

All is Number

Golden Section in Xenakis' "Rebonds"

BY GREG BEYER

"Mathematical systems of proportion originate from the Pythagorean concept that 'all is number' and the belief that certain numerical relationships manifest the harmonic structure of the universe." (Ching)

One of the founding fathers of our "revolutionary" percussive heritage, composer John Cage, wrote an article in *Dance Observer* in 1944, titled "Grace and Clarity," in which he spoke of the importance he placed on structural devices used to determine a work's form. Music "occupies a length of time...and the manner in which this length of time is divided first into larger parts and then into phrases...is the work's very life structure."

The manner in which Cage divided time in his music during that period of his career was to utilize a concept he called "micro-macrocosmic rhythmic structure." I contend that in "Rebonds," Xenakis used the concept of the Golden Section (filtered through the mind of Le Corbusier and his *Modulor*) as a similar device to determine formal organization.

WHAT IS THE GOLDEN SECTION?

The Golden Section, also known as the Golden Mean or Golden Ratio, is the unequal division of a line segment such that the ratio of the smaller part to the larger part is the same as that of the larger to the original whole. This unique division yields an irrational number known as *phi* ϕ , 1.618034....

Looking at Figure 1, we can say A is to B as B is to C.

The line segment C is the Golden Section of B, and the line segment B is the Golden Section of A. Furthermore, line segment C can be divided into two unequal parts that would yield D and E, each one resembling the next in exactly the same relationship. This continuation on into theoretical infinity is called a *Recursive System*. A *Recursive System* is perhaps not unlike a set of Russian dolls. Open the largest and there is its exact image, just a little smaller. Open the second and there is an identical third, etc.

According to Ruth Tatlow's article in *The New Grove Dictionary of Music*, the *Golden Section* is a relatively recent term for the original *Golden Number*. This term was coined in 432 B.C. by Meton the Athenian, who discovered the 19-year Lunar Cycle through the use of this calculation. It was originally written in gold, hence the name. In the Christian tradition, it has been in constant use for centuries as a means to calculate the Ecclesiastical Paschal full moon, and thence Easter Sunday.

It has been historically regarded to yield harmonious proportions in works of nature and, through imitation of such perceived nature, in works of man. A lot

of ink has been spilled questioning the veracity of statements that Golden Section proportion was well known and advocated in architectural design in the time of the Greeks. Queries have also been raised concerning its accuracy as a tool for analyzing the exact shapes of natural objects like pinecones and nautilus shells. Here we need not concern ourselves with such debate, as Xenakis in his own writing shows a clear understanding of and fascination with the Golden Section ratio.

WHO WAS XENAKIS?

"I am a classical Greek living in the twentieth century" (Matossian)

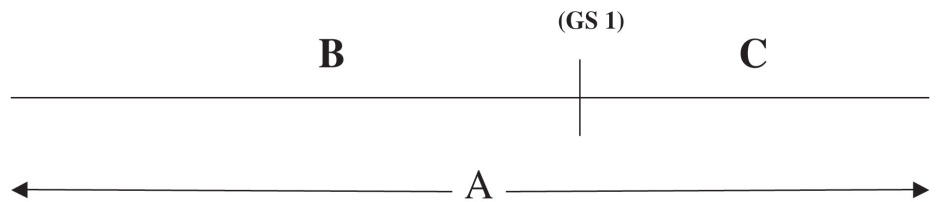


Figure 1. The Golden Section, A is to B as B is to C.

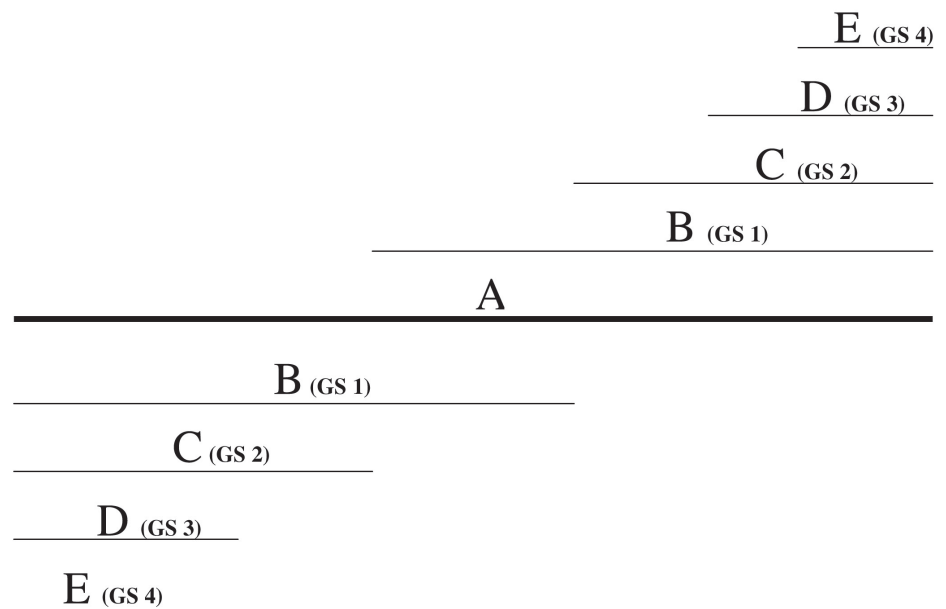


Figure 2. Generating a *Recursive System* with Golden Section Divisions

"The only subjects that have inspired (my composition) are ancient (Greek) tragedies, because they remind me of my youth..." (Varga)

Noritza Matossian, in her book *Iannis Xenakis*, provides a wonderful and in-depth perspective of the composer's early life. I highly recommend reading it. In what follows, I will try to highlight some important details of his biography to provide what I believe to be an essential background to the ensuing analysis of "Rebonds."

As Xenakis hints above, his early life was tragic. He was born in Romania to Greek parents. He had a close spiritual and psychological connection with his mother, who introduced him to music and planted the seeds of his lifelong love of music. However, when Iannis was only five, his mother became very sick and died. Over the next five years his father grew more distraught and distant from Iannis and his two younger brothers. When Iannis was 10, his father sent him to a new boarding school for boys on the remote Greek island of Spetzai. Having been born in Romania, his Greek accent was not that of the Athenian boys who dominated his class, and he soon became an outcast.

Already emotionally unstable due to the death of his mother and distance of his father, he spent the next three years of his life lonely, miserable, and defenseless. Finally, at age 13, he began a process of gradual personal development—of intellectual and physical enlightenment. He spent hours in the school library cultivating his instinctive attraction to classical Greek tragedy and poetry, and also became an intensely competitive sportsman.

At 17, Xenakis graduated and returned to Athens, where his father had returned, having fled Romania from the growing threat of Nazi Germany. That threat was not long in coming to Greece, however, and the next several years of Xenakis' life, from 1939–47, were spent in the crosshairs of international forces and interests. Greece was occupied first by the Axis forces of Germans, Italians, and Bulgarians, and afterward in 1944 by the British. All these regimes offered very little respect to or hope for the nationalist desires of the Greeks.

Xenakis became a prominent leader of the organized Resistance fighters

against both occupations, and in that role he was fierce and reckless. In December of 1944 he was caught in the line of fire of British Sherman tanks patrolling the streets of Athens. Two of his companions died instantly; half of his face was completely destroyed. His father bribed a policeman to get him into a hospital where he would spend the next three months recuperating. That same battle signaled the end of the Greek Resistance.

After being released from the hospital, Xenakis returned to the Athens Polytechnic Institute to receive his degree as an engineer. Known for his involvement in the Resistance, however, Xenakis did not fare well in civilian life. At school he was forced to enlist in the army. Many of his own countrymen aligned themselves with fascist powers and wished to see an end to his life. In September 1947, with the help of his father, he fled underground and was forced into exile, leaving Greece behind forever.

XENAKIS IN PARIS

"Enthusiasms, hopes, all were dead, seemed to me that life could give me no...creative joy" (Matossian)

"...there was a great renewal...both spiritual and intellectual...when one is unhappy one thinks more and the works which are artistic...feel the effects to a more elevated degree..." (Xenakis)

When Xenakis got himself to Paris, his spirit was devastated. Fortunately he earned his engineering diploma and came into contact with a few Greek immigrants of his background who were employed by the famous architect Le Corbusier. Through these connections he landed his first job. At the time, Le Corbusier's name meant nothing to Xenakis; he was simply happy to have employment. His first assignments were as an engineer, calculating measurements for a large government-sponsored housing project called *L'Unité d'Habitation de Marseille*. This project was of utmost importance to Le Corbusier; it was his personal *Parthenon*.

LE CORBUSIER AND THE MODULOR

Xenakis was made to calculate proportionate measurements for *L'Unité* using a system of mathematical unification Le

Corbusier called his *Modulor*. In an interview with Balint Andras Varga, Xenakis said this about the subject:

“Le Corbusier rediscovered the Golden Section for himself after reading Matila Ghyka’s book about it [*Geometry in Nature and Art*]. In the 1920s Ghyka had published several books on the relationship between the arts and geometry, as well as mathematics. Le Corbusier read those books and then forgot about them—at least, he pretended to...Incidentally, he changed the name of the Golden Section and called it *Modulor*. What was his method? Taking the height of an average man (6 foot—i.e., not an average Frenchman, but a Scandinavian, who is taller) as a basic unit, he then worked with the golden proportions of that unit.” (Varga)

Figure 3 is a pencil drawing taken out of Matossian’s *Iannis Xenakis*. The numbers therein are not intuitively obvious, nor are they explained in the accompanying text. These numbers do come up, however, in “Rebonds,” as we shall later see, and some quick explaining now may prove helpful.

From what I can understand, these numbers are Golden Section chains, *Recursive Systems*, of numbers that are still larger and “above” the figures in the chart. These larger figures are simply various multiples of six. The two separate systems (on either side of the central vertical) are generated, I believe, from the numbers 480 (6 x 80) and 960 (6

x 160). The left system is generated using $480 / 1.618034$, yielding (in whole integers rounded off by dropping all decimals) 296, 183, 113, 70, 43, 27 etc. The right system uses $960 / 1.618034$, yielding 593, 366, 226, 140, 86 etc.

Xenakis had no objection to using the *Modulor*, for it strongly resonated with his own love of ancient Greek culture and with his personal psyche.

XENAKIS THE COMPOSER

“The simplicity and elegance of the Modulor fired him to broach the question of whether such a set of proportions could become the basis for musical compositions as well.” (*Matossian*)

Having established financial stability, Xenakis was soon thinking about music. After various failed attempts at finding a teacher who was interested in his fledgling efforts in composition, Xenakis finally found someone who would have a pivotal effect on his career: Olivier Messiaen. Messiaen recognized that Xenakis was different and encouraged him to follow that difference, to nurture it. Xenakis’ background in mathematical engineering and now architecture was given *carte blanche* to influence his musical thought. Quite by accident, Xenakis began experimenting with rhythmic exercises:

“I used to have a tape-recorder, a bad one, which left a little noise on the tape when you pressed the [record] button. When I noticed

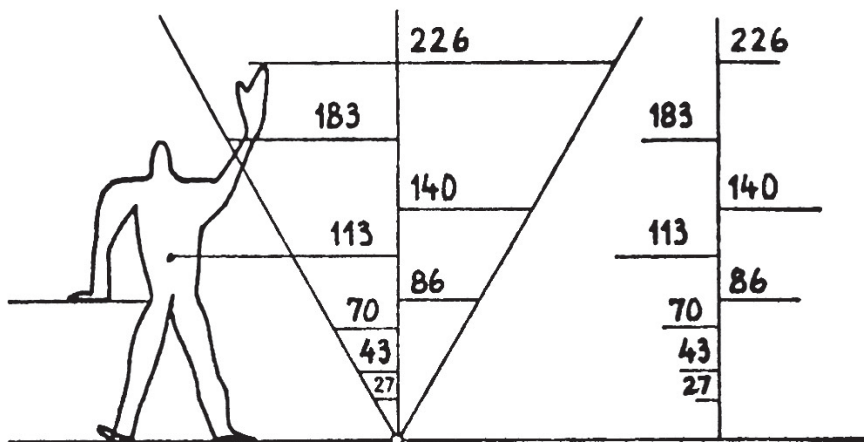
that, I exploited it. I measured the length of the tape and marked it at certain points in pencil. I pressed the button of the machine at every mark, and when I played it the noises followed one another according to the Golden Section. In other words, I received an exact aural picture of that proportion.” (Varga)

XENAKIS THE ARCHITECT

It took five years working as an engineering assistant to Le Corbusier for Xenakis to muster the courage to broach the subject of collaboration as a fellow architect. Le Corbusier accepted the offer, and during the years between 1954 and 1957, they worked on multiple projects. Xenakis helped design the Phillips Pavilion at the 1956 Brussels World Fair, and essentially single-handedly designed the highly successful *Couvent de St. Marie de la Tourette*.

Xenakis put his whole self into the convent. Even Corbusier referred to it as the *Couvent de Xenakis*. Le Corbusier was in India working on another project at the time, and only sent occasional mandates to Xenakis for use in the design. One such idea was a great façade of glass, based on a similar construction Corbusier had come across in India. He suggested the use of multiple panels of glass separated by beams of metal, organized in a regular grid. Xenakis developed the idea, rejecting the monotonous grid in favor of what are now called his famous “musical screens of glass.” Xenakis used the *Modulor* to obtain a progression of rectangles of the same height but of varying width. These were arranged in rows with changing densities and intervals to give an asymmetrical appearance. In the final design, he stacked multiple layers of these “ondulations,” offset by a regular grid of concrete squares above.

For Xenakis, this work became extremely important on a personal and spiritual level as well as a professional one. Although not Catholic himself, Xenakis nevertheless used the process of designing a building with religious significance to explore and come to terms with his own spirituality. In a letter to one of the monastery’s priests a year after the completion of the project, Xenakis wrote: “I was very happy working on your monastery. Of course I brought to this work the ideas of Le Corbusier but above all it was an occasion for me to express thoughts and acts of faith repulsed



The proportional values of the Modulor based on the human scale. (Le Corbusier: *the Modulor*)

Figure 3. Corbusier’s *Modulor* (Matossian)

by modern life...Your monastery was for me a point of condensation, of historic knowledge and Platonic 'reminiscences,' of epochs lived at other times..." (Matossian)

If Xenakis considered himself a "Classical Greek living in the twentieth century," then it becomes clear how he allowed his creative work to penetrate his own psyche on multiple levels. The use of classical Greek constructs such as the Golden Section become more than calculations, they become acts of faith.

THE CONFLUENCE: GOLDEN SECTION PROPORTION IN MUSICAL FORM: "REBONDS" (1987-89)

Jumping ahead some 30 years, Xenakis continued to be compelled to use Golden Section as a unifying device of formal construction in his music. In "Rebonds," the use of the *Modulor* shall become readily apparent.

A quick description of the work may prove helpful. "Rebonds" is a multi-percussion solo. It is in two movements labeled *A* and *B*, which may be performed in either order. Movement *A* is for drums alone, and its construction follows a singular course of ever-increasing complexity and density. It is something akin to the flow of a river from its source to its final destination at the sea. Movement *B* is for drums and a set of woodblocks. Unlike *A*, this movement is sectional; the woodblocks suddenly rip into the longer

sections of monochromatic drumming, separating the three larger sections of the work with their distinctive sound and texture. Woods and drums remain oil and water until the third major section at the very end. The trajectory of the music is that of two seemingly opposing forces that gradually achieve synthesis through an incredible effort of the part of the performer.

Take some time now to recall the concept of *Recursive Systems* generated by the use of *Modulor* calculation. It is in this manner that we shall proceed, looking more closely at each movement of the work to find events that coincide with each series of Golden Section divisions.

MOVEMENT B

The timeline of this movement is 87 measures of 4/4 time, yielding 1,392 sixteenth notes. The music is sectional, clearly divided along lines of instrumental timbre (i.e., drums or woods) and musical material (sixteenth notes, thirty-second notes, and tremoli). Figure 4 portrays this manner of division.

LARGE-SCALE EVIDENCE OF GOLDEN SECTION FORMAL PATTERNING

Calculating the Golden Section *Recursive System* of this overall timeline (1,392 / 1.618034), we generate the series 860, 532, 329, 203, 126, etc. What I shall call GS1 is the first meaningful cut of 1,392, yielding both 860 and 532. Looking again

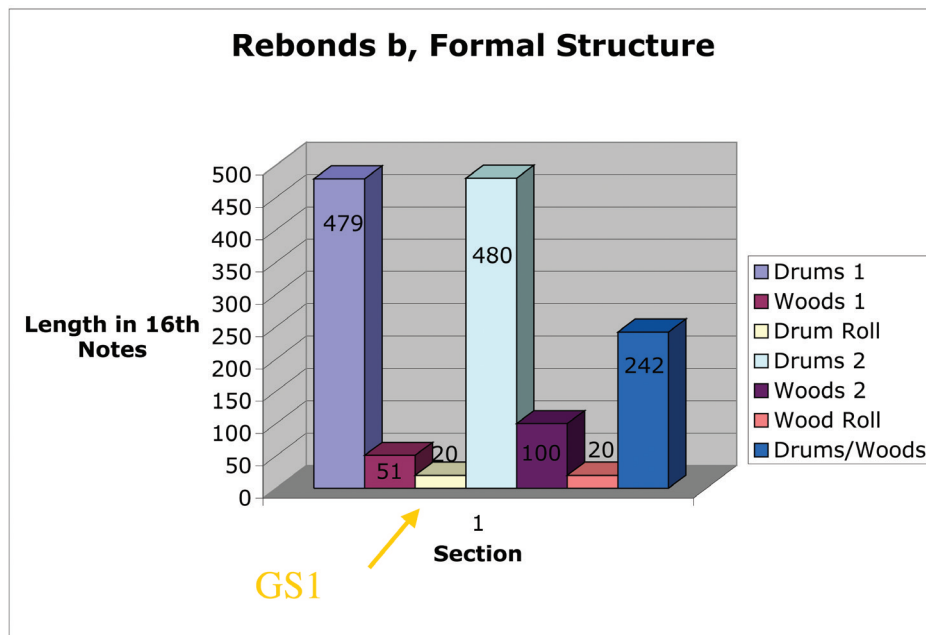


Figure 4. "Rebonds" *B*, formal structure divided into sections.

at Figure 4, GS1 takes on significance as the point that determines the placement of the very first tremolo of the piece, the long bongo roll that begins in m. 34, on the “and” of 1.

A similar roll on bass drum is located in m. 46, beat 4. It is the 733rd sixteenth note of the piece, a point that has nothing to do with the *Recursive System* derived from the overall length of the movement. Is this a crushing blow to our fledgling theory? Let’s reconsider.

SMALL-SCALE EVIDENCE OF GOLDEN SECTION FORMAL PATTERNING

This bass drum roll falls inside the second major section of sixteenth-note drumming (“Drums 2” in Figure 4). The length of this section, 480 sixteenth notes, is virtually identical to the length of “Drums 1.” Recall the explanation of Figure 3. The left-hand series of numbers is generated by the *Modulor* of 480 (6 x 80), 297, 183, 113, 70, etc. The bass drum roll is located at the 183rd sixteenth note of Drums 2. It is in the exact same spot relative to this subsection as the bongo roll is relative to the whole.

Referring back to Cage, this sort of patterning logic smacks of “Micro-macrocosmic rhythmic structure,” but perhaps even more importantly, it refers

to itself. The individual section of music, in this case Drums 2, somehow reflects the whole. This sort of patterning is emblematic of the very idea of a *Recursive System*.

“MICROCOSMIC” STRUCTURING: GOLDEN SECTION EVIDENCE AT THE MOLECULAR LEVEL

As mentioned previously, “Drums 1” is also (essentially) 480 sixteenth notes long. Do the *Modulor* divisions of its timeline reveal important events on the surface of the music? At first glance, they do not. But let’s take an even closer look at the musical material of these 30 measures of music.

Figure 5 reveals an underlying sequence of numbers that represent the rhythmic patterning of the five-note melodic line played by the hand of the performer that is not playing the continual sixteenth notes on the high bongo. This melody is repeated in various rhythmic permutations 38 times, and each row in Figure 5 represents one repetition.

The left-hand column refers to the specific repetition, numbered 1–38. Each of the five columns in the middle represents one of the five notes of the melody, in order. The number values in these columns identify the number of sixteenth notes

Example 1. “Rebonds” B, GS 1, bongo roll, mm. 34–35

Example 2. “Rebonds” B, Small-Scale mirroring, bass drum roll, mm. 46–47

that constitute each note of the actual melody. Rests figure into the note that comes immediately before, so, in measure one, although the first note is printed as a quarter note followed by an eighth rest, the number representing this note is 6, as if it were a printed dotted-quarter note. The right-hand column provides the sixteenth-note sum of the melody in each repetition.

The two large regions in red indicate the sections of music in which the separate musics of the two hands seemingly become one; i.e., the five-note melody takes on the continuous sixteenth notes of the high bongo. This musical device, two separate textures becoming one, is a motif that characterizes the movement.

The squares in gold indicate the loci of the Golden Section divisions. There are

Pattern Number	Tom, 2acc.	Grande Caisse	Low Bongo, acc.	Tumba	Grande Caisse2	Pattern Total
1	6	2	3	2	1	14
2	6	2	3	2	1	14
3	5	3	3	2	1	14
4	6	2	3	2	1	14
5	4	2	2	3	1	12
6	4	2	2	2	1	11
7	4	2	2	3	1	12
8	4	3	2	2	1	12
9	4	2	2	3	1	12
10	3	3	2	2	1	11
11	4	3	2	2	1	12
12	5	3	2	2	1	13
13	6	3	2	2	1	14
14	6	2	2	3	1	14
15	6gs 1	3	3	2	2	16
16	6	3	3	2	1	14
17	4	2	3	2	1	12
18	3	2	3	3	1	12
19	3	2	3	2	2	12
20	3	2	3	2	3	13
21	3	2	3	3	3	14
22	3	3	3	3	3	15
23	2	3	3	gs 1 3	2	13
24	2	2	4	3	2	13
25	2	2	3	2	2	11
26	2	3	3	2	2	12
27	1	3	3	2	2	11
28	1	3	2	3	1	10
29	1	3	3	gs 2 2	1	10
30	2	3	3	2	1	11
31	2	3	2	3	2	12
32	1	3	2	3	1	10
33	2	3	2	2	1	10
34	3	3	3	2	1	12
35	5	2	3	2	1	13
36	7	2	3	2	1	15
37	6	2	3	2	1	14
38	6	2	3	2	1	14
Sum	143	95	101	88	52	478

Figure 5. Numeric flow chart for Drums 1, "Rebonds" B mm. 1-30

four points, representing the first two cuts of Golden Section placed in either direction along the musical timeline. It may help to refer back to Figure 2 to clarify how these divisions work.

The 22nd repetition of the melody is colored in blue. It is the only repetition in which all five values are equal. Every drum is played three sixteenth notes apart. It is interesting to note this repetition's proximity to the first Golden Section division.

The green squares indicate points of interest that I would like to explain in a bit of detail, along with a few other interesting patterns that emerge through analysis of Figure 5.

1. The original pattern, 6-2-3-2-1, is found twice at the top and twice at the bottom of the chart. The two red lines that run diagonally across the chart indicate this. Xenakis fills 30 measures of music with a singular idea that undergoes a series of permutations only to circle back and arrive as it was initially, unchanged.

2. The only two notes that undergo serious transformation are the outer two. The inner three notes of the melody are always values of either 2 or 3. There is only one exception, found in repetition 24. This value of 4 is very close to the first Golden Section division (GS 1).

3. The sections in red are very proximate to the Golden Section cuts.

4. Repetition 15 has the highest pattern total, 16, and two interesting points come to light here. First, the GS 1 in the other direction is located here. Second, here and on either side of this location the first note of the melody returns with some stability to a value of 6.

5. Notice the arrows pointing to various regions along the column representing the fifth note of the melody (Grande Caisse 2). This column begins with 14 values of 1. It ends with half that, seven values of 1. In between these two "series of 1" is sandwiched a region of 17 values. This set of 17 values is almost perfectly symmetrical in and of itself, beginning and ending with 2, three values of 1, etc. Notice that the axis of this symmetry is again GS 1.

6. The diagonal line toward the bottom of the chart uses the seven values of 1 (at the end of the fifth note column) as its starting point. The tumba ends with six values of 2. The low bongo ends with five values of 3. The grande caisse 1 ends with four values of 2. The double-accented tom *would* end with three values of 6, but Xenakis throws in a value of 7. It is the only value higher than 6 anywhere on the chart.

Other interesting details manifest themselves along Golden Section divisions in movement B. However, the above information suffices to give cred-

ibility to the argument, and I should now like to discuss Golden Section rationale found in movement A.

MOVEMENT A

Unlike the sectional music of movement B, this movement provides a singular, river-like flow of rhythmic material. A thrice-repeated statement on the highest and lowest drums at the opening of the work gives fair warning that these two sounds shall become architectural pillars of the complex phrases still to come. Because there are no small formal sections to speak of, we shall only concern ourselves with the overall timeline of the work.

This movement contains 60 (6 x 10) measures of music in 4/4 time, yielding 960 sixteenth notes (6 x 160). The *Modulor* divisions of this length are those of the right-hand series in Figure 3: 593, 366, 226, 140, 86. Thinking musically (imagine for example the sonic results of Xenakis' experiments with his tape recorder), the points themselves create a kind of rhythmic accelerando. See Figure 6.

When we set this *Recursive System* against the music of A, details on the surface of the music begin to reveal themselves as structurally important.

GS 1, 593 (m. 23, the "a" of 4): This anchor serves as an axis of rotation, exactly 10 sixteenth notes after the first double accent in the movement (on the low tom), and 10 sixteenth notes before the final accent in a cluster of single accents around this point. This final accent is also on the same low tom. (see example 3).

GS 2, 367 (m. 38, the "e" of 1): This location immediately precedes two double

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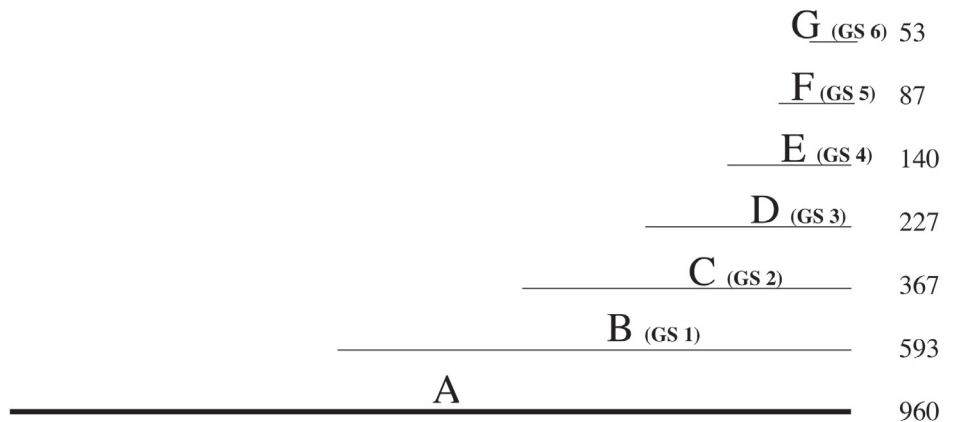


Figure 6. The Recursive System as rhythmic crescendo in "Rebonds" A

accents in the same measure on the second tom. (see example 4).

GS 3, 226 (m. 46, the “e” of 4): This point falls in the middle of a series of 12 double accents on the lowest drum that begins in measure 43 on the “a” of 2. GS 3 marks the seventh double accent of this series. The length of the phrase that links this double accent to the eighth (three sixteenth notes long) is significantly shorter than any of the other phrases that make up this series. It audibly stands out from the others. (see example 5).

GS 4, 140 (m. 52, beat 2): Here falls the incredibly powerful silence, a “rip” in the powerfully dense texture that has been building up from the beginning of the movement. (see example 6).

GS 5, 86 (m. 55, the “e” of 3): This point falls at the midway point of the six powerful strokes on the outer two drums that slowly decrescendo. (see example 7).

GS 6, 54 (m. 57, the ‘and of 3’): Exactly at this point Xenakis composed a dramatic echo. In the middle of the very soft final moments of the piece, we receive a recurrence of the texture that occurred at

Example 3. “Rebonds” A, GS 1, “axis of rotation.”

Example 4. “Rebonds” A, GS 2, two double accents.

Example 5. “Rebonds” A, GS 3, exceptionally short phrase.

Example 6. “Rebonds” A, GS 4, powerful silence.



Example 7, “Rebonds” A, GS 5, architectural pillars.



Example 8, “Rebonds” A, GS 6, Echo.

GS 5—a sudden nearby explosion that one could imagine hearing in the distance after a battle seems to have passed. (see example 8).

WHY IS THIS IMPORTANT?

I hope to have made clear that in “Rebonds” Xenakis used the Golden Section construction (as made systematic through Le Corbusier’s *Modulor*) to unify formal design, not just within the movements but between the movements themselves. After all, the fact that *A* is 60 measures long and *B* is 87 measures long is not just coincidental. From the perspective of theory or of composition, this is all well and good.

But for a performer, why bother knowing any of this information while learning “Rebonds”? Is such understanding and detail really necessary? One could easily argue that it is not. After all, from the audience perspective, perception of Golden Section proportion requires that one be aware of the whole as well as the particulars simultaneously. This cannot actually happen in a real-time medium like music in the same fashion that it can when regarding the architecture of the Parthenon, for example. Furthermore, from a player’s perspective, in no way does this understanding act as a substitute for the hard work of learning the notes—of learning all the details from moment to moment.

It is important to remember that this is only one tool, only one way of looking at the music. It is not *the* interpretation, and can only be a poor substitute for the immediacy of one’s own visceral experience in performance.

HOWEVER...

To briefly speak from personal experience, having worked on this piece many times, *A* had always been problematic. It is long. The rhythms are all very similar. The material is monochromatic. There is a danger of becoming “bogged down” in the growing thickness of drumming. Both from the vantage point of memory and of endurance, this movement had never been easy to hold onto and to convey in a musically convincing manner.

In performance now, I have found that this analysis provides the aid of concrete musical anchors, not just arbitrary points chosen along the timeline as good as any other. These points are immensely helpful in terms of phrasing and of memory, and therefore I see them as a perfectly valid tool to use in forming an interpretation. The analysis clarifies the importance of the double accents along the musical timeline. It gives them clearer meaning. The analysis lends similar understanding to *B*.

Finally, I find it extremely revealing to tie in something of Xenakis’ own life into the narrative of the music. Although Xenakis was a hard line formalist and would certainly reject any such suggestion, his preoccupation with Golden Section as a means to construct music nevertheless strikes me as intriguing. Xenakis’ use of Golden Section is, I believe, an indication of his own creative and spiritual expression, connecting him to his passionate conception of the world and ideas of ancient Greece. For Xenakis it was a tool he used in search of himself and his own spiritual place in the world.

The act of performing “Rebonds,” then,

can also become a philosophical or spiritual pursuit, just as is often claimed about performing the works of Messiaen or Bach.

“All music turns out to be ethnic music.” —Steve Reich

Many thanks to Nils Vigeland, whose incredible analytical mind is largely responsible for planting the seed of the idea for this article.

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REBONDS

Composer: Iannis XENAKIS
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Greg Beyer specializes in repertoire that places non-western instruments into the context of contemporary musical thought. Second-prize winner of the 2002 Geneva International Music Competition, Beyer has given performances and master classes throughout the United States, Europe, and Brazil. Living in New York City, Beyer is an active freelancer in the contemporary music scene. Since August 2004, Beyer was a Visiting Assistant Professor of Percussion at Northern Illinois University. **PN**