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*Multi-temporality and pitch permutations: Creating
networks of time and tone as raw material for
composition*

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Multi-temporality and pitch permutations: Creating networks of time and tone as raw material for composition

Commentary on the Portfolio of Compositions

Submitted for the degree of Doctor of Philosophy by Composition

Chad Langford

Durham University

Department of Music

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Abstract

The following commentaries will examine my recent music from both technical and aesthetic viewpoints, focusing in particular on my exploration of both harmonic permutation fields and polyrhythmic space, and the various ways in which these have been used to create harmonic/temporal networks as raw material for composition. Whilst investigating the development and subsequent interactions of these two techniques, the commentary will also consider how this approach has evolved organically from the desire to create pre-compositional material which is both flexible and simple to define, but which also has the potential for diverse compositional outcomes, providing the composer a rich seam of material to work during the compositional process. In the interest of clarity, we will consider the harmonic and temporal aspects of my approach separately in sections 2.0 and 2.1, respectively, leaving section 2.2 to outline a more unified conception of working methods which have resulted from this research, building on the ideas presented previously.

Portfolio contents:

YAMAHA/ENIGMA (2011), for disklavier, computer, and projector	14'00"
<i>As an 'automated' electroacoustic piece, there is no score for YAMAHA/ENIGMA. A video rendering may be found on the accompanying CD. The complete SuperCollider code is available upon request from the composer.</i>	
MARIA LUNAREM	
<i>Sea of Islands</i> (2012), for cello solo	8'00"
<i>Border Sea</i> (2013), for flute, viola, and piano	8'00"
<i>Sea of Waves</i> (2013), for oboe, bass clarinet violin, piano, and percussion	5'00"
<i>Eastern Sea</i> (2012, rev. 2013), for alto flute, cor anglais, clarinet, piano, violin, viola, cello, and percussion	6'40"
MAKURA SADAMEMU (2014), for bass clarinet, bass flute, and computer	11'00"
IMPERFECT INFORMATION (2014), for flute, bass clarinet, violin, cello, and piano	12'00"
ORBIT/APHELION (2011-2015), for string quartet	9'30"
PERFECT INFORMATION (2014-2015), for orchestra	18'00"

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1.0 Introduction

1.1 Revealing clarity in obscurity: working with intricate networks of time and tone

Despite continuing compositional innovations in the areas of pitch organization, temporal space, and gesture, there remains much fertile territory yet to be explored. Building upon the foundations laid by composers such as Charles Ives, Magnus Lindberg, Olivier Messiaen and Elliott Carter, this portfolio presents two core techniques: the long- and short-range permutation of unordered pitch collections, and the formal and gestural use of polyrhythmic space. Across six diverse compositions, we will see how each of these discrete techniques have become incorporated into a unified conception, to be employed in various ways as a formal determinant at all temporal levels. It should be stated clearly at the outset that larger questions of aesthetics – not to mention many additional compositional parameters such as instrumentation and orchestration – are not avoided, and that these necessarily interact with the compositional work. The reader will understand that, given the relatively compact scope of a doctoral commentary, certain choices of focus must necessarily be made, and in these areas in particular there is certainly additional material of value which could be included in this document. However, due to their central importance in my compositional development over the past four years, the research contributions as outlined in this set of commentaries are most centrally located within the pitch permutational and multi-temporal aspects of musical organization, investigating how these can be used to create and control characteristic architectures, and, most critically for my own practice, perceptual clarity and ambiguity in the score.

Through the establishment of two simultaneously-unfolding patterns, we can create complex *harmonic* and *durational* interrelationships; intricate networks of tension and release which can then be used as raw material for composition. It is interesting to uncover the 'hidden' potentialities latent in these parallel harmonic and temporal structures. Figure 1 illustrates in brief the core techniques. The reader can observe two discrete, through-going pulse streams: groupings of 12 sixteenth-note quintuplets in the viola, against groupings of 20 sixteenth-note septuplets in the piano. In addition, the grouping in the piano part defines the boundaries of the simultaneously-unfolding *harmonic rhythm*, a rhythm which is ultimately governed by an underlying permutational ordering pattern. Having initially investigated these two techniques (permutational harmonic development and polyrhythmic organization) separately in

earlier, smaller-scale compositions, over the course of this research I have developed and consolidated them into a cohesive methodology, bringing them to bear on larger-scale formal structures.¹ This approach represents a very generalized, flexible system; one which allows for a multitude of compositional outcomes whilst providing much potential for new discoveries.

The image shows a musical score for two instruments: viola (top staff) and piano (bottom two staves). The key signature has one flat (B-flat). The top staff (viola) features two phrases. The first phrase starts with 'arco' and a five-measure phrase, followed by a dynamic marking of *ppp* and a crescendo to *mf*. The second phrase also starts with 'arco' and a five-measure phrase, followed by a dynamic marking of *ppp* and a crescendo to *mf*. The bottom two staves (piano) feature two phrases, each starting with a dynamic marking of *pp* and a seven-measure phrase.

Fig.1 – Temporal stratification of the viola (top) and piano in *Border Sea* (2013), mm.98-99.

1.2 Research context

This research contributes to a developing body of work produced over the last century by a number of diverse composers; a corpus which highlights the temporal aspect of music as a central compositional concern for exploration and development. We can trace the idea of ‘multi-temporality’ – music which is built upon multiple, simultaneously-unfolding temporal strata – back several centuries to the gradual emergence of precise rhythmic notation first explored and defined in the *ars antiqua*, through to the polyphonic counterpoint of the *ars nova* and, later, the development of highly consequent harmonic/temporal structures such as the fugue. After a period of consolidation in the eighteenth and nineteenth centuries, Charles Ives helped launch these general ideas into the modern age with his ground-breaking explorations of superimposed, starkly contrasting musical strata in works such as *Central Park in the Dark* (1906), *Symphony No. 4* (1924), and the *Concord Sonata* (1919, rev. 1947). Through his seminal *Studies for Player Piano* (1948–1992), Conlon Nancarrow’s work pursued these ideas much further. From 1948 until his death in 1992, he took the exploration of layered temporal strata to new conceptual heights within the context of a

¹ As Göran Folkestad points out in his meta-analysis of six studies of music composition in music education, it is the conception of large-scale form rather than local/surface detail that is most difficult for students to come to grips with as they learn to compose music. Folkestad (2004, 88).

more methodically investigative rigor; a rigor made possible through the extremely precise temporal execution offered by the player piano.² Looking deeper into the 20th century, we see that many more composers in turn began to investigate multi-temporal ideas in their own practice, with the post-WWII proliferation of recording technology also opening up previously unimaginable possibilities for early adopters such as Pierre Schaeffer, Pierre Henry, and Luc Ferrari, as well as inspiring multi-temporal innovation in the acoustic compositions of Karlheinz Stockhausen and György Ligeti. An initial stage of this development came to fruition with the *Double Concerto* (1961) of Elliott Carter, who, from 1950 until his death in 2013, developed and perfected an elegant system of polyrhythmic formal structuring which allowed for the precise definition and control of multiple, simultaneous pulse streams at all temporal levels. Looking ahead to composers of the present day, it is true to say that regardless of style or aesthetic concern, the development of composers' conceptions regarding the use of multiple time screens (to use Elliott Carter's term) continues apace, with composers as stylistically diverse as Brian Ferneyhough, Bryn Harrison, Magnus Lindberg, and Sam Hayden all exploring new possibilities of multi-temporal organization in a multitude of very personal, intriguing ways. In the realm of electroacoustic music and studio composition we find similar explorations in recent work by Bernhard Lang, Nick Collins, and Laurel Halo, to name but a few. The scores and recordings of these and many other artists have served as key inspirations and focus points for my own research.

1.3 Contents of the thesis

This commentary describes and demonstrates the process of composing with two parallel, interacting patterns: 1) a 'chain' of harmonic permutations created from an unordered collection of pitch sets, and, 2) the complex temporal divisions of polyrhythmic space. Initially described separately in sections 2.0 and 2.1, we will see how each of these techniques are used together as part of an integrated system of composition in section 2.2, examining my approach from the standpoint of practical artistic work and highlighting some interesting phenomena which I have observed along the way. When appropriate, we will discuss examples from the literature which may serve to clarify or to otherwise provide relevant background information. Sections 3.0 – 3.5 provide detailed analysis of the pieces submitted in the portfolio.

² See also Collins (2012) for computer-based extensions of Nancarrow's ideas .

2.0 'Method ringing': pitch sets and permutations

2.0.1 Basic procedures of pitch set permutations

All of the music submitted with this portfolio was composed by the manipulation of collections of pitch-class sets. It seems appropriate to begin by defining several key terms relating to pitch-class sets which will occur again and again throughout this commentary. Most of these terms have come into common use in the years since Allen Forte published *The Structure of Atonal Music* in 1973; surely a clear sign that the consideration of musical pitch organization from the highly flexible, generalized vantage point of the generic *unordered pitch-class set* has much to recommend it, not only for analysts but for composers as well. In most cases I will refer to the sets by their actual pitch content as used in the music, and we will refer to a group of pitch-class sets (shortened to *pc sets* from this point) as a *collection*. When discussing computer code we will use integer notation (as used in the code itself) to describe pc sets (i.e., [0, 4, 10] instead of 'C, E, Bb'). The term *inversion* will invariably be used to describe *chordal* inversion in the classic sense, i.e., as a rotation of vertical pitch order.

If we repeatedly subject a collection of pc sets to some order permutation operation (see Fig.2) we can create long 'fields' of harmonic raw material in a manner similar to what Messiaen referred to as the 'Interversion of Notes'³ in his classic *Technique de mon langage musical*. Though in this chapter Messiaen was primarily concerned with the use of permutation as a generator of melodic development, the harmonic fields which we construct by subjecting a *collection of pc sets* to a similar operation takes this idea a step further. These resultant fields represent complex patterns of harmonic



Fig.2 – Two permutations of the collection [1,2,3,4,5] create a new harmonic 'field'.

interrelationships; intricate networks of intervallic tension and release which can then be 'composed' in some way into the structure of a finished work. Of course, thinking about one's musical material in terms the manipulation of discrete collections is what

³ The French term 'interversion' can serviceably be translated as 'reversal', which, in the context of his example, we can take to mean a sort of 'order permutation'. Messiaen (1944/1956: 35).

many composers do: regardless of our chosen material, at some point we must decide which elements to use and which to exclude. Functional tonal harmony aptly exemplifies this approach, using sets of pitches which relate to one another in more or less fixed grammars.⁴ It follows that we may generalize basic set-theoretical principles to describe and manipulate any collection of sound material of interest, bearing in mind that it is up to the composer to establish relations between these individual elements by some means in order to create the characteristic grammatical relationships of the work.

The idea for working with pc sets in permuted orders occurred to me after a first-hand introduction to the very British practice of ‘change’ or ‘method’ bell-ringing, which I witnessed at the church of Saint Andrew in Great Ryburgh, Norfolk, during the summer of 2008. In a ringing tower, the bells (typically between six and eight) are each attached to special mechanisms which allow them to rotate freely, controlled by ropes which are pulled from below. Traditionally, the bells are rung in various permuted orders, according to specific algorithms called ‘methods’. The methods must be carefully constructed not only to ensure that each permutation occurs only once, but also that individual bells don’t jump too many positions in the successive orderings, ensuring that they all have enough time to ‘reset’ before ringing again (for example, a bell ringing in the last position of one round could not then immediately ring on the first position in the next round).⁵ An *extant* or a *full peal* is rung when all possible permutations have been performed (without repeat) in one session by a group of ringers, a feat requiring considerable concentration and skill.⁶ For a bell tower with six bells this means 720 unique permutations (or 4,320 individual strikes). For an eight-bell tower the figure jumps to 40,320 permutations. The effect of listening to method ringing can be deeply meditative, with the steady pulse of constantly-shifting permutations creating endless melodic variety within the framework of what is necessarily an extremely restricted set of pitches; one is immediately struck by the simplicity of the basic idea coupled with the depth of the resulting effect. Listening to a group of skilled ringers puts us in mind of the infinite; seemingly endless, abstracted melody, evoking the variety of the universe of possibilities contained within restricted systems. It did not take long for me to begin to

⁴ Various combinatorial aspects of tonal harmony are explored in Bigand, Poulin-Charronnat (2009: 59-70).

⁵ For more information about applications of group theory to method ringing, see Intermont & Murphy (2011: 223-228). It is important to note that this requirement (limiting the bell transpositions to performable rotations), which severely restricts the number of allowable permutations in actual method ringing, is not necessarily applicable when using similar permutation methods in purely compositional applications.

⁶ See Intermont & Murphy (2011: 225), Johnson (2006: 22-23), and Price (1969: 131-132).

imagine music constructed from a vast expanse of permuted *harmonies*, where the same five or six harmonic structures could be constantly reordered, inverted, transposed and thoroughly explored until all possible relationships had been exhausted.⁷

2.0.2 Interval content, set inversions, and voice leading

My initial experiments with potential compositional applications of permuted pc sets eventually became *Rivers of Europe* (2009), for piano and soundtrack. As shown in figure 3 below, the harmonic content was based on a 6 by 6 collection; six pitch sets, each comprised of six pitches. The sets themselves were composed intuitively at the keyboard, attempting to keep the closest possible voice leading whilst also seeking to



Fig.3 – The collection of six pc sets used in *Rivers of Europe*.



Fig.4 – *Rivers of Europe*, bars 1-9. Three permutations of the collection create the characteristic opening for *Rivers*: [6,4,1,2,5,3], [1,6,5,3,4,2], [5,4,1,3,2,6]. Each harmony is freely inverted (in the sense of vertical pitch rotation) to obtain the desired voice leading.

⁷ In his opening essay from the *Elliott Carter Harmony Book*, John Link highlights this (seemingly) natural predilection for what he terms ‘combinatorial completion’ in composers as diverse as Bach and Babbitt, Chopin and Carter. Hopkins and Link (2002: 9–10).

ensure that the total set would contain the broadest possible intervallic and pitch content. This was intended to guarantee a measure of variety in the balance of intervals and pitches throughout the permuted harmonic fields (see Fig.4 for an example of this as used in the opening bars of *Rivers*). We can observe similar concerns of pitch organization in the work of many composers, particularly in much of Elliott Carter's work after 1950, where specific intervals are identified with particular instruments, tempi, or instrumental groups to create characteristic harmonic/temporal associations throughout the work.⁸ In the case of *Rivers*, this intervallic variety was intended to

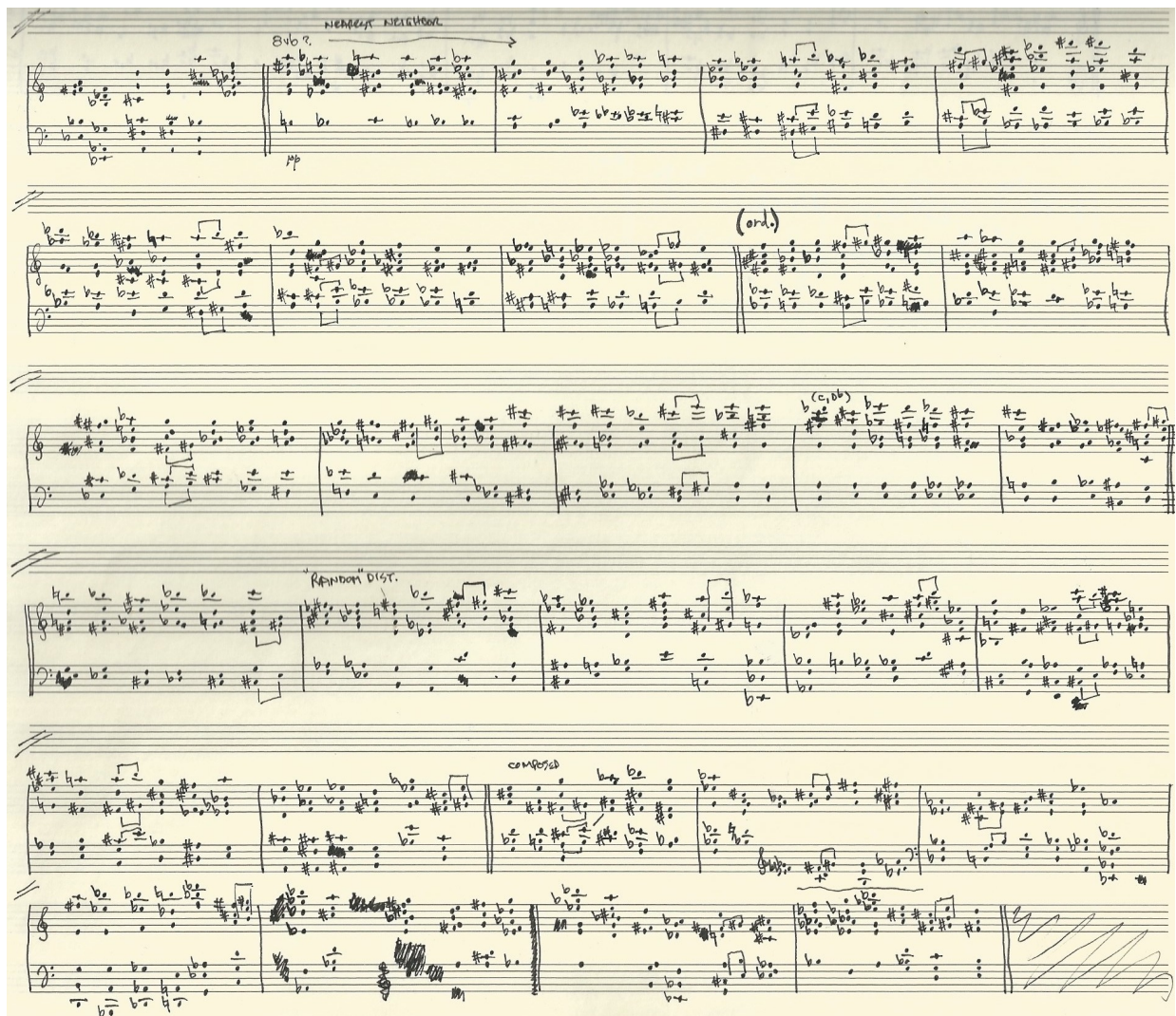


Fig.5 – Fragment of permutation/voice leading sketches for *Rivers of Europe*.

prevent one interval class from becoming too prevalent in the resultant permutation series, as it would necessarily be occurring again and again with its associated pc set. Preliminary sketches for *Rivers* were largely comprised of hand-written manuscript (see

⁸ By the end of the 1940s, Carter and many of his New York contemporaries had become less interested in the formal elaborations of the European serialists than in finding ways to express the complexity of modern lived experience. Schiff (1983: 132-135).

Fig.5) of large sections of the resultant harmonic field permutations, exploring various options of voice leading, registration, and inversion. I remember finding this process immensely satisfying, as I grew more and more intimately familiar with the individual harmonies and the various subtleties of their interrelations.⁹ Nearest neighbor, random inversion (using a computer), and deliberate ‘farthest neighbor’ voice leadings between sets were explored in detail in these sketches. For the actual piece, the sections of sketch which attempted the smoothest possible voice leading were most frequently used, in combination with certain sections of random inversion. In subsequent compositions I have used various techniques to navigate these harmonic fields, but the goal has always been the same: to reveal latent ‘hidden’ relationships within a complex pre-existing harmonic network. In this regard, I understand Toru Takemitsu when he states that, “My interest in manipulating numbers is not directed at creating music theory. On the contrary, by using numbers I want to integrate music with the real, changing world.”¹⁰

2.0.3 Permutations and repetition: Transposition, inversion, and creating harmonic ambiguity

Let us construct a new collection of pc sets similar to the ones we have examined above, and create a harmonic field from the first few permutations (Fig. 6). If we consider this as the harmonic raw material upon which we want to build a new composition, we can immediately imagine that through the successive permutations our perception of any one pc set and its constituent pitch elements will be continually



Fig.6 – The same permuted collection [1,2,3,4,5] from Fig.1, this time with the pitches freely inverted. We can easily imagine that the larger the individual pc sets in a collection, the more inversionally complex they become, with resultant effects on a listener’s perception of repetition in the whole permutation field.

⁹ Regarding sketch-making: I see no other way to fully explore the potential of your material. I have observed that as my own practice has matured, the number of sketches that I typically produce during the composition of a piece has increased substantially. This could partly be attributed to the fact that the materials I am working with have grown more complex. Sketching can be a way to better understand the latent potentialities in the relationships between harmonic material and temporal organization; relationships that might otherwise remain obscure. From a pedagogical perspective, Schönberg (surely no amateur when it came to teaching composition!) would seem to agree, having asserted that, “To make sketches is a humble and unpretentious approach toward perfection.” Schönberg (1967: 117).

¹⁰ Takemitsu, Toru, *Confronting Silence* (Berkeley: Fallen Leaf Press, 1995), 102.

modified by its changing relationships with its neighbors. With each permutation it is as though we are viewing similar objects through different filters; we are constantly confronted with sensations of both familiarity and obscurity which interact with one another in compelling ways. These perceptions can be accentuated or attenuated via our other compositional choices, such as the prevailing temporal environment, local rhythmic gestures, timbre, and global form. In addition, there are countless ways to modulate the listener's perception of repetition through the modification of the pc sets themselves. Typical examples could include inversion, transposition, or the use of subsets, i.e., using only a selection of the elements contained in a particular set.

We may also choose to highlight the 'numerical', repetitive aspects inherent in permutation fields, an approach used in Section 1 of *YAMAHA/ENIGMA* (2011), composed for the Yamaha Disklavier and laptop. Inspired by the general idea of encoded language (as specifically related to the workings of the ENIGMA cipher machine used by the Axis powers in WWII), at a deeper level the piece can be understood as a 'love letter' to the act of reading itself. We will look at the piece in depth in Section 3.0 of the commentary, but for now let us look at a fragment of code (written in SuperCollider) which describes the behavior of the piano in Section 1:

```

~harmonySet = [[2, 11, 4, 1, 6], [10, 5, 8, 2, 4], [1, 8, 3, 11, 5], [11, 6, 9, 2, 8],
              [2, 7, 10, 6, 0], []];

~sectionOnePianoRoutine = Routine({
  15.do({ |i|
    ~dummy = ~harmonySet.permute(i);
    ~dummy.size.do({ |i|
      m.allNotesOff(16);
      ~dummy[i].do({ |pitch, count|
        var trans = [60, 72, 84].choose;
        m.noteOn(16, pitch+trans, ~pianoVolume);
        0.08.wait;
      });
      ~tempo.wait;
    });
  });
});

```

Fig.7 – Fragment of code generating the harmonic permutations in *YAMAHA/ENIGMA*.

Here, the Routine simply executes arpeggiated iterations of the first 15 permutations of the ~harmonySet.¹¹ The clock-like regularity of the repeated rhythm (and the fact that the Disklavier is alone onstage, ‘playing itself’) creates a strong impression when coupled with the visual projections which accompany the musical material (see commentary in Section 3.0 for more details). In *YAMAHA/ENIGMA*, this layer of permutation is superimposed over another layer of *duration* permutations which are manifested through the segmented and reordered playback of pre-recorded music. These two layers of simultaneously-unfolding permutations form an interlocking set of patterns, ‘wheels within wheels’, which further suggest the inner workings of the ENIGMA machine. The effect is not unlike what Messiaen achieved in the first section of *Quatour pour le fin du temps*, where the composer employs two interlocking permutation patterns in the piano and cello, each of which is also composed of two interlocking patterns.¹² In *Quatour*, the piano pattern consists of a series of 29 chords which are mapped over a series of 17 durations. These patterns are sufficiently complex such that any direct perception of repetition is somewhat tempered, leaving the listener only with a vague sense of recursion; of perceiving some deeper pattern that somehow continually eludes her. Clearly, repetition and the artistic control we exert over a listener’s *perception of repetition* are powerful tools for the composer. There are, of course, countless examples of this throughout the canon. In his study on the music of Takemitsu, Peter Burt refers to the composer’s use of what he terms ‘referential sonorities’¹³ in Takemitsu’s post-1980 output, which often help to ground the listener in a music that can at times seem to exist in a sort of vast, wandering formlessness. By repeating certain ‘signpost’ harmonies (or any recognizable material), Takemitsu helps us to close cognitive loops in time, confirming or thwarting expectation and thereby continually changing the context and meaning of the music heard previously.

¹¹ Attentive readers will notice one empty set included at the end of the ~harmonySet. This was inserted to create occasional spaces in the ongoing permutation texture, creating a (somewhat randomized) sense of irregular rhythm within the successive patterns. The *permute* function in SuperCollider creates successive permutations of an array via an index (*i*), which is read as an index into a factorial ($n!$, where n is the size of the collection). This is the permutation algorithm which has been used for all of the compositions discussed in this portfolio.

¹² ‘It has been calculated that for the music to work its way through every possible heterophonic combination set up by these parallel processes, “Liturgie de cristal” would last for about two hours.’ Hayes, Malcolm, “Instrumental and Choral Works to 1948”, in Peter Hill, ed., *The Messiaen Companion* (London: Faber & Faber, 1995), 184.

¹³ In this section Burt is discussing *A Way a Lone* for string quartet which contains “a few of the rare instances of contrapuntal writing in Takemitsu’s music.” He suggests that Takemitsu provides “points of repose in the overall scheme” through the use of ‘referential sonorities’ and ‘referential thematic statements’. Burt (2001: 198).

We can take this general idea a step further when we observe that any harmonic relationships, if sufficiently articulated, may also serve as a functional connection between *groups* of otherwise self-contained pieces, as is the case with four of the works included in this portfolio. The four pieces which make up *Maria Lunarem* were all composed with the same pitch collections, establishing a unified harmonic vocabulary which ties together pieces which otherwise exhibit stark contrasts in instrumentation, texture, and form. Of course, such a shared harmonic relationship may be conceived as structurally integral to a group of pieces, or may simply be the product of the composer's continuing interest in certain material; material which they may wish to explore further over several pieces.¹⁴

In terms of set modifications, we have two standard operations which can be used to control local cohesion or to create ambiguity in the permutation field. By using intervallic transpositions and/or inversions of a given set we by definition abstract its interval relationships to encompass all of their possible realizations within 12-pitch class space. Depending on the musical argument that the material manifests, the composer must be aware that they are at some level asking the listener to track the interval profile of a given set through its various transformations across the flow of the permutation field. On reflection we can imagine that the ease or difficulty this engenders is largely contingent upon the size of the pitch sets and the similarity or dissimilarity of their intervallic content. In my own work I have tended to use smaller sets of four, five, or six pitches, ensuring that each set has its own perceptible interval profile in a way that using larger sets of 10 or 11 pitches would not.¹⁵

2.0.4 The permutation of rhythm and duration

Inspired by contemporaneous innovations in pitch organization, many composers in the early 20th century sought to broaden their conception of rhythm and meter through the use of various systems. Taking the cue from the new ideas of pitch organization introduced by Schönberg and his followers, it did not take composers very long to begin experimentation with different approaches to the systematic organization of local

¹⁴ Peter Burt has highlighted Takemitsu's repeated 'pilfering' of his own compositional treasure chest, often cutting out snippets or even larger sections of music wholesale, to use as fodder for subsequent, though thematically unrelated, work. Burt (2001), 183.

¹⁵ See Cohen (2005) for more information on 'optimum complexity', and recent research into test subjects' reactions to music exhibiting varying degrees of complexity.

and structural rhythms. In particular, Messiaen's handling of rhythm – his so-called 'rhythms with added values'¹⁶ – an approach which he outlined in his *Technique de mon langage musical* of 1944, provided an elegant, flexible new way of thinking about the construction of rhythm. In my own compositional practice I have come to view this seemingly simple idea, adding together short durations to create chains of more-or-less irregular rhythmic values, as a more generalized technique for the musical handling of non-cyclical motion. I use the word 'motion' here to highlight the fact that duration (elapsed time) is the true correlate of movement and gesture, and that rhythms or larger temporal structures needn't rely on *a priori* beat groupings or strictly periodic metrical frameworks. In his primer on Messiaen's musical language, Anthony Pople puts it succinctly: "Of course, not just any extra note, rest, or lengthening will do. It is important to note that the added value in each case is calculated to knock the rhythmic pattern from the realm of Western (hyper-)metrical music into Messiaen's ametrical style."¹⁷ We will see how this conception of rhythm, one that is rooted in locally non-cyclical motion and gesture, has been a key feature of my recent work within more complex temporal spaces.

Around the time that Messiaen wrote his *Technique* many composers (including Messiaen himself) were searching for other new possibilities of rhythmic structuring. Extending the idea of harmonic serialization, many experimented with mapping their harmonic material onto sets of duration units which were themselves somehow serialized. Linking these general ideas to our earlier discussion of harmonic order permutations, we can imagine a similar approach to rhythm and form; the creation of a rhythmic stream consisting of a small set of permuted durations. Just as we have seen previously in our discussion of harmonic permutation fields, the *perception of local patterns* or longer-range periodicity in such a stream would depend on several factors, perhaps most importantly: the proportional relationships between its constituent elements; the length of the various durations in the set; whether or not the durations in the set are fixed, or are somehow proportionally modified through the course of the piece. In Section 3.0 we will examine my use of a simple permuted fixed-duration field in *YAMAHA/ENIGMA*.

¹⁶ Messiaen (1944/1956: 16).

¹⁷ Pople, Anthony, "Messiaen's Musical Language: an Introduction", in Peter Hill, ed., *The Messiaen Companion* (London: Faber & Faber, 1995), 36.

2.1 Working in polyrhythmic space

2.1.1 Introduction and basic concepts

At some stage in their pre-compositional planning, a composer must decide, either explicitly or implicitly, consciously or unconsciously, how they wish to organize the temporal space of their composition. Will the various musical elements rely on some internally or externally derived coordinating pulse? Will certain temporal parameters be left to the performers, as in some improvisatory or aleatoric music? For many, these questions of temporal organization represent more than simply one compositional parameter among many, but rather form a critical part of the artist's conception, a central technical and aesthetic concern. My strong interest in rhythm and musical time likely had its origins in my activities as a working bassist during the 1990s and 2000s. The process of learning the various rhythmic patterns and grammars required to successfully function in different styles of music instilled a deep curiosity about pulse, meter, and the microrhythmic subtleties of timing and 'groove'.¹⁸ Crucially, these ideas were not simply abstract, but arose directly out my own experience of the *physical* practice of playing an instrument; of *creating musical time* with others in live performance. For me, this created a strong link between the idea of yet-elapsing musical time and its true correlate, motion (as a product of physical effort), as well as the idea of music as a reflection of a *virtual physical gesture*. As I learned to compose, many of these concerns began to manifest themselves in my evolving conception of composed rhythms, contrapuntal writing and, eventually, *polyrhythmic* spaces. I consider the temporal space of a composition to be polyrhythmic when it features at least *two simultaneously-unfolding common-unit divisions* that each create *discrete* pulse streams which move at *different rates*. This definition does not stipulate the musical function of the polyrhythmic division nor its extent, which may be extremely local (manifested in one or two beats or phrases), or global (structurally integral to the entire work).

From the standpoint of practical composition, working with multiple pulse streams can be exhilarating, continually offering the composer unique insights into rhythm and counterpoint, as well as medium- and large-scale form. By using layered polyrhythmic ratios, composers can define discrete, stratified temporal layers within which they can

¹⁸ See Madison (2006) and Danielsen (2006) for detailed information on groove and microrhythm.

realize a wide spectrum of contrapuntal/harmonic/rhythmic scenarios, from local and regional structures composed by *integration and cooperation* between the elements of the various polyrhythmic limbs, to the *absolute stratification* of these temporal layers (think Ives's dueling marching bands). Like any compositional approach, working with polyrhythms can also present considerable challenges, not least in the area of ensemble coordination and (potentially) unwieldy beat subdivisions. Thus, there are a few practical concepts that we must first touch upon before proceeding further.

The composer approaching polyrhythms for the first time will immediately notice that using polyrhythmic spaces often necessitates the precise calculation of beat subdivisions and pulse lengths, in addition to forcing us to think a bit differently about fundamental concepts such as meter, notation, and ensemble. Moreover, the decision to use medium- or long-range polyrhythms as an integral element in any formal structures may raise several additional aesthetic concerns to which the composer will need to respond, i.e., what exactly does 'long-range' mean in terms of our chosen polyrhythm? Does the composer intend the polyrhythm to function as a frame for the entire piece, thus creating a total form through the gradual working out of its individual limbs? If this is not the case, then what place does the polyrhythm have in the total form; what purpose does it serve and how does it relate with other sections of the piece? In addition, we must determine how the individual 'structural' pulse points of each limb will be musically expressed. Do they represent strictly-observed execution points for short musical events, or perhaps for lengthier statements or phrases? Will the events begin before or end after the actual time point, creating a kind of expanded, 'blurred', or otherwise 'fleshed-out' time point?¹⁹ Finally, given the (often quite lengthy) time spans taken to complete some long-range polyrhythms, what are the implications (if any) for listeners in terms of directly perceiving the unfolding polyrhythm? Is a more-or-

¹⁹ See Doornbusch (2002) for more information on composers' attitudes to pre-compositional planning and more or less strictly-interpreted algorithmic formulae. I have spoken to many composers to whom this idea of 'fiddling' with a strict background framework (whatever this might constitute in individual cases) is anathema. I remember asking one such composer if he felt free to 'compose around' the time points in his background structure, starting a bit earlier or later than was scheduled in the formal plan, as the needs of the music dictated. "Oh no, never; because otherwise this [*gesturing at a sketch of his formal plan*] is meaningless." Of course, there are other ways to think about the expression of background structure. To take certain works of visual art as an example: experience tells us that we may observe a 'hidden' ordering of certain elements which may be comprised of geometric shapes, strong lines, or any number of other organizing forms that live in the background, giving structure to the foreground elements. Certainly these background shapes are as 'present' in the overall affect as the elements in a painting's foreground, though they need not be *precisely* delineated by the foreground. Rather, they are hinted at; used to provide general structural underpinning for the whole. It follows that the background temporal structure of a composition needn't necessarily rely on the *absolute* delineation of each structural/formal time point by the foreground material, and that the composer should feel free to sharpen or weaken the listener's perception of any underlying structures as she sees fit.

less accurate perception of any structural high-integer polyrhythm important to the apprehension of your work as a musical / poetic whole?

2.1.2 A curiously warped space: the morphology of polyrhythms

If we examine the lowest-integer polyrhythms, we observe several interesting properties which are shared by all polyrhythms, regardless of the complexity of their integer ratios (see Fig.8). We define 'low-integer' polyrhythms here as those with ratio integers not exceeding readily-performable beat subdivisions. We can take 12 as a natural limit, although with other variables to consider (tempo being the primary one) there is clearly no fixed boundary. The chart below shows several simple, low-integer polyrhythms from 2:3 up to 6:7. The ratios shown are mutually prime and in-phase, meaning that each *polyrhythmic limb* (discrete pulse stream) shares only one attack point with the other (here, the first pulse). Each polyrhythm completes its *cycle* (the time it takes complete each of its limbs) in one beat (one second in this example). We can immediately see that:

1. All the polyrhythms are symmetrical ('palindromic') around a central axis.
2. Their axis of symmetry may be *articulated* (as in all even:odd ratios) or *unarticulated* (all odd:odd ratios); i.e. the axis is articulated either by the central pulse point in the even ratio (as in all even:odd ratios), or by a point of silence located precisely between the two centermost pulse points of the limb with the larger integer (as in all odd:odd ratios).
3. Each polyrhythm has a unique *inter-onset interval* profile.

For this example we define the *inter-onset interval* (IOI) to be the duration between successive pulse points of the *composite rhythm* formed by the pulse points contained in *all polyrhythmic limbs*. The IOIs may be found by dividing the cycle duration (in this case one second) by the product of all the ratio integers (thereby giving the *minimum subdivision unit* necessary to express the polyrhythm), and then graphing out the time points of each limb as was done in the chart. It is interesting to note that in ratios where there is strict *alternation* of pulse points between the two limbs, as in 6:7 (i.e., there are no repeated pulses in one limb before the other limb's subsequent pulse), that the IOI profile contains no repeated values. Note that we do not consider low-integer *even:even* ratios to be polyrhythmic here, as they either, *a*) manifest a time-point overlap between limbs to the extent that the composite rhythm is identical to one of the constituent limbs (as in the example of 2:4), or, *b*) can be reduced to *even:odd* ratios,

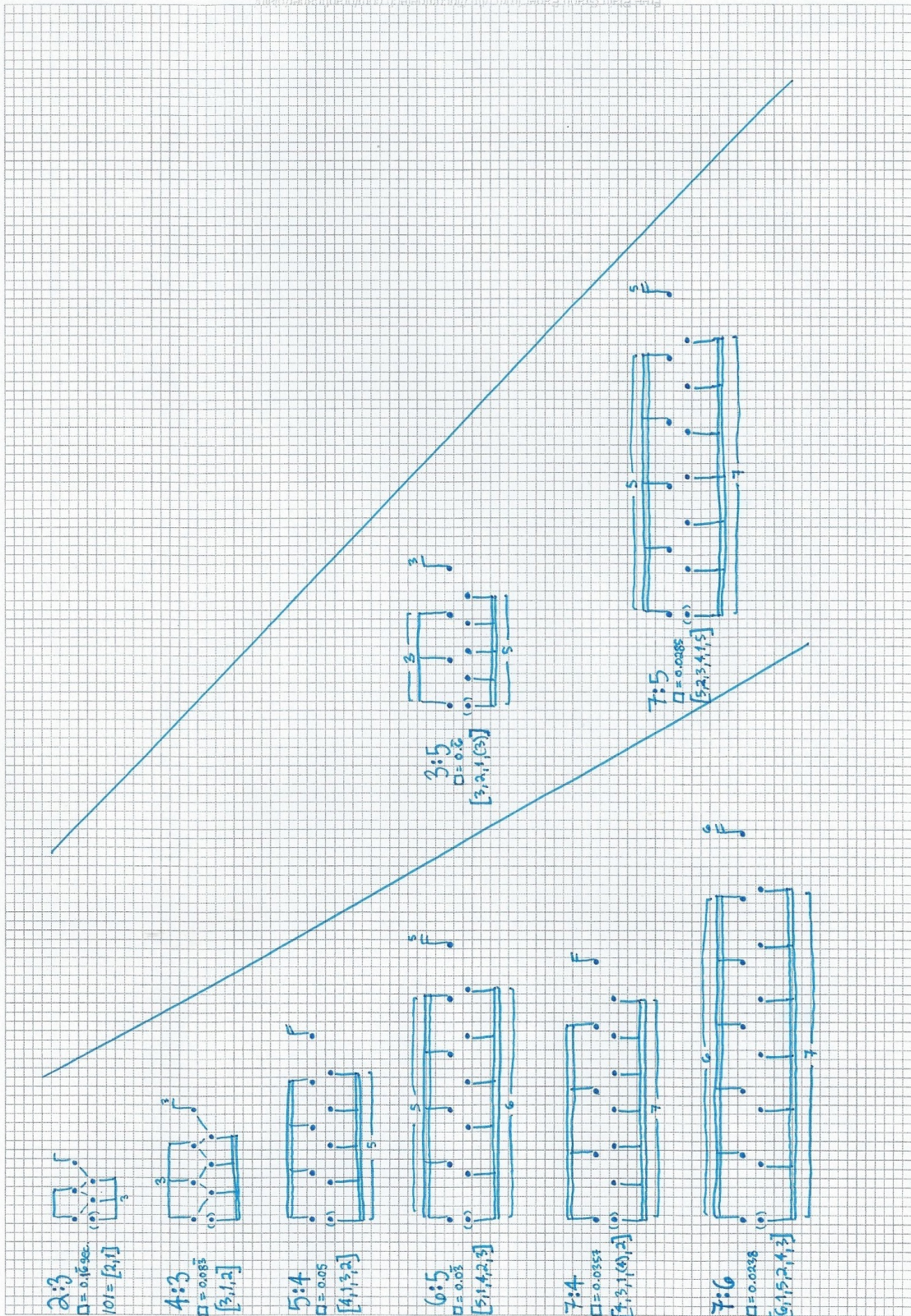


Fig.8 – Low-integer polyrhythms, showing IOI profiles and minimum beat division durations.

as in the case of 6:4. The key parameter to consider here is whether the ratio integers are *mutually prime* (or *co-prime*), meaning that, assuming that all pulse streams begin together (and are thus *in phase*), there is only that one initial point of coincidence between limbs before the cycle completes (Fig.9).²⁰ We shall see that these basic patterns hold true again and again as we look at higher-integer polyrhythms in the following section.



Fig.9 – The co-prime polyrhythm 6:7 in two possible settings. The first two bars show the polyrhythm *in phase*, with the two elements sharing one coincidence point. The second two bars offset the 6-element by one eighth note, creating an *out of phase* iteration of 6:7 with no coincidence points between limbs

2.1.3 Basic calculation of high-integer polyrhythms. Considerations of practical notation

If we wish to accurately express a high-integer polyrhythm within the framework of practicable, standard music notation there are a number of factors that must come into consideration. In his chapter on Elliott Carter's various uses of rhythm as a formal determinant, Andrew Mead²¹ has done much of the heavy lifting for us, not only providing a useful formula for calculating the notational expression of polyrhythms, but also offering many practical insights into the ramifications how ratio choices effect the necessary unit subdivisions in the music. Readers can refer to his chapter for more specific details; for our purposes here we can focus on several of the most important points by way of an example. Let us imagine that we wish to express the polyrhythm 61:63. We are seeking to define two *equal time spans*, one comprised of 61 *elements* (using Mead's term) and one of 63 elements; in each case these must be multiplied by some *fraction* of a *common unit of duration*. We must bear in mind that these fraction

²⁰ Note that by offsetting one limb of a co-prime, in-phase polyrhythm by some duration we cause it to become *out of phase*, creating a polyrhythm which may have *no points of coincidence* between limbs (after an idea by Douglas R. Hofstadter). I used this technique as a medium-range formal determinant in *Perfect Information* (2015). See Hofstadter (1985: 177-178).

²¹ Mead (2012: 147) This chapter alone goes quite a long way to clarifying some of the more difficult technical aspects of Carter's practice. See also Link (1994) and Bernard (1988) for more information on the specifics of Carter's use of long-range polyrhythms and how his process evolved.

multipliers should be practical (i.e., performable) subdivisions at our desired tempo. Mead's general formulae for the calculation of polyrhythms are shown in Figure 10:

Limb P: with prime factors a, b
 Limb Q: with prime factors x, y

Formats:

P	Q	Fractions	Multiples of time-span units
y/b	a/x	$P(y/b) = Q(a/x) =$	ay
x/b	a/y	$P(x/b) = Q(a/y) =$	ax
x/a	b/y	$P(x/a) = Q(b/y) =$	xb
y/a	b/x	$P(y/a) = Q(b/x) =$	yb

By substituting the integers of our chosen polyrhythm (61:63) for P and Q we arrive at:

	61	63	Multiples of time-span units
Format A	9/1	61/7	549
Format B	7/1	61/9	427
Format C	7/61	1/9	7
Format D	9/61	1/7	9

Fig.10 – Andrew Mead's formulae for constructing polyrhythms. See Mead (2012: 147)

As seen above, we often find that there are several ways to express a given polyrhythm by altering the fractions and the unit durations employed. Mead refers to these various realizations as *formats*. If we set the time-span unit at one quarter-note in each case (we could choose any note value), then for Format A the elements for each limb of 61:63 are 9 quarter notes (9/1) and 61 septuplet sixteenths (61/7) respectively, with the polyrhythm completing its cycle after 549 quarter notes. Format B gives another option, with limb elements at 7 quarters and 61 nonuplet sixteenths respectively, completing after 427 quarter notes. We see that Formats C & D are not practical here as they both rely on unit divisions of 61 in the first limb, but a composer could easily use formats A & B.

Fig.11 – The 35-bar and 15-bar formats of the polyrhythm 21:25, as used in *Border Sea*.

2.1.4 On using polyrhythmic formats

Mead’s use of the word ‘format’ is appropriate here, as it reflects the basic beat-division configuration operative within a given temporal environment. By using different available formats a composer is able to potentially alter the tempo and beat subdivisions through which a polyrhythm is expressed, but, crucially, without altering the integrity of any through-going regional or global polyrhythmic structures. However, formats do much more than this. As many polyrhythmic ratios will have two or more possible formats available, they give the composer an additional way of thinking about the total form, facilitating the use of a variety of tempi and beat subdivisions across different sections of the piece, again while still preserving the integrity of any global polyrhythmic structures.

Figure 11 shows the two formats in the polyrhythmic structure 21:25, which is used as medium-range formal determinant in my piece, *Border Sea* (2013). Many

listeners will recognize the technique known as “metric modulation”, a technique most associated with Elliott Carter (and a term which Carter himself did not coin, and only later in his career began using), whereby two sections of music in different tempi and with differing beat subdivisions can be seamlessly juxtaposed whilst preserving the through-going polyrhythmic pulse streams. If we consider the large-scale polyrhythmic form from the standpoint of its available formats, then it is easy to see why perhaps Carter himself did not immediately think that this one specific aspect of his technique (the so-called ‘metric modulation’ itself), which necessarily occurs at any change of format, was particularly noteworthy. In fact, the modulation is really the byproduct of switching between available tempo / beat division environments (formats) within a large-scale polyrhythmic structure. The ‘modulation’ itself may be less important than the relationship between the ‘origin’ and the ‘destination’, i.e. between two differently-divided polyrhythmic temporal spaces.

```

PolyCalc {
  *new { |limb1 = 61, limb2 = 63|
    var limb1factors = limb1.factors;
    var limb2factors = limb2.factors;
    var limb1FirstFactor, limb1SecondFactor, limb2FirstFactor, limb2SecondFactor,
        temp;
    var formatDurations;

    if(limb1factors.size == 1, { limb1factors.add(1) });
    if(limb2factors.size == 1, { limb2factors.add(1) });

    if(limb1factors.size > 2, { temp = limb1factors[0]*limb1factors[1];
      limb1factors.removeAt(0); limb1factors.removeAt(0);
      limb1factors.add(temp);
    });

    if(limb2factors.size > 2, { temp = limb2factors[0]*limb2factors[1];
      limb2factors.removeAt(0); limb2factors.removeAt(0);
      limb2factors.add(temp);
    });

    limb1FirstFactor = limb1factors[0];
    limb1SecondFactor = limb1factors[1];

    limb2FirstFactor = limb2factors[0];
    limb2SecondFactor = limb2factors[1];

    formatDurations = [
      [limb2SecondFactor/limb1SecondFactor, limb1FirstFactor/
        limb2FirstFactor],
      [limb2FirstFactor/limb1SecondFactor,
        limb1FirstFactor/limb2SecondFactor],
      [limb2FirstFactor/limb1FirstFactor, limb1SecondFactor/
        limb2SecondFactor],
      [limb2SecondFactor/limb1FirstFactor, limb1SecondFactor/
        limb2FirstFactor]
    ]
  }
}

```

```

];

("Format A - "+limb1+": "+limb2SecondFactor+"/ "+limb1SecondFactor+"
 "+limb2+": "+limb1FirstFactor+"/ "+limb2FirstFactor+
 " Number of duration units: "+((limb2SecondFactor/
 limb1SecondFactor)*limb1)).postln;
("Format B - "+limb1+": "+limb2FirstFactor+"/ "+limb1SecondFactor+"
 "+limb2+": "+limb1FirstFactor+"/ "+limb2SecondFactor+
 " Number of duration units: "+((limb2FirstFactor/
 limb1SecondFactor)*limb1)).postln;
("Format C - "+limb1+": "+limb2FirstFactor+"/ "+limb1FirstFactor+"
 "+limb2+": "+limb1SecondFactor+"/ "+limb2SecondFactor+
 " Number of duration units: "+((limb2FirstFactor/
 limb1FirstFactor)*limb1)).postln;
("Format D - "+limb1+": "+limb2SecondFactor+"/ "+limb1FirstFactor+"
 "+limb2+": "+limb1SecondFactor+"/ "+limb2FirstFactor+
 " Number of duration units: "+((limb2SecondFactor/
 limb1FirstFactor)*limb1)).postln;

formatDurations.round(0.001).postln;
"...".postln;
}
}

```

Fig.12 – My class *PolyCalc* provides a SuperCollider implementation of Mead’s handy formula, allowing the user to enter two integers and quickly see the range of available formats.

2.1.5 Strange attractors: Thoughts on rhythm and meter in polyrhythmic space

In his explanatory notes to *Mode de valeurs et d'intensités*, Messiaen highlights the fact that the notated meter of 2/4 is merely for ease of performance, thereby discouraging the performer from attempting to fit the music into any accustomed *a priori* metric framings.²² When creating music in polyrhythmic space we may find ourselves thinking about notated meters in a similar way, simply selecting them by virtue of either pure convenience or correspondence with particular format unit durations. This is nothing new, as the bar line has always had a tenuous relationship with musical meter as it is performed and perceived.²³ As composers have sought ever-new approaches to rhythmic organization and temporal flow, any conceptions of meter as a locally repetitive, cyclical force of forward musical motion which is somehow directly reflected in the time signature have often been redundant, or at least of minimal consideration. In my own work using polyrhythmic space I have gradually become aware of how the very act of composing with two or three layers of discrete pulse streams – streams

²² Messiaen (2008: 13).

²³ See Cooper and Meyer (1960: 88 - 89) for more information about the historical inconsistencies surrounding notated meters.

which can often affect one another locally in, at times, quite unexpected ways – can produce a different sense of forward motion, one that is naturally reflected in the more complex local and global temporal relationships between the elements of the polyrhythmic limbs. Speaking from experience, these time points (the individual elements in each limb) can naturally exert strong, attractive motional forces across the time skein, creating a complex web of continual temporal flux. One feels oneself composing toward and away from time points in the underlying structural layers, using them as rhythmic poles around which the push and pull of musical time can be organized. Can these irregular motional forces in polyrhythmic space be potentially understood as some kind of complex meter? Or, taking a step back: when composing stratified rhythms in polyrhythmic space, what happens to the idea of meter? Recent research has greatly increased our understanding of the cognition of musical meter as well as its function and manifestation in the temporal structure of music, although much remains unclear. Epstein (1995) and Kramer (1988) both view meter as part of a bipartite overall temporal structure, with meter on the side of what they both term ‘chronometric time’ and rhythm on the side of ‘integral time’. Epstein highlights the importance of a perceptible *periodicity*,²⁴ but for Kramer this is less important, as he focuses more on its manifestation through metric *accent*, also asserting that we can even perceive ‘deep meter’ at the highest levels of temporal structure, even up to the duration of an entire movement.²⁵ London (2012: 15-18) takes these ideas further in his study of the cognitive facets of meter, developing the idea of metric *entrainment*, whereby meter functions in the perceptual middleground as a framework for motional continuity and listener expectation; the cognitive entrainment to a metric pulse. Viktor Zuckerkandl was one of the first theoreticians to conceive of meter as a wave, beating at multiple levels of periodicity across the temporal skein.²⁶ Applying this concept to our question of meter in polyrhythmic space, it would seem logical to infer that any polyrhythmic structure has the potential to create *multiple* simultaneous metric waves which must be somehow collated and internalized by the listener. The wave conception

²⁴ “[Chronometric time] results in musical time divided into evenly spaced and in large part evenly articulated units. Periodicity is its essence...” Epstein (1995: 22-23).

²⁵ Kramer seems to assert that meter is somehow only a compositional byproduct of local rhythmic activity when he states that “Music drives toward rhythmic accents, not metric accents (unless, of course, the two coincide).” Kramer (1988: 115).

²⁶ Writing about the evolution of our modern (metered) music notation from a rhythmically ‘free’ plainchant, and the corresponding relationship between rhythm and meter, Zuckerkandl points out that, “It developed, however, that confinement to the strict rule [meter] did not destroy rhythm but, in the course of time, led to the evolution of a completely new rhythm – rhythm bound to the law of meter....And it is not rhythm despite meter, but, on the contrary, rhythm from meter, rhythm fed by the forces dammed up in meter.” Zuckerkandl (1956: 151-200).

of meter has been adopted and developed by many researchers since Zuckerkandl, some of whom have also begun to explore how listeners group local rhythmic patterns into multiple high-level patterns of meter, and how specialist and non-specialist listeners rely in different ways on regular and irregular pulse configurations. Based on recent research into dynamic attending theory (DAT), Mari Riess Jones has hypothesized the existence of what she terms *metric binding*:

Entrainment is a biological process that realizes adaptive synchrony of *internal* attending oscillations with an *external* event. Different event timescales correspond to marked (i.e., accented) metric levels. Time spans within a metric level can elicit a corresponding neural oscillation, which has a persisting internal periodicity, manifest as a *temporal expectancy*. It 'tunes into' recurrent time spans at a given level by adjusting its phase in response to *temporal expectancy violations* at that level.²⁷

Building on four assumptions regarding neural oscillations which she claims are shared by several current DAT²⁸ models (that they are *self-sustaining*, *stable*, *adaptive*, and that *multiple related oscillations* can be triggered by multiple time levels), she goes on to propose that:

Whenever two or more neural oscillations are simultaneously active, over time their internal entrainments lead to binding and formation of a *metric cluster*. A metric cluster comprises sets of co-occurring oscillations with interrelationships that persist due to acquired internal bindings. Entrainments among internal oscillations promote binding, which strengthens as a function of:

1. Duration of co-occurring oscillatory activity.
2. Phase coincidences, and
3. Resonance (i.e., relatedness) among oscillator periods.

For composers experienced with working in polyrhythmic space, this hypothesis may ring true on several levels, as our compositional process is often centrally concerned with the construction of just these types of *metric clusters* (to use Jones's term); i.e., multiple musical (thus, neural) oscillations of pulse streams which may have varying degrees of duration, phase coincidence, and resonance, as outlined in Jones's three points above. Speaking in general terms, we understand that whilst music based upon what is necessarily a more *irregular* network of attractive forces may create practical problems for performers (in terms of ensemble coordination – specifically, the coordination of different simultaneously-operative pulses and, possibly, meters) as well as listeners (some of whom may lack the listening experience or even the ability to effectively entrain with more complex rhythmic/metric structures), that it can nevertheless be a vehicle for rich, deeply affecting artistic experiences.

²⁷ Jones (2009: 81-92).

²⁸ Also see London (2012, 9-24) for a concise summary of attentional theory, also as it specifically relates to metric perception and cognition.

To conclude this section, let us briefly return to the question of gestural rhythm and metric continuity/discontinuity as it relates to larger formal constructs. From the standpoint of practical composition, the widespread use of gestural rhythms and phrases can frequently create additional problems of formal development, the main one being: how do these more-or-less *isolated* rhythmic gestures help to move the music forward? I use the word 'isolated' here to describe a gesture that is composed to be in some way (rhythmically or harmonically) *self-sufficient* (i.e., it has no directly-connected rhythmic antecedent, and no immediately obvious consequent). Conceptually, it comes more or less from nothing (silence/stilness), returning to nothing.²⁹ Such gestures may (while still exhibiting their properties of self-sufficiency) be composed within a sequence of similar gestures (which may or may not overlap), forming part a larger gestural whole. Magnus Lindberg highlights this very issue in his program note to *Corrente II* (1992):

After having written a Piano Concerto in 1991 preceded by three works for different orchestral effectives (*Kinetics*, *Marea* and *Joy*) I felt that I had come to an end with a certain musical expression and also compositional technique. All these works were based upon an extended chaconne principle with chord chains cycling around, undergoing constant transformation and being articulated in a very gestural way. The musical paradox and evidently also the challenge was the discrepancy between a brick-like method expressed in a world of gestures (with all difficulties involved in conceiving music out of phrases) aiming at a continuity in terms of progression and development.³⁰

What Lindberg means specifically by "aiming at a continuity in terms of progression and development" is not completely clear, but from the context it is logical to intuit that Lindberg was (at least in part) searching for a more through-going sense of temporal continuity (as opposed to music composed of gesture/phrase islands, i.e., the 'brick-like method' described above); one that could perhaps make more use of the *periodicity of meter*, with its in-built continuity of forward motion? It is also interesting that he mentions his so-called 'chaconne principle' of harmonic organization in this context as well, as it is an idea not unrelated to our discussion of pc set permutations in Section

²⁹ Takemitsu was a master of this type of writing, in which gestural islands rise in isolation and fall back again into imperceptibility. See *A Way A Lone II* and *Twill By Twilight*.

³⁰ Lindberg, Magnus, *Programme note: Corrente II* (1992), <<http://www.musicsalesclassical.com/composer/work/7689>> [accessed 10 April 2015].

1.1. As described by Ilkka Oramo,³¹ Lindberg's 'chaconne principle' abstracts the idea of the historical chaconne by creating chains of pc sets with specific pitch/register mappings which are more or less fixed throughout the work. In practice, he typically composes through these reservoirs of pitches in the same order, creating strong harmonic relationships based on global repetitions, but with a huge amount of local rhythmic control and flexibility. As Oramo points out in his analysis of Lindberg's *Corrente II*, the composer did not, in fact, abandon the chaconne principle for this piece as stated in the program note (indeed, Oramo's analysis shows that the piece is actually built around the composer's most rigorous working out of the chaconne principle up to that time), but rather has gone on to use it in the majority of his subsequent work.

To summarize the main points in our discussion of rhythm and meter in polyrhythmic space, we have seen that:

1. the potentially attractive motional forces operative between polyrhythmic elements can very naturally be made to function as both foreground rhythmic 'signposts', as well as the foci of middleground metric pulses and background structural supports,
2. the individual elements can be as strongly- or weakly-emphasized as the composer wishes, and can be operative at various levels of magnification within the temporal structure, providing as much fine or coarse rhythmic detail as the needs of the music dictate, and
3. from a contrapuntal standpoint, the composer has enormous freedom in determining the nature of the relationships between polyrhythmic layers (the spectrum between stratification and integration).

If working with a high-integer polyrhythm over the course of a longer section of music, she is able to exploit the (by definition) *absolute stratification*³² of the polyrhythmic elements to create music which is made up of perceptibly discrete layers. At the

³¹ Oramo, Ilkka, *Studies in music and other writings: 'Chaconne principle' and form in the music of Magnus Lindberg* (2004), <<http://www.musicsalesclassical.com/composer/work/7689>> [accessed 10 April 2015]

³² Recall that polyrhythms constructed of integers which are co-prime and in-phase have only *one possible point of coincidence* per cycle. Such polyrhythms which are rendered *out of phase* (by offsetting one limb by some duration) will have no coincidence points, making them ideal for exploring textures of absolute stratification.

opposite end of the spectrum, she may also compose a more integrated music, weaving a unified structure through the layers, exploring the latent possibilities of microrhythmic coordination and development through the composite rhythm.

A final word: as we will see in my own compositional practice, it is critical to note that the polyrhythmic canvas as we have defined it thus far can be viewed as the temporal analogue to the permuted 'harmonic fields' which we discussed in Section 2.0, in that it creates complex patterns of *durational* interrelationships through a section of music; intricate networks of temporal tension and release which can then be used as raw material for composition. Again, it is the composer's task to uncover the interesting 'hidden' potentialities latent in these parallel harmonic and temporal structures.

2.2 Composing with multiple pulse streams

2.2.1 Creating relationships between streams I: microrhythms and ‘organic’ gestures

As we discovered in the previous section, the polyrhythmic striation of the temporal canvas offers the composer a number of challenging and intriguing ways to create richly-layered temporal networks in the score. Indeed, at whatever level of magnification we examine our time skein, we find the potential for subtle, intricate relationships between the various strata of our layered canvas. For listeners, these relationships are often most visceral if we zoom in to the levels of sub-beat, beat and local gesture, where intricate tangles of microrhythmic interrelationship are continually created by the push and pull of the discrete pulse streams as they slide across one another. Figure 13 shows a section from *Border Sea* (2013) for flute, violin, and piano, which demonstrates how this can be used to project a dynamic sense of motion with two instruments.

The overarching polyrhythmic situation is 21:25, but here, as in several sections of the piece, these pulse layers are repeatedly ‘swapped’ between players. In the excerpt, this is reflected in the changing subdivisions of each player’s line. By removing any consistent timbral markers, the discrete polyrhythmic layers become more indistinct, but the overall rhythmic ‘flavor’ (a result of the unique IOI profile of the beat subdivisions used) keeps the local rhythm coherent. As the two instruments continually alternate between the various simple subdivisions available within the pulses of their respective streams, a highly active, microrhythmically intricate temporal surface emerges, giving a strong impression of two independently-developing organic processes which interact with one another in complex ways. What is the driving force behind these microrhythms? Referring back to the chart of low-integer polyrhythms in Fig.8 and examining the IOI profiles for each of these beat subdivision polyrhythms, it is easy to see how these very small IOI durations can create an extremely intricate rhythmic surface. We can also understand the greater potential for rhythmic inaccuracies in performance, resulting from the small durational differences (and their extremely complex ratios) that necessarily exist between polyrhythmic elements.³³ At a slow tempo, the array of durations contained in the IOI profiles would be trivial to perform, provided we assign a practical duration as our *minimum subdivision unit*.

³³ See Stockhausen (1959: 16) for more information about what he terms the ‘irrational of perception’, the extremely short *minimum subdivision unit* which would be required to express all beat subdivisions from 1 to 11.

Musical score for "Border Sea" (mm. 26-37). The score is divided into three systems. The first system (mm. 26-29) features a Flute (Fl.) part with a tempo marking of quarter note = 70 and a *poco* marking. The Viola (Vla.) part includes a *pizz.* marking and dynamics of *mf*, *p*, *mf*, and *p*. The Piano (Pno.) part includes dynamics of *mf*, *subito p*, *mf*, *p*, and *pp*. The second system (mm. 30-33) features the Flute part with dynamics of *pp* and *mp*. The Viola part includes dynamics of *mf*, *p*, *pp*, and *p*. The Piano part includes dynamics of *p* and *mf*. The third system (mm. 34-37) features the Flute part with dynamics of *pp*, *mf*, *pp*, and *mf*. The Viola part includes dynamics of *p*, *mf*, *p*, *pp*, *mf*, and *p*. The Piano part includes dynamics of *p* and *pp*. The score includes various rhythmic markings such as triplets and quintuplets, and dynamic markings like *poco*, *subito p*, and *pizz.*

Fig.13 – *Border Sea*, mm. 26-37. Note alternating pulse divisions between the viola and piano.

Far from our workaday low-integer temporal divisions – the simple ‘octave ratios’ or ‘2-relations’ of 2:1 (to use Stockhausen’s terms)³⁴, 3:2 or other multiples of whole integer values – these low-integer, beat-level polyrhythms define a short stretch of temporal space which is ‘irrationally’ yet symmetrically divided. Most importantly, each of them can be understood as the ‘meat and potatoes’ of any larger structures we wish to create in polyrhythmic space, for the simple reason that their pulse ratios will be used to express any higher-integer polyrhythm, making their unique beat-level IOI structure the crucial determining factor of the general rhythmic character of that

³⁴ Stockhausen (1959: 11). The charts which Stockhausen included on p. 17, 27 & 28 of this article were a key early inspiration that got me thinking about the implications of beat-level subdivisions in a more consequent way.

polyrhythm as expressed at the local level. Naturally these relationships will hold for any level of ‘magnification’ (augmentation or diminution) in the musical texture.

2.2.2 Creating relationships between streams II: integration and stratification

For composers like Elliott Carter, finding a personal approach to temporal complexity became the central concern of his compositional practice:

It is toward this time dimension that my own interest has been directed since about 1940, and whatever musical techniques I have used are contributory to the main concern of dealing with our experience of time, trying to communicate my own experience of it and my awareness of this experience in others. This, as I listen to most other contemporary music, is dealt with in a very routine way, in spite of the fact that sometimes most unusual and fascinating combinations of sound are being presented.³⁵

As we saw in Section 1.2, when first coming to grips with working in polyrhythmic space we soon realize that the discrete layers can offer us a range of possible contrapuntal conceptions situated between two poles of full integration/cooperation on the one hand and absolute stratification on the other. Carter refers to this stratification in his *First String Quartet*:

Here the first movement is a contrapuntal fantasy which is built on four main and several subsidiary themes each in a different speed and each having a different character. These themes of course have influence on each other and modify each other in the course of the piece. Yet a great deal of the interest in the first quartet comes from passages in which four themes are stated simultaneously – interacting somewhat, yet also stratified by means of their being in different tempos.³⁶

It is intriguing that here Carter seems most interested in the passages of simultaneity and their temporal stratification. This relates to his statement in the previous excerpt, that his main concern is ‘dealing with our experience of time’, and wishing to ‘communicate my own experience of it and my awareness of this experience in others.’ Indeed, it is often these superpositions of ‘unrelated’ material and their unexpected interactions – the ‘happy accidents’ of cross-reference and distorted/modified meanings which can result – which form a large part of the musical interest of this approach. Consider the opening section of *Perfect Information*, where I use the winds to create a sound mass of

³⁵ Carter (1977: 243).

³⁶ Carter (1977, 245).



Fig.14 – Using ‘nested’ polyrhythms in *Perfect Information* and *Aphelion*. The first and second lines are polyrhythms of 6:5 and 8:5 respectively (with each of their top voices offset by one quarter note), and have a cycle of 20 eighth notes; the third line is 7:4 (also with one quarter note offset) with a cycle of 21 eighth notes; the bottom line is 4:3 (one half note offset) with a cycle of 24 eighths. These constituent patterns create an *overall* polyrhythmic structure of 5 : 5.25 : 6 half notes, with a cycle duration of 315 quarter notes, or 78.75 4/4 bars.

stratified layers based on the superposition of four nested polyrhythms (Fig.14).³⁷ The musical argument proceeds by the gradual emergence and subsidence of a ‘sense of cooperation’ between layers, as transient structures intermittently take shape and then quickly fade away. Eventually, the entrance of the remainder of the orchestra begins to ‘enforce’ a sense of cohesion upon the still-folding wind texture, obscuring it somewhat beneath burgeoning, unified gestures in the orchestra. This development reaches its apotheosis at the beginning of the second section, with a region of unison rhythmic jabs articulated by the strings and percussion.

Precisely the same ‘nested’ polyrhythmic scheme was used in quite a different way for the *Aphelion* section of my string quartet, *Orbit/Aphelion* (Fig.15). Here, the music was composed of completely integrated harmonic gestures, with each instrument forming part of a unified contrapuntal conception. This was also the case in the central section of *Sea of Waves*, (Fig.16) the third piece in the series *Maria Lunarem*, where the various instruments, though separated into rigid pulse stream divisions, make quite a game of finishing one another’s sentences, rudely interrupting, and otherwise creating quite a lively (poly)rhythmic conversation.

³⁷ Refer to the material on *Perfect Information* in Section 3.5 for more detailed information.

"Aphelion"

Chad Langford

The musical score for "Aphelion" for string quartet, bars 1-7, is presented in two systems. The first system includes Violin I, Violin II, Viola, and Cello. The second system includes Violin I, Violin II, Viola, and Cello. The music features complex polyrhythmic patterns with triplets and various dynamic markings such as *pp*, *mp*, *p*, and *mf*. Performance instructions like *pizz.* and *arco* are also present.

Fig.15 – *Aphelion* for string quartet, bars 1-7. The music is composed within the polyrhythmic framework outlined in Fig.6. The constituent polyrhythmic layers have been developed and/or cut away, 'revealing' the characteristic gestures of the piece which are 'latent' in the underlying structure.

Of course, there are a number of factors which determine the degree of integration or stratification we perceive between the various layers of a piece of music. Each of the diverse examples shown above demonstrates how as listeners we rely not only upon music's temporal dimension to infer integration or stratification, but also on harmonic content and timbre. The rather static 'melodic' gestures employed by the various instruments in the opening of *Perfect Information* create no feeling of coordinated action; on the contrary, we have the distinct sense that the occasional locally-ordered gestures we may perceive merely occur through accident of placement. The stratified temporal space reinforces this, with the assistance of wind choir's innate timbral

The image displays a musical score for the piece 'Sea of Waves', specifically bars 87-94. The score is arranged in five staves: Oboe (Ob.), Bass Clarinet (B. Cl.), Percussion (Perc.), Violin (Vin.), and Viola (Vlc.). The music is characterized by a complex polyrhythmic structure, with a 5:6:7 ratio cycling every 4/4 bar. The score includes various dynamics such as *p* (piano), *mf* (mezzo-forte), and *f* (forte), as well as articulations like *pizz.* (pizzicato) and *arco* (arco). The percussion part features a prominent, driving rhythm. The woodwind and string parts provide harmonic support and melodic lines, often with slurs and accents. The overall texture is dense and rhythmic, with a strong sense of cyclical motion.

Fig.16 – *Sea of Waves*, bars 87-94. The piece is built around a simple polyrhythm of 5:6:7 which cycles each 4/4 bar. Whilst this does give a strong sense cyclical meter at bar level, it is made somewhat ambiguous by the irregularity of the constituent subdivisions.

characteristics, it being the most heterogenous orchestral group.³⁸ By contrast, in *Sea of Waves* (Fig.16) we feel a full sense of musical cooperation between layers due to the unified harmonic gestures, gestures which are constructed within a metric framework that is reinforced in the bar-by-bar repetitions of the much simpler polyrhythmic space³⁹; one which offers more opportunities for the discrete pulse streams to coincide.

³⁸ See Adler (2002: 164). "...the woodwind choir is perhaps the most quarrelsome of all the families within the orchestra. It is difficult for wind instruments to tune with one another, and only the finest players can accomplish any kind of balance or blend of their colorful and diverse timbres." This was very much in my mind when thinking about which instruments should perform the opening texture of *Perfect Information*.

³⁹ *Sea of Waves* uses a one-bar cycle of 5:6:7, creating a high degree of perceptible cyclical motion (meter). This is in contrast to higher-integer ratios which can take many bars to cycle and have more complex metric profiles.

2.2.3 Polyrhythms as a medium-range formal determinant

Several of the pieces submitted with this portfolio use high-integer polyrhythms as a medium-range formal determinant. In this context the term ‘medium-range’ is used to define a polyrhythm that completes at the level of the phrase group, usually around 60 - 90 seconds of music. I first employed this technique in *Safety In Numbers* (2011), where it was used in quite a straightforward way to generate rhythmic material. On a deeper level it also functioned to create cohesion through the medium-range repetition of form, as we shall see later in this section.

3:5:7 polyrhythmic cycle with shared beat unit.

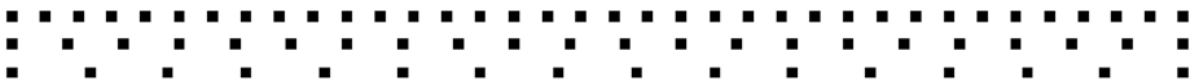


Fig.17 – The basic pulse pattern for *Safety In Numbers*. The cycle is comprised of pulses every 3, 5, and 7 eighth notes, creating a polyrhythm of 15:21:35.

In sketching out early ideas for *Safety In Numbers*, the three polyrhythmic layers were constructed ‘from the bottom up’; that is, by initially outlining the pulse streams using a *common beat division*, in this case the eighth note. By layering pulse durations of 3, 5, and 7 eighth notes (see Fig.17) we create a polyrhythm of 15:21:35, which completes after 105 eighth notes. The resulting overall form is still, of course, a polyrhythmic structure, but one which does not require *polyrhythmic space* for its expression, as each limb requires the *same beat subdivisions* to properly express its elements. This is a subtle distinction, but an important one. We can understand why if we imagine two

Fig.18 – Two possible formats of 5:7. The upper format uses a *shared minimum subdivision unit* of one 32nd note, while the limbs of the lower format have discrete subdivision values.

percussionists performing two different formats of the 5:7 polyrhythm shown in Fig.18. To the listener these two excerpts would be indistinguishable, but in the second format the underlying beat subdivisions are different for each limb, meaning that music composed *within the stream* of each limb will also be polyrhythmic; not the case in the first format, where the underlying beat subdivisions are shared by both limbs, potentially creating frequent pulse coincidences. For composers wishing to work with highly stratified temporal layers, the disadvantage of using such formats lies precisely in this non-differentiation of shared beat units; that it necessarily becomes more difficult to create a true sense of temporal stratification, as this is largely a product of the microrhythmic networks between the pulse layers which are 'built into' formats which use discrete pulse divisions. In a certain sense, what we are talking about is merely a function of the 'level of magnification' (the total cycle duration, in this analogy). By setting the *minimum subdivision unit* required to express a polyrhythm to a *shared beat or beat subdivision* we are bringing the entire polyrhythm into 'notational phase' with the metrical framework. By increasing or decreasing this level of magnification (increasing or decreasing the cycle duration), we again move the polyrhythm out of notational phase, which very often necessitates the need for discrete pulse divisions in each limb.

I have continued to explore this approach in subsequent compositions, manifesting the structure of the underlying polyrhythmic framework in different ways. We will discuss the specific methods used for each piece in Sections 3.0 – 3.5, but an important one to mention here is one that I have termed *redaction/revelation*, where the underlying medium-range polyrhythmic structure is initially obscured (redacted) in some way, and is slowly 'revealed' via an additive process of its constituent elements over subsequent iterations. The most explicit example of this approach occurs during the climactic buildup in *Border Sea*. From bar 42 each 13-bar section (with the exception of one 3-bar interruption by the 15-format at bar 55) gradually 'reveals' the underlying polyrhythm bit by bit (21:25 using the 35-format, employed here at the greatest diminution level in piece).

2.3 Personal reflection: ‘*These pitches tell a story*’

‘I finally agreed to take to my benefit all my past experiences. Before, I always started everything again from zero. I agreed to consider all these crossings: serialism, minimalism, tautology, random architecture, post-modernism, and so on. I’ve done electronic compositions, compositions for orchestra; I have done pictures, radio art, reports (true and untrue ones). Now, I compose with all that.’

– Luc Ferrari, *Far West News*, episode 1: 4.⁴⁰

I am remembering an evening back in the winter of 2008 at the Korzo Theatre in Den Haag. An evening of student compositions, it was the first concert performance of my music in Europe, just a few months after relocating to the Netherlands to begin my formal composition studies at the Koninklijk Conservatorium. For the occasion I had produced *Antiquariaat*, a short piece for solo laptop which over the course of its seven-minute duration slowly modulates the pulse speeds of three discrete streams containing successions of pitches from two sets. Written in SuperCollider, the code for the work describes its various components: the pitch series, instruments used (two percussion synths and a sample grainer), and the patterns for the cyclical oscillation of tempi. The pitches I chose were composed intuitively at the piano, with an eye to including the widest possible variety of intervals. While the final musical environment was entirely created by the subtle harmonic and rhythmic counterpoint produced by the independently-oscillating tempi of each stream, I did not construct these relationships by hand, second-by-second, as I would have done with an acoustic composition. Rather, the unfolding harmonic argument of the piece was a product of experimentation with various patterns in SuperCollider, making the temporal structure of the work almost completely algorithmic; its simple-yet-satisfying structure and stately formal development were a ‘happy accident’ in many respects. After the concert, I was approached by one of the teachers at the Conservatorium who, telling me how much he had enjoyed the piece, fixed me with a meaningful look and declaimed, “*These pitches tell a story*”. While I certainly agreed with him, I was intrigued by an unresolved question: how could a succession of algorithmically-permuted pitch collections give such a strong impression of coherent, even *inspired* narrative/temporal flow? Figure 19 shows the code for one of the iterations of the piece:

⁴⁰ Ferrari, Luc, (2002) *Far West News: Episode 1* [CD]. Paris: Signature/Radio France.

```

~celeste = Ppar([
  Pbind(
    \instrument, \celeste,
    \pitch, Prand([~c1row1, ~c2row1posPole, ~c2row1negPole]/3, 5),
    \pan, Pfunc({ rrand(-0.9, -0.7) }),
    \decay, Pseg( Pseq([2,4,1]*3, inf), Pseq([6, 10, 20], inf),
    'exponential'),
    \dur, Pseg( Pseq([2,4,1]*3, inf), Pseq([6, 10, 20], inf),
    'exponential'),
    \masterVolume, Pfunc({ rrand(0.55, 0.65) })).play(~swissmiss),

  Pbind(
    \instrument, \celeste,
    \pitch, Prand([~c1row1, ~c2row1posPole, ~c2row1negPole]/2, 5),
    \pan, Pfunc({ rrand(-0.1, 0.1) }),
    \decay, Pseg( Pseq([2, 4.1, rrand(0.97, 0.98)]*3, inf),
    Pseq([6, 10, 20], inf), 'exponential'),
    \dur, Pseg( Pseq([2, 4.1, rrand(0.97, 0.98)]*3, inf),
    Pseq([6, 10, 20], inf), 'exponential'),
    \masterVolume, Pfunc({ rrand(0.55, 0.65) })).play(~swissmiss),

  Pbind(
    \instrument, \celeste,
    \pitch, Prand([~c2row1, ~c1row1posPole, ~c1row1negPole]/3, 5),
    \pan, Pfunc({ rrand(0.7, 0.9) }),
    \decay, Pseg( Pseq([2, 4.2, rrand(0.94, 0.96)]*3, inf),
    Pseq([6, 10, 20], inf), 'exponential'),
    \dur, Pseg( Pseq([2, 4.2, rrand(0.94, 0.96)]*3, inf),
    Pseq([6, 10, 20], inf), 'exponential'),
    \masterVolume, Pfunc({ rrand(0.55, 0.65) })).play(~swissmiss)
], 1);

```

Fig.19 – Code fragment for *Antiquariaat*.

One of the key parameters in each of the three code blocks here is **\dur** (duration), which uses **Pseg** to define three slightly different exponentially-curved accelerandi and ritardandi sequences between the notes articulated by each **Pbind** object. Over the course of the work, the tempo modulations function as medium-range formal determinants, with the successive swells of out-of-phase tempo modulations creating alternating passages of tension-building, dense rhythmic activity and of slackening, easing release.⁴¹

A second element in the piece approached local rhythm from a different standpoint, creating a virtual gallery of 30 softly ticking but completely unsynchronized ‘clocks’ (Fig.20) or metronomes, all ticking slowly at 36 beats per minute (0.6 beats per second):

⁴¹ See Collins (2012) for more information on realtime tools for sinusoidal tempo mapping in SuperCollider.

```

30.do({ itemI
  var pan, bps, volume;
  pan = rand2(1.0);
  bps = 0.6;
  volume = rrand(0.009, 0.012);
  Synth(\ticktockWithEnv2, [\masterVolume, volume, \pan, pan,
    \freq, item, \bps, bps]);
  k = [rrand(3.1, 3.2).round(0.001), rrand(4.1,
    4.2).round(0.001)].choose;
  k.wait;
});

```

Fig.20 – Code for the ‘ticktock’ metronome instruments in *Antiquariaat*.

Each time the computer executes the above **.do** loop, it essentially flips a coin, pausing the loop for a randomly-calculated duration between *either* 3.1-3.2 seconds or 4.1-4.2 seconds before going through the loop again to create another **Synth** ‘ticktock’ instrument. As the computer runs through the loop 30 times, the number of clocks gradually increases one by one over 90-120 seconds, until the background stereo field is completely scattered with a highly complex yet clearly periodic ticking rhythm which gradually thins out again as each clock ‘dies’, having expended its three-minute life span.⁴²

Looking back, I can see that many of the individual components of the piece clearly represent the seeds of several of the key ideas we have detailed previously: harmonic development from a permuted reservoir of pitch sets; creating ‘flow’ through the use of independently-moving pulse streams; microrhythmic complexity, initially obscured, which is clarified or ‘learned’ through repetition. These are all to be found (albeit in quite primitive stages of conception and execution) in *Antiquariaat*. As we shall see in our survey of the portfolio pieces in Section 3, how ‘these pitches’ *relate to one another in time* can often turn out to be the most critical factor in their more-or-less successful storytelling.

⁴² Of course, this is a similar idea to György Ligeti’s *Poème Symphonique* of 1962, which employed 100 metronomes on stage, each fully wound and set to different speeds. The key difference here is that the 30 ‘metronome’ instruments used in *Antiquariaat* are all set to precisely the same speed, with the result that periodicity is guaranteed at all times (due to the randomized initiation points), in spite of the constantly-evolving/devolving rhythmic profile of the whole. In addition to sounding fantastic, an idea intrigued me; that one could, with repetitive exposure, actually *learn and internalize* at least some portion of a highly complex rhythm with up to 30 constituent elements. This idea has returned (in various guises) again and again in my subsequent work.

3.0 YAMAHA/ENIGMA

3.0.1 Concept and the ENIGMA machine

For as long as humans have possessed complete writing, they have also sought ways in which to disguise the meaning of their most important communications from all but the intended recipient. Taking the general idea of the encoding and decoding of written text as a starting point, *YAMAHA/ENIGMA* utilizes several classic techniques from the world of codes and cryptography and sets them in motion over 14 minutes. Using permutations and rotations, symbols from telegraphy and texts from Sei Shounagon, Augustine of Hippo, Walt Whitman and my own meditation on silent reading, the piece is actually a rather mysterious love letter to the act of reading itself, the amazing, everyday act of 'decoding' written symbol into sound and meaning, which the linguist Steven Roger Fischer has termed one of human society's 'quiet triumphs'.⁴³

The initial conception for *YAMAHA/ENIGMA* was to create a working 'musical model' of the machine, one that would perhaps function algorithmically, generating the piece from a set of initial conditions in the manner to how the ENIGMA would have been used in practice. However, as the compositional process unfolded, I found myself becoming less interested in trying to mimic the actual mechanics of the machine,⁴⁴ and more interested in the actual *idea of reading*; how written language itself represents a highly efficient, organic structure for encoding sound and meaning. Taking this as a starting point, I decided to set several key texts which would engage in a reflective way with language and language cognition; texts which would be gradually 'revealed' to the audience in various ways through the video projection component. The projected texts were all framed within the strict visual/notational paradigms of the ENIGMA system (in practice, ENIGMA messages were typically printed left-to-right in groups of 5, in long vertical rows, with several columns to a page), with many of the strictly-interpreted permutational rhythmic and harmonic elements also occupying pride of place on the musical surface.

⁴³ Fischer (2004: 206). See Fischer's fascinating three-volume series on the histories of language, writing, and reading.

⁴⁴ Having created a software model of the ENIGMA as a first step in the compositional process, I was dissatisfied with the obvious mappings of pitch or other audio to the various wheel positions and combinatorial outcomes which were returned by the machine. The idea of *written language* itself as a symbolic encoder of sound and meaning seemed a more interesting focal point for the work, retaining the formal trappings of codes and cryptography as a framing device.

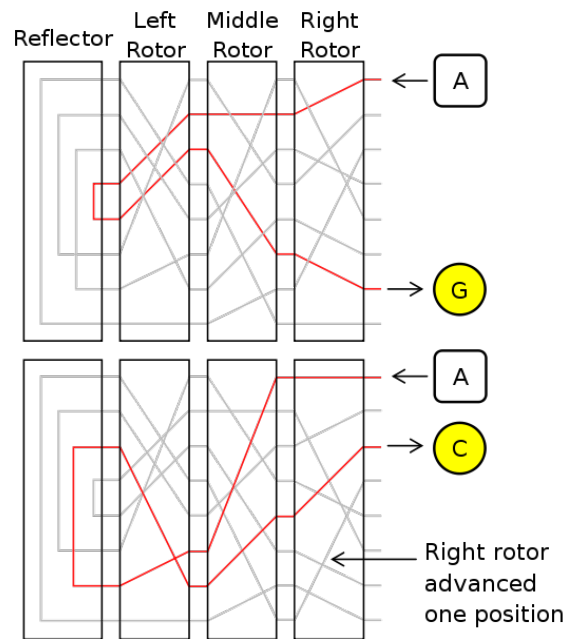


Fig.21 – Illustrating the ‘scrambling’ effect of the internal wiring contained in the wheels of a four-rotor ENIGMA. Pressing ‘A’ initially returns ‘G’, but pressing ‘A’ again yields ‘C’, due to the rotor action and the complex wiring.

Diagram courtesy of MesserWoland, Jeanot, and Matt Crypto at http://en.wikipedia.org/wiki/Enigma_machine#/media/File:Enigma-action.svg

The ENIGMA family of cipher machines was used by several of the Axis powers in WWII, and represented the cutting edge of encryption technology of the day. At that time, the codes were thought by many to be unbreakable, but, as is now widely understood, it was in large part the occasional sloppiness of the Germans (perhaps brought on by a certain hubris as to the strength of the ENIGMA codes) regarding the choice of keys, the frequency at which keys were changed, and even the physical security of their daily passbooks, which allowed the Allies to gradually obtain enough critical elements to assist them in cracking the system. The heart of ENIGMA is a set of four connected wheels, each having 26 possible (alphabetic) positions which were stepped forward with each keystroke on ENIGMA’s typewriter-like keyboard interface. Each time a key was depressed, the first (rightmost) wheel moved 1 letter position forward, with the subsequent wheels only ratcheting forward when the *previous* wheel had made a full rotation (see Fig.21). In addition, the internal wirings within each wheel (which transmitted the electrical charge from the connecting pins on one side of the wheel to the other) were also ‘scrambled’ in a prescribed manner, making the whole system extremely combinatorially complex.⁴⁵ In practical use, the initial positions of the

⁴⁵ For more detailed information on ENIGMA see also Churchhouse (2005) and Kahn (1967: 394-434).

four wheels needed to be agreed prior to encryption. The receiving party, having set their ENIGMA to the same initial wheel positions as the transmitting machine, was thus able to decrypt the message.

3.0.2 ‘Wheels within wheels’: discrete layers and formal structures

The formal structure of the piece is organized into four sections. Sections 1 and 3 focus on the idea of the ‘impenetrability’ of encrypted information which, while aesthetically pleasing (both visually and aurally) in the context of the composition, ultimately communicates only on a musical level. In contrast, the texts which are projected with the video component in sections 2 and 4 are comprised of plain English and Dutch, and are thus readily understandable to speakers of those languages. The music of *YAMAHA/ENIGMA* is built upon three discrete, yet interacting layers of activity:

1. Order permutations of a 5-by-6 collection of pc sets, iterated in various ways by the Disklavier.
2. A pre-recorded soundtrack which was edited together by hand, splicing 600 short tape fragments into 120 duration-permutational segments.
3. A voice layer, tied at various stages to the piano, soundtrack, or an algorithmic process of the computer.

Figure 7 showed a section of the code (written in SuperCollider) which governs the piano permutations for Section 1 of the piece. In this and the other sections where the piano material occurs, the permutations were intentionally left to be quite ‘mechanical’ sounding, with no variation in register, dynamics, or tempo. The soundtrack was constructed from a recording of a free improvisation recorded earlier in 2011 with Milana Zaric (harp), Miguelangel Clerc (guitar), Mei-Yi Lee (percussion), Igor Maia

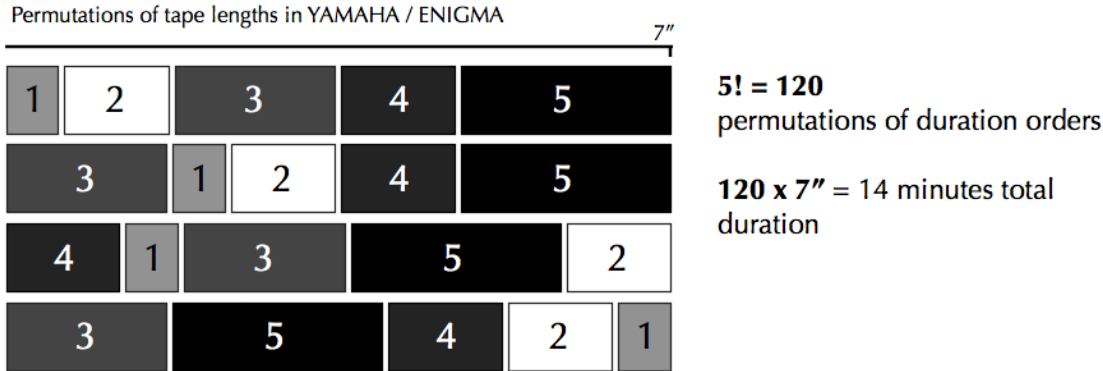


Fig.22 – Duration permutations used for the tape soundtrack in *YAMAHA/ENIGMA*.

(mixing desk), and Chad Langford (electric double bass). The digital recording was edited to 14 minutes, transferred to ¼-inch tape, and then segmented by hand following the convention shown in Figure 22. The length of the piece as a whole is determined by the cycle duration of this duration set (the set [1, 2, 3, 4, 5] shown in Fig.22). Each permutational cycle lasts 7 seconds, resulting in a combinatorially-complete performance lasting 14 minutes.

The female voice heard in Sections 1 and 3 is used to articulate individual phonemes of the letters contained in a short poem (see all of the texts in the Appendix). In Section 1 these phonemes largely function as a sort of ‘visual percussion’ or even an ‘orchestration’ of the animated letter scrambling. In addition, they provide a somewhat ‘humanizing’ element, as the voice articulates what appear to be random letters (chosen by some process obscure to us) from the five letter streams, each of which are gradually revealed in the video projection. In fact, the voice *does* articulate a ‘hidden’ message (the poem) letter by letter, but this is virtually impossible to perceive in performance, the (intentional) difficulty arising from a number of factors: the shortness of the phoneme samples, their sporadic rhythmic delivery, and the simple fact that in spoken English each letter can have a variety of pronunciations. For each successive letter in the ‘hidden’ poem of Section 1, the computer randomly chooses one sample from an array of possible pronunciations of that letter, meaning that the chosen pronunciation is quite often ‘incorrect’ in the context of the word being articulated. The point here is not comprehension, but rather the surreal effect created by the disembodied female voice ‘learning to speak’, as it were.⁴⁶

Section 3 introduces a new visual element, that of the ‘Baudot’ code, a 5-bit system invented by Émile Baudot in 1870. The system was a predecessor to the International Telegraph Alphabet, and consisted of a matrix of 5 vertical slots which could be either on or off, zero or one. *YAMAHA/ENIGMA* draws parallels between the Baudot configuration and the 5-across matrix used for the printed ENIGMA codes, arranging the Baudot sequences of section 3 into a 5x5 dot grid, where they function to articulate the same ‘hidden’ poem used in section 1. In section 3, this effect is primarily visual,

⁴⁶ A similar effect (albeit within a totally different surrounding musical texture) was achieved in the opening sequence of Jonathan Glazer’s 2013 film *Under the Skin*, where the alien is teaching herself the phonemes of spoken English whilst taking on human form.

presented as an alternative to the alphabetic characters used in the remainder of the piece.

Section 4 finishes the work by returning to the strict rhythmic permutations executed by the piano in section 1, this time at a fortissimo dynamic. Utilizing the full range of the piano keyboard, it articulates a long, slow diminuendo which stretches over 4 minutes to the end of the work. The poem, written in Dutch by the composer, engages with the idea of language learning and the often disorienting modulations of internal voice that can occur as the learner gradually gains mastery. As the piano reaches the softest dynamics allowed by the Disklavier's mechanisms, notes occasionally begin to drop out, leaving the last seconds of the soundtrack to finish unaccompanied.

3.0.3 Summary

One striking feature of the piece as a whole is the equal weight generally given to each layer of material throughout the entire work. Typically, none of these layers is highlighted or otherwise pushed into the foreground in any way, creating a real sense of discrete, parallel processes (perhaps unrelated) which are being simultaneously observed. It is for the listener to locate and focus on particular transient associations of interest, as they occur in the perceptual moment. This effect is necessarily weaker in Sections 2 and 4, which include more-or-less legible texts, as these unavoidably dominate the perceptual foreground. However, the manner in which the texts are presented with the 'accompanying' musical material in these sections (the 'scrambling' effect which occasionally 'reveals' text; the strict 5-character formatting which somewhat impairs easy reading) binds them as tightly as possible with the surrounding layers. On the most general level, *YAMAHA/ENIGMA* is about the curious simultaneity of *presence and absence* which is inherent in written language. The visual theatre of the piece,⁴⁷ accentuated by the use of the 'disembodied' female voice as a musical component, contributes to a pervasive, remarkably surreal atmosphere of absence – somehow reminiscent of the strange potentiality which we sometimes feel having entered a room which was until only recently occupied. This atmosphere resonates with

⁴⁷ *YAMAHA/ENIGMA* premiered in one of the great halls in the Museum Speelklok in Utrecht, where the Disklavier was positioned centre-stage with a pin spotlight illuminating it from above. The text was projected onto a screen directly above and behind the piano, with the entire performance space kept as dark as possible, creating an otherworldly atmosphere which accentuated the general feeling of absence and 'disembodiment'.

the chosen poems and texts on several levels, in particular the Whitman, which relies on its own implications of the presence or absence of the author within the work he creates.

3.1 *Maria Lunarem*

3.1.1 Concepts, form, and general harmonic and thematic links

Comprised of four separate short pieces, *Maria Lunarem* represents a first experiment with a more ‘modular’ approach to both formal organization and thematic interrelationships, ideas which I had long wanted to investigate within the context of an extended set of interrelated pieces. While each of the constituent pieces in *Maria Lunarem* exhibit highly contrasting instrumentation, texture, form, and temporal atmosphere, all four are bound together through a carefully designed formal plan which includes shared harmonic collections and thematic material, in addition to the central framing device projected by the titling and how this reflects the musical character of the pieces in different ways. The title *Maria Lunarem* refers to the ‘seas’ (*maria*) of Earth’s moon, with each of the four constituent pieces taking their names from one of these lunar formations. Whilst the choice of individual titles is largely poetic, there are nevertheless key correspondences between what each title suggests and the general musical approach or atmosphere employed in the piece. Regarding the set as a whole, the pieces were designed such that they may be performed individually, in sub-groups, or as a complete set, in which case the ‘suggested ordering’ follows a plan of increasing instrumental forces, a ‘waxing’ of the total ensemble:

1. *Sea of Islands*, for cello solo
2. *Border Sea*, for flute, viola, and piano
3. *Sea of Waves*, for oboe, bass clarinet, violin, cello, and percussion
4. *Eastern Sea*, for alto flute, cor anglais, clarinet, violin, viola, cello, piano, and vibraphone

In terms of pitch organization, each of the pieces is constructed from permutations of the same collection (Fig.23), although the manner in which these permutation fields are utilized differs substantially from piece to piece.



The pieces also share strong thematic links which are organized and gradually accumulated in an additive way through the 'suggested order'. Thus, key thematic material from *Sea of Islands* is used in *Border Sea*, and material from all three of the preceding pieces can be heard in *Eastern Sea*, which also shares one motive with the first piece in the set, *Sea of Islands*, suggesting a 'circular' form. The one exception to this thematic linking principle is *Sea of Waves*, which, as the most formally (and polyrhythmically) straightforward piece with the shortest duration, functions as a kind of 'interlude' within the full set. Though *Sea of Waves* is thematically unrelated to the larger group, it remains strongly bound to its neighbors due to the shared harmonic core material, although its more playful sections do set it slightly apart from the other pieces, most of which project a more searching, reflective atmosphere.

From the vantage point of temporal organization, each of the pieces explores a different durational striation of the canvas, incorporating a variety of approaches to medium- and long-range formal structuring along the way:

<i>Sea of Islands</i> :	(no structural polyrhythm) – isolated, gestural rhythms
<i>Border Sea</i> :	21:25 – long-range & medium-range, multiple format
<i>Sea of Waves</i> :	3:5:7 – short range, cyclic/metrical
<i>Eastern Sea</i> :	15:21:35 – medium-range, shared beat unit

In addition, these general structural scenarios are realized within one of two general, overarching temporal atmospheres: a more *gestural* approach to local rhythmic construction (*Sea of Islands* and *Eastern Sea*) on the one hand, versus a more *developmental*, horizontal approach (*Border Sea* and *Sea of Waves*) on the other.

3.1.2 *Sea of Islands*

Sea of Islands explores a strict approach to local rhythmic structuring by drawing its individual, isolated gestures from single harmonies in the main *Maria* collection (see Fig.23). In almost all cases, these gestures are comprised of short 5-note figures which are rhythmically cast within various tuplets of 3, 5, 6, and 7. Following a short introduction (mm. 1-7), the cello plays the entire first section exclusively *pizzicato*, slowly establishing the permutational harmonic atmosphere. The pitch order and registration of the various pc sets are continually altered with each iteration of a particular harmony across the permutation field, again creating a sensation of

continuous development within a restricted system that was a key feature in certain sections of *YAMAHA/ENIGMA*. In *Sea of Islands*, these individual figures are typically isolated from one another by either rests or, more often, double stops. As the piece develops, this disposition of material starts to give a feeling of music which is somehow unfolding on multiple levels, continually switching between two different strata. This feeling, established during the first half, is strengthened in the second by the sudden reintroduction of arco playing at bar 40, which, alternating with the continuing pizzicato gestures, significantly expands the total pitch range, creating new correspondences between pitch, playing technique, and dynamics. Apart from the low 'fade-in' arco gestures which introduce the second half of the piece (from bar 40), the notes played arco are typically higher and softer, whilst notes played pizzicato are lower and louder, reinforcing this correspondence and the perception of two, simultaneously-unfolding musical strata.

Sea of Islands is framed by two motives which return later in subsequent pieces of the *Maria Lunarem* cycle. The descending figure in bars 1 and 2 is a direct reference to the 'falling' figure near the end of *Eastern Sea* (mm. 23-31), closing a formal loop between the first and final pieces of the cycle. In addition, the codetta of *Islands*, which runs from bar 61 to the end, introduces a completely new triplet gesture which will return at critical moments in subsequent pieces. Compared with the main thematic material of *Islands*, the simple, repetitive nature of these final gestures is quite striking, effectively setting them somewhat apart from the rest of the piece, not least due to their organization into larger 'irregular' groupings of two and three – groupings which are, in keeping with the rest of the work, also separated by rests, pauses, or fermatas. Through their similar use in the climactic section of *Border Sea*, these gestures begin to establish themselves as an important 'referential gesture' in the larger cycle as a whole.

3.1.3 *Border Sea*

If *Sea of Islands* represents one of the simplest, most straightforward harmonic/temporal plans in *Maria Lunarem*, then *Border Sea* (second in the cycle, but the last piece composed) is the certainly the most involved, utilizing a structural polyrhythm of 21:25 as a medium-range formal determinant, coupled with a thorough exploration of the polyrhythm's two viable formats, used as integral elements in the overall formal plan. As

with all the pieces in *Maria Lunarem*, permutations of the 'Maria' collection shown in Fig.23 were used for generating all pitch material.

The more complex rhythms of the piece are woven into the bottom-level structural polyrhythm, which is expressed variously through a 35-bar and a 15-bar format (see Fig.11). The 35-bar format, at a tempo of $q=70$, comprises the main polyrhythmic frame for the work, with several sections also utilizing diminutions which substantially reduce the unit pulse from one bar to one eighth note (see bars 42 to 97). The tempo of the 15-bar format is considerably slower at $q=42$, and it functions as a recurring formal 'interruption' – initially appearing only in short 3- or 4-bar fragments, cutting into the main 'flow' of the 35-bar format – creating a similar sense of parallel development of some 'hidden' musical stratum as was explored in *Sea of Islands*. Work by the writers Mario Vargas Llosa⁴⁸, Eleanor Catton, and Italo Calvino have served as key extra-musical inspirations which informed this 'bipartite' approach to strictly-observed sectional divisions. Directly following the more 'sectional' climax of the 35-bar format material (mm. 85-97, quoting the climactic theme from *Islands*), the uninterrupted appearance of the 15-bar format (mm. 98-112) provides the true *structural* climax of the entire work, not only recapitulating material heard in its earlier fragmentary statements, but also clarifying the nature of the whole 15-bar structure, as well as its relationship with the surrounding music.

As we saw briefly in Section 2.2.0, the critical feature which effects all the musical constructions in *Border Sea* is the 'plaiting' of the polyrhythmic streams through the ensemble; i.e., the pulse layers are repeatedly rotated or 'swapped' between the three players. In the sections where this occurs, the technique is most noticeable through the changing beat subdivisions of each player's line. From a purely compositional (experimental) standpoint, this idea resulted in surprising subsidiary effects. Firstly, by removing any consistent timbral markers the discrete pulse layers become somewhat 'blurred', but the overall rhythmic 'flavor' (a result of the unique IOI profile of the pulse subdivisions used) keeps the *composite* rhythms coherent. In addition, the constantly-shifting pulse speeds in each instrument create a quite visceral sensation of instrumental

⁴⁸ The transparency of the steady background 'pulse' of strict, 20-page chapters in *Aunt Julia and the Scriptwriter*, coupled with their invariant alternation between the two scenes of action belie the experiential complexity of the material as manifested within this seemingly 'simple' formal conceit. See Vargas Llosa (1977) and (1994), and also Catton (2013) and Calvino (1983).

characters which are continually 'jumping tracks'; changing speeds on the fly as they move from stream to stream. In certain of these sections, the 21:25 polyrhythm was reduced via a diminution of $\frac{1}{8}$, making the common unit one eighth note, and the cycle length 35 eighth notes. A third pulse stream was then added *at the eighth note* (creating a total polyrhythm of 21:25:35), and the three pulse streams were subsequently 'plaited' through the ensemble. As the instruments continually alternate between the various simple subdivisions available within the pulses of their respective streams, a highly active, microrhythmically intricate temporal surface emerges, giving a strong impression of three independently-developing processes.

3.1.4 Sea of Waves

In contrast to the multi-format, polyrhythmic complexity of *Border Sea*, the temporal organization of *Sea of Waves* is built around a simpler polyrhythm of 5:6:7 which cycles each 4/4 bar. While this short polyrhythmic cycle duration does create a strong sense of cyclical meter at bar level, it is made somewhat ambiguous by the irregularity of the constituent subdivisions. While the mathematically elementary ratios of 5:6:7 as used in the work are *perceptually* non-trivial, this short piece examines various possibilities of cross-strata polyphonic integration within a more playful thematic atmosphere than that of the previous two pieces in *Maria Lunarem*. Indeed, the various instruments, though constantly separated into rigid pulse stream divisions, often interrupt, finish one another's sentences, and in general create quite a lively (poly)rhythmic conversation. This sense of musical cooperation between the strata largely results from unified harmonic gestures which are realized across the three pulse layers, gestures which are constructed within a metric framework that is constantly reinforced in the bar-by-bar repetitions of the much simpler 5:6:7 polyrhythmic space. Due to the one-bar cycle, this is a space which offers considerably more frequent opportunities for the pulse streams to coincide than was the case in *Border Sea*.

The permuted harmonies of the *Maria* collection are again used for all harmonic material, this time in strictly 'horizontal' realizations. Melodically, the piece is constructed almost entirely of gestures with parabolic curve shapes, exploring the idea of using different overlapping exponential slopes to create characteristic contrapuntal relationships. By layering various combinations of longer and shorter curves, as well as by using different 'steepnesses', we are able to control the pacing and flow of the

rhythmic surface in interesting, often surprising, ways. Critical to the main concept is the idea that the 'parabolic' nature of the curves employed can be reflected both in the pitch and the duration domains. This piece represents a first attempt at working with the resulting accelerandi and ritardandi in a consequent way across three discrete pulse streams.

Formally, the piece is quite 'classically' conceived, with the action divided roughly into three sections. The opening bars set the tone by establishing the signature 'gravity' gesture, articulated by the cello and bass clarinet. The cello 'bounces' something up into the air, which falls back to earth via the bass clarinet. This is the main scenario which is explored in various ways through the rest of the work; different curves or curve sections which are either orchestrated (using two or more instruments), or which overlap in a contrapuntal way with other, differently-proportioned curve gestures. The second section begins with a percussion solo, subsequently reintroducing the instruments and leading to a multi-layered 'dance', where highly regular, repeated rhythmic figures in each discrete pulse stream interact with one another in complex ways, creating a remarkably balanced, multi-temporal counterpoint. The variety of textures and intersecting tempi in this section create quite a visceral impression of three dimensional pitch/temporal space. The final section recapitulates the opening material, leading to a quiet fade by the suspended cymbal.

3.1.5 *Eastern Sea*

The first piece composed in the *Maria Lunarem* series, *Eastern Sea* treads quite a narrow path in terms of formal structure, as it seeks to actualize and bring to satisfactory conclusion the narrative arc of *Maria's* four constituent pieces, whilst simultaneously functioning as its own, self-standing work – a work which nevertheless is composed in large part from key motives and harmonic material heard previously in the cycle, each with their own accumulated associations. Employing the largest ensemble used in the series thus far, *Eastern Sea* makes the colorful orchestration of the melodic material and chord voicings a primary compositional concern, exploring many interesting possibilities within the context of what is essentially a reduced chamber orchestra. Structurally, the piece uses an underlying medium-range polyrhythm of 15:21:35 which is expressed through a shared common unit, with pulses every 3, 5, and 7 eighth-notes

(see Fig.17). In addition to this low-level expression of the polyrhythm,⁴⁹ diminutions are frequently used to further animate the rhythmic surface.

The formal tension of *Eastern Sea* arises from the dialogue between two contrasting harmonic/thematic worlds which continually alternate with one another in short, 4-5 bar segments throughout the course of the work, creating the same feeling of 'parallel development' that we have seen in earlier pieces of the cycle. The characteristic opening (bars 1-4) immediately establishes a quiet, reflective atmosphere, introducing many of the main thematic gestures which are unique to *Eastern Sea*. By bar 4, however, we already begin to notice a few 'thematic interlopers', namely, the 'parabolic' clarinet gesture from *Sea of Waves* and various cello motives taken from *Sea of Islands*, both of which are slipped rather unobtrusively into the contrapuntal texture. These lead us directly into the first contrasting section (bars 5-9), which is comprised of a layering of several previously-heard themes, all layered over a dark, low-register rhythmic motive in the piano, a motive which will become central to what will subsequently be revealed as the quiet, structural climax of the work. What we will refer to as the 'falling' theme in this final section (bars 21-31) is comprised of several instrumental partnerships. The 'falling' theme itself is heard in the alto flute and the cello (heard previously in the characteristic opening of *Sea of Islands*), with additional partnerships of bass clarinet and viola, and cor anglais, violin and vibraphone. The piano material remains isolated by its low range, as well as its separate rhythmic stratum, and it serves as a foundational rhythmic pedal throughout the section. Within the context of the total form of *Eastern Sea*, this 'falling' theme is striking in several ways. In terms of rhythmic structure, the texture is built upon simultaneous divisions of the bar into 6, 8, and 9, while the material contained within each of these divisions is highly cyclical and extremely regular. In addition to providing a stark contrast to the ametric irregularities of the isolated 'gestural islands' which constitute the bulk of the material contained in the main sections (bars 1-4, 10-14, and 19-20), the slow, stately *perpetuum mobile* of the 'falling' section is completely motoric and exhibits the strangely hypnotic 'wheels within wheels' character that we have observed in pieces such as *YAMAHA/ENIGMA*.

⁴⁹ This is most clearly visible in the piano part during the opening bars, which, following a tacit on beat 1, faithfully articulates the *composite rhythm* formed by the 3, 5, and 7 eighth-note pulse layers. The shorter rhythmic values in the winds and strings frequently express different levels of diminution of the 'main' eighth-note format throughout the piece.

3.1.6 Summary

Considered together, the pieces of the *Maria Lunarem* cycle represent a remarkably consequent, complete record of the development of the core harmonic and temporal processes which this compositional research has addressed. Since the pieces were all composed within a relatively short time, from January 2012 to August 2013, they take to their benefit a certain cohesion of approach, and clear compositional trajectories. They reflect the systematic exploration of a variety of possibilities of thematic development and temporal and harmonic organization, many of which increase substantially in complexity over the course of the cycle. From purely gestural approaches to simpler, shorter metric cycles, and on to higher-integer, medium and long-range structural polyrhythms, *Maria Lunarem* demonstrates how multiple, starkly contrasting temporal organization may be used to good effect across a series of movements, as well as within the same piece. In these and many other respects, the pieces of *Maria Lunarem* served as valuable compositional studies for the larger-scale works which would follow.

3.2 *Makura Sadamemu*

3.2.1 Text and concept

Makura Sadamemu is a setting of an ancient Japanese poem for bass flute, bass clarinet, and computer. The poem is comprised of several wonderful ambiguities which provide a rich underpinning for many possible interpretations, not only from the standpoint of poetics and compositional aesthetic, but of formal structure as well.

よひよひに
枕さだめむ
かたもなし
いかに寝し夜か
夢に見えけむ

*Night after night, I decide
I shall arrange my pillow thus,
but to no avail!
I wonder-- that night, when I slept,
how was it that I saw you in my dream?*

– translation by Dr Kendra Strand

To understand the fundamental ideas around which *Makura* is structured, we will begin with a deeper look at the poem, taking into account its formal organization, as well as the ambiguous nature of the language used. The poem itself poses challenges of its own for the modern Japanese translator, in no small part due to its arcane language.

Fortunately, I was able to get help from my friend Dr. Kendra Strand, a specialist in the translation of these antiquarian Japanese *waka*. The excerpt below is taken from the explanatory material she provided for the front matter of the printed score:

This traditional Japanese poem, or *waka*, is composed of 31 syllables in five lines (5-7-5-7-7). It appears in the *Kokinshū* (*A Collection of Poems Ancient and Modern*), a poetic anthology from 905 that includes both new and old poems of its time. Although the poem is brief, its language is complex in its ambiguity. The phrase “night after night” (*yoiyoi ni*) lends a sense of endless repetition and of time passing. It is as though the poet declares “I’ll arrange my pillow thus” (*makura sadamemu*) every night before sleeping, only to awake disappointed every morning, crying, “But there’s no way for it!” (*kata mo nashi*). The poet, who could be either a man or a woman, has in mind one specific dream (*yume*) of a lover that he or she desperately wishes to see again. But thinking of “dreams” as plural paints a picture of the poet caught up in this desire during waking hours, and of spending sleepless nights in thought. Finally, the conceit of seeing a lover in a dream was often used to refer to an actual midnight rendezvous, which, like a beautiful dream, is so precious that it is over too quickly, and haunts the lovers with its memory.

From a poetic standpoint it is clear that the text, though short, is rich in imagery and has clear emotional resonances, deriving largely from its theme of a yearning, unrequited love. The image at its heart, that of a lover rearranging his or her pillow each night in vain, is simple and very strong. Taking this image as a focus point, I decided to create a musical structure of continuous rearrangement and regeneration, casting the whole within a quiet atmosphere of unearthly, nocturnal fantasy.

3.2.2 Polyhythmic form

Makura represents a first attempt at using a three-limb polyrhythm as a formal determinant. The ratios of 9:17:28 were selected not only for their mutually prime relationships, but also for a certain aesthetic attractiveness when projected as sinusoidal waves (Fig.24). This polyrhythm-as-sine wave conception is incorporated into the work globally by its mappings to various parameters in the electronics, as well as to structural features in the written instrumental parts. In addition, the pitch material performed by the computer functions within a harmonic system of three simultaneous octave divisions of 9, 17, and 28. These divisions are used to create microtonal harmonic 'clouds' which cluster around five important structural pitches which color various sections of the work (see Fig.25).

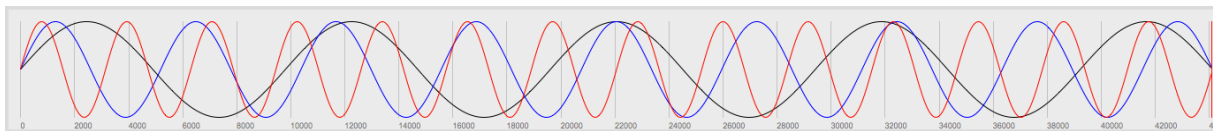


Fig.24 – A sinusoidal projection of the first half of the polyrhythm 9:17:28 (read left to right), up to its central axis.

In the electronics, each of the three polyrhythmic waves can be perceived in the very slow phase modulations of three banks of sine-wave instruments which dominate the background texture. This slow phasing brings each bank gradually in and out of harmonic stability, with the peaks and troughs of each wave creating maximum stasis, and the zero-crossings causing the most modulation. In the instrumental score, the individual pulse events of each of the three limbs are used to determine entry and exit points for the instruments, as well as some durations. The relative stability or instability of the accompanying texture in the electronics was taken into account as I composed the instrumental material.

The piece consists of nine main sections (denoted by the double barlines and rehearsal markings A through I in the score), with a short introduction. Each of the main sections is 18 bars in length, with the exception of the central section E, which is 24 bars. These sections are intended to function both as 'harmonic boundaries' which define the frontiers between the different harmonies in the background sine modulations, and also as resynchronization points for the players and the computer (see section 3.2.3 below for more information on sync).

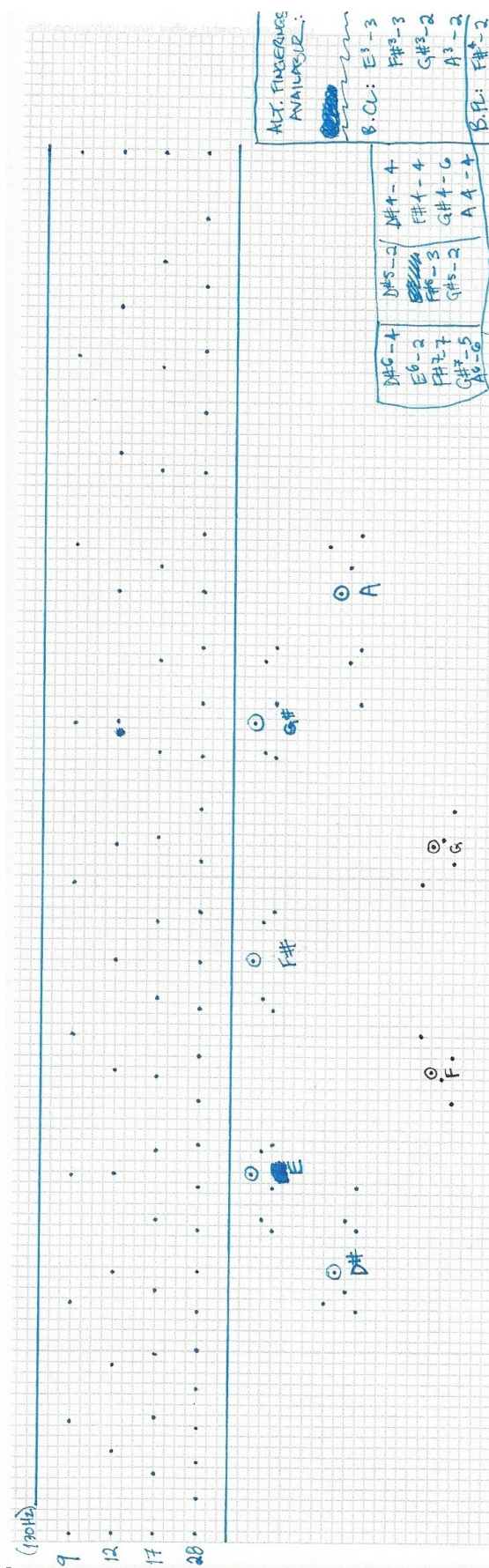


Fig.25 – Sketch page outlining the multi-tuning system in *Makura Sadamemu*, showing the overlapping octave divisions of 9, 12, 17, and 28. The key structural pitches in the 12-pitch octave division (circled) are surrounded by ‘clouds’ of pitches from the other divisions.

3.2.3 The electronics: syncing with performers, live control, and software instruments

Makura Sadamemu provides a simple, clean solution to the problem of synchronization of the performers with the computer. Although in many respects the computer represents the perfect solution for the precise calculation and performance of complex temporal phenomena,⁵⁰ when integrating the computer within a group of human players additional problems of ensemble coordination can come into play. In the case of *Makura*, this was solved by scheduling regular resynchronization points within the work's strict 18-bar sectional structure. At each section break, the computer fixes the values of the modulatory sine waves until the operator gives a cue for the players to continue on to the next section. Pressing the 'play' button on the controller – in sync with the conductor cue given to the players – signals the computer to continue with the sine modulations until the next section break. There is, naturally, a certain amount of

The image displays a musical score for two instruments: bass flute and bass clarinet. The score is organized into three systems. The first system consists of two staves. The top staff is marked 'W.T.' with a downward-pointing triangle above the first measure. It features a sequence of eighth notes with accents, grouped by brackets labeled '3'. The bottom staff is marked 'J.W.' with an upward-pointing triangle above the first measure. It features a sequence of eighth notes with accents, grouped by brackets labeled '5'. The first system is marked with dynamics *pppp* and *f*. The second system also consists of two staves. The top staff is marked 'W.T.' and the bottom staff is marked 'J.W.'. Both staves continue the polyrhythmic pattern with brackets labeled '3' and '5' respectively. The second system is also marked with dynamics *pppp* and *f*. The third system consists of two staves. The top staff is marked 'W.T.' and the bottom staff is marked 'J.W.'. The top staff continues with eighth notes and accents, with brackets labeled '3'. The bottom staff continues with eighth notes and accents, with brackets labeled '5'. The third system is marked with dynamics *pppp* and *f*. The word 'niente' is written below the bottom staff of the third system. The word 'ord.' is written above the top staff of the third system, with a downward-pointing triangle above the final measure.

Fig.26 – The introductory pattern for the bass flute and bass clarinet in *Makura Sadamemu*. The polyrhythm 3:5 is gradually 'revealed' with each iteration, and subsequently 'redacted'.

'drift' between the players and the computer which is necessarily accrued during the course of each section, but this is considered trivial within the musical context. In addition to the background sine wave banks, the computer also articulates several extended additive/subtractive rhythmic cycles, one of which begins at section B. The

⁵⁰ "In composing music, we are composing time, that is, we are articulating it into a variety of temporalities. I believe that this affirmation acquires a very concrete meaning through the use of the computer, which constitutes a tool for shaping time at all possible levels." Vaggione (1993: 102).

basic idea of these patterns is illustrated in Figure 26, where the flute and clarinet 'reveal' the polyrhythm 3:5 in an additive way, subsequently subtracting elements after achieving maximum density at the midpoint of the overall pattern. The computer's first such rhythmic cycle is comprised of two sub-cycles: the low-integer polyrhythms 3:5 and 4:5, both of which are gradually 'revealed' in turn with each subsequent iteration.⁵¹ These polyrhythms are manifested by sharp, percussive amplitude envelopes applied to the microphone input and reverb mix levels of the flute and clarinet channels, resulting in sudden 'amplitude bumps' in those instruments, which are panned to the extreme left and right in the stereo field. The metronome, activated by the laptop operator and operative from sections C through E, is also amplified, and is thus also effected by these amplitude bumps.

This idea of using low-integer polyrhythms as cyclical, additive percussion instruments is further explored with the 'syllabic cycle' which is operative during sections E and F, and again (in truncated form) from mm. 129 to the beginning of section H. The pattern is comprised of a repetitive one-beat, three-limb polyrhythm of 3:4:5.⁵² These values are reflected in the original Japanese through the words' syllabic patterns:

3 syllables: *yoini, makura, ikani, yumeni*

4 syllables: *sadamemu, neshiyoka, miekemu*

5 syllables: *katamonashi*

These word pattern cycles also gradually 'reveal' the underlying polyrhythm (3:4:5) in a manner similar to the 'amplitude bump' cycles described above, as syllables are gradually added one by one during the subsequent iterations of the cycle.

⁵¹ All of the low-integer cyclic polyrhythms in *Makura* are used in a manner similar to Fig.26. As the cycle progresses, more elements are added to the available polyrhythmic 'slots', beginning with the posterior time slots and filling in slot by slot toward the anterior. After reaching maximum density, when all the slots have been filled, elements are removed, beginning with the posterior slots.

⁵² In a discussion of his *Etudes for Piano*, Ligeti refers to low-integer polyrhythms: 'The ratio 5:3 is of course mathematically simple, but perceptually very complex. We do not count the pulses but rather experience two qualitatively different tempo levels.' Ligeti (1988: 5-6).

3.2.4 Summary

Makura Sadamemu represents the most thorough investigation of both large and small-scale polyrhythmic organization that I had up to that point attempted. The complexity of the three-limb polyrhythm 9:17:28, its close integration of the electronics and the performers, the distinctive rhythmic characteristics arising from the locally-applied, beat-length polyrhythms (3:4:5, in various combinations), the text, and the notated parts for the flute and clarinet – all these factors contribute to the creation of a tight, highly integrated network of relationships which allow the ‘regeneration/rearrangement’ theme to be explored to maximum effect. In section 3.3 we will continue to see this consequent investigation of low-integer polyrhythms, and how they can help to create characteristic gestures which serve as a main focal point for compositional development.

3.3 *Imperfect Information*

3.3.1 Concept

Imperfect Information continues the investigation of low-integer polyrhythms and how these may be used to create characteristic organic gestures which define a particular musical layer. The title, a term taken from game theory, describes a scenario in which players cannot know the state of all game materials at any one time (the typical situation in many card games, for example). Taking this general idea – critical information which is somehow hidden or redacted from a user – as a focus point, the music unfolds through two parallel processes: 1) the establishment of a near-constant pulse pattern using strict, consequent permutational harmonic collections, and, 2) a sequence of more or less ‘irregular’ gestural patterns which seek to somehow unite with the stately, regular motion of the first process. To achieve this effect, the ensemble is divided into two discrete layers, with the piano functioning as the rhythmic constant, providing the pulse drone against which is set the highly gestural orchestrations of the flute, bass clarinet, violin, and cello. The primary polyrhythmic ratio under examination is 3:8, which is typically articulated between the quarter-note triplet pulses in the piano

Fig.27 – The collection [1,2,3,4,5] as seen in Figs.1 and 3, this time in a dual-layer configuration.

and the sixteenth-note ‘echo’ and ‘swell’ figures which recur consistently in the winds and strings. Harmonically, the piece is based upon a two-layer order permutation of a collection of 5 pc sets (Fig.27). These permutations are performed quite strictly in the piano (no transpositions or inversions used), resulting in an extremely audible permutational structure in a manner similar to the Disklavier material we examined in Section 1 of *YAMAHA/ENIGMA*. However, the complex pitch structures formed by the overlapping harmonic layers create a strong sense of harmonic ambiguity in the whole,

Introductory section. ♩ = 44

The musical score shows the following details:

- Flute:** Enters in measure 4 with eighth-note triplets, marked *non vib.* and *p*.
- Violin:** Enters in measure 4 with eighth-note triplets, marked *non vib.* and *mp*.
- Bass Clarinet:** Enters in measure 4 with eighth-note triplets, marked *non vib.* and *mp*.
- Cello:** Enters in measure 4 with eighth-note triplets, marked *non vib.* and *mp*.
- Piano:** Provides a steady quarter-note triplet pulse throughout. Dynamics are *p*, *ppp*, *mp*, *ppp*, and *mf*.

Fig.28 – Opening bars of *Imperfect Information*. The quarter-note triplet pulse in the piano serves as the frame for the composite rhythm of eighth-note triplets and sixteenths in the rest of the ensemble.

continually changing the context and meaning of the repetitive piano chords. In addition, the steady triplet pulses of the piano are occasionally broken by a triplet half-note ‘pause’, creating a constantly shifting sense of phrase length and virtual meter in the underlying pulse (Fig.28). These pauses are also permutationally derived, and are thus integrated with the piano’s unfolding harmonic field in an intimate way.

3.3.2 Gesture and ambiguity

The primary rhythmic component in the piece is derived from ambiguities arising from the expression of a 3:8 polyrhythm. In a typical scenario, the steady quarter-note triplet pulse in the piano functions as a reference point for sixteenth-notes in the rest of the ensemble. Ambiguities arise from the fact that here, one limb or the other does not begin its ‘phrase’ on the beat, but rather at some point *between* beats. Figure 29 shows how this works in practice. At rehearsal B, the flute, bass clarinet, and cello all begin their repeated octave unisons on the last sixteenth note of beat 1, subsequently changing rhythmic subdivisions for one beat to eighth-note triplets, before returning to sixteenths to finish the gesture. The piano continues its constant quarter-note triplet pulse, making the overarching polyrhythm 3:8. The relationship between these two overlapping tempi would certainly be much clearer had the polyrhythm begun *gesturally in phase*, with both instruments playing on beat one of the bar. The ‘late’ entry of the winds and strings, combined with the fade-in from pianissimo and the

B Section I.

The musical score for Section I, rehearsal B, illustrates a complex polyrhythmic texture. It features five staves: Flute (Fl.), Violin (Vln.), Bass Clarinet (B. Cl.), Viola (Vc.), and Piano (Pno.). The Flute, Violin, Bass Clarinet, and Viola parts consist of eighth-note triplets with dynamic markings ranging from *pp* to *mf*. The Piano part features a steady eighth-note triplet pulse, also marked with dynamics like *mf* and *ppp*. The notation includes various articulations and phrasing slurs, highlighting the 'gesturally out-of-phase' entries of the winds and strings relative to the piano's pulse.

Fig.29 – A polyrhythm of 3:8 used for various gestures around rehearsal B. The relationship between limbs is made quite ambiguous due to the gesturally out-of-phase entries of the winds and strings.

one-beat triplet syncopation (the eighth-note triplet 'E's on beat three of this bar are on the 'off-beat' of the triplet pulse in the piano) keeps the true polyrhythmic relationship somewhat ambiguous. This ambiguity is accentuated by the fact that, with each successive entry, the repeated sixteenth-note gestures in the winds and strings are kept 'gesturally out of phase' in *different positions relative to the piano pulse*, creating a polyrhythmic relationship with the piano triplets (which are themselves continually changing their phrase lengths, implied by the irregular half-note pauses) that is quite difficult to pin down.

3.3.3 Formal structure

Imperfect Information is divided into four main sections of approximately equal length, plus an introductory section. The bulk of the music unfolds within the strict framework of the piano's triplets at the notated tempo of $q=44$. The tempo change to $q=50$ in Section 2 (rehearsal D) creates a subtle sense of pushing forward, coupled with the change to eighth-note pulse durations in the piano in that section. After building to a somewhat frustrated climax at the end of bar 84, Section 3 explores textures of simultaneous augmentation and diminution, stretching out the wind/string gestures from the previous sections by a factor of four, and setting this against highly accelerated, single-note incarnations of the piano pulse material. Section 4 closes the work with a restatement of material from Section 1, this time with only sparse chordal interjections

in the piano, leaving the music to move off into the distance. The tension which is held through much of the piece stems in large part from the harmonic ambiguity between the two layers, as well as the 'perceptual mismatch' between the piano's regularity and the more unpredictable gestures in the winds and strings. This tension is only partially resolved by the arrival at bar 82, where the unified rhythms of the winds and strings momentarily 'match up' with the piano in a very consonant harmony. The moment is fleeting, however, and both layers quickly move on, speeding toward an abrupt cessation of motion at the end of bar 84.

3.3.4 Summary

While *Makura Sadamemu* was, at least in part, a study of how several low-integer polyrhythms could be used to create various integrated, characteristic gestures, *Imperfect Information* focusses primarily on the properties of one basic polyrhythmic relationship, that of 3:8. During the compositional process, it became clear to me that these sorts of polyrhythms, where one of the limbs has element durations substantially greater than the other, can be extremely effective in creating a certain perceptual complexity in the temporal strata. From the standpoint of performance this seems counterintuitive, as the constituent pulses (subdivisions of 3 and 8) are quite simple to execute. However, when additional factors (as explored in the piece) come into play, such as the gesturally out-of-phase elements in the winds and strings and the irregularity of the piano phrase lengths, the resulting (composite) rhythmic picture is far from trivial.

3.4 *Orbit/Aphelion*

3.4.1 Overview

Exhibiting highly contrasting musical environments and relying on vastly different technical resources, the two short string quartets *Orbit* and *Aphelion* are nevertheless intended to function as complimentary ‘companion pieces’; a further experiment with the ‘modular’ approach to form which I explored in *Maria Lunarem*. Whilst each quartet is certainly capable of functioning on its own as a self-standing work, when performed together they create a vital, coherent whole, despite the fact that each piece is comprised of elements almost entirely absent in the other. Written nearly four years apart (*Orbit* was composed in the autumn of 2011, *Aphelion* in the spring of 2015), the two pieces certainly come from different places in terms of compositional resources and technique. Nevertheless, it is perhaps these very differences that establish an intriguing formal tension between the two works. Where *Orbit* is based on an extremely restricted set of pitches, *Aphelion* deploys rich, dual-layer collection permutations; while the rhythmic surface of *Orbit*, though irregular, is bound within a single pulse division scheme, the temporal canvas of *Aphelion* is comprised of complex multi-polyrhythmic striations. Though a small amount of shared material creates a literal connection between the pieces, it is more the sense of elaboration of the motives and gestures between *Orbit* and *Aphelion* which creates a true feeling of interrelationship.

3.4.2 *Orbit*: concept and formal structure

Whilst composing *Orbit*, I had a clear image in my mind of an extremely close-up view of the Earth; specifically, a view from low-Earth orbit, moving at 7 km/s, unencumbered by any man-made artifacts. This was the (admittedly somewhat terrifying) scene as it might be experienced by a solitary human, floating in absolute silence, 1000 kilometers above the surface. This poetic image yielded several ideas for musical gestures which could effectively animate such a scene: the constancy of a single high, soft, glassy pitch; melodic shapes fragmented into ‘islands’, separated by irregular silences; sharp, unexpected percussive attacks.

The pitch material used in *Orbit* is drawn exclusively from the d minor scale, with minimal use of the 6th degree (Bb). At least initially, this creates a small amount of ambiguity as to the actual scale or mode being expressed, an ambiguity which is

somewhat enhanced by the high-register 'A' drones (tonicizing the 5th degree to a certain extent) which form a near-constant backdrop to the piece. The scale material and the distribution of its individual pitch elements, once established, is extremely straightforward and uniform throughout. The formal structure is also fairly transparent in that it is built around four-bar sections, each of which is always marked by a quarter-note tremolo in three of the instruments, with the fourth articulating (or re-articulating) the drone. The 9/8 meter is never truly established, but is rather continually undermined by syncopations, silences, or occasional duple eighth-note rhythms, resulting in a highly irregular temporal surface (Fig.30). This irregularity is mitigated by the logical melodic (tonal) development of the pitch structure, which, once set in motion, is always



Fig.30 – The ametrical structure of *Orbit*.

moving toward some sort of stasis or resolution, be it in a V-I resolution (real or implied), or the simple return to the high, sustained drone. Formally, the piece moves toward and away from a modulation of the drone pitch from 'A' to 'D', which occurs between bars 25 and 28, the midpoint of the work, and the only point at which the 'A' drone is absent. The increased density and rhythmic activity of the forte and fortissimo

percussive interjections which lead to this moment, coupled with the change to artificial harmonics in the drone voice (mm. 21-36), creates a subtle sense of increasing tension over the course of the piece which is gradually eased towards the final bars.

3.4.3 *Aphelion*: concept and formal structure

Though *Aphelion* was written to function as a companion piece to the earlier quartet, there was an additional, underlying motive: to explore the practical working-out of a more complex three-limb structural polyrhythm, one where each limb would itself also be comprised of individual polyrhythmic cycles. As shown in Figure 31, the first and second lines are the polyrhythms 6:5 and 8:5 respectively (with each of their top voices offset by one quarter note), and have a cycle of 20 eighth notes; the third line is 7:4 (also with one quarter note offset) with a cycle of 21 eighth notes; the bottom line is 4:3 (one half note offset) with a cycle of 24 eighths. These constituent patterns create an overall polyrhythmic structure of 5 : 5.25 : 6 half notes, with a cycle duration of 315 quarter notes, or 78.75 4/4 bars. The whole polyrhythm functions as a formal determinant for the piece.

The image shows a musical score for four staves, likely representing different instruments in a quartet. The top two staves are in treble clef, and the bottom two are in bass clef. The time signature is 4/4. The score illustrates a complex polyrhythm. The first staff has a 6:5 polyrhythm with a cycle of 20 eighth notes, featuring three triplet markings. The second staff has an 8:5 polyrhythm with a cycle of 20 eighth notes. The third staff has a 7:4 polyrhythm with a cycle of 21 eighth notes. The fourth staff has a 4:3 polyrhythm with a cycle of 24 eighths. Red annotations highlight specific rhythmic patterns and offsets across the staves.

Fig.31 – The *Aphelion* polyrhythm: using ‘nested’ low-integer polyrhythms of different lengths to create a larger structure.

In terms of pitch structure, *Aphelion* is based on the same 5 by 5 collection as the *Maria Lunarem* pieces and *Perfect Information*. It also uses the ‘dual-layer’ approach, with the violins realizing one permutational set and the viola and cello another. As with the earlier pieces we have examined which utilize this technique, the complexity of the overall harmonic field is continually modulated by these changing constituent layers,

The image displays a musical score for the piece "Aphelion". It features four staves: Violin I (Vln. I), Violin II (Vln. II), Viola (Vla.), and Cello (Vc.). The score is divided into two systems. The first system covers measures 21 to 26, with a tempo marking of $q=42$ and a *rall.* instruction. The second system covers measures 25 to 30, with a tempo marking of $q=63$. The score includes various dynamics such as *pp*, *p*, *mp*, *mf*, and *ppp*, along with articulations like *pizz.* and *arco*. The piece is 5 measures long, as indicated by the number '5' in the top right corner.

Fig.32 – A five-bar interpolation of $q=42$ in mm. 22-26, before returning to the base tempo in *Aphelion*.

becoming more or less dissonant by turns, with occasional correspondences between layers also creating pockets of a 'unison' harmonic stasis.

Aphelion uses the same tempo sets as *Perfect Information*, and these will be discussed in detail in Section 3.5. The base tempo is $q=63$, with a small repertoire of alternate speeds ($q=50$, $q=42$, and a brief accelerando which briefly takes the tempo up to $q=105$ at the midpoint of the piece) which define shorter, 'interpolated' sections of 3-6 bars (Fig.32). In terms of the underlying structural polyrhythm and the piece's sectional divisions, *Aphelion* has a quasi-symmetrical form, though any true sense of this is somewhat undermined by the more irregular, non-symmetrical deployment of these short sections in alternate tempi.

3.4.4 Correspondences and summary

The formal clarity of *Aphelion* relies on two key motivic gestures borrowed from *Orbit*: 1) the repeated open-string tremolos which regularly occur as part of the 6:5 and 8:5 polyrhythms in the violins, and 2) the high 'drone' pitches, which are developed and used in a more flexible, generalized way in the latter piece. In the case of the tremolos, these are transplanted (nearly) wholesale into the latter piece, providing an extremely clear connecting referent between the two quartets. The more 'fragmented' or 'atomized' use of the high-pitch drones in *Aphelion*, however, creates a subtler link to the earlier work; one which is further strengthened by the coda on *Aphelion's* final page. This slower, concluding restatement of the 'drone' figure which is first heard near the beginning (mm. 6-9, in the first occurrence) at the slightly faster tempo of $q=50$, aligns the two pieces very closely in the manner of their conclusions. It is also important to note that, whilst the total harmonic environment is considerably more complex in *Aphelion*, these sections at $q=50$ also provide a somewhat expanded 'echo' of the restricted more minor scale used in *Orbit*. In addition, both of the aforementioned gestures are part of the '5' limb of the structural polyrhythm of 5:5.25:6 (see Fig.31) which is articulated by the violins, and have the shortest cycle period, recurring regularly every 2.5 bars. This creates a strong middleground continuity in the violin material which continually provides strong metrical reference points for the longer polyrhythmic cycles manifested in the viola and cello.

In the following section, we will see how this idea of a three-limb, multi-polyrhythmic cycle was used within the orchestral texture of *Perfect Information*, creating a highly stratified characteristic opening. We will also examine the continued development of the 'redaction' techniques discussed previously, and the use of low-integer polyrhythms as a formal determinant across all temporal levels.

3.5 *Perfect Information*

3.5.1 Concept and formal structures

Perfect Information is the most formally complex work we have examined thus far. Over its 18-minute duration it develops two recurring, interrelating themes of *revelation* and *redaction*, utilizing various contrasting techniques, from the juxtaposition and superposition of various low-integer structural polyrhythms, to the rhythmic *decimation* or *granulation* of fundamental thematic material which is later reconstructed or 'revealed' through subsequent iterations.⁵³ By gradually uncovering raw, generative harmonic material which is initially obscured, the global form of the work traces one long (and intriguingly *meandering*) path between two strongly contrasting temporal states: the *absolute stratification* of a set of harmonic structures cast within multiple temporal levels at the beginning of the piece, and these same structures in a strictly *homophonic* realization, cast within one temporal layer in the final section. The title *Perfect Information* is a term borrowed from game theory, referring to a situation where all the participants *know the state of all game materials* at every point in the action. Board games such as chess are commonly-cited examples of games with *perfect information*, with card games such as poker or bridge providing apt examples of games with *imperfect information*, as these games rely on multiple elements which are variously hidden from the players at different points in the game. What intrigued me here was the seemingly simple idea that, given sufficient complexity in the interactions between the game materials, simply knowing their current state provides neither player any advantage; rather, it is precisely upon these complex interrelations that games with perfect information rely to generate sufficient interest and challenge in successfully navigating the game environment. This idea is attractive on several levels, not least of which is the universe of possibilities which are contained within restricted systems, an idea which we have seen in several earlier pieces. Many of the organizational structures which make up *Perfect Information* reflect this idea of infinity-in-simplicity in various ways, whether it be through the simple, low-integer polyrhythms which are frequently employed as medium- and short-range formal determinants, or the use of one single (unpermuted) harmonic collection. Indeed, the most complex polyrhythmic structure in the work is the one used for the opening section, where the same 'nested' polyrhythm employed as a long-range formal determinant in *Aphelion* is used to fracture what

⁵³ Though they predate my first encounter with the *Redaction Paintings* of Jenny Holzer, these ideas were certainly sharpened by Holzer's series. See Holzer (2007).

would have been a simple, homophonic presentation of the harmonic collection. Let us examine *Perfect Information* section by section to see the various ways in which its thematic ‘information’ becomes more perfect over the course of the work.

3.5.2 Part I: stratification and the establishment of the polyrhythmic layers

The harmonic foundation of *Perfect Information* is one section of a dual-layer permuted harmonic field (Fig.33), based again on the *Maria* collection.



Fig.33 – The dual-layer permutation field used in *Perfect Information*.

This section contains twenty individual elements, used in various ways as a reservoir from which all the harmonic material in the piece is derived. The opening section (bars 1-79) contains repeated statements of the harmonic field, in a strict presentation of one element per 4/4 bar. The fragmented temporal strata which ‘decimate’ or ‘granulate’ the rhythmic surface are derived from the ‘nested’ polyrhythm which was used in *Aphelion* (see Fig.31). Here, the complete 79-bar cycle of the polyrhythm is used to define the temporal structure of the entire first section. Recall that the constituent elements of the *Aphelion* polyrhythm are each based on the low-integer polyrhythms 5:6, 5:8, 4:7, and 3:4, and that together these form three different durations of 5, 5.25, and 6 half-notes which create the larger polyrhythmic structure. As we will see, all of the formal devices used in *Perfect Information* are derived entirely from these simple low-integer polyrhythms, employed across a variety of temporal levels.

Over the course of the characteristic opening, the complex polyphony which results from the shattering of the rhythmic surface by the *Aphelion* polyrhythm gradually begins to yield to several new, superimposed polyrhythmic structures which will become important later in the piece. The ‘cascading’ effects in the strings and horns which enter at bar 66 begin to hint at a new short-range structuring of 4:5, which is realized over a 4-bar duration. However, this material barely allowed to establish itself before it is interrupted by a new texture at bar 80. Here, the strings, harps, and

keyboards introduce a long chain of rhythmic material which is derived from composite rhythms of an ordered set of polyrhythms 3:4, 4:5, 3:5, and 4:7. This material continues to build formal tension until its release by the wind choir at bar 112, with the reintroduction and the first full, uninterrupted statement of the ‘cascading’ gestures heard previously in the strings. The strings join in at bar 120, creating a 4-bar iteration of a structural 3:4 polyrhythm articulated between these two choirs.

3.5.3 Part II: ‘Decimation patterns’ and the gradual emergence of homophonic gesture

At the beginning of Part II, the cascading figures of the 3:4 polyrhythm yield to a quiet restatement of the main harmonic field by the piano, harps, and strings, this time with a much finer, more ‘granular’ shattering of the rhythmic surface. During the compositional process I came to refer to these intricate rhythms as *decimation patterns*, as the initial conception of the material in these sections was of pre-existing material which had been somehow ‘decimated’ or shot through with irregular silences, interfering with the original continuity of the harmonic movement (Fig.34).

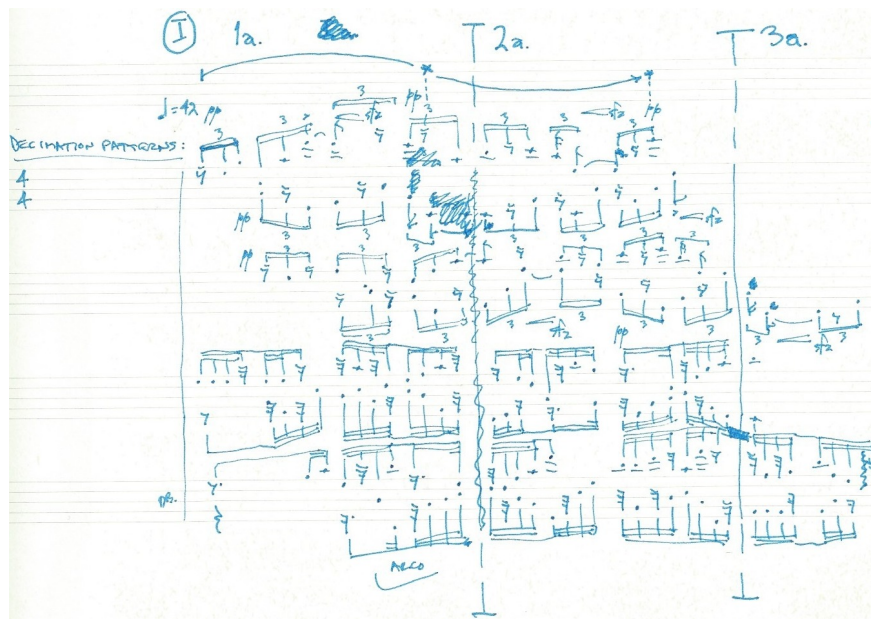


Fig.34 – Sketch page showing the ‘decimation patterns’ used in the second half of *Perfect Information*.

Unlike the material from the opening of the piece, which utilized a nested multi-polyrhythm to achieve this effect, the 'decimation patterns' used from bar 148 to the end of the work were composed intuitively, using a layered, roughly four-bar structure to define eight layers of intricate rhythmic surface. The interest here is in how the more or less 'random' distribution of the constituent harmonic elements can, through their own individual melodic movements, create a fantastic sense of hyper-polyphony. As the strings, and subsequently the woodwinds, join in this complex melodic texture, this sense of melodic tangle is heightened by the use of occasional dynamic swells which briefly rise above the cacophony and establish their own melodic profile across the entire ensemble.

The introduction of the sustained notes in the winds and brass from bar 168 start to undermine the decimated polyphonic texture, beginning the gradual, inevitable emergence of the as-yet 'hidden' homophonic background material. This material attempts to establish itself in spite of continual interruptions of decimated patterns, which themselves start to change character, by bar 175 coming to resemble more the 'cascading' figures heard in Part I. By bar 190 these interruptions have ceased entirely, at last presenting the first clear statement of the underlying homophonic material. The main harmonic field of the piece is finally presented unambiguously by the woodwind chorale from bar 197, with high-energy, low-volume skitterings in the strings, leading to the massive restatement of the chorale in the winds and brass at bar 222, the structural climax of the work. This material is, again, rudely interrupted by a final interpolated 15-bar section of re-stratification, this time via the structural polyrhythm of 3:5, articulated by the woodwinds and strings over three, five-bar cycles, with the winds variously 1, 2, and finally 3 quarter-notes out of phase at each iteration. The climatic material which had been interrupted finally completes at bar 243, and the piece closes with a last, quiet statement of the chorale in the winds, closing a formal loop with the opening section.

3.5.4 Summary

Perfect Information consolidates many of the techniques which had been explored in earlier pieces, bringing them to bear on the formal requirements of a larger-scale orchestral work. Working within this large-ensemble framework, it became feasible to explore not only the massive array of possibilities within the realm of orchestral color,

but also to explore more extreme polyrhythmic textures; textures which would necessarily be more difficult to realize in an unconduted, smaller ensemble. From the standpoint of formal coherence, the work's biggest challenge is in the creation of a convincing environment which allows the co-existence and parallel development of both its highly stratified and homophonic material, a challenge which I found to be far from trivial, despite the extremely unified nature of the harmonic framework. In a certain sense, the whole piece could be described as one, massive crossfade between two contrasting temporal conceptions, with various structural interruptions and digressions along the way. In most cases, this crossfade was realized by 'cross-pollinating' motives and rhythmic gestures across various portions of the work, and by carefully managing the statement and restatement of material heard previously, creating associations and closing cognitive temporal loops.

4.0 Further Considerations

As we have seen, the research contributions of this portfolio fall under two main categories:

1. The long- and short-range permutation of unordered pitch collections, and,
2. The use of polyrhythmic space as a gestural and formal determinant at all temporal levels.

Considering both of these compositional aspects as parts of a unified conception, we have examined how each has contributed to the development of a generalized system of composition which facilitates the creation of coherent harmonic/temporal networks as raw material for composition; networks which can be used to create and control characteristic architectures, as well as perceptual clarity and ambiguity in the score. Along the way, we have also seen how many of these compositions have also explored methods of bipartite sectioning of thematic material which somehow alternates throughout the work, giving the feeling of the parallel development of diverse, 'hidden' elements which inform one another across boundaries of range, dynamics, tempo, and characteristic atmosphere. In all these respects, the pieces have undertaken to explore the remarkable compositional freedom that may be found within highly restrictive formal schemes.

In Luc Ferrari's fascinating quote from *Far West News*, the composer spoke of having 'finally agreed to take to take to my benefit all of my past experiences,' and that, in the past, he 'always started everything again from zero.' The American design science revolutionary R. Buckminster Fuller also had something to say about this in the 'principles of self-discipline' outlined in his final book, *Critical Path*.⁵⁴ Throughout his remarkable career, Fuller always advocated for 'doing one's own thinking', questioning conventional wisdoms and not passively accepting received knowledge in the absence of experiential information. This is often more difficult than it seems. Regardless of our individual fields of endeavor, this approach to learning about and interacting with the world requires the simultaneous operation of two parallel processes. The first process engenders a constant critical engagement with the material of interest, 'starting everything again from zero', to use Ferrari's phrase. The second demands a certain

⁵⁴ For a wonderful passage on seeking 'to do [one's] own thinking, and confining it to only experientially gained information', see Fuller (1981: 123-126).

openness of spirit which allows us to deeply internalize information and synthesize potentially disparate strands of experience into a unified, individual artistic product. As many artists will understand, whether consciously or unconsciously, these two processes are complimentary; one looking outward, the other within, constantly interrelating and further informing one's conception. Through my exploration of the various techniques outlined in this commentary, I have, in nearly all cases, based my initial ideas on those of colleagues and predecessors, often simply taking an idea wholesale and attempting to find my way within it. This is, to my way of thinking, one possible expression of the idea of 'starting from zero'. Through the process of *working in the other's footsteps*, a composer may come not only to a much richer understanding of the music of his predecessors and contemporaries, but also, in an organic way, to new paths and possibilities which had previously lain dormant or unexplored. I have become convinced that this is the best way for the journeyman artist not only to explore, refine, and internalize new ideas, but also to carry them forward, transformed and developed in all manner of personal ways, creating new *possible musics* through the syntheses of techniques and aesthetic conceptions built upon cultural artifacts of the past, as well as the rich language of contemporary art as it is spoken today.

Appendix: The texts

YAMAHA/ENIGMA *(Texts listed in order of appearance in the piece)*

Sei Shounagon, from the *Pillow Book* 134, (ca. 1002).

*Letters are commonplace enough,
yet what splendid things they are.*

St. Augustine of Hippo, from the *Confessions* 6.3, (ca. 397-400).

*When he was reading,
he drew his eyes along over the leaves,
and his heart searched into the sense,
but his voice and tongue were silent.*

Walt Whitman, from "So Long", (1860).

*Camerado! This is no book;
Who touches this, touches a man;
(Is it night? Are we here alone?)
It is I you hold, and who holds you;
I spring from the pages, into your arms.*

Chad Langford

*Wat hoort u, als u aan het lezen bent?
Hooft u uw eigen stem,
de stem van iemand anders?
Klinkt uw stem hetzelfde
als wanneer u spreekt?
Als het een vreemde taal is
die u nu leest,
hoe klinkt dat dan?
Is het uw eigen stem?
De stem van iemand anders?
Als u die taal vlot kunt lezen,
waar gaat het geluid naartoe?
Wordt het geluid verminderd, en de zin vergroot?*

*Hoe komt dat?
Wat hoort u, als u aan het lezen bent?
Is de stem van de schrijver, uw eigen stem geworden?*

*Een eindeloze ketting,
van schrijver naar lezer.
Een onsterfelijke getuige.*

*What do you hear when you read?
Do you hear your own voice,
The voice of another?
Does your voice sound the same
as when you speak?
If it is a foreign language
that you are now reading,
how does that sound?
Is it your own voice?
The voice of another?
If you can read the language fluently,
where does the sound go?
Is the sound lessened, and the sense
heightened?
Why is that?
What do you hear when you read?
Does the voice of the writer become
your own voice?
An endless chain,
from writer to reader.
An immortal witness.*

Makura Sadamemu

よひよひに
枕さだめむ
かたもなし
いかに寝し夜か
夢に見えけむ

*Night after night, I decide
I shall arrange my pillow thus,
but to no avail!
I wonder-- that night, when I slept,
how was it that I saw you in my dream?*

– translation by Dr Kendra Strand

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