allows rather subtle shifts in emphasis to be effected.

There are eight basic sonic entities used in *La Légende d’Eer*, present or dominant at different times (see Figure 11). Each is treated to a great deal of studio manipulation, including transposition, filtering, and reverberation. Each is also varied in terms of density. These techniques serve, on one level, to create links between the different entities. For example, the high whistling tones of the opening, smooth at first, are varied with tremolo/
amplitude-modulation effects to create a more striated variant. This developed sonority resembles high transpositions of the rattling ceramic sonority, itself narrowly filtered to produce a recognizable identity of pitch. These two entities in turn resemble the high, narrow-band version of the granulated undulating noise, and even the drum [tsuzumi] element, transposed and mixed to create a texture of high density. Thus, while the entities are relatively distinct, they can also be related along different parametrical continua.

La Légende d’Eer can be divided into eight sections. The first is the clearest, containing only the high, whistling sounds that Xenakis calls “sonic shooting stars.” Over 6 min, this layer alternates between the smooth sound and the striated variant. The second section begins when other sounds begin to enter and the high sonority starts to fade out. This is a transitional passage, as five different entities are introduced one after another, none of them dominating the sound-field. A rustling noise alternates with a brassy synthetic sonority, until, at 17'13'', this entity begins to layer a number of tracks upon itself, commanding most of the attention. With the abrupt arrest of the brass voices, the fourth section begins with percussive sounds alone, a mixture of the plucked mbira [African thumb piano], the rattling ceramics, and the tsuzumi. At 25'00'', a rich electronic entity enters and gradually saturates the texture. The pulsating, wave-like contours of this sonority strongly resemble the pounding undulations of the second section of Jonchaies, the orchestral score Xenakis completed around the same time (Xenakis 1977). After close to 8 min, this entity begins to fade out, and the brassy sonority takes over again. A number of other sounds enter too, and the brass is less dominant. A wild metallic sonority, sounding like a cross between the amplified and distorted braying of a donkey and an electric guitar, is prominent throughout this passage. Up to that point, the general range of the sounds had been descending. The lowest transpositions of the brass and metallic entities carry the music through to the final section, where they fade out over some 3 min as the high tones of the opening enter and carry on to the end.

The pavilion that was designed to house this piece, together with the light show that went along with it, was constructed from red vinyl stretched over a metal frame. The design somewhat resembles the Philips Pavilion, although the point of departure was to create a form that would have the
maximum volume for the minimum surface of outer shell. Rejecting the obvious solution—the sphere—as being acoustically and visually poor, Xenakis created a more complex form. As he put it, “the effect of the architectural form has a quasi-tactile influence on the quality of the music or spectacle presented within it. This is beyond any considerations of optimal acoustics or proportions” (Xenakis 1978). There is an aesthetic character that the structure imposed on the performances within it. In the case of Le Diatome, the point of departure was the sphere, but with the design’s double curvature, its “flights,” it is an architecture “open to the world.”

Stage Four: UPIC

Throughout 1972–1978, during which Xenakis was heavily involved in overseeing the multifaceted production of Polytome de Cluny and Le Diatome, he was also working with his engineers at CEMAMu on the development of a novel approach to digital sound synthesis. The UPIC (Unité Polygogique Informatique de CEMAMu) is a computer music system enabling the user to create sounds by means of a graphic interface (Lohner 1986). All the elements of the sound are designed with an electromagnetic pen on a large electromagentic drawing board. (Recent versions have replaced the pen and drawing board with a mouse.) These elements include the waveforms, the dynamic envelopes of the sounds, and the “arcs,” or notes. Interesting sounds can be obtained by designing noisy waveforms and complex envelopes, and also by layering as many as several hundred notes (Marino et al. 1993). Xenakis had always sketched much of his music on graph paper, so such an approach to sonic composition was perfectly natural. It has also proven to be an engaging medium for young children (and many others, of course) to approach creating sounds on the computer.

Polytome de Mycènes; Mycenae Alpha

Mycenae Alpha, Xenakis’s first piece created on the UPIC, was completed in the summer of 1978, not long after the opening of Le Diatome. It was, like La Légende d’Eer, produced for a multimedia performance, though also conceived to be an independent concert piece. The Polytome de Mycènes was an outdoor spectacle mounted at the historic site of Mycenae in Greece. Similar in style to Persepolis, this event included torches on the mountainsides, searchlights crossing the sky, and also incorporated several of Xenakis’s “Greek” instrumental and choral works. Mycenae Alpha, under 10 min in length, served as an electronic interlude between the other pieces.

The music is noisy and dense, made up primarily of massive clusters designed so that the score would also be visually compelling [see Figure 12]. The basic impetus is to move from complex textures to more stable ones and back again (or to a new complex sound). Interspersed are moments of more focused, simpler sonorities. The main limitation of that first version of the UPIC was that it was not possible to mix the different “pages” of the graphic score. Xenakis’s piece, then, is a succession of different gestures, one following on the other. In addition, each of these “pages” could be no longer than one minute in duration. Mycenae Alpha is built from 12 such graphic/sonic entities, two being repeated, to make a total of 14.

In this piece, a structural distinction can be drawn between complex sonorities created by means of masses of relatively stable note-segments, and others created from dynamic arcs. It is easy to design intricate glissandi on the UPIC merely by picking up the electromagnetic pen and tracing them onto the design board—held notes, in fact, are treated as a sub-class of the more generalized “arc.” The design of the waveforms [a hand-drawn waveform is written into a look-up table] is also critical to the sonorities created. The timbres tend to be noisy, but also static. Variation is achieved through the layering of the notes and the dynamic envelopes.

Mycenae Alpha is remarkable for demonstrating the innovations of the UPIC system. Clearly, though, this piece is far more limited in its sonic content than La Légende d’Eer. But, for the polytome at Mycenae, the harsh sonorities would have matched the savage magic of the landscape, so permeated with ancient myths.

Harley
Pour la Paix

In 1981, Xenakis was commissioned by Radio-France to produce a radiophonic work for the Prix Italia (although apparently it was never entered in the competition). In response, he put together a rather strange, collage-like work for reciters, choir, and electronic sounds created on the UPIC. The texts are taken from two works by the composer’s wife (a celebrated author in her own right), Françoise Xenakis: Écoute and Les morts pleureront. Part of this same selection of texts was used in the work composed just prior to this, Nekuia, for choir and orchestra.

Pour la Paix exists in four forms. The full version lasts over 26 min, and includes all three elements: the spoken text, the sung parts, and the electronic fragments. There is an abridged version comprising the ten choral sequences on their own. The other two versions present the work in pre-recorded form, either completely on tape or with just the reciters speaking their texts live. The spoken texts constitute roughly half the work, there are ten sung passages, and there are numerous sequences of UPIC material.

The electronic sounds heard in Pour la Paix cover a much wider timbral range than those in Mycenae Alpha. Some are cinematic, evoking the sounds of war, for example, in response to a passage of text. Others are more abstract, and the remaining fragments are supportive, to accompany either the choir or the recited parts. The choir parts range from straightforward chanting on a restricted set of notes, as in the first sequence, to more complex sonorities—a compendium, really, of elements from Serment, an a cappella choral work from earlier that same year.

In spite of the intensity of the texts, poetic railings on war and death, Pour la Paix is rather disappointing as a radiophonic creation. The sequences of material mostly succeed each other with little overlap, with the exception of the electronic sounds which sometimes appear in conjunction both with the spoken and sung parts. The production lacks sonic depth and spatial organization, a puzzling weakness considering the level of sophistication common in all kinds of broadcasts, not to mention Xenakis’s other electroacoustic works. This would be his only foray into the medium of radio art, in any case.

Tauriphanie

In 1987, Xenakis was given his last opportunity to produce a multimedia event. The Festival de Montpellier commissioned him to create a work for the ancient Roman arena in the Provençal town of
Arles. Bull fights were still held in that same arena, so the focus of the event became the incorporation of bulls into the proceedings (along with the famous white stallions of the nearby Camargue region). The plan was to wire the bulls with radio microphones to capture their snorting breaths. These sounds would then be processed in real-time using the new version of the UPIC system, which would be installed in a tower in the middle of the ring. Spotlights were to project patterns of light onto the floor of the arena and the animals would create dynamic stochastic patterns as they moved around the ring. To top it all off, twelve percussionists were stationed around the upper seats of the round arena, and they performed selections from Xenakis’s percussion music [Idmen B, Pléiades, and Psappha].

In the end, a lack of time and resources forced Xenakis to drop the amplification of the bulls. Instead, he incorporated brief samples from this unusual source into a tape work created at CEMAMu on the UPIC. This piece, Taurhiphanie, was projected in the arena along with some live manipulation of fragments of the sonic material using the UPIC. The animals did not cooperate in creating interesting stochastic patterns; they tended to huddle at one end of the ring or another, apparently traumatized by the pounding of the amplified percussion and the extreme dynamic range of the electronic sounds. The performance was not an unqualified success.

Taurhiphanie, though, remains as perhaps Xenakis’s most successful piece created using the UPIC. At just under 1 min in duration, it is slightly more substantial than Mycenae Alpha, and, given the technological improvements of the UPIC, it is clearly conceived as an organic whole rather than a succession of parts, as in the earlier two pieces.

The first 5 min form a continuous gesture, the layers of sustained sounds gradually rising until a high point is reached at 4'22". At that point, the sounds begin to descend again, but are interrupted at 5'28". After a series of shorter, disruptive gestures, a sustained sonority takes over at 5'57" featuring some stable intervals—a “still point.” By 6'45", fractures appear in the texture, with a variety of sonorities making brief entrances. The range of timbres is relatively wide for a synthesized score, though still not as rich as pre-UPIC works such as La Légende d’Een. A break at 8'00" prepares for a return to the bands of sliding sounds from the opening section, this time interrupted by dramatic interjections of more concentrated, sweeping sounds that heighten the intensity of the passage. As the music nears its conclusion, the sustained sounds begin to diverge, some migrating higher, some lower. The piece ends abruptly, as if cut off. Most of Xenakis’s electroacoustic works end in similar fashion.

While there is a certain roughness to Taurhiphanie that might indicate a lack of finesse in the shaping of certain details, there is also a strong sense of assurance and cohesion. As with the other pieces that had their sources in multimedia creations, this music stands on its own and carries on a vitality that long-past spectacles cannot retain through mere documentation.

**Voyage absolu des Unari vers Andromède**

In 1989, Xenakis produced his most ambitious UPIC work, a commission for the inauguration of an International Exposition of Paper Kites in Japan. *Voyage absolu des Unari vers Andromède* extends the image of a kite soaring through the air to a cosmic voyage through space in the direction of the Andromeda galaxy. While the music is not excessively programmatic, one may easily imagine traveling through space while listening, with various “episodes” occurring along the way.

The formal outline of *Voyage absolu* is conceived on a broad scale, though the 15-min, 25-sec duration is still nowhere near the breadth of Persepolis or La Légende d’Een. The piece is structured in two parts. The first, lasting until 8'40", is the more turbulent, with numerous sonic scrubbings and short dramatic gestures surrounding more ongoing layers of arching contours. One striking texture occurs at 4'48", where a percussive noise pulsation briefly sets up a regular beat that might go over well at a techno club. The second part is much more serene, as the sustained sounds undu-
late more slowly. In this section, the added sonorities are less prominent in the mix, though there are many discrete gestures heard in the background. The sonic arcs evolve both higher and lower, and there are well-defined episodes where timbres and densities clearly shift. The music at 10'38", for example, is quite sparse, though by 11'30" it starts to build up again. The final few minutes encompass a gradual ascent into the high register, decorated with aliasing effects that produce low buzzing sounds.

Erod

By the time he reached the 1990s, Xenakis was clearly not well. In addition, he was preoccupied with developing his stochastic synthesis algorithms. He did, however, return to the studio to produce one last UPIC piece. Erod was created at Les Ateliers UPIC in 1997 for a commission from the Bath Festival in England. Xenakis worked closely with Brigitte Robindoré, and they evidently experimented with deriving new sounds from recordings of earlier scores, both electroacoustic and instrumental. The piece lasts less than 5 min, and it was withdrawn soon after its premiere. (The contribution of Ms. Robindoré to the production of the piece was so integral that Xenakis could not in good faith put his name on it.)

Stage Five: Stochastic Synthesis

As early as the late 1950s and early 1960s, Xenakis speculated about the possibility of synthesizing new sonic waveforms on the same basis as his ST algorithm for stochastic composition. He carried out some experiments to that end at Indiana University, and continued at CEMAMu in Paris. His first results were applied to electronic sounds produced for Polytape de Cluny and La Légende d’Eer. Until the mid 1980s, though, the main preoccupation at his research center was the development and promotion of the UPIC system. In 1986, with the loan of a minicomputer from Hewlett Packard, Xenakis was at last able to return to this project.

By 1991, his team had succeeded in developing a computer program that would not only synthesize sounds stochastically, but would also implement macro-compositional procedures similar to those defined for the algorithm implemented in 1962 (Serra 1993).

On the synthesis level, the aim was to generate a waveform that could be varied continuously according to some stochastic function. In searching for the most efficient way to do this, Xenakis and his assistants eventually adopted a waveform cycle as the basic unit (rather than, say, a sample), simplified as a series of line segments rather than a curve [see Figure 13]. The degree of change, both vertical and horizontal, from one point in a cycle to the corresponding one in the next, is calculated on the basis of a probability formula. The cycle is varied both in its amplitude (vertical extent) and frequency (horizontal extent). If each cycle of a sonic waveform varies radically, the resulting sound will be very unstable, or noisy. In order to obtain a range of timbres, a second-order process needed to be set in place to control the boundaries, or degree of possible change, for each operation. This process could of course be dynamic, effecting gradual shifts in the rates of change. On the higher level, processes were implemented in order to select the number of “voices” (waveforms) activated at any one time, their points of entry in the time-line of the piece, and the duration of each of these segments for each voice. With these basic tools it became possible to input control data so as to generate an entire piece digitally on the basis of stochastic functions.

GENDY301; GENDY3

Xenakis's first compositional product from this GENDYN (GENeral DYNamic stochastic synthesis) algorithm was GENDY301, presented at the 1991 International Computer Music Conference in Montreal, Canada. A newly-generated work derived from similar control data was produced later that same year for the Journées de Musique Contemporaine in Metz, France. This work, titled GENDY3, is the version that has become known through sub-
sequent performances and release on compact disc. In spite of the close relation of the two pieces in terms of their genesis, they in fact sound completely different.

GENDY301 is the shorter of the two, at 14 min 15 sec in duration. It also exhibits a wider dynamic range than the other better-known piece, with extremely loud textures entering suddenly on top of narrower-range sonorities. In addition, it contains more breaks of silence. Xenakis never stated his dissatisfaction with the piece, but he may have decided not to release a "family" of works as he had produced in 1962 with the data from his ST program. [Those pieces include ST10 for mixed ensemble, ST/4 for string quartet, ST/48 for orchestra, Amorsima-Morsima for mixed quartet, Morsima-Amorsima for mixed ensemble [withdrawn], and Attrées, for mixed ensemble.]

At 18 min 45 sec in duration, GENDY3 is clearly more substantial than the earlier version. Upon listening, it is apparent that, as in the ST scores, clearly defined sections are integral to the algorithm. The piece is structured, from the listener's perspective, as a succession of eleven short sections, each lasting from one to two minutes, the overall progression expanding these durations slightly. The sections are distinguished by registral placement and scope, and degree of instability in either frequency or timbre. Each sound is relatively consistent in its settings throughout a section, though there are always mixtures of types, and the individual layers are often laced with a great deal of silence, to avoid oversaturation. What is surprising about GENDY3 is the degree of harmonicity present. Every section contains some number of sustained voices, cutting in and out in stochastic fashion, and there are most often consonant relationships between the stable pitches. In some sections, there are also less stable voices, either in terms of frequency [creating glissandi] or timbre, resulting in noisy or rapidly fluctuating sonorities. There are some surprisingly lifelike timbres at certain points, including vocal-sounding and brassy [though more like organ stops than real brass instruments] sounds. In fact, there is a great deal of organ-like tone to the held sonorities. It is also true that the unstable sonorities, because of their novelty, stand out from the other sounds in the sections where they occur.

S.709

After producing the two GENDY works in 1991, Xenakis continued tweaking the GENDYN algorithm [Hoffmann 2000b]. For a monograph concert at Radio-France in December 1994, a new piece was generated. S.709 focuses more on unstable, dynamic sonorities. These are produced by allowing the vertical and horizontal points of the waveform segments to vary more widely and rapidly. With a duration of just 7 min, this is a much shorter piece than GENDY3, but the degree of sonic activity—the acoustical intensity—justifies the truncated architecture.

There are no clear sections in S.709 by which a
formal outline can be perceived. Instead, the music is highly fragmented. The harmonic, sustained tones of GENDY3 are entirely absent. By contrast, each of what seem to be no more than three or four “voices” are in constant fluctuation in terms of pitch, timbre, or both. Amplitudes, too, are highly modulated. While there are some consistencies—certain characteristic sonorities—each voice undergoes considerable transformation, both gradually and in sudden shifts. The density of sonic information within each voice surely dictated the reduction in the number of layers. In fact, for much of the time, there is only one layer sounding at a time.

Taken together, the GENDY pieces and S.709 demonstrate the wide range of possibilities inherent in the General Dynamic Stochastic Synthesis algorithm.

**Conclusion**

Once he developed a workable compositional algorithm in 1962, Xenakis integrated his creative processes and experimental approach with computer technology throughout the remainder of his career. It is worth noting, though, that some of the procedures he developed prior to 1962 could also have been programmed, had Xenakis had access to computing facilities. He applied his stochastic [and other] functions to his instrumental and vocal music, and worked at CEMAMu to generate new sounds digitally. Toward the end of his career, he at last found a way to reconcile his higher-order compositional concerns with the generation of the sounds [waveforms] themselves. Even so, Xenakis didn’t drop everything else in order to work with these long-awaited tools. The acoustical richness of live instruments and voices remained compelling, as the vitality of his late orchestral scores such as Dämmerschein [1994] or Ioolkos (1996) attests.

In the domain of electroacoustics, Xenakis’s music evolved a great deal, from origins in the musique concrète style through more abstract noise-based sonorities that were fashioned into continuously evolving waves of intensity, to the incorporation of transformed instrumental sounds, to, finally, digital synthesis. A detailed assessment of his achievements in this domain in relation to other work in the field remains to be undertaken. It is safe to say, however, that Iannis Xenakis followed a singular path, guided by his unique character as a Greek revolutionary, trained in engineering, influenced by architecture, self-taught in music. The seeds he sowed, his works, and his technical or conceptual innovations, have proven, and will continue to be, fruitful for succeeding generations.

**Acknowledgments**

I am grateful to Radu Stan of Éditions Salabert for supplying me with archival recordings of the electroacoustic works of Xenakis otherwise unavailable at the time of my research. I am also grateful to Brigitte Robindoré for detailing the production of Erod, Xenakis’s last computer piece, and for allowing me to hear it. Others who have been helpful in various ways in my research include: Cornelia Collyer, Cort Lippe, Gerard Pape, Jean-Michel Raczinski, Curtis Roads, and Malcolm Smith. Thanks also go to Doug Keislar for his help in editing the article. I would also like to acknowledge the support of Iannis Xenakis himself, who permitted me to work with the UPIC system at CEMAMu during 1985–1987, and who was generous in many other ways.

**References**


*Computer Music Journal*