COMPOSING TIMBRE SPACES,
COMPOSING TIMBRE IN SPACE:
AN EXPLORATION OF THE POSSIBILITIES OF MULTIDIMENSIONAL TIMBRE REPRESENTATIONS AND THEIR COMPOSITIONAL APPLICATIONS

A FINAL PROJECT
SUBMITTED TO THE DEPARTMENT OF MUSIC
AND THE COMMITTEE ON GRADUATE STUDIES
OF STANFORD UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF MUSICAL ARTS

Leah Christinne Reid
June 2013

ABSTRACT

This final project is comprised of three works completed over the past two years, and an introductory paper that briefly outlines the approaches to timbre taken in each piece. All three of the compositions approach timbre from a different perspective and explore the possibilities and compositional applications of multidimensional timbre representations. The final project does not present a comprehensive history of timbre, all the research that has been undertaken on the topic, or a complete account of the composers who have used timbre models. Rather, the models and compositions presented here are meant to provide insight into my own compositional thought process. The three original pieces illustrate a trajectory through which composing with timbre yielded new creative insights and compositional techniques. Emergent in these works is a common theme and exploration of "timbre space" and "timbre *in* space."

The first piece presented in this portfolio is *Ostiatim,* for string quartet. It explores timbre space as a morphing device for sculpting material. *Ostiatim* was premiered by the Jack Quartet.

The second piece, *Clocca,* for chamber ensemble, examines timbre space as a structuring device. *Clocca* was premiered by the Talea Ensemble.

Finally, the third piece in the collection, *Occupied Spaces,* for two piano and percussion, explores a series of timbral spaces, presented as "rooms," which grow, shrink, and continuously shift in shape. Unlike *Ostiatim* and *Clocca,* this final piece explores timbre *in* space. *Occupied Spaces* was premiered by the ensemble Yarn/Wire.

TABLE OF CONTENTS

LIST OF FIGURES

SUPPLEMENTAL MATERIALS

Recording of *Ostiatim* — performed by the Jack Quartet, 2011
Recording of *Clocca* — performed by the Talea Ensemble, 2012
Recording of *Occupied Spaces* — performed by Yarn/Wire, 2013
Original size 11 x 17 score of *Ostiatim*
Original size 11 x 17 score of *Clocca*
Original size 11 x 17 score of *Occupied Spaces*

ACKNOWLEDGEMENTS

I wish to thank my primary adviser Mark Applebaum and advisors Jonathan Berger, Brian Ferneyhough, and Jaroslaw Kapuscinski for their invaluable insight, support, and guidance throughout my time at Stanford University. Thanks also goes to Sean Ferguson from McGill University, who first opened my ears to the world of timbre.

Special gratitude goes to my parents, Christinne and Ronald Reid, and my husband, James DeMuth, for their unwavering support and encouragement. This final project is dedicated to them.

I. INTRODUCTION

"The whole of our sound world is available for music-mode listening, but it probably takes a catholic taste and a well-developed interest to find jewels in the auditory garbage of machinery, jet planes, traffic, and other mechanical chatter that constitute our sound environment. Some of us, and I confess I am one, strongly resist the thought it is garbage. The more one listens the more one finds that it is all jewels."

—Robert Erickson, *Sound Structure in Music* (1975, p.1)

1.1 What is Timbre?

Timbre is a complex dimension of auditory perception. Its definition is elusive. The most widely used definition of timbre, that of The American National Standards Institute (1960) describes the term as "that attribute of auditory sensation in terms of which a listener can judge two sounds...having the same loudness and pitch as dissimilar"—in effect, a definition based on what is excluded from the term. Unlike pitch and loudness there is no simple, objective, or single dimensional scale that describes this phenomenon (Rossing, 1990). Timbre can, however, be described as a multidimensional attribute of sound, where many physical aspects correlate with perceptual dimensions pertaining to "spectral, temporal, and spectrotemporal properties of sound events" (McAdams, 2006).

As timbre became increasingly central in my composition, I adopted a hybrid model that integrates both the "color" and "texture" of sound, and incorporates both static and dynamic attributes of timbre. The "color" of sound is described in terms of an "instantaneous snapshot of the spectral envelope," while the "texture" of a sound describes the "the sequential changes in color with an arbitrary time scale" (as cited in Rossing, 2012). This view of timbre has been developed at CCRMA by Hiroko Terasawa and Professor Jonathan Berger, and hints at two important compositional elements in a piece: 1) static, vertical pitch and chordal structures, and 2) dynamic, horizontal temporal processes. While these elements are important, this definition is still rather vague as to the descriptive factors of timbre. In order to better understand how to compose with timbre it becomes necessary to view the physical parameters associated with timbre perception.

1.1.1 Timbral Parameters

The multidimensionality and complexity of timbre is best illustrated by the following list from Traube's lecture "Instrumental and Vocal Timbre Perception" (2006):

- Temporal Envelope
- Spectral Envelope
- Absolute Frequency Position of Spectral Envelope
- Variations of Harmonic Contents
- Position of Spectral Centroid, or rather the brightness or sharpness of a sound
- Harmonic and Noise Components Ratio
- Inharmonic Ratio
- Odd/Even Harmonic Ratio
- Synchronicity of Partials
- Onset Effects:
    - Rise time, presence of noise or inharmonic partials during onset, unequal rise of partials, characteristic shape of rise curves
- Steady State Effects:
    - Vibrato, amplitude modulation, gradual swelling, pitch instability

Traube's list notably focuses on the overall spectrum, as well as the dynamic features of individual components. These parameters begin to give one a better idea of what timbre actually is, but they still do not give a full view of how these parameters interact or provide a basis for one to compose with timbre. This is where a spatial or geometric model of timbre is beneficial.

1.1.2 What is a Timbre Space?

The complexity of timbre is clear when one attempts to visually represent it in space. Since the 1970s, many multidimensional perception studies have been conducted, and researchers have tackled timbre's dimensions from various angles to find the best descriptive words to characterize them. These multidimensional "spaces" are commonly referred to as timbre spaces. A timbre space is "a model that predicts the perceptual results such as auditory stream formation, [and] timbral interval perception" (McAdams, 2006). Depending on the stimuli tested, different correlates are produced. For example, Lakatos' study in 2000 included recorded wind, string, percussion, and combined sounds; Grey's 1977 study used recorded and modified instrument tones; Iverson & Krumhansl's 1993 study used attack and remainder portions of tones; and McAdams' 1995 study used FM-synthesized simulations of orchestral instrument tones. The aim of these studies is to "find robust descriptors that explain perceptual data across studies, [to] develop perceptually relevant acoustic distance models for measuring similarity objectively, [and to] find powerful descriptors for sound categorization and source identification" (McAdams, 2006). The understanding of these descriptive terms, spaces, and their dimensions offer perspective on how timbre should be treated in a compositional model.

1.2 Select Timbre Models and Their Compositional Applications

There are many timbre models worth studying in the pursuit of understanding timbre. While I will not go into detail about every timbre model in the literature, for the purpose of this project I will examine three classic timbre models and their possible compositional applications: Pollard and Janson's tristimulus model, and both Grey's and McAdams' timbre spaces. Here is a list of some of the other models I have found particularly useful: Singh & Woods (1970), Pratt & Doak (1976), Von Bismark (1974), Grey & Gordon (1978), Wessel (1979), Krumshansl (1989), Iverson & Krumshansl (1993), Lakatos (2000), and Peterson & Barney (1952). While the examination of these and other timbre spaces is useful for cultivating a definition of timbre, the real question for me is how does one use timbre as a compositional model?

1.2.1 Pollard & Janson (1982)

The first model, Pollard and Janson's tristimulus method (1982), was inspired by the RGB color model developed in the world of visual perception. The RGB color model describes the way three primary colors—red, green, and blue—can be mixed to create an infinitely broad array of colors. The musical tristimulus model is a timbre descriptor that measures the mixture of harmonics in a given sound in three bands. The first band, or tristimulus, measures the relative weight—or rather amplitude—of the fundamental of the sound; the second measures the relative weight of the second, third, and fourth mid-frequency harmonics; and the third measures the relative weight of the remaining high-frequency harmonics. The model is often arranged in a triangular space where the three dimensions meet in a single point. The corners represent the maximum values of each band. This model in itself represents a steady state spectrum and was specifically designed to analyze the timbre of a single tone. While it lacks a representation of time, one can convert the tristimulus model into a temporal model by imposing a trajectory within the space. A diagram of the tristimulus model can be seen in figure 1.

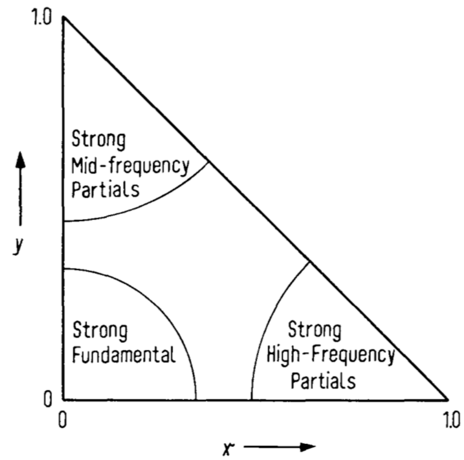


Figure 1. Diagram of Pollard & Janson's tristimulus model. Adapted from "A Tristimulus Method for the Specification of Musical Timbre," by H.F. Pollard and E.V. Janson, 1982, *International Journal of Acoustics,* 51, p.166.

The tristimulus model could potentially inform compositional decisions both by selecting (either algorithmically or arbitrarily) points within the space, as well as imposing trajectories between multiple points. At each point, a different ratio of the fundamental to upper partials is possible. Therefore, one could develop a timbral "harmonic" progression in which particular partials are highlighted and emphasized while the fundamental stays the same. The tristimulus model is, conceptually, a framework for additive synthesis in that the position in the space dictates the respective ratios of amplitudes of the fundamental, low-order, and higher partials. Additive synthesis has been extremely important in the works of spectral composers.[1]

1.2.2 Grey (1977) and McAdams et al. (1995)

Next, I will briefly discuss both Grey's 1977 and McAdams' 1995 timbre spaces. In the former, Grey analyzed sixteen instrument tones and created computer synthesized

[1] "[Additive synthesis] creates complex sounds by combining simple sounds with different amplitudes. The mixture stops on organs are the oldest form of additive synthesis" (Fineberg, 2000, p.111). An example of additive synthesis used in a composition can be seen in Gerard Grisey's *Partiels.*

stimuli with equal pitch, loudness, and subjective duration. Listeners rated the dissimilarities for all pairs of tones (Grey, 1977). The resulting timbre space can be viewed in figure 2. The first dimension, labeled *brightness*, represents the spectral envelope of the sound. Brighter sounds are seen at the bottom of the cube. For example, a sound that has "low brightness" would be a French horn or a violoncello playing *sul tasto*. In contrast, a sound that had "high brightness" on this scale would be an oboe or a muted trumpet (Traube, 2006).

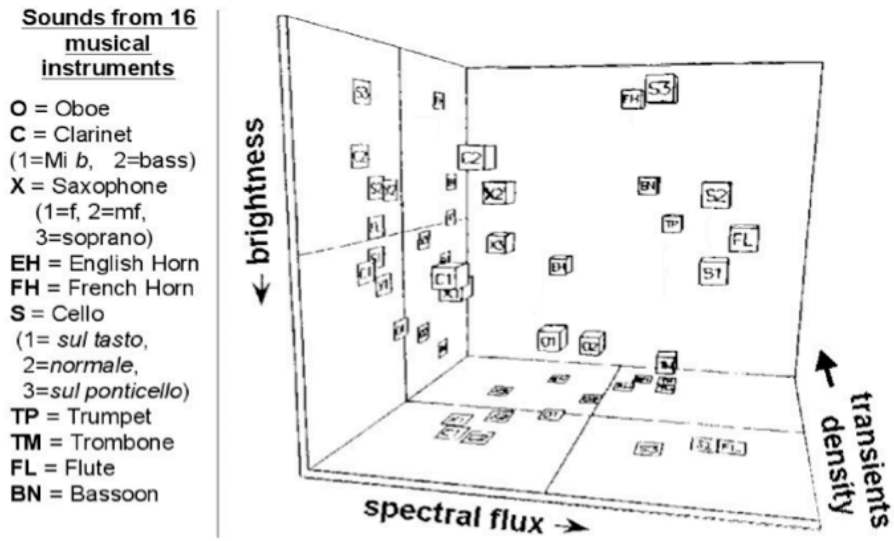


Figure 2. Grey's timbre space. Reproduced and altered in "Instrumental and Vocal Timbre Perception," by C. Traube, 2006; adapted from "Multidimensional Perceptual Scaling of Musical Timbres," by J. M. Grey, 1977, *Journal of the Acoustical Society of America,* 61.

Dimension 2 represents the spectral flux of the sound and explains how the sound evolves over time. In this model, the greater the flux, the more to the right of the cube it appears. "This dimension is related to a combination of the degree of fluctuation in the spectral envelope and the synchronicity of onsets of the different harmonics" (Traube, 2006). To illustrate, sounds that have high synchronicity and low fluctuation are clarinet and saxophone; sounds that have low synchronicity and high fluctuation are flute and violoncello (Traube, 2006).

The third dimension, labeled as *transients density*, "represents the degree of presence of the attack transients" (Traube, 2006). Examples of sounds with more transients include: strings, flute, and single reed instruments such as clarinet and saxophone. Examples of sounds that have fewer transients are: brass, bassoon, and English horn (Traube, 2006).

McAdams' timbre space is essentially a verification of Grey's studies and can be viewed in figure 3. In this study, "McAdams and his colleagues (1995) employed eighteen FM timbres, including both instrument imitations and hybrids... Dissimilarity ratings were made on a nine point scale, with nine being 'very dissimilar'" (McAdams, 2011, p.88). The experiment selected a three-dimensional model with attack time, spectral centroid, and spectral flux. The first dimension is labeled *rise* or *attack time*, which is essentially the same as transients density; the second is *spectral centroid*, which is equivalent to brightness; and the third is *spectral flux* (which is labeled the same in Grey's study) (McAdams et al., 1995).

Both of these models were created using a technique called multidimensional scaling (MDS) which is a statistical technique used for data visualization. MDS is a tool that studies "(dis)similarity" ratings, reveals relationships, and then maps them into a geometric space (McAdams, 1995). They are then interpreted by an investigator that "...attempts to interpret the configuration with regard to factors which may explain the ordering of points along the various axes, or dimensions, of the space" (Grey, 1977, p.

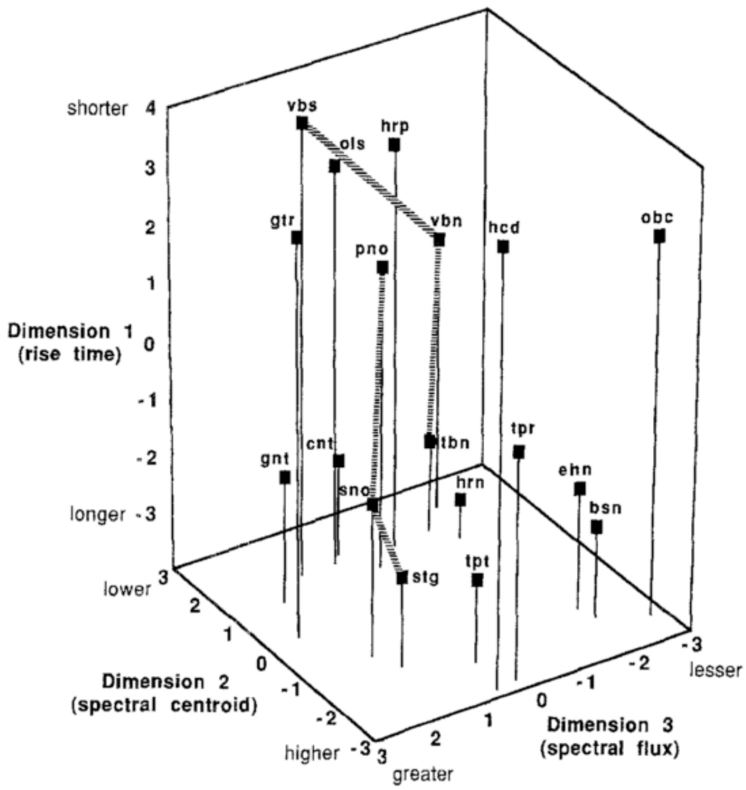


Figure 3. McAdams et al.'s timbre space. Adapted from "Perceptual Scaling of Synthesized Musical Timbres: Common Dimensions, Specificities, and Latent Subject Classes," by S. McAdams, S. Winsberg, S. Donnadieu, G. De Soete, and J. Krimphoff, 1995, *Psychological Research,* 58(3), p. 185.

1270). For both Grey's and McAdams' studies, this technique clusters the sounds based on their timbre, placing those with similar timbres close together and those with dissimilar ones far apart.

There are many possibilities for both Grey's and McAdams' timbre spaces as compositional models. Since both spaces are essentially the same, I will briefly discuss two possible compositional applications as they relate to Grey's timbre space.

If a composer were to compose with Grey's space, they would be dealing with the sound's brightness, spectral flux, and transients density. While I can imagine many compositional scenarios, I will present two. In Grey's timbre space, instrumental relationships are established. Each instrument essentially can be identified by a set of coordinates in this space. These distances could be used to inform orchestration decisions. For example, one could set up a trajectory whereby the piece started with sounds that were close together on the model and then gradually moved to sounds that were far away from each other. Interestingly, in this model the saxophone and the muted violoncello are closer together than the muted violoncello and the violin.

Another idea would be to ignore the instrumental relationships illustrated in the space and simply focus on the dimensions themselves as a compositional model. If one were to structure a piece after Grey's model, the dimension of brightness could decide the bow position of the performers, ranging from *sul tasto* to *sul ponticello*. The spectral flux dimension could control the rhythmic aspect of a gesture, or even a piece's overall form. For example, if one analyzed a bell sound, one would observe partials emerging and dissipating at different rates. These changes over time contribute to the bell's characteristic timbre. If one were to orchestrate this bell sound, one could analyze and notate these changes, controlling either the entrance of the instruments, proportions in a piece, or even derive rhythms from these changes. The third dimension, transients density, could control the articulations of the piece, and could range from sharp attacks, such as a snap pizzicato, to a gradual *crescendo dal niente* on a tone. Because the model is not simply a series of dimensions but rather a space, the challenge would be to imagine how these different parameters would interact. A diagram of the proposed compositional timbre space can be seen in figure 4.

While both Grey's and McAdams' timbre spaces are quite informative and give one means to think about the proximity of sounds, they both are limited to pitched

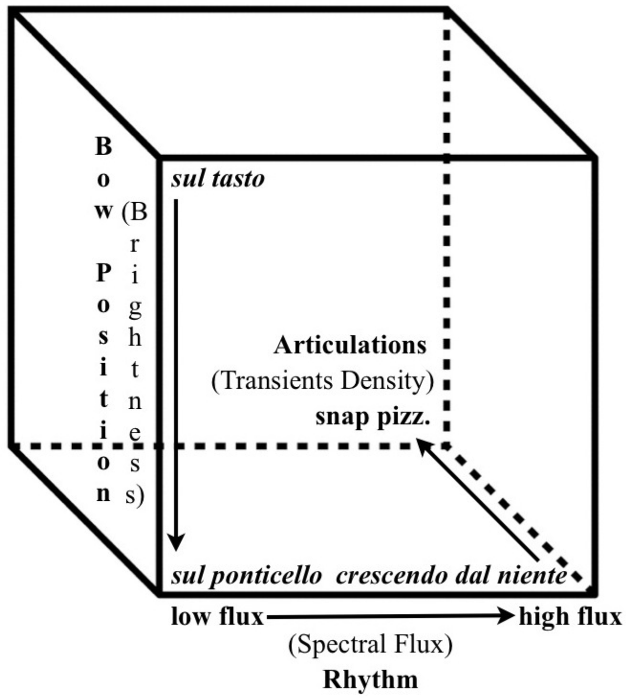


Figure 4. Proposed compositional application of Grey's timbre space.

instrument sounds and thus omit any sound with a noise spectrum. Since noise is an important parameter in contemporary music, any compositional timbre model would need to address this crucial dimension.

1.3 The Temporality of Timbre

Timbre representation is typically rooted in Fourier analysis which describes a discrete spectral slice solely in the frequency domain. By piecing these discrete "snapshots" sequentially we can create a representation in the time-domain (this is called a spectrogram). As previously mentioned, the perception of timbre has both "static" and "temporal" aspects. To illustrate, I will reduce a few perceptual studies down to their basic forms, representing only their title, year, and dimensions (McAdams, 2006):

- Grey & Gordon (1978)
    - Dimension 1 = Spectral centroid
    - Dimension 2 = Attack synchronicity/spectral flux
    - Dimension 3 = Attack centroid
- Krumhansl (1989)
    - Dimension 1 = Attack time
    - Dimension 2 = Spectral centroid
    - Dimension 3 = Spectral deviation
- McAdams et al. (1995)
    - Dimension 1 = Attack time
    - Dimension 2 = Spectral centroid
    - Dimension 3 = Spectral flux

As is the case with most perceptual timbre models, all of the studies listed above have at least one dimension that describes the "brightness" of the sound (spectral centroid), and one dimension that describes the sound's temporal nature (spectral flux, attack synchronicity, spectral deviation, and attack time). One can view a sound's transformation over time in sonograms.

Because our perception of timbre has a temporal element it is important to understand how the envelope of a sound works. Each sound has a beginning, middle, and end, or rather an attack, sustain, and decay. The attack portion of a signal envelope traces the sound signal from zero intensity to its maximum amplitude; the steady state is the portion of the signal that remains fairly constant; and the decay is the portion of the envelope that traces the drop in amplitude to zero (Vassilakis, 1995). The temporal shape of an envelope plays an important role in defining the timbre of a sound. Understanding how the three "sections" of a sound work is essential for composing with timbre as a compositional model.

In Musique Concrète, Pierre Schaeffer made use of these elements in his compositions. To illustrate, figure 5 elegantly depicts a possible solution for how timbre and time could interact. In Schaeffer's system, the "*Plan mélodique ou des tessitures* [describes] the evolution of pitch parameters with respect to time...[the] *Plan dynamique ou des formes* [outlines] the evolution of intensity parameters with respect to time...[and the] *Plan harmonique ou des timbres* [describes] the reciprocal relationship between the parameters of pitch and intensity represented as a spectrum analysis" (Manning, 2013, p. 30-31). For more information on his studies of the nature and inner structure of sounds defined in the concept of the *object sonore,* I refer the reader to his informative book: *Traité des objets musicaux* (1966).

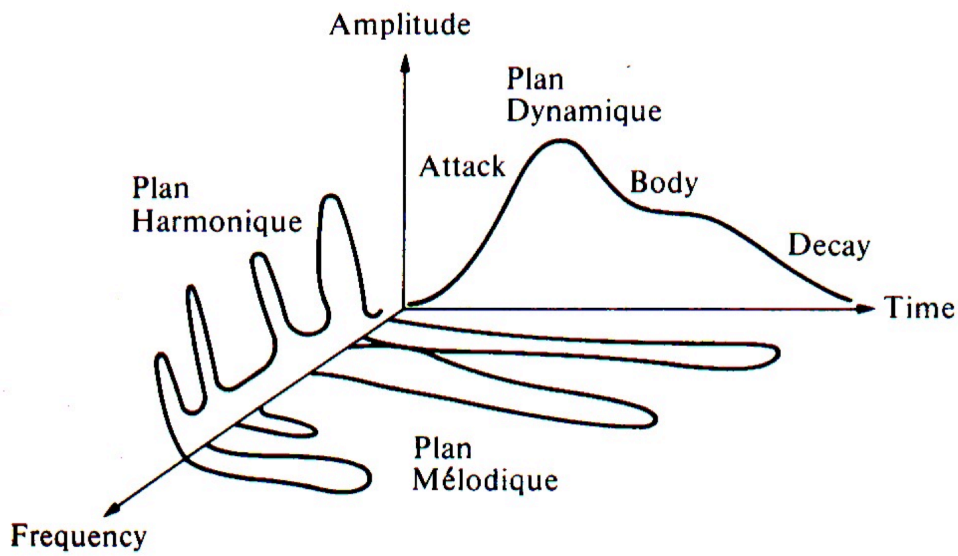


Figure 5. Musique Concrète diagram. Adapted from *Electronic and Computer Music* (p.31), by P. Manning, 2013, New York: Oxford University Press.

If one were to center a composition around timbre, at the bare minimum one would have to define how the static and temporal components of the piece were behaving. There are many ways to approach this. For example, one could model a piece on an already existing sound, such as a bell tone or a clarinet's multiphonic. An example of such a work is Jonathan Harvey's *Mortuos Plango, Vivos Voco*. In this piece Harvey used the spectrum of a bell tone and sound of the singing voice of a boy. The composition has eight sections that are set around eight pitches from the bell's spectrum. In this piece Harvey transforms one bell sound to another through glissandi and a pivot through a center tone. The eight spectra of the piece are static snapshots of sound, and the temporal elements of the piece are the transformations and modulations between these snapshots (Harvey, 1981).

While understanding that timbre has both static and temporal elements is important, the composer also needs to master the understanding and manipulation of the perception of time. As Julio D'Escrivan's surmised in his article "Reflections on the Poetics of Time in Electroacoustic Music," time becomes a poetic element. The composer can "speed up" or "slow down" time. The experience of time can be subjective and people often perceive that time has different "speeds." This subjectivity of time has to do with the psychological state of the listener (1989). As noted in Philippe Manoury's paper "The Arrow of Time," pleasant experiences seem to move by "too quickly" while boredom seems to make time "slow down." These variations in state gives one the concept of form (Manoury, 1984).[2]

1.4 Timbre Models in Select Compositions

I have been influenced by many different works, composers, and theorists, including: Gérard Grisey, Tristain Murail, Joshua Fineberg, Jonathan Harvey, Arnold Schoenberg, Olivier Messiaen, Claude Debussy, Wayne Slawson, Fred Lerdahl, Robert

---

[2] A more extensive description of this process can be found in Grisey's "Tempus ex Machina: a Composer's Reflection on Musical Time."

Cogan, Edgard Varèse, Helmut Lachenmann, Harry Partch, Pierre Henri, Herbert Eimert, Luc Ferrari, La Monte Young, George Crumb, Luigi Nono, Gyorgy Ligeti, Anton Webern, Philippe Manoury, Andre Dalbavie, John Cage, Jean-Claude Risset, and Claude Vivier, to name a few. However, there are not many composers that make timbre the primary concern in their works. While the first composers that may come to mind are from the spectral school, notably Grisey and Murail, the timbral systems of Krystof Penderecki, Mathias Spahlinger, and Kaija Saariaho are particularly compelling. Timbre is of primary importance in their music and manifests itself in every aspect of the compositional process, from pitch to form. Their systems seem to resonate most strongly with my current exploration of timbre. I will briefly present their models and explain my interest.

1.4.1 Krystof Penderecki: Classification and Timbral Categories

Penderecki's approach to timbre in the early sixties was inspired by Drobner's book Instrumentoznawstwo i akustyka, a classic Polish handbook for organology and acoustics. Penderecki studied the ways sounds were generated and understood timbre primarily as a function of materials that were employed in the process of sound generation. In his book, Drobner labeled the sound source a *vibrator* and the body which agitates the vibrator an *inciter.* The combination of the two is a sound *generator*. This terminology became a point of departure for a timbre organization system elaborated by Penderecki in eight of his pieces written between 1960-1962: *Anaklasis* for 42 strings and percussion; *Threnody—To the Victims of Hiroshima* for 52 strings; *String Quartet No. 1*; *Dimensions of Time and Silence* for mixed choir, strings, and percussion; *Fonogrammi* for flute and chamber orchestra; *Polymorphia* for 48 strings; *Fluorescence*s for orchestra; and *Canon* for string orchestra and tape (Mirka, 2001).

In his system, Penderecki derived timbral categories based upon materials most commonly used in the construction of musical instruments and accessories, including metal, wood, leather, felt, and hair. All of these materials can serve as both *vibrators* and *inciters*. However, for practical reasons, while the role of inciter can be played by any of the listed materials, the vibrator can only be made of metal, wood, or leather. These three sounding bodies become primary material categories and can interact with any material, including themselves. Hair and felt, on the other hand, never interact with each other or itself within Penderecki's system (Mirka, 2001).

The matrix in figure 6 illustrates the possible pairs of interacting materials. Every pair in the diagram indicates one type of sound generator as well as the type of timbre characteristic of sounds generated by it (Mirka, 2001).

vibrators / inciters	m	w	l
m	mm	wm	lm
w	mw	ww	lw
l	ml	wl	ll
h	mh	wh	lh
f	mf	wf	lf

Figure 6. Pairs of materials in Penderecki's timbre system. Adapted from "To Cut the Gordian Knot: The Timbre System of Krysztof Penderecki," by D. Mirka, 2001, *Journal of Music Theory,* 45(2), p. 437.

While the system explains the individual categories of sounds used in Penderecki's music, it does not explain how these sounds interact. Penderecki solved this problem by grouping sounds together into sets which he called *segments*. Generators in the segments often featured the same principle material which was excited in different ways. For example, if the main material in a segment was wood then it could be excited by metal, leather, or hair. Segments therefore became defined based on their main materials and can be viewed as the elementary building blocks of the composition (Mirka, 2001).

Penderecki's timbre system controls both the morphology and the succession of segments throughout a piece. The eight pieces that were written using this system are structured around the timbral oppositions between metal, wood, and leather as primary materials. These opposing timbral poles provide the overarching structural components for a piece. For example, if a segment whose main material is wood is followed by a metal segment, one will perceive a timbral opposition. These poles can also be treated transitionally, and one timbre can gradually morph into another one (Mirka, 2001).

While Penderecki only used this timbre system for three years, from 1960-1962, it offers a great insight into his view of timbre. This system fascinates me because Penderecki essentially created a lexicon of all possible sounds and structured his pieces based around these choices. In my own model, I similarly make exhaustive lists of the sounds that can be created by the available instruments and group them based on pre-defined qualities. While I do not use material classification as the basis for my timbre system, the process of categorization, creation of poles, and morphing between these poles is quite similar.

1.4.2 Mathias Spahlinger's Timbre Space

Spahlinger's *128 erfüllte augenblicke* is an example of a piece that uses a compositional timbre space model as a formal structuring device. The piece itself consists of 128 one-page pieces for soprano, clarinet in B-flat, and violoncello. The performers are in charge of choosing both the pieces that they will perform (because not all 128 need be played) and the order in which they will perform them. They can repeat each piece freely and separate them by any duration of pauses. If all 128 pieces were played consecutively with only brief pauses between them, the resulting duration would be approximately one hour. Each piece is labeled by a three-digit code and an inequality symbol. The code indicates the piece's position in a three-dimensional matrix printed in the preface to the score. The three numbers of the code represent the specific location of the piece in the structure. The inequality symbols—given as either an increase (<) or decrease (>) sign—show the piece's tendencies across unspecified dimensions (Blume, 2008).

The matrix consists of three dimensions (figure 7): the first dimension is responsible for durations (long to short); the second dimension is responsible for the amount of noise present in the sound (ranging from pure pitch to no pitch at all); and the third dimension determines the amount of pitches present in the piece (ranging from few to many) (Blume, 2008).

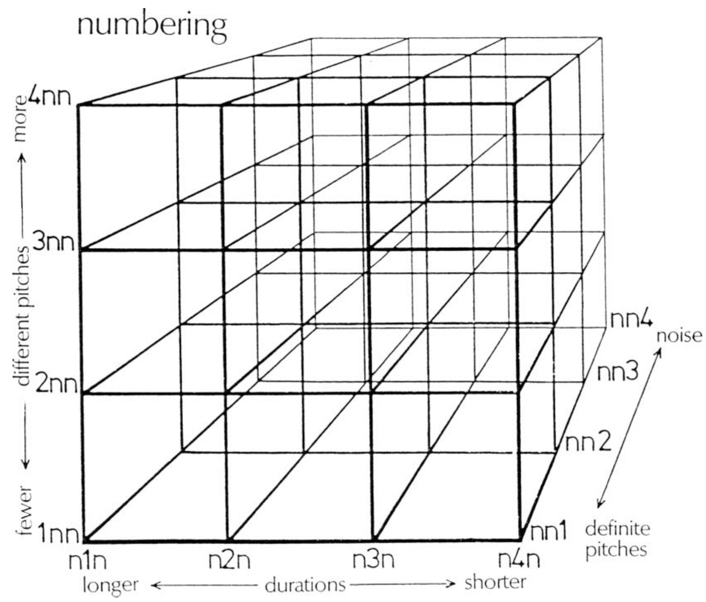


Figure 7. Timbre space from Spahlinger's *128 erfüllte augenblicke*. As adapted from the preliminary remark to *128 erfüllte augenblicke,* by M. Spahlinger, 1975.

The matrix configuration is theoretically set up to allow the listener to be able to tell where the individual piece is within the space. This interpretation is aided by the division of each dimension into four units. Each unit (labeled 1-4 in its slot), controls a distribution of identifiable extremes. For example, in the duration axis, the scale ranges from longer to shorter. Instead of breaking this down into extremely short, short, medium, and long, the units each contain a range of events. For example, in the type n2n (the *2* refers to the second unit along the duration axis) long values dominate the majority of the sounds. In contrast, n3n has more short than long values (Blume, 2008).

In the case of the pitch to noise dimension (the third digit), nn1 indicates that the sounds are pitched; nn2 denotes that there are mostly pitched sounds with a few noisy ones; nn3 signifies that the piece consists of mostly noisy sounds with some clear pitches; and nn4 is essentially noise (Blume 2008).

In the “different pitches” axis (indicated by the first digit), 1nn means that all the sounds have the same pitch; 2nn means that the majority of the pitches are repeated; 3nn means that pitches rarely repeat themselves; and 4nn means that no pitch is repeated (Blume, 2008).

While the dimensions and units of the piece seem fairly straightforward, the inequality symbols are a little more vague. Each piece appears to represent a motion relative to its position in an unspecified direction which either gradually increases or decreases along individual axes in terms of its rate of pitch repetitions, noise factor, or shortness/longness of notes. These transitional factors can combine with one another or cross paths. In essence, the inequality signs suggest movement within each piece (Blume, 2008).

I find this timbral model interesting because it sets up identifiable coordinates for the listener. In my own pieces, I similarly use categories that explore noise and the amount of material present at any one time.

1.4.3 Kaija Saariaho’s “Timbral Axis”

Saariaho’s work approaches timbre from many different angles. I have been intrigued by both her works and her “timbral axis” (illustrated in figure 8). Using this axis, Saariaho formally controls the timbral organization of her compositions. Similar to both Penderecki’s and Spahlingers’ spaces, Saariaho sets up a system that allows for clear timbral poles. These poles create a sense of tension and relaxation in her music and could be described as *sine waves* versus *white noise*, or *clear* versus *noisy* sounds. In her article “Timbre and harmony: interpolations of timbral structures” Saariaho pondered: “along this axis, generally speaking, ‘noise’ replaces the concept of dissonance and ‘sound’ that of consonance” (Saariaho, 1987, p.93). Saariaho uses this axis to develop both musical phrases and larger forms which she believes creates inner tension in her works.

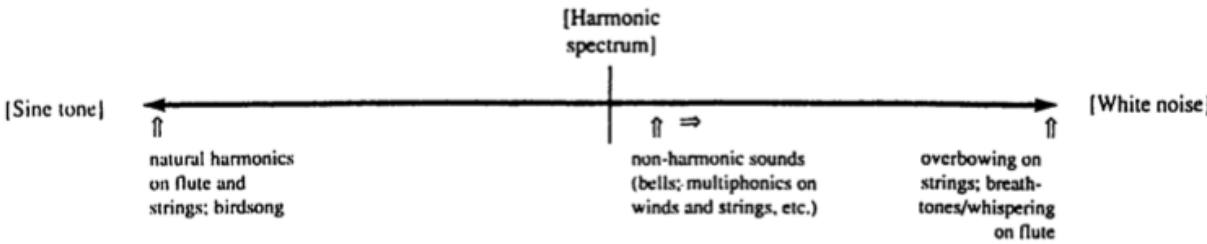


Figure 8. Saariaho’s “timbral axis.” Adapted from “The Works of Kaija Saariaho, Philippe Hurel and Marc-André Dalbavie—Stile Concertato, Stile Concitato, Stile Rappresentativo,” by S. Pousset, 2000, *Contemporary Music Review,* 19(3), p. 83.

Saariaho often speaks of how she perceives timbre and harmony as separate entities, timbre being a vertical process and harmony a horizontal one. She thinks that “harmony... provides the impetus for movement, whilst timbre constitutes the matter which follows this movement. On the other hand, when timbre is used to create musical form it is precisely the timbre which takes the place of harmony as the progressive element in music” (Saariaho, 1987, p.94). These two elements can become confused when timbre becomes an integral part of form and when harmony is confined to determining the general sonority. As with many spectral and post-spectral composers, timbre and harmony end up as indistinguishable through the morphology of the sounds. Saariaho’s sound axis is reminiscent of the system used by Grisey which controls the harmonic progression from harmonicity to inharmonicity, as well as the temporal progression from order to disorder (Rose, 1996). The concept of the “timbral axis” was important in Saariaho’s first major orchestral work, *Verblendungen,* which was composed at IRCAM, and can also be seen in her piece *Jardin secret I.*

Saariaho's timbral axis has been very influential in my works, and I have based a few of my compositions on it, including my piece *Sparrow (Spero).* Also, in my most recent timbre model, my *noise* dimension behaves very similarly to Saariaho's "timbral axis."

1.5 Timbre Models in My Music

While I have been attracted to timbre models conceived by other composers and researchers, I have sought a model for my purposes that is less limited and open to deeper dimensionality. Saariaho questioned the mono-dimensionality of her axis. She pondered, "...I wonder if there might be ways to organize timbre in more complex—hierarchical?—ways" (Saariaho, 1987, p.93). The goal for creating my own compositional timbre model was to find a way to allow the perceptual properties of timbre to address and control any aspect of a composition across multiple dimensions.

For my own works I propose a set of two interlocking spaces or "cubes" as I like to call them. Diagrams of the timbre spaces can be seen in figure 9.

The first cube essentially controls the frequency components of the sound. This compositional timbre space has the following three dimensions: spectral flux, spectral centroid, and noise-to-pitch ratio. The first dimension, spectral flux, measures the Euclidean distance between two spectra, or rather, the change of spectral energy over time. By extension, this dimension can be used to control rhythms or the frequency of pitch changes. This analogy provides a measure of density in time analogous to spectral flux at the intra-event level. For example, in my model, a sound with high flux means that there is a high rhythmic activity, or that pitches are changing quickly, while a sound with

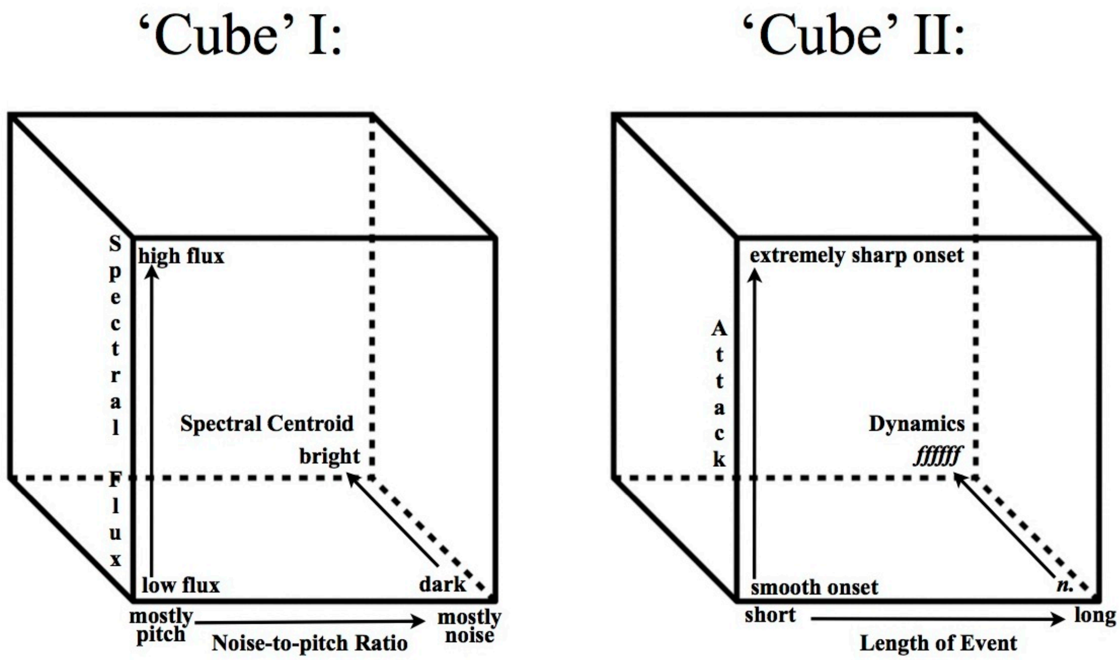


Figure 9. Timbre spaces used in my own works

low flux would be one in which there is either a low rhythmic activity, or the pitches are stagnant.

The second dimension controls the noise-to-pitch ratio and is similar to Saariaho's "timbral axis." On one end of the axis there are sounds that are mostly "pure" pitch—that is, sounds that are close to sine waves. By contrast, the other end of the axis is "mostly noise."

The third dimension controls the spectral centroid, or rather, the average centroid over time, and controls the brightness and darkness of the sound. For example, if the space was evaluating the spectral centroid for a violin sound, this axis would have four reference points—*con sordino*, *sul tasto*, *normale*, and *sul ponticello*—plus every shifting possibility in between.

In this model, each dimension changes depending on the source material inserted into it and the function of the desired result. To illustrate I will briefly examine some of the compositional possibilities of the noise-to-pitch axis. This dimension could be used to control the bow and finger pressure of a string player (pure sounds being harmonics and noisy sounds being increased bow pressure), or it could be used as a filtering device for material (a single filtered frequency on the "mostly pitch" end and the maximum number of desired frequencies on the "mostly noise" end). One could also use this model to learn more about a sound's timbral characteristics, or one could map a composition's instrumentation onto the space, thereby creating spatial coordinates for every sound they wish to use and "seeing" the possible relationships among them. Using this model timbre itself can be used to control and inform a composition. It can be used to derive rhythms, generate a form, harmony, and rate of material, or simply inform the orchestration of the piece. With this model one can work with any sound or instrumentation. While this process is far more intuitive than scientific, it abstracts the original sound and allows one to base a piece's timbral decisions upon an already existing acoustic model.

Cube I is, however, missing key information, namely: the quality of the attack, the dynamic level, and the length of the event entering into the space. To solve this dilemma I use a secondary cube to inform these decisions. This second cube works in conjunction with cube I. The first dimension—attack—controls how the sound or gesture's articulations are treated, ranging from no attack (or a smooth onset) to a sharp attack (sharp onset); the second dimension controls the length of the event, sound, or gesture that enters into the timbre cube; and the third dimension controls the dynamics. Virtually any aspect of a composition can be viewed and decisions can be made based on these two combined cubes.

This space was used in three of my most recent pieces: *Ostiatim, Clocca,* and *Occupied Spaces*.

II. *Ostiatim* (2011)

2.1 Introduction

Through a series of fifteen fragments, *Ostiatim* explores the sounds produced by doors and the emotional inflections of the people who interact with them. The title, meaning “door-to-door,” is meant to depict the timeline of the piece. Each fragment should be treated like a fleeting memory. Sometimes connections are made, and other times the moment slips away.

The composition was inspired by the sculpture *Memory* by Anish Kapoor. I saw the work at the Guggenheim Museum in 2010. The sculpture plays with one’s memory by giving the viewer limited access points from which to view it. The majority of the sculpture is hidden from view, and the observer is charged with mentally placing the pieces of the puzzle—what the entirety looks like—together.

The sculpture inspired *Ostiatim* in many ways. Firstly, the title of the sculpture, *Memory,* influenced the fragment form of the piece and the long pauses often found between fragments. Secondly, the overall number of fragments (fifteen) was based on the ribbing from a particular angle of the sculpture. From this view (seen in figure 10), the sculpture has fifteen sections that all meet and touch at both an inner and outer circle. Finally, the source materials for the piece, door sounds, were chosen because they

Figure 10. Anish Kapoor's *Memory.* Adapted from *The Deutsche Bank Series at the Guggenheim Anish Kapoor Memory,"* by D. Heald, Retreived May 31, 2013, from http://web.guggenheim.org/exhibitions/kapoor/index2.html. Copyright 2008 by The Solomon R. Guggenheim Foundation.

reminded me of both the passageways that one had to walk through, and the window that one had to look into in order to view the sculpture. Similarly for me, the shapes formed by the sculpture's ribbing were reminiscent of doors. *Ostiatim* takes these shapes and translates them into doors, or rather uses them as catalysts for exploring the emotions of the people who interact with them.

I began work on the piece by recording a variety of door sounds. I was amazed to find that specific emotions can be inferred based on how one opens, closes, or knocks on a door.[3] While the sound of doors is common in electronic music my goal was to acoustically orchestrate these doors and abstract them, teasing out gestures and melodies

[3] I became intrigued by the idea after examining the research done by Stanford student Laurel Anderson on the possible emotional inflections of door sounds. The research paper was completed for the class "Psychophysics and Cognitive Psychology for Musicians," taught by Jonathan Berger at Stanford University.

in the process and allowing the listener to hear the same sounds with different musical intentions.

The six sounds used in this piece are: doorchimes, westminster doorchimes, a door banging, a door slamming, knocking, and a door creaking. For each sound, I made dozens of analyses, both of the sound's original form, and of compressed and expanded temporal forms. Then I chose a certain number of these analyses and built a program in OpenMusic[4] to help me study them more carefully. I quantized the frequency analyses into chromatic semitones and then chose between one and three versions of each of these sounds. Finally, I arranged them into fifteen fragments.

2.2 Form

The fifteen fragments of the piece were arranged according to a set of simple pre-defined rules: no two pairs of sounds could repeat in the same order twice over the course of the piece[5] and the sounds were meant to be gradually introduced over time. The form for the source materials in *Ostiatim* can be seen in figure 11.

2.3 Timbre as a Morphing Device

In this piece timbre was largely treated as a morphing device. After determining the overall form of the piece I began to massage the analyses of the sounds and form material. The first pass at the piece was composed with cube II in mind. I focused on

---

[4] OpenMusic (OM) is a visual programming language based on Common Lisp. The program is a particularly useful environment for music composition. OM was designed by the IRCAM Music Representation research group.

[5] For example, if the sound doorbell chimes (listed as A) and door banging sounds (listed as B) were played in succession, the AB pattern could not occur again over the course of the piece.

fragment number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
doorbell chimes	A			A’											A”
door banging		B						B’					B”		
door slamming shut			C			C’					C”				
door creaking open					D				D’			D”			
westminster doorbell chimes							E							E’	
knocking										F					

Figure 11. *Ostiatim*’s Form

articulations, the dynamic curve of the fragments, and the length of events. I also zoomed into the sounds and pulled out melodic components, or zoomed out to focus on overarching gestures. After I had completed this process I took each fragment, approached my first cube, and worked on the music’s trajectories and timbral characteristics. I used this cube to obscure, stretch, and highlight material, sometimes following the natural tendencies of the sounds, and at other times going completely against the grain of the original timbre. An example of the varying outcomes can be seen in the differences between fragments 1 and 4, both of which were derived from a doorbell chime sound, and between fragments 5 and 9 which originated from a sound of doors creaking open.

Each of the fifteen fragments examines either a point in the cube, a trajectory, or a combination of the two. The cube for *Ostiatim* is arranged around a string quartet, and each dimension accommodates different characteristics of either the development or the production of the sound. Figure 12 depicts the way material was viewed inside the space. In *Ostiatim* the spectral flux dimension controls the frequency and rhythm of pitch changes, the spectral centroid controls bow placement and mute usage, and the noise-to-pitch ratio controls bow and finger pressure.

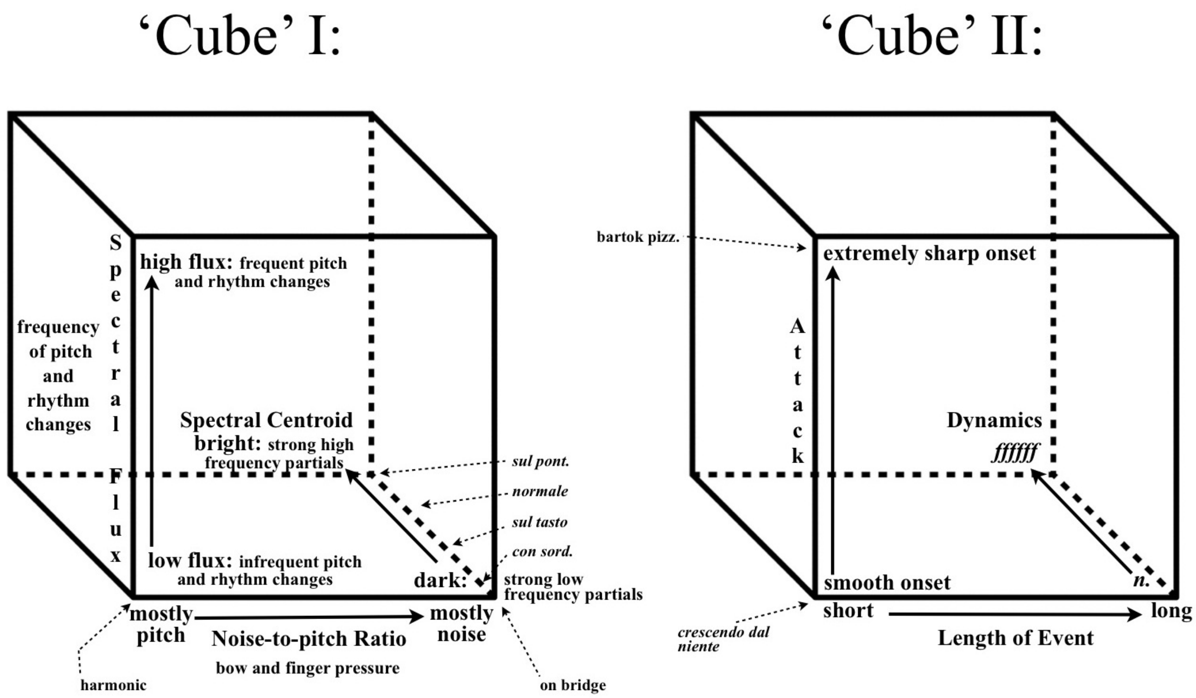


Figure 12. Timbre cubes as they relate to *Ostiatim*

In order to better understand how these cubes were used and how the fragments fit into them, I will provide two in-depth examples that illustrate the resulting trajectories and highlight some of the key properties in other fragments.

Fragment 1 (doorbell chimes) is an example of the exploration of a single point in space. The fragment is comprised of small bursts of material with sharp onsets. This point can be described as having a mid-spectral centroid, a mid-high noise-to-pitch ratio, and a mid-high spectral flux. A visual representation can be seen in figure 13.

Fragment 2 (door banging) exemplifies some of the possible trajectories that can be created in the space. The fragment has two parts: measures 8-14 and measures 15-17. In terms of articulations, the first part juxtaposes aggressive pizzicati with arco sounds, and the second part features delicate pizzicati and soft mid-noisy tremolos. Each part has differing spectral flux coordinates. The first part of the fragment has a high spectral flux

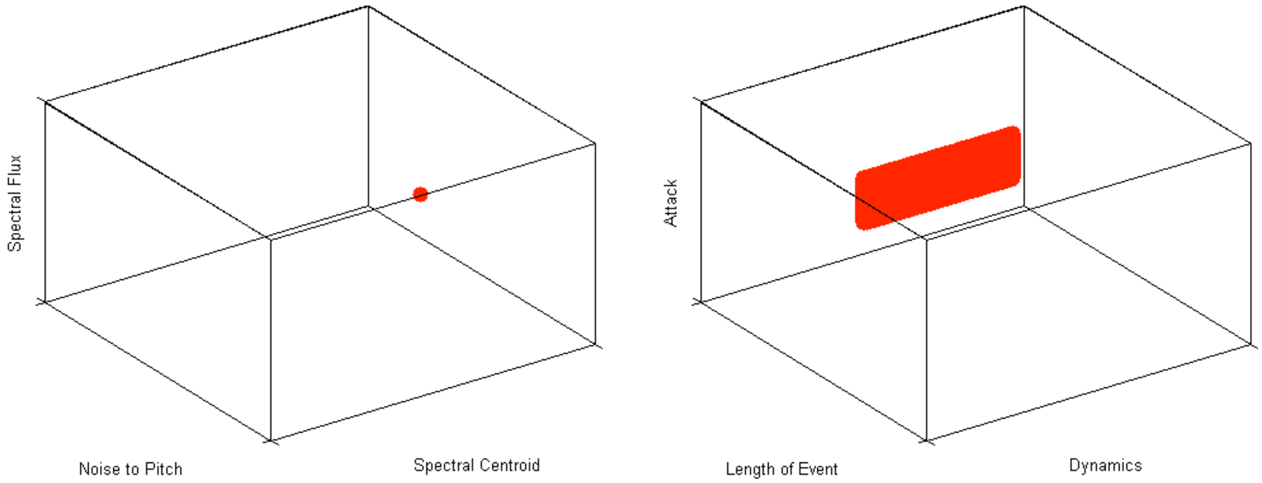


Figure 13. *Ostiatim's* Fragment 1—points in space for cubes 1 and 2

while the second part has a mid-low flux. The spectral centroid has multiple trajectories. One can observe the motion in the second violin and the violoncello. For example, in measure 8 they move from *sul ponticello* to *ordinario* which can be viewed as a movement from a high to a mid spectral centroid. Another example can be seen in measure 12 with a movement back to *sul ponticello.* Here, the spectral centroid shifts back to high. In measure 13 they shift to *sul tasto* which can be viewed as a movement to a low spectral centroid. The violoncello then does one more movement to *sul ponticello,* and then plays *ordinario* in measures 13-15 which can be viewed as the trajectory of a high to low spectral centroid.

In terms of the noise-to-pitch axis, in measure 8 both the second violin and the violoncello move from over-pressured bowing to *normale* bowing. This can be viewed on the timbre cube as a movement from a high noise-to-pitch ratio to a mid-low one. The opposite motion can be seen again in measures 11-12 and 13-14. Furthermore, in the second part of this fragment (measures 15-17) the second violin and viola explore a mid-high noise-to-pitch ratio while the first violin (mm.15-17) and the second violin (mm.17) explore a mid-noise coordinate. A visual representation of these trajectories can be seen in figure 14.

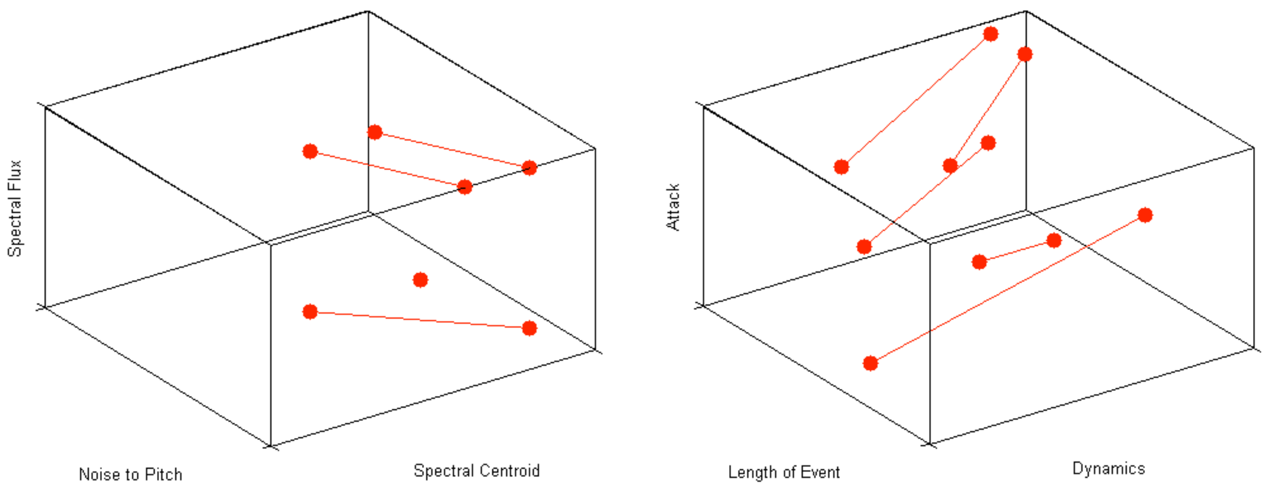


Figure 14. *Ostiatim's* Fragment 2—trajectories in space for cubes 1 and 2

While I will not go into detail on every fragment, I will point out some highlights: fragment 5 (door creaking open) primarily explores the noise-to-pitch axis through finger pressure; fragment 6 primarily has to do with the mode of attack, dynamics, and length of events; and fragment 7's primary motion is one from a high spectral flux in measures 47-50 to a low spectral flux in measures 51-53.

There are also overarching timbral poles and trajectories occurring in the piece. For example, the "brightest" fragment is number 12 while the "darkest" one is fragment 14. Also, the noisiest fragment is number 10 while the "purest" one is fragment 14.

The finished composition is a series of abstracted door sounds that explore both the gritty noisy aspects of these sounds and the beautiful "emotional" side of them. The finished product is not meant to be a replica of the original but rather an interpretation of it.

With this piece I was working with a type of musique concrète instrumentale. The term was coined by composer Helmut Lachenmann. In essence, musique concrète instrumentale honors the original sound sources by observing what happened within the sounds. Here is an example given by Lachenmann himself: “If I hear two cars crashing—each against the other—I hear maybe some rhythms or some frequencies, but I do not say ‘Oh, what interesting sounds!’ I say, ‘What happened?’ The aspect of observing an acoustic event from the perspective of ‘What happened?’, this is what I call musique concrète instrumentale” (Steenhuisen, 2004, p.10).

III. *Clocca*

3.1 Introduction

The next piece in my portfolio is titled *Clocca,* and is for chamber ensemble. *Clocca* is a piece that explores sounds associated with time. The latin title, meaning “bell,” is a precursor to the English word “clock,” and is meant to illustrate the intrinsic connection between time, clocks, and bells.

The piece was written as a response to *Sparrow (spero)*, for flute, violin, horn, piano, percussion, and live-electronics, which I wrote in 2008 at McGill University. While both pieces have entirely different focal points, they are both structured around the same bell sound. This bell resides in a historical meeting house in my home town of Jaffrey, NH. Similar to many New England towns, this bell sounds every hour. While it is one of the sounds of my childhood, the bell's location and history are also important. It is housed in a meeting house that was erected on June 17, 1775 during the battle of Bunker Hill. Tradition tells us that the workers could hear the sounds of cannon fire from Charlestown. The bell tower was added in 1822 and the bell was cast by the Paul Revere Foundry (Stephenson & Seiberling, 1994). The form for *Clocca* is based on the structure of this bell sound.

3.2 Form: Timbre as a Structuring Device

I began this piece by analyzing the bell's spectrum and spectral flux. I reduced the bell sound to its 37 most salient partials and analyzed their decay. An analysis that illustrates the 37 partials and their cut-offs can be seen in figure 15.

Figure 15. Analysis of *Clocca's* bell sound illustrating 37 paritals and their cut-offs

The overarching form of the piece is a retrograde of the bell sound followed by an original bell sound. I used the bell's individual partials as structuring mechanisms. Other bell sounds commonly associated with time and bells were also inserted between the structural partials as blocks of material. For the retrograde of the bell sound I calculated the timings of each partial and then multiplied them by a factor of seven.[6] A diagram that lists the partial numbers and the approximation of their cut-offs in seconds can be seen in figure 16.

Partial	Original End Point	x 7	x7 Minutes	and Seconds	-267.4: Time from first partial entrance
2884	0.2	1.4		1.4	266
1228	0.3	2.1		2.1	265.3
2415	0.35	2.45		2.45	264.95
932-984-848	0.4	2.8		2.8	264.6
3548	0.4	2.8		2.8	264.6
3392	0.5	3.5		3.5	263.9
632-520	0.8	5.6		5.6	261.8
1494	0.9	6.3		6.3	261.1
2059	1	7		7	260.4
2642	1	7		7	260.4
752-732	1.6	11.2		11.2	256.2
3512	1.6	11.2		11.2	256.2
1120	2	14		14	253.4
2708	2	14		14	253.4
3064	2	14		14	253.4
2348	2.1	14.7		14.7	252.7
828-928	2.3	16.1		16.1	251.3
1764	2.3	16.1		16.1	251.3
2503	2.3	16.1		16.1	251.3
4004-3940	2.4	16.8		16.8	250.6
3632	2.8	19.6		19.6	247.8
3108	3.1	21.7		21.7	245.7
1911	3.5	24.5		24.5	242.9
1000-1052	4	28		28	239.4
1383	4.1	28.7		28.7	238.7
688-732	4.2	29.4		29.4	238
2088	4.66	32.62		32.62	234.78
1612	4.7	32.9		32.9	234.5
2588	5	35		35	232.4
1084	5.1	35.7		35.7	231.7
1580	5.3	37.1		37.1	230.3
788	5.5	38.5		38.5	228.9
1176	7.1	49.7		49.7	217.7
296	9.9	69.3	1	9.3	198.1
483	20.6	144.2	2	24.2	123.2
381	35.1	245.7	4	5.7	21.7
236.0	38.2	267.4	4	27.4	0

Figure 16. Partial numbers and cutoff times for the bell sound

[6] The number seven was chosen because it best represented the proportions I had envisioned for the piece.

In the piece, each partial is presented in retrograde as it would appear in the bell sound. For example, the partial that lasts the longest, number 37, has a frequency of 236 and lasts 38.2 seconds. In the piece itself this is the first presented partial and was structured to enter 4 minutes and 27.4 seconds before the climax. As the bell gets closer to its attack, the introduction rate of partials increase. The piece ends with an "original" 38-second version of the bell, played forward and in "real time." For each retrograde bell partial entrance I generated a series of spectra that moved from the original bell's spectrum to an increasingly distorted spectrum. The fundamental frequency of each spectrum gradually shifts down. The original bell's partials function as center frequencies in the distorted spectrum and were part of the process that derived the new spectra. In the piece itself each original partial is played as a held note while the new spectral components are articulated through sweeping upward or downward gestures. The gradual distortion of the spectra and original entrance partials can be seen in figure 17.

While the original bell does provide the overall vertical structuring points for the piece, other material associated with time and bells is used as well. These are inserted between structural moments. The first partial of the piece is not even presented until approximately two minutes into the piece and simply appears to blend into the background. The piece begins with large blocks of materials derived from other bell and clock sounds. Examples of these other sounds are: alarm clocks, kitchen timers, chimes, school bells, domestic clocks, fire alarms, wind chimes, and some more abstract representations of sounds such as crickets and dripping water.

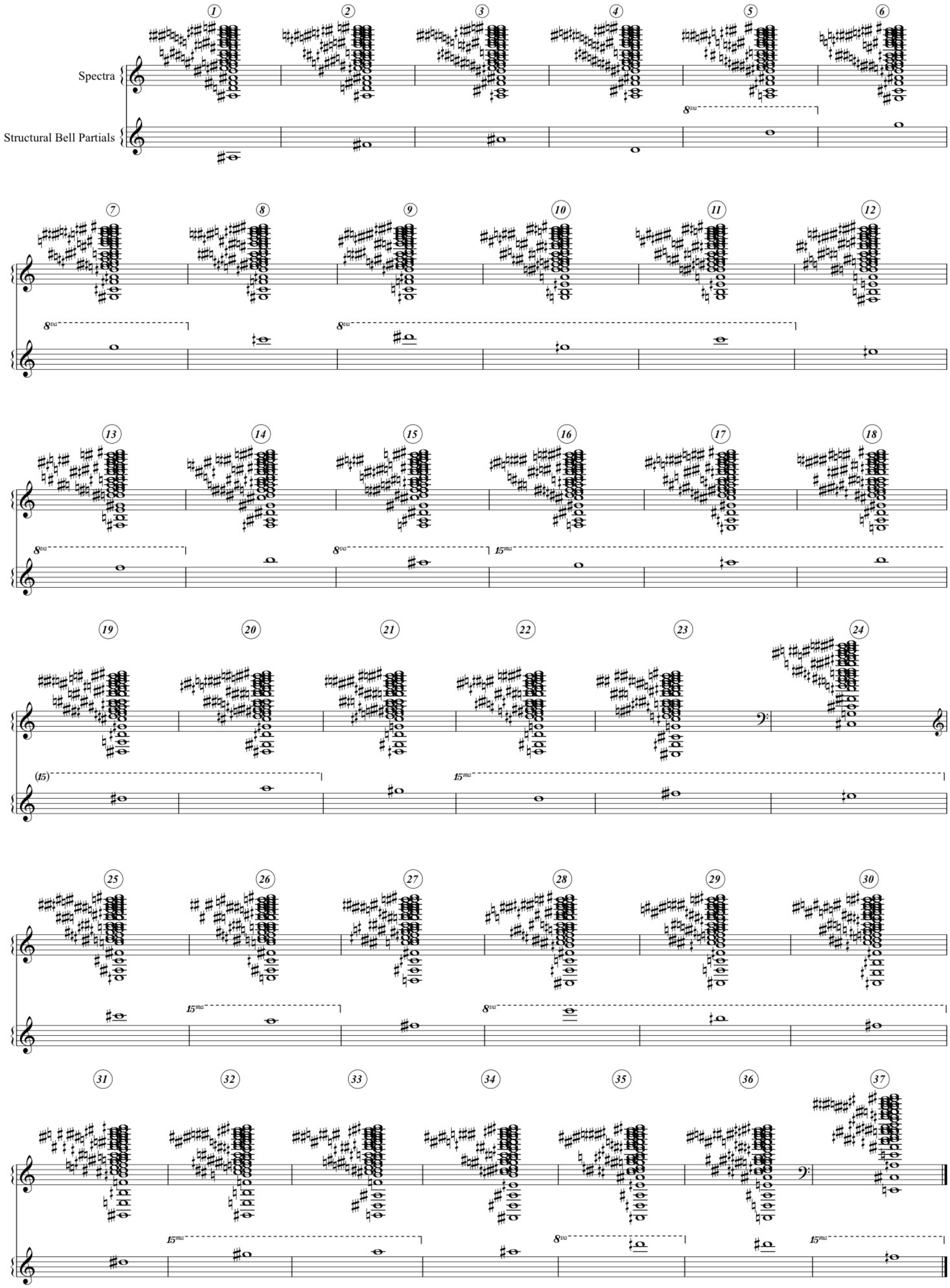


Figure 17. Structural partials and gradual distortion of spectra in *Clocca*

The blocks gradually become shorter and shorter as the piece progresses and more bell partials are introduced. The partials become so frequent as they near the bell's attack that they completely overtake the material. As previously mentioned, the piece ends with a single iteration of the overarching bell sound. This "coda" of sorts is the first time the listener hears all of the bell's partials together.

Figures 18 and 19 are graphical representations of the form that help illustrate the processes occurring in *Clocca*. Figure 18's vertical lines depict the piece's structural partials and their beginning and end points. The horizontal lines illustrate the 37 entrance points. Figure 19 visually depicts the blocks of material over time.

In terms of the piece's timbral trajectory, the two iterations of the bell sound (elongated retrograde and original) provide the large-scale trajectory of the piece, while the individual blocks provide separate small-scale ones. To illustrate I will discuss two examples. The first example illustrates the small-scale trajectories and occurs from measures 1-59, and the second occurs from measure 134 to the end.

At the beginning of the piece, I began with a sparse, dry, and percussive timbre. The source material is dripping water, a reference to the modern clock's water clock origin. The piece begins with percussive woodwind and wooden percussion drips, and gradually increases in density, activity, and noise. The strings enter with a subtle introduction of select bands of the original bell sound and then add to the dripping texture before gesturally sweeping upwards. This section is followed by the piano playing "clock" material. It begins with regular, metrical "ticks" that gradually become sporadic and are interrupted by a shocking, bright, and metallic "alarm clock" sound. This alarm

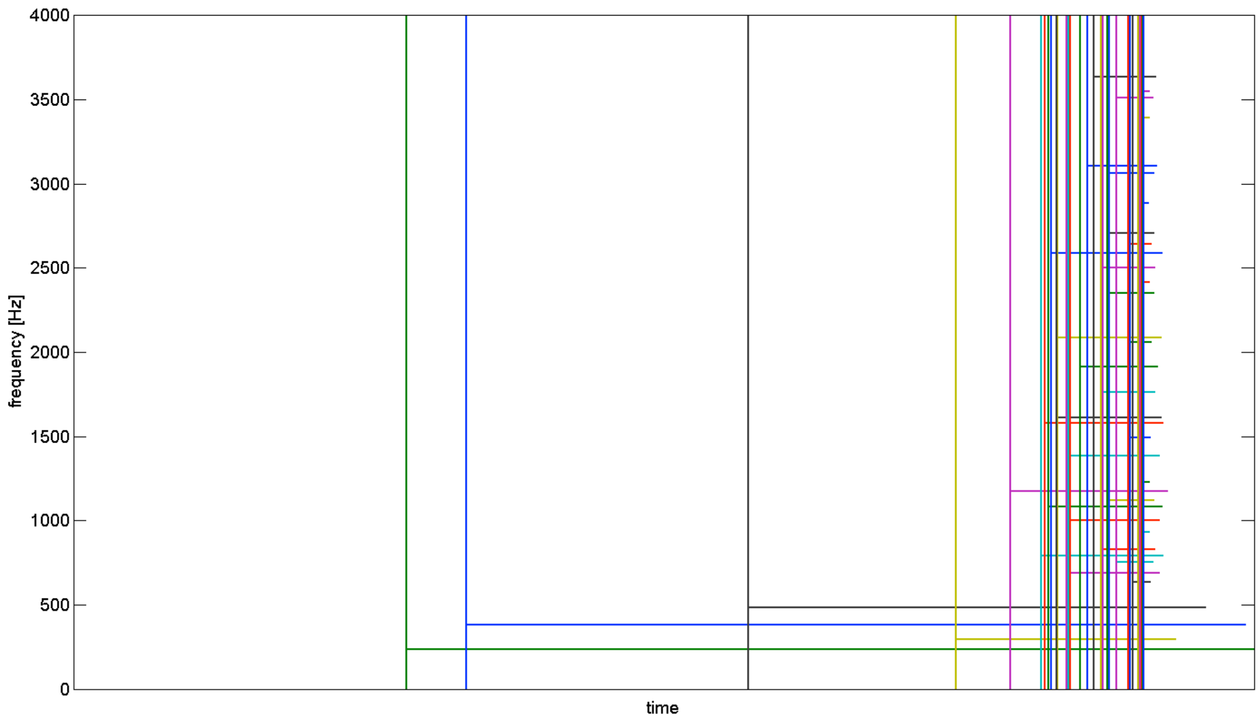


Figure 18. Graphical illustration of *Clocca's* structural partials

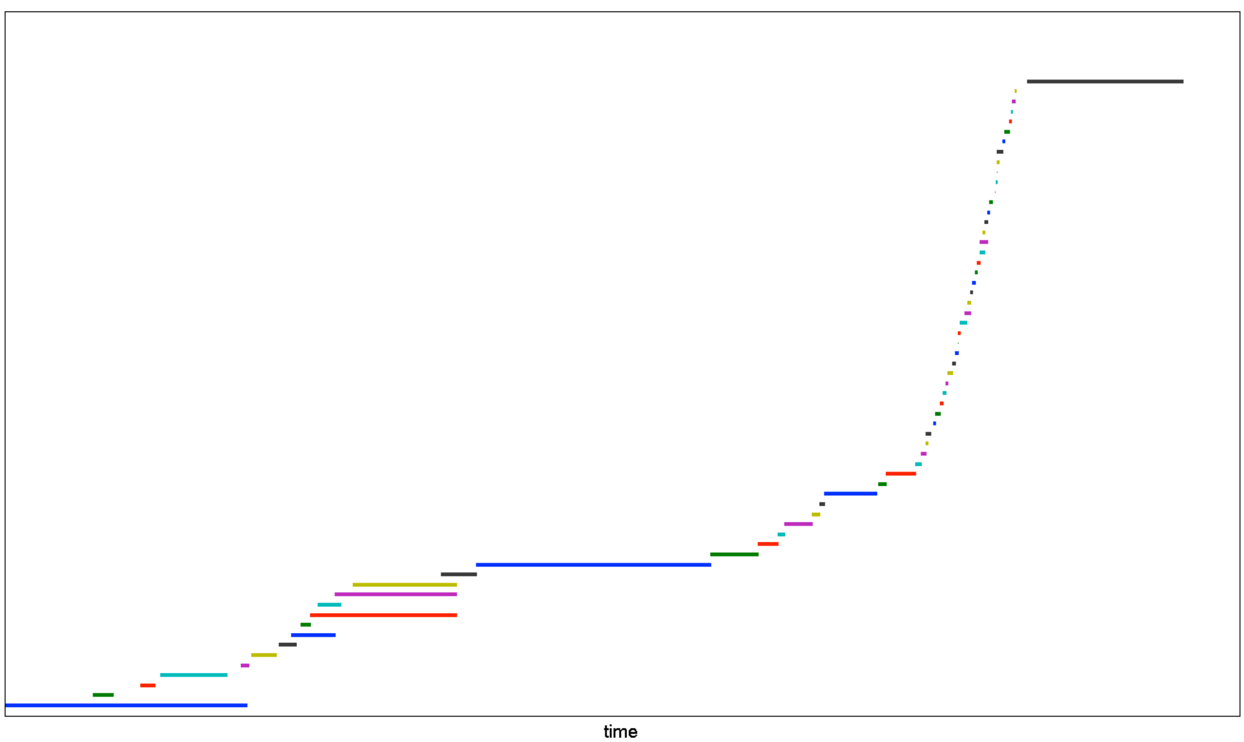


Figure 19. Graphical depiction of *Clocca's* block structures

clock is the brightest moment so far in the piece.

The second example, taken from measure 134 to the end, illustrates both the structural bell sounds and the juxtaposition of the formal block sections with the structural partial sweeping materials. A key identifier between the two is that the structural partial's sections contain microtones, while the block materials do not. In this example, the blocks gradually become shorter and shorter as the structuring partials overtake the material.

3.3 Treatment of Time

Time is also an important structuring device that lends itself to the overarching treatment of timbre in the piece. As previously discussed, timbre has a temporal component and in order to use it as a compositional model, a composer must work with the manipulation of perceived time. In *Clocca* I set up varying time "speeds." I "slow down time" with more stagnant textures such as the wind-chime section and the fire alarm brass duet in measures 62-75. I then "speed it up" through sudden changes in timbre, dynamics, and large gestural sweeps. I structured the overall temporal form of the piece to move from these slow, static textures to an exponential increase in energy and perception of time. For example, from measure 103 until the climax at measure 153, time is meant to "speed up."

IV. *Occupied Spaces*

4.1 Introduction

The third piece presented in this portfolio is *Occupied Spaces*, a work for two pianos and percussion. It was premiered by the ensemble Yarn/Wire. The idea for the piece originated through the concept of timbre *in* space and the topic of Normalized Echo Density (NED). NED describes how the reflections of a sound in a given space interact over time, and the texture that results. Some of the key terms and components associated with NED are: the sound's clarity, focus and blur, the perception of smoothness and roughness or rather the degree of granularity of the sound, the ratio of direct to reflected signal in the sound, the dryness or wetness of a signal, and the description of the number of reflections per second of an acoustic signal. For example, noises with low NED would be perceived as "sputtery" and noises with high NED, would be perceived as "smooth" (Huang, Abel, Terasawa & Berger, 2008).

Occupied spaces is a piece that explores timbre through a series of eleven "rooms" or conceptual spaces. Some of these spaces have been modeled after physically existing rooms, others are either imagined (and do not follow the rules of physics), or occur inside one's mind/head.[7] There are three impulses in the piece: a zipper, a clap, and a balloon pop. These impulses form the material that is inserted into the various rooms. The sounds are filtered to various degrees, and over the course of the piece frequencies

[7] The room that occurs "inside" the listener's mind/head includes two categories. The first is a figurative and imagined space that is devoid of walls and quite literally can be thought of as the listener imagining material. The "physical" space is the listener's skull cavity. This "space" somewhat changes in dimensions as the piece progresses and is (clearly) imagined.

are added to the impulses, thereby creating an increasingly dense—and by analogy—noisy texture.[8] For example, in measure 7 near the beginning of the piece, only a single frequency is present within the room. By contrast, over 43 partials are present during the climax in measure 289. The full spectrum of the clap can be seen in measure 288. Similarly, the full spectrum of the balloon pop can be seen in measure 289. The zipper is treated gesturally and is often marked through steady sweeps upwards and/or accelerating tremolos in tam-tams, gongs, or other metallic percussion. Specific "zipper" pitches can be periodically heard, for example in measures 34, 71, 110, 135, 139, 156, 166, and 174.

4.2 Form

The piece's overall form is divided into an introduction and six main sections. Each section determines which rooms are presented, how many rooms can be present at any one time, and the degree of the noise-to-pitch ratio. Also, in each section impulses have been organized into various strands of material. Each strand comes from a two-part theme that is presented in the first section. Each section takes this theme and destructively varies it. The original theme can be seen in figure 20. This first iteration can be found in measures 7-33. As one can see, part A of the theme is comprised of balloon material, and part B of clap material.

The piece begins with an introduction of the zipper in room 1[9] that hints at some of the characteristics of the rooms, followed by section 1 that introduces rooms 2-4 and

[8] While the densification of frequencies in itself does not equate with an increased level of noisiness, in the case of *Occupied Spaces*, the impulses themselves are different noises. Therefore, as more frequencies are added, by analogy, the true "noisy" nature of the sound is revealed, thus creating an increasingly noisy texture.

[9] In *Occupied Spaces,* the zipper always occurs in room 1.

Figure 20. Example of *Occupied Spaces* two-part theme

the two basic strands of thematic material. Section 2 introduces rooms 5 and 6 and the strands begin to grow and overlap. Section 3 presents rooms 7 and 10 and the possibility of three simultaneous strings and two overlapping rooms. Section 4 introduces room 8 and strings begin to multiply and deteriorate the "structure" of all the rooms.[10] The zipper attempts to overwhelm the material but it is repeatedly interrupted and cut off by room 8. Section 5 begins after a final failed attempt by the zipper and the first iteration of room 9. The balloon and clap theme begins section 6 and tentatively attempts to reset the rooms, however, they have deteriorated and reflections begin to multiply. The strands proliferate while the reflections increase in density until they have completely saturated all of the rooms. A final iteration of the clap, balloon, and zipper form the climax of the piece. Section 6 is marked by the second iteration of room 9, which takes the third climactic impulse (the zipper, which finally succeeds in overwhelming the material) and leads the listener into the final new room: number 11. This last room reminiscently employs a

[10] The deterioration is accomplished through a combination of the rooms misbehaving and by an uncontrollable increase in the number of reflections and echoes. As the rooms begin to increasingly overlap and thematic strands of material begin to multiply, the rooms begin losing or exchanging some of their characteristic components, thereby dissolving into the listener's imagination (room 1).

small bandwidth of frequencies from the previously heard impulses, creating a ghost-like resonance. The piece closes with a brief recap and final presentation of fragments of the original theme and a brief presentation of select rooms. A visual representation of the overarching formal structure of the piece can be seen in figure 21 and a graph that illustrates the individual timings of the rooms can be seen in figure 22.[11]

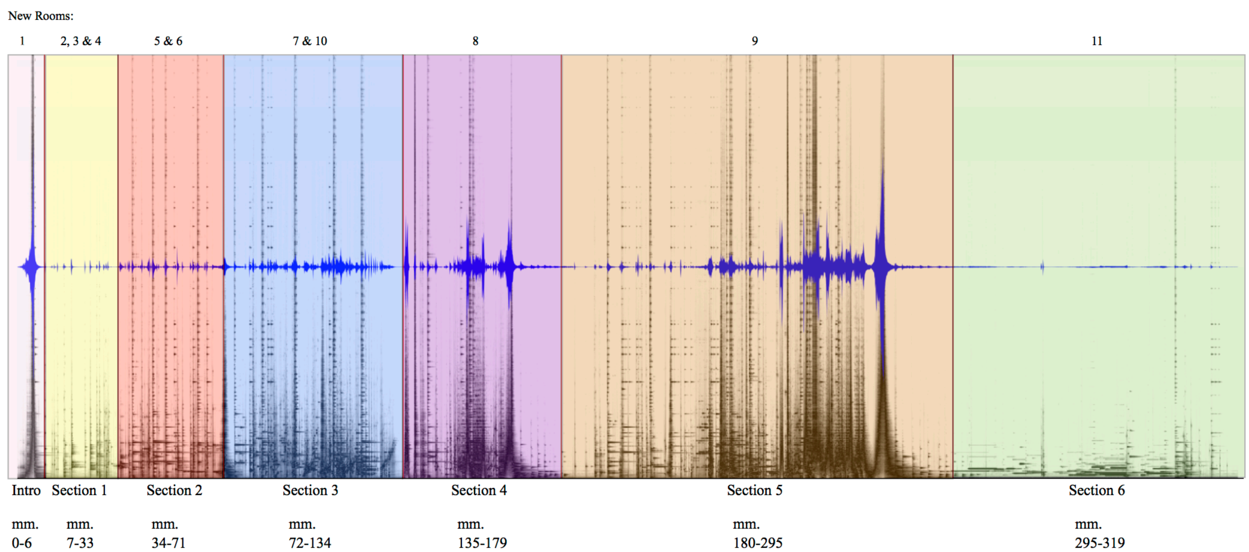


Figure 21. Spectrogram and graphical representation of *Occupied Spaces*' form

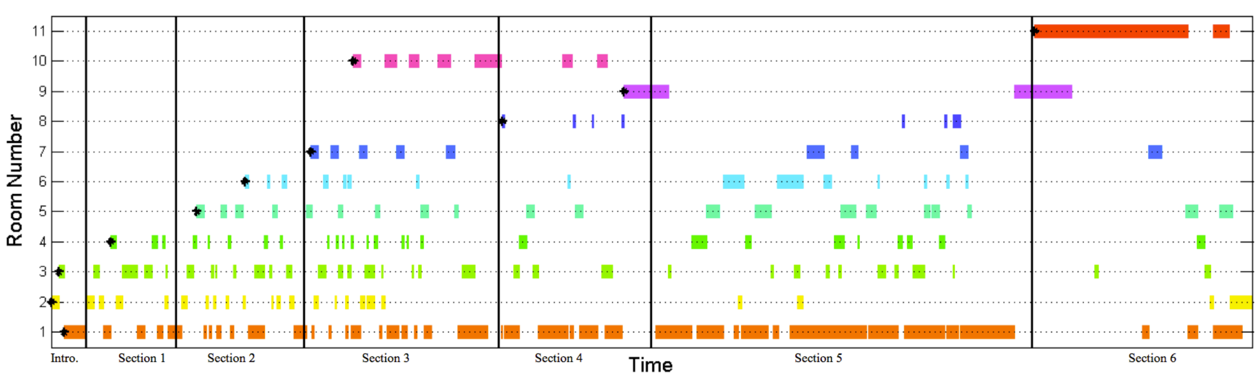


Figure 22. Graphical illustration of the temporal room spatialization

[11] Figures 21 and 22 illustrate different aspects of the form. The timings for figure 21 were taken from the premiere performance, whereas the timings for figure 22 were taken directly from the score. Slight differences are the consequence of performance liberties. Figure 22 depicts the room start and stop times. Please note: after section 4, the rooms have deteriorated to a point that many are unrecognizable. For the purpose of the graph they have been listed as room 1, however, they stem from other spaces.

As previously mentioned, each section controls the noise-to-pitch ratio present at any given time. Each section ranges from having one to multiple noise trajectories and strands of thematic material. Similarly, the overall piece moves from small bands of filtered material to the sound's "full spectrum[12]." Figure 23 illustrates the frequencies of the largest band in the first five sections. It is worth noting that, between the clap and the balloon, in sections 1-4 there is only one common pitch present at any given time. In section 5 there are many common pitches present. As previously mentioned, the rooms have deteriorated and there are so many layered strands of material that both the balloon and clap pitches become nearly indistinguishable.

4.3 Eleven Rooms: Timbre *in* Space

Now that the treatment of the zipper, clap, and balloon material has been discussed, it is important to understand how the rooms themselves work, and how they interact with the inserted sounds.

When creating the form of the piece I decided there would be eleven individual rooms. In my research, I looked at different impulse responses in various rooms, analyzed reverbs, created delay patterns, and considered the resonant properties of different spaces. Similar to the NED properties already discussed, I came up with room classifications that were based on the following specifications: how dry/wet the sound is, how many reflections there are, the degree of granularity, the characteristics of the overall sound, and how resonant the space is. I wanted to make sure I covered a broad range of room possibilities so I first determined what the extremes of the rooms would be. The two

[12] The "full" spectrum is taken to be all spectral components retained after initial filtering and reduction.

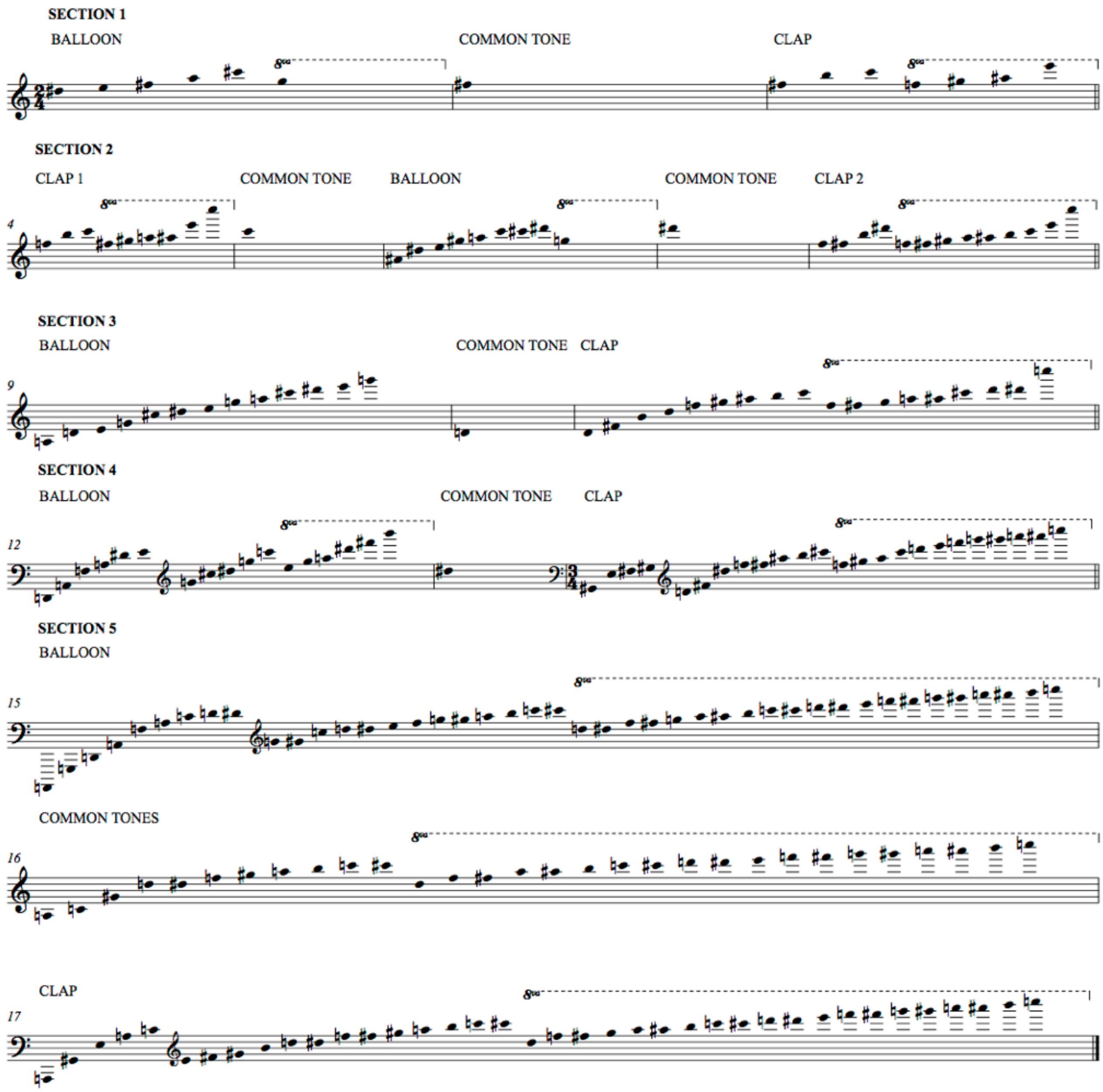


Figure 23. Frequencies of the largest bands for sections 1-5

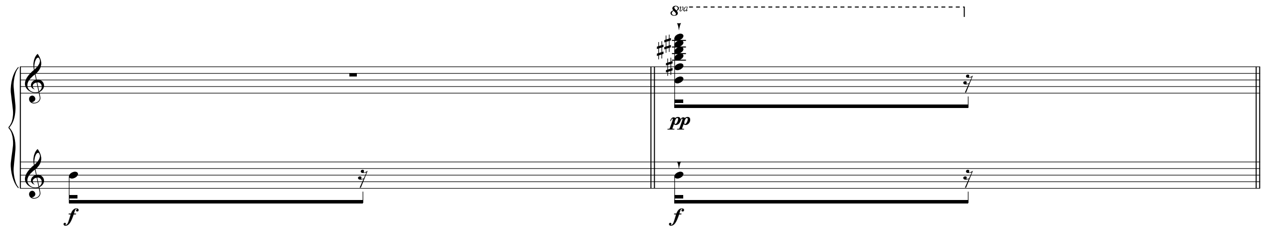
extremes of the piece can be characterized by an anechoic chamber and an imaginary room with infinite reverb. Then, I decided how I wanted the other rooms to ideally fill in the remaining gaps. Next I created or found models of rooms that matched my specifications. From these models I analyzed each room and found its specific resonant properties, determined the exact rhythm of the reflections (if there were any), and analyzed the room's dynamic curve. Then, I inserted the impulses themselves into each room and analyzed the results. I carried out this process with both the original noise impulses and with a single pitch—B4. The resulting analyses can be seen in figure 24. After completing this process I orchestrated the results, choosing the instruments that best followed the room's characteristic properties. The rooms themselves are described below, and the resulting orchestration can be viewed in figure 25.

Room 1 first appears in the introduction from measures 1-6. As previously described, this room is imaginary and "places" the impulse material inside the listener's head/mind. In essence, the material is either left untouched (if it is inside the listener's mind), or has a slight echo (it if is inside the listener's head) and is devoid of any further manipulation. The impulse can be played by any instrument; however, the piano most commonly plays this material.

Room 2 is first introduced in measure 7. This room is the driest of all the (actual) rooms and has no reflections or added resonance. The room is essentially an anechoic chamber. The inserted material remains very short with no sustain. In this space the impulse is colored by what would be the naturally occurring harmonic series for the given pitches. These harmonics are always three dynamic levels lower than the impulse material. For example, if the impulse is ***f***, then the emphasized harmonics would be ***p***. The impulse and the room can be played solo by either piano 1 or 2, or in combination by both pianos.

1 Instrumentation: any
First appearance: mm. 1-7

2 Instrumentation: pianos 1 & 2
First appearance: mm. 7



3 Instrumentation: xylophone & marimba
First appearance: mm. 10

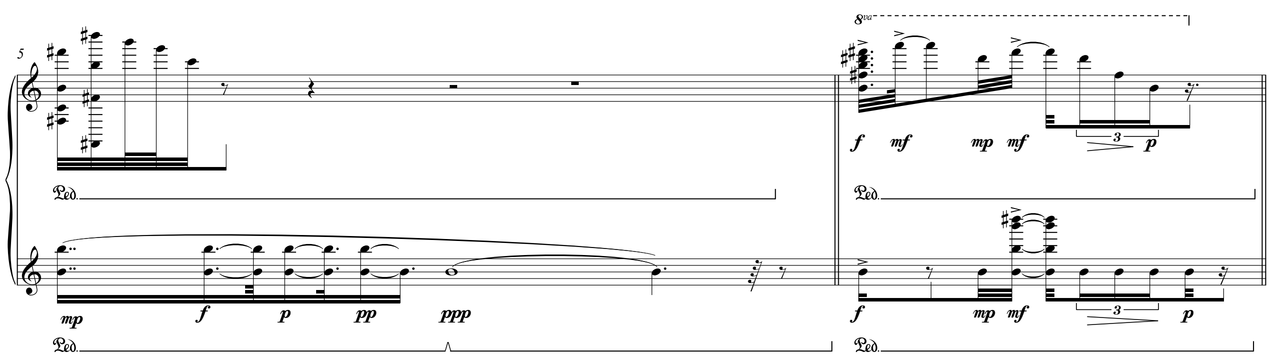
4 Instrumentation: toy piano, piano 2, cow bell, suspended cymbal and marimba
First appearance: mm. 15

The xylophone and marimba natrually sustain the material. Regardless of what is written in the score, the result will remain constant.

These pitches are a resonant characteristic of the room. Depending on the impulse material the upper notes may change. The A3 will remain constant.

5 Instrumentation: piano (either 1 or 2), wind chimes, crotales and vibraphone
First appearance: mm. 39

6 Instrumentation: piano 1, celesta and triangle
First appearance: mm. 56



7 Instrumentation: celesta, vibraphone, glockenspiel, crotales
First appearance: mm. 73 (beat 5) - 75

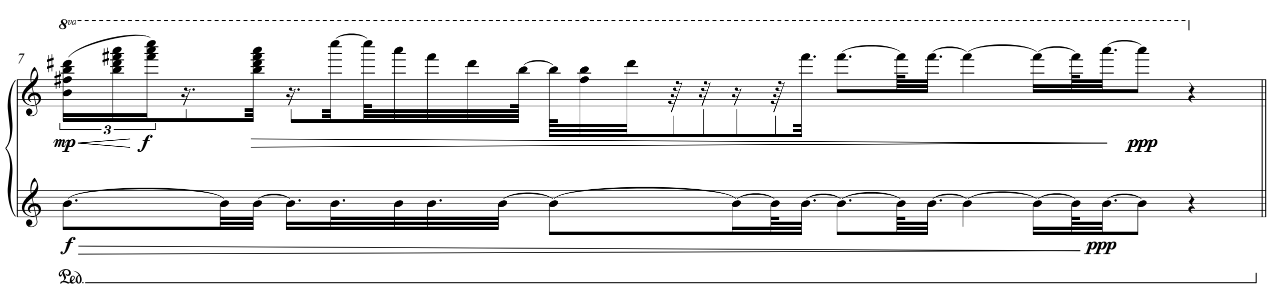
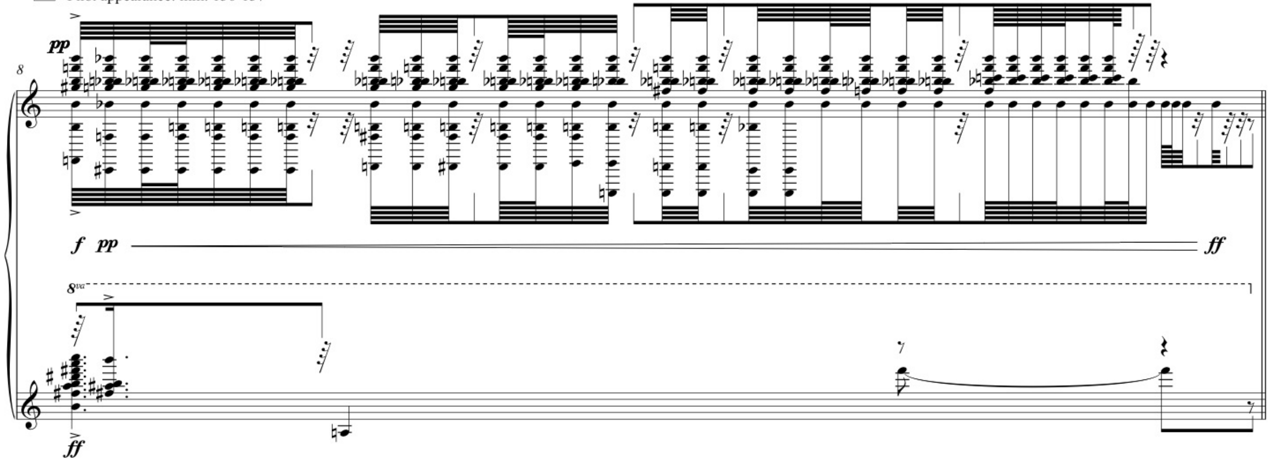
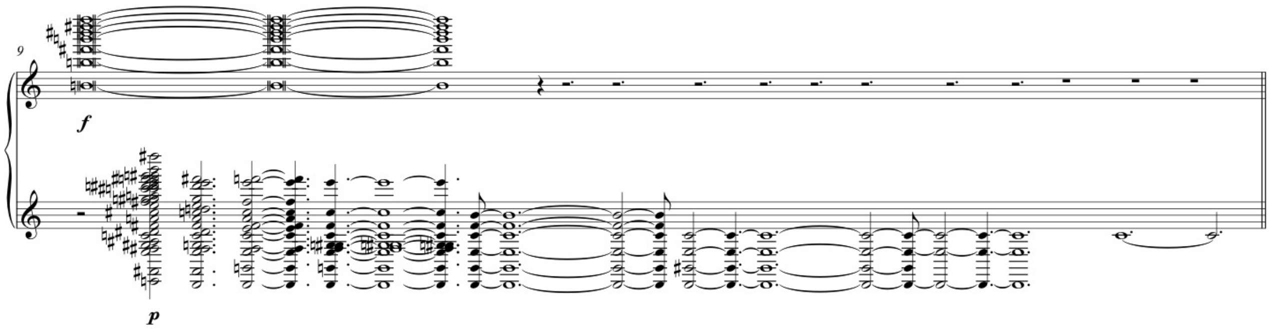


Figure 24 (Part I). Original analyses of rooms on the pitch B4

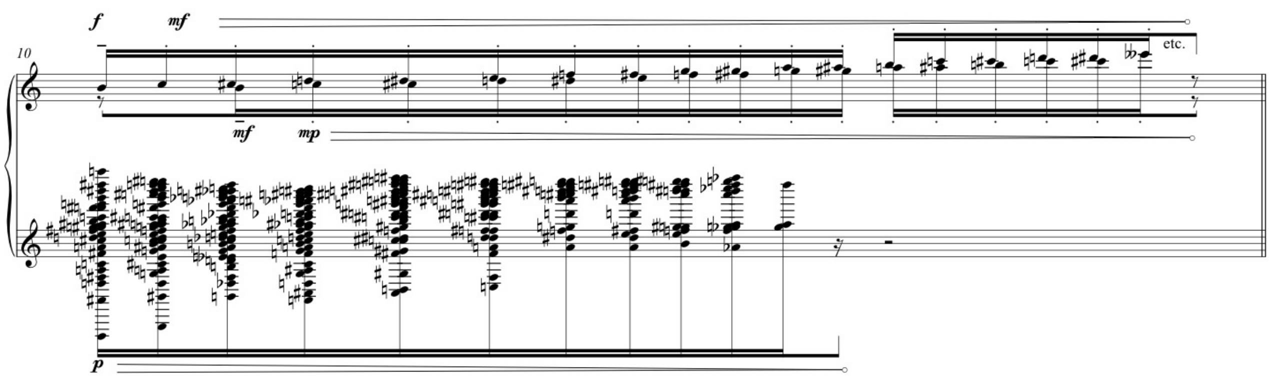
8 Instrumentation: piano 1 & 2, timpani and marimba
First appearance: mm. 136-137



9 Instrumentation: vibraphone (motor on), tubular bells, bass drum, pianos 1 & 2
First appearance: mm. 177-181



10 Instrumentation: pianos 1 & 2, marimba, xylophone and vibraphone
First appearance: mm. 90-94



11 Instrumentation: pianos 1 & 2 (e-bows) and bowed vibraphone
First appearance: mm. 296-300

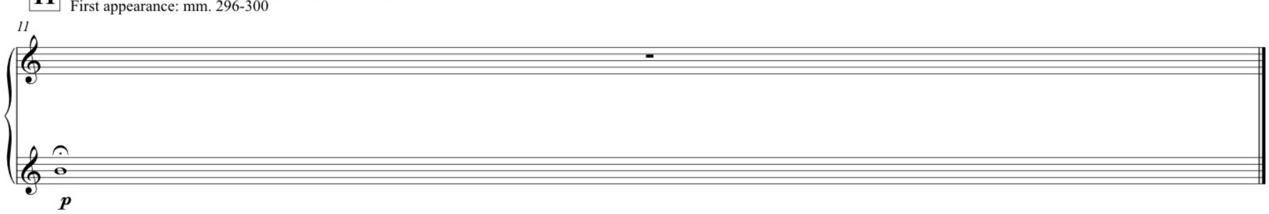


Figure 24 (Part II). Original analyses of rooms on the pitch B4

Figure 25 (Part I). Orchestration of rooms

Figure 25 (Part II). Orchestration of rooms

Figure 25 (Part III). Orchestration of rooms

Figure 25 (Part IV). Orchestration of rooms

Figure 25 (Part V). Orchestration of rooms

Room 3 first appears in measure 10 and is the brightest of all the rooms. This room alters the perception of the original impulse. The overall effect of this room is an EQed sound that is extremely dry and bright. The room has one reflection and a short reverb of approximately two seconds. The reflection always occurs one sixteenth-note after the impulse and is slightly sustained. Similar to Room 2, the impulse's natural harmonics are present; however, in Room 3 the harmonics are emphasized and overshadow the original impulse. In the dynamic curve of the room, the harmonics are always three dynamic levels higher than the impulse material and the reflection is one dynamic level lower than the impulse. For example, if the impulse is ***p**,* then the emphasized harmonics (or rather the resonance of the room) would be ***f***. For this room the impulse is articulated by the marimba and the room/harmonics are played by the xylophone.

Room 4 is introduced in measure 15 and has a slight reverb of just under 1.4 seconds, a high resonant factor, and one audible reflection. The room distorts the sound of the impulse by adding inharmonic components and adds both a high resonance that occurs with the attack of the sound and a low addition tone that occurs with the reflection.

In this room the impulse is played by the toy piano which is naturally inharmonic. The resonance of the room is emphasized by piano 2 and the suspended cymbal which is played simultaneously by the toy piano at one to two dynamic levels lower than the impulse. The piano plays one dynamic level lower than the toy piano and the cymbal plays two levels lower. The reflection is played by the marimba, piano 2, and the cow bell, and occurs one sixteenth-note after the impulse. The marimba and cow bell represent the room's resonance.The marimba always plays an A4 and one to three additional pitches from the room's natural resonance. This reflection is one dynamic level lower than the original impulse. The piano's reflection is a high harmonic of the original impulse and is two dynamic levels lower than the original impulse.

The first instance of Room 5 occurs in measure 39. Room 5 has a moderate reverb and an overall sound that is slightly sputtery. There are four clear reflections following the impulse. The room emphasizes the first natural harmonic (an octave higher) of both the impulse and three of the following reflections. The reflections have the following dynamic curve: two dynamic levels higher, one lower, two lower, and then three lower than the initial impulse. For example, if the impulse was ***mp,*** the reflections would be ***f, p, pp,*** and ***ppp,*** respectfully.

Overall, the room has a "shimmery" quality, which is reflected by the orchestration. The granularity of the impulse is orchestrated via a sweep of the wind chimes that coincide with two 32nd notes played by the vibraphone, followed by two 64th notes and one 32nd note in the crotales. The room's natural resonance is played by both the vibraphone and the crotales. The vibraphone plays an A#3 and C4, and the crotales play a G6 and C6. After playing the room's resonant pitches, the vibraphone and crotales emphasize harmonics from the impulse.

Room 6 first appears in measure 56. This room has seven reflections and an approximate reverb time of 3.6 seconds. The overall sound of the room is highly resonant, bright, and metallic. Piano 1 plays the initial impulse plus six reflections.

During the third reflection the piano also highlights some of the sound's upper harmonics. In the orchestration the celesta acts as the part of the room that emphasizes the impulse's harmonics which it cycles through with each reflection. The triangle both colors the impulse and highlights individual reflections. The dynamic characteristics of the room follow the subsequent sequence: impulse; followed by the first reflection which is one dynamic level lower than the impulse; reflection 2 which is two dynamic levels lower; reflection 3 that features a slight surge in the signal and is only one dynamic level; and reflections 4, 5, 6, and 7 which naturally fade to three dynamic levels lower than the original impulse.

Room 7 is not heard until measure 73 (beat 5) and persists to measure 75. Room 7 is highly reflective, has a moderate reverb, and an overall sputtery sound. The room has a high resonance and is the most "metallic" of all the rooms. The impulse has eight clear reflections that gradually fade. The room highlights the impulse's upper harmonics and causes a kind of swirl pattern that slowly dissipates. The impulse and initial attack is highly colored by harmonics.

In this room the impulse is played by the celesta. The vibraphone and the celesta play the subsequent reflections. The glockenspiel, crotales, and the celesta play the sputtery metallic harmonics that are emphasized in the room.

Room 8 is first introduced in measures 136-137. This room is very dry and has a maximum number of reflections. It is an "imagined" space and reflections increase in intensity as time passes—something that would not naturally occur in a real room. In my original analyses 33 clear reflections could be identified. However, due to the speed of the reflections I simplified them into a multi instrument tremolo.

The instruments used to orchestrate this room are marimba, timpani, piano 1, and piano 2. The marimba plays a figure (common in both the original analyses and the orchestration), and represents part of the natural resonance of the room. The timpani plays the reflections of the impulse. Piano 1's left hand plays the impulse, while the right hand plays the dark and gritty resonance of the room, followed by harmonics of the impulse (mixed with room's resonance) as a tremolo. Piano 2 plays harmonics of the original impulse.

Room 9 only appears twice throughout the piece. It first appears from measures 177-181**.** Room 9 is the most reverberant of all the rooms. It is also highly reflective and sputtery. The reverb tail is approximately 20-25 seconds. The resulting resonance of the room seems to pulse and is dark and low in pitch.

The room was orchestrated using pianos 1 and 2 as the impulse, and the bass drum and vibraphone as the resonance and reflections of the room. The vibraphone's motor is on for this section and provides a pulsing sensation. The tubular bells articulate a single clear reflection and the cymbal and bass drum color the impulse, helping orchestrate the gritty nature of the room.

Room 10 first appears in measures 90-94. The room is very dry and has many clear reflections. This room is somewhat odd because it starts with the impulse and then articulates a repetitive strand of sporadic and sputtery sixteenth-note reflections that step upwards chromatically. The impulse and the strand are echoed as well. This echo begins on the third sixteenth-note of the original strand. The room itself has a resonance that presents itself with the initial impulse.

For orchestration, room 10 uses both pianos, the marimba, xylophone, and vibraphone. The impulse, first strand, and echo begin in pianos 1 and 2. Strand one then moves to the marimba while strand two moves to the xylophone. The overall effect is that the sounds are thinning out and becoming dryer and brighter. The room's resonance is played by the vibraphone. In the original analysis the resonance is quite dense and gradually steps upwards with the reflections. I simplified this in the piece and the vibraphone plays a single four-note sustained chord.

The eleventh and final room of the piece represents an imaginary space that has a smooth onset and an infinite sustain. There are no reflections in this space, simply an "infinite reverb." This sound is achieved by the pianists playing e-bows on the piano strings and occasional bowed vibraphone sounds. Room 11 first appears in measures 296-300 and is the last new room presented.

In *Occupied Spaces* the impulses interact with the rooms. Both are essentially convolved. The rooms morph the inserted material and provide their own timbral trajectories. The finished piece is the result of the collision of two formal elements: the rooms themselves and the material inserted into them.

V. Summary and Conclusions

My primary objective as a composer is to write beautiful and stimulating music. For me, "beauty" is embodied by temporal, and in particular, timbral attributes. Over the past five years I have been working towards a compositional model in which the "color" and “texture” of available sounds are derived from models of timbre spaces.

While I have been attracted to other composers’ and researchers’ timbre models (including Penderecki, Spahlinger, Saariaho, Grisey, Slawson, Lerdahl, Cogan, and Erickson, to name just a few), I found them too limited in their scope and therefore strived to create one that combined many models into one. In my own research I have pored over the literature, studied perceptual timbre models, and picked a few studies, including Pollard and Janson’s tristimulus model, Wessel’s timbre model, Grey’s timbre space, McAdams’ timbre space, and the vocal tract filter, and tried to imagine how these studies could inform a composition. While this exercise was useful and suggests ways for a composer to manipulate musical parameters, they are missing a key element: no unpitched percussion or noise elements are explained. In order to encompass this crucial dimension I proposed a set of two spaces. The first space covers the frequency components of the sound and has the following dimensions: spectral flux, spectral centroid, and noise-to-pitch ratio. The second space controls the evolution of the sound and controls the attack quality, event duration, and the dynamic curve for any entering sound, gesture, or material. With this model, one can work with any sound or instrumentation. While this process is intuitive, it allows one to base a piece’s timbral decisions on an already existing acoustic model.

In my most recent works I have used nature sounds as stimuli and “everyday” sounds as material for my pieces. I am fascinated by the “color” of sounds and timing of events that surround us in our everyday lives. They are filled with rich material and offer incredible musical possibilities. With my model one can insert material into the space and zoom in and out of it as one desires. Similar to painting, with this model the composer not only gets to choose the "landscape," the composer can also control the perception and magnification of the material. The dimensions change slightly depending on what one chooses to highlight. Similar to visual art, the resulting piece would not be a copy of the source, but rather a representation of it.

The three pieces that form my final project examine both the compositional application of timbre spaces and the exploration of the concept "timbre *in* space." Each piece approaches timbre from a different perspective. *Ostiatim* explores the orchestration of noise and the use of timbre as a morphing device. Timbre informs the overarching formal structure as well as the material in *Clocca;* and *Occupied Spaces* explores timbre *in* space through filtered impulses and a series of rooms or spaces.

With each piece I compose I understand more, not only about timbre and the different ways to approach my composition model, but also about time and space. With this model each composition serves as a piece of a puzzle whose image reveals a more clear and complete understanding of not only timbre, but all musical parameters.

VI. Scores

6.1 Score for *Ostiatim*

The score for *Ostiatim* appears on pages 60-70.

Ostiatim

15 Fragments

By Leah Reid

For String Quartet

Notation key:

Abbreviations:

sul pont. = sul ponticello
ord. = ordinary
P = pressure
N = normal
IR = irregular
f.n. = fingernail
f.t. = fingertip

Finger Pressures:

= harmonic finger pressure
= half harmonic finger pressure
= normal finger pressure

Dynamics:

= crescendo from niente

= decrescendo to niente

Accidentals:

= quarter tone flat

= quarter tone sharp

= three quarter tones flat

= three quarter tones sharp

Noteheads:

= play on the bridge

= tap/hammer the string with finger

= tap body of instrument

Other:

= gradually increase speed to a tremolo

= gradually decrease speed from a tremolo to a sustained note

= moving towards, increase in, gradually becoming

= allow the sound to 'wilt'

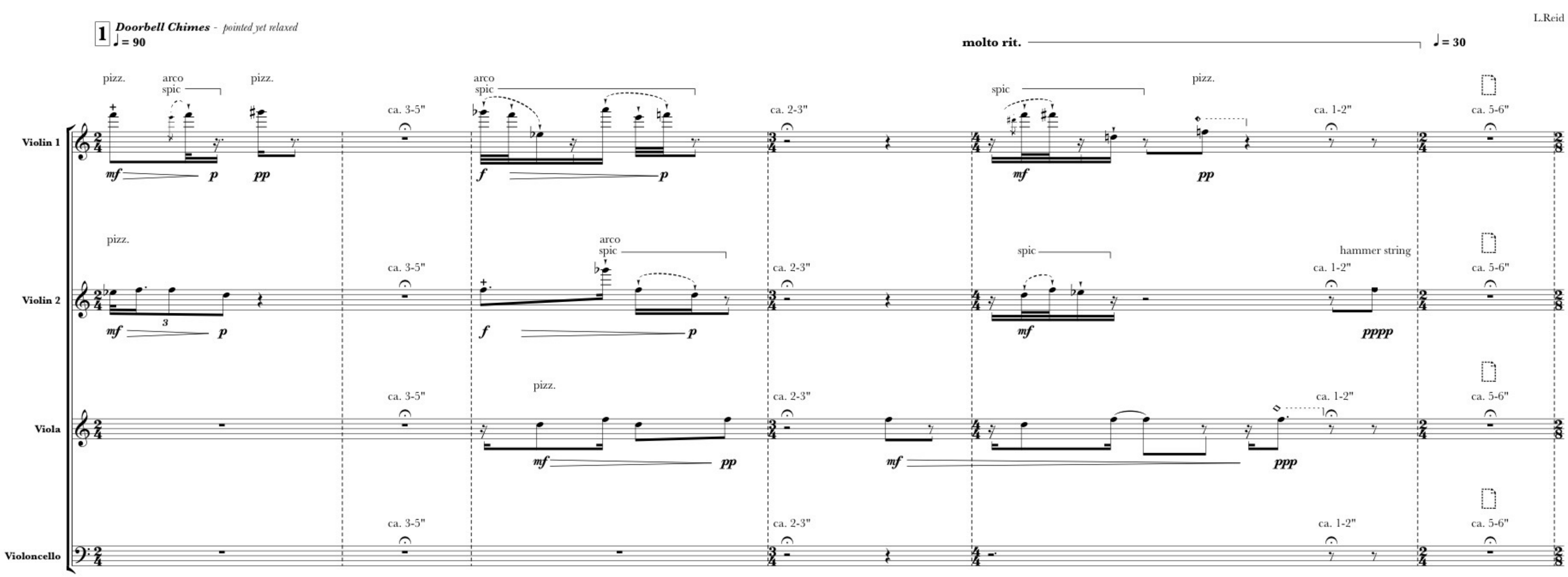
= There are two different size noteheads in the piece. Large noteheads should be treated normally, and small noteheads should be treated as grace notes.

General Notes:

- score is written in C
- accidentals carry through the bar
- the piece is approximately 11 minutes in length

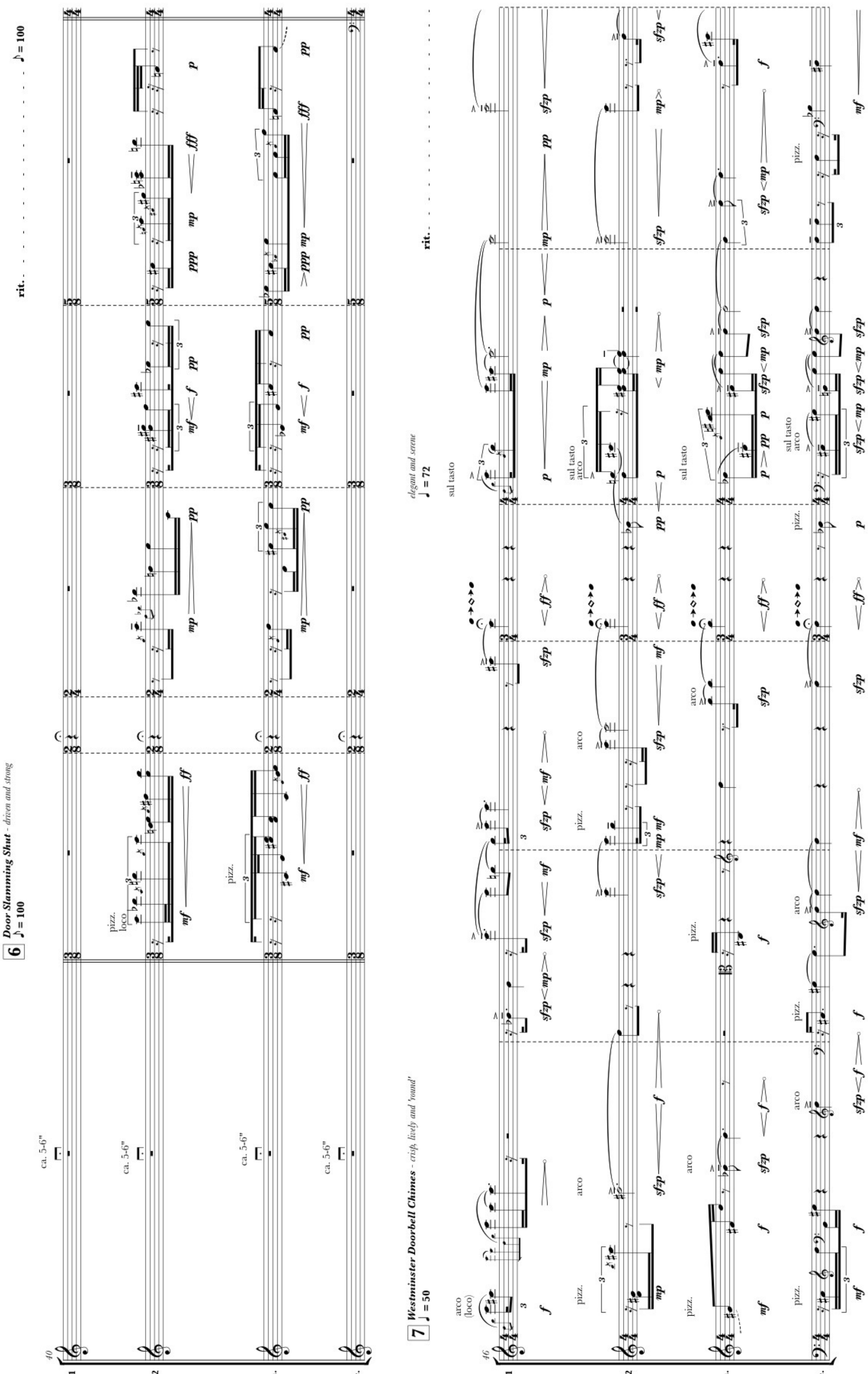
Ostiatim

15 Fragments




A tempo (♪ = 184)
2 Door Banging - fiery and aggressive
Vln. 1
Vln. 2
Vla.
Vc.
sul pont.
P
N
arco
pizz.
ord.
ca. 2-3"
sul tasto
(N)
* Vln.2 & Vc. - the grace notes in fragment 2 should be played as fast as possible
* Vln.2 & Vc. - treat small noteheads as grace-notes
♩ = 40
(Doorbell Chimes)
3 Door Slamming Shut - forceful vs. calm
♪ = 120
pizz
lightly tap string with fingertips
ca. 7-9"
ca. 3-4"
arco
on bridge
* Emerge from "nothing" allowing the sound to fade in and out.
*Let the bow slide down the string and gradually move towards the indicated pitch.
© L.Reid 2011

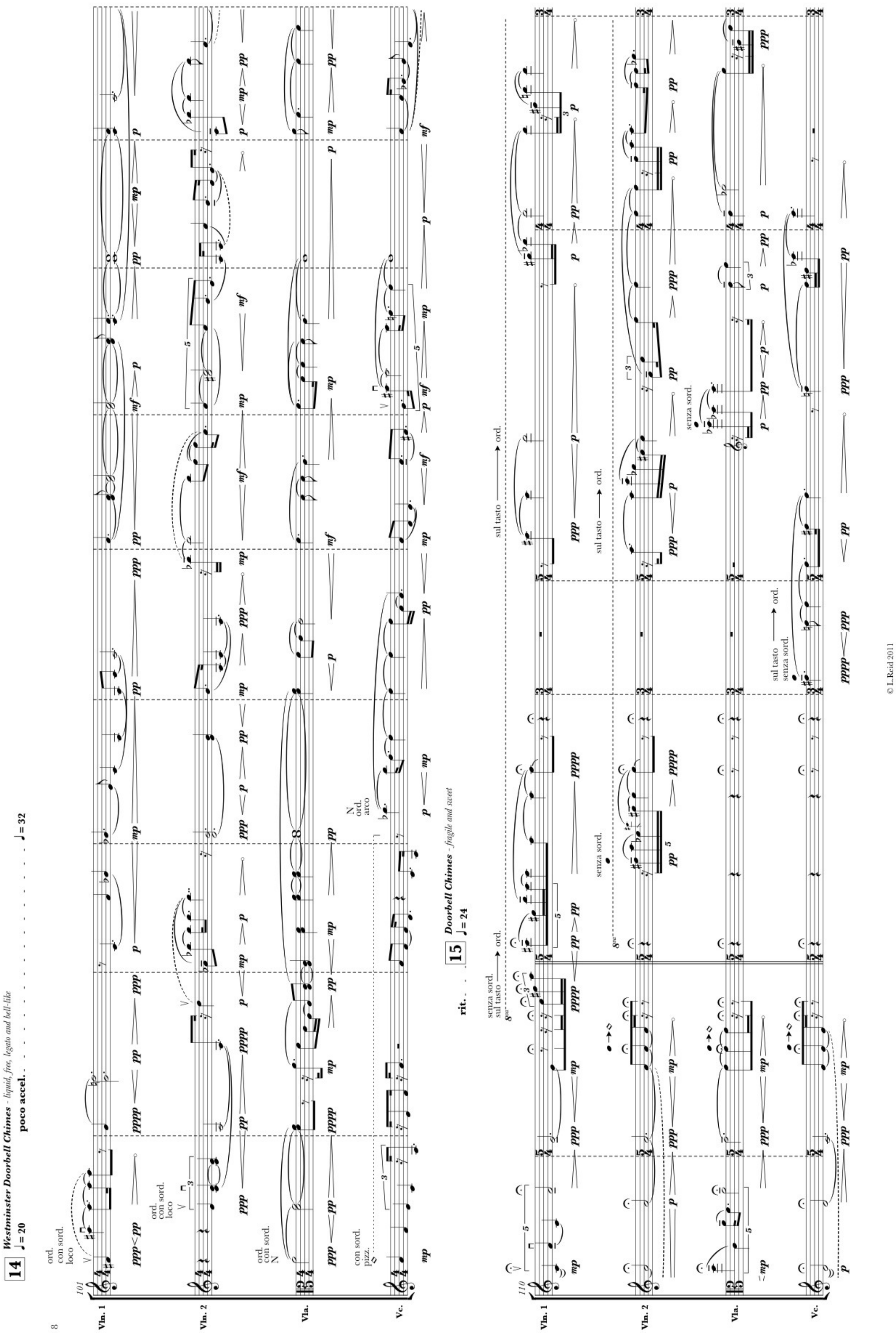

4 Doorbell Chimes - delicate
♩ = 55
poco rit.
♩ = 30
molto accel.
Vln. 1
Vln. 2
Vla.
Vc.
sul tasto
arco
pizz.
ord.
IR.
(pizz.)
*Vln.2 - allow the sound to fade in and out
5 Door Creaking Open - light, timid and precise
♩ = 90
rit.
♩ = 69
(ord.)
(arco)
loco
ord.
arco

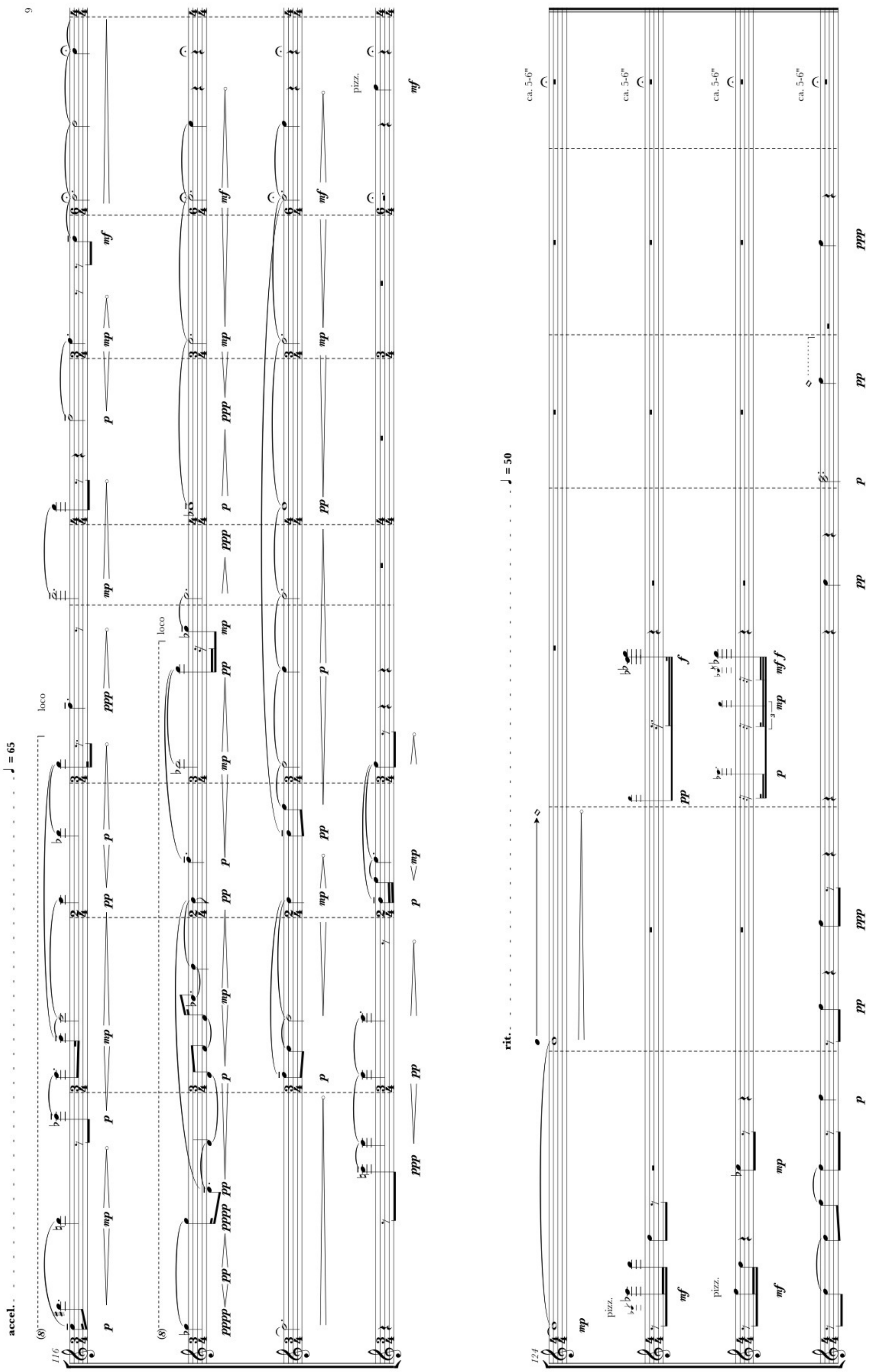

4
6 Door Slamming Shut - driven and strong
♪ = 100
rit.
♪ = 100
7 Westminster Doorbell Chimes - crisp, lively and 'round'
♩ = 50
elegant and serene
♩ = 72
sul tasto
Vln. 1
Vln. 2
Vla.
Vc.
© L.Reid 2011


8 Door Banging - careful...
molto accel.
violent and aggressive
timid and fading into the background
rit.
♩ = 50
♩ = 100
5
Vln. 1
Vln. 2
Vla.
Vc.
sul pont.
pizz.
arco
l.v.
loco
hammer string
sul tasto
ca. 2-4"
ca. 6-7"
9 Door Creaking - romantic and lush
♩ = 40
rit.
♩ = 30
10 Knocking
♪ = 160
ord.
sul tasto arco
senza vib.
vib.
ca. 2-3"
ca. 3-5"
timidly knock on the tailpiece
slowly, cautiously, and slightly unevenly knock on the back of the instrument


71
Vln. 1
Vln. 2
Vla.
Vc.
ca. 3-4"
ca. 9-10"
urgently knock on the body of the instrument -starting from the tailpiece and moving towards the scroll
slow
fast
11 Door Slamming Shut - driven and agitated
♪ = 120
accel.
♪ = 200
pizz.
arco
loco
*Vla. - as loud as possible
12 Door Creaking - airy and fleeting
79
extreme sul pont.
ord.
timidly knock on instrument, moving up the body from tailpiece to scroll
tap nose of instrument with fingertip
tap scroll with fingertip
tap scroll with fingernail


7
Vln. 1
Vln. 2
Vla.
Vc.
rit.
♪ = 110
sul tasto
extreme sul pont.
ord.
knock bottom of instrument
tap the body of the instrument moving from the scroll down to the f-holes
tap body with fingertip
tap: scroll–nose–scroll
tap body moving from f-hole to tailpiece
13 Door Banging - ferocious
♩ = 68
loco
arco
sul pont.
ca. 5-6"
ca. 6-7"
* Vla. & Vc. alternate: thumb–f.n.–thumb
© L.Reid 2011


8
14 Westminster Doorbell Chimes - liquid, free, legato and bell-like
♩= 20
poco accel.
♩= 32
Vln. 1
Vln. 2
Vla.
Vc.
ord.
con sord.
loco
pizz.
arco
rit.
15 Doorbell Chimes - fragile and sweet
♩= 24
senza sord.
sul tasto
ord.
© L.Reid 2011



9
accel.
♩ = 65
loco
pizz.
rit.
♩ = 50
ca. 5-6"
Vln. 1
Vln. 2
Vla.
Vc.

6.2 Score for *Clocca*

The score for *Clocca* appears on pages 72-105.

Clocca

By Leah Reid

FOR CHAMBER ENSEMBLE

Clocca

Instrumentation:

- Flute: (Piccolo (sounding 1 octave higher) and Flute)
- Oboe: (Oboe and English Horn)
- Clarinet in B ♭
- Trumpet in B ♭
- Trombone
- Percussion:
    - triangle
    - 5 wood blocks
    - ratchet
    - snare drum
    - bass drum
    - glockenspiel (sounding 2 octaves higher)
    - xylophone (sounding 1 octave higher)
    - vibraphone
    - tubular bells
- Piano
- Violin
- Viola
- Violoncello

General Notes:

- The score is in C
- Accidentals carry through the bar
- Unless otherwise marked, all trills should be played a semi-tone higher
- The piece is approximately 11 minutes in length

Notation Key - All:

Abbreviations:

IR = irregular

Dynamics:

= crescendo from niente

= decrescendo to niente

Accidentals:

= quarter tone flat

= quarter tone sharp

= three quarter tones flat

= three quarter tones sharp

Other:

= gradually increase speed to a tremolo

= gradually decrease speed from a tremolo to a sustained note

= moving towards, increase in, gradually becoming

= allow the sound to 'wilt'

= There are two different size noteheads in the piece. Large noteheads should be treated normally, and small noteheads should be treated as grace notes.

Notation Key - Winds & Brass:

Abbreviations:

K.C. - key click

P.T. - percussive tonguing

L.P. - lip pop

P.S. - percussively spoken

Noteheads:

- key click

- air sound

- percussive tonguing / lip pops / percussively spoken

Notation Key - Strings:

Abbreviations:

ord. = ordinary

P = pressure

N - normal

S.P. - sul ponticello

S.T. - sul tasto

Noteheads:

= play on the bridge

= tap body of instrument

Finger pressures:

= harmonic finger pressure

= half harmonic finger pressure

= normal finger pressure

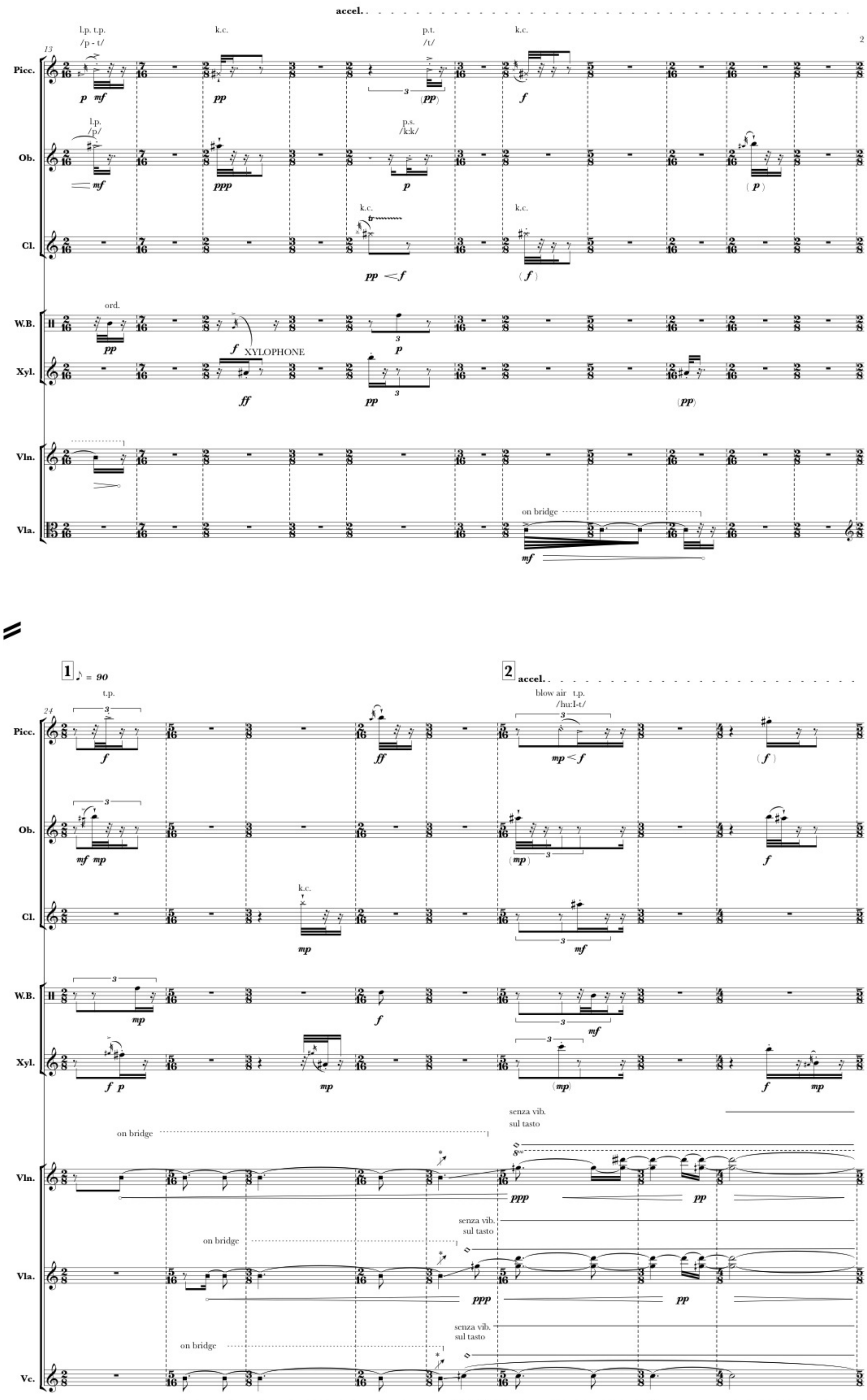
Note to Percussionist:

- The clockenspiel and vibraphone need to be stacked. The wood blocks and triangle should be in lose range as well

- The vibraphone's motor should be off

Clocca

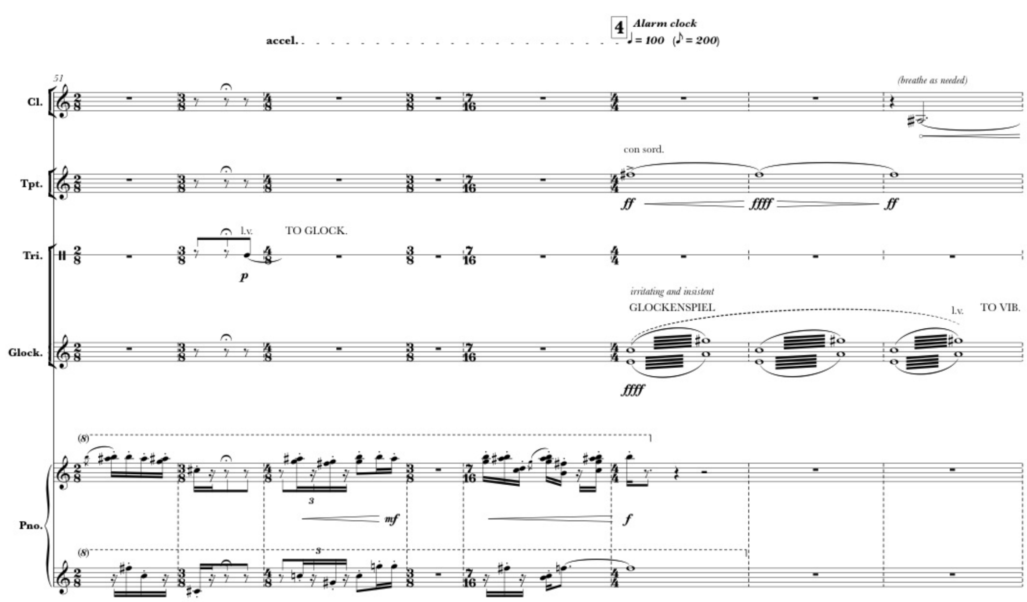

Drips of water
♪ = 42
accel.
♪ = 66
L.Reid
Piccolo
Oboe
Clarinet in B♭
Trumpet in B♭
Trombone
Wood Blocks
Xylophone
Piano
Violin
Viola
Violoncello
l.p. p.t.
/p - t/
blow air
/ʃ-----------------u/
k.c.
suck in air p.t.
/hu--I------t/
l.p.
/p/
blow air
/s--------
p.t.
/t/
l.p. p.t.
/p - t/
p.t. l.p.
/k - p/
(*as possible)
WOOD BLOCKS
dampen
XYLOPHONE
on bridge

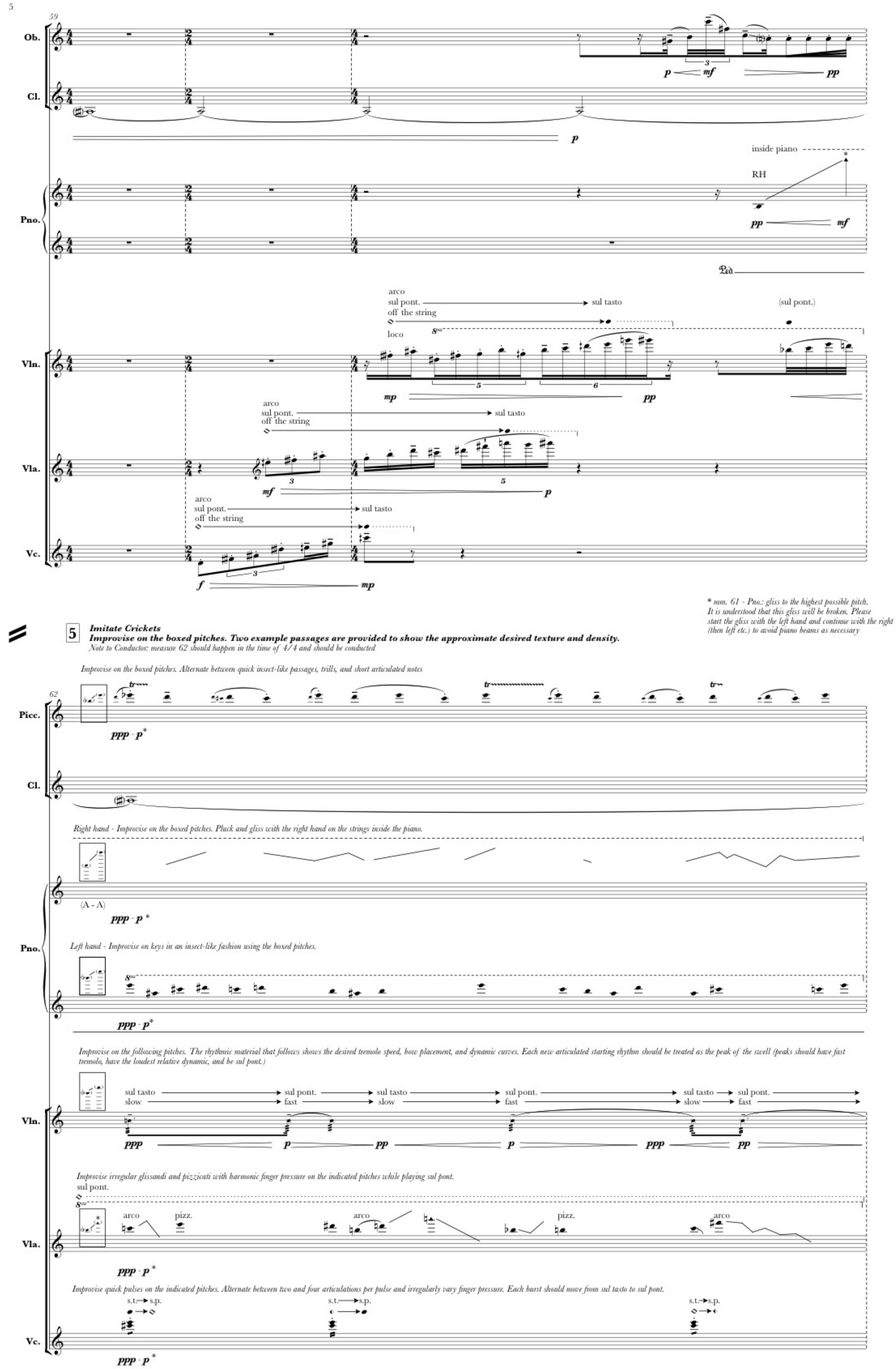


* mm. 28 - Vln., Vla., Vc.: Let the bow slide down the string and gradually move towards the indicated pitch


♪ = 110
accel.
Picc.
Ob.
Cl.
W.B.
Xyl.
Vln.
Vla.
Vc.
air flutt.
k.c.
flutt.
con vib.
slow rate of vib. to an irregular and wide pulse
senza vib.
sul pont.
♪ = 140
speed up tonguing and transition to flutt.
loco
ord.
pizz.
arco


3 Ticking Clock
♪ = 120
4
46
Picc.
Ob.
Cl.
Tri.
Xyl.
Pno.
Vln.
Vla.
Vc.
subito mp
sfzp
fff
flutt.
TRIANGLE
l.v.
TO TRI.
percussive yet light - like a ticking clock
sul tasto
extreme sul pont.
arco

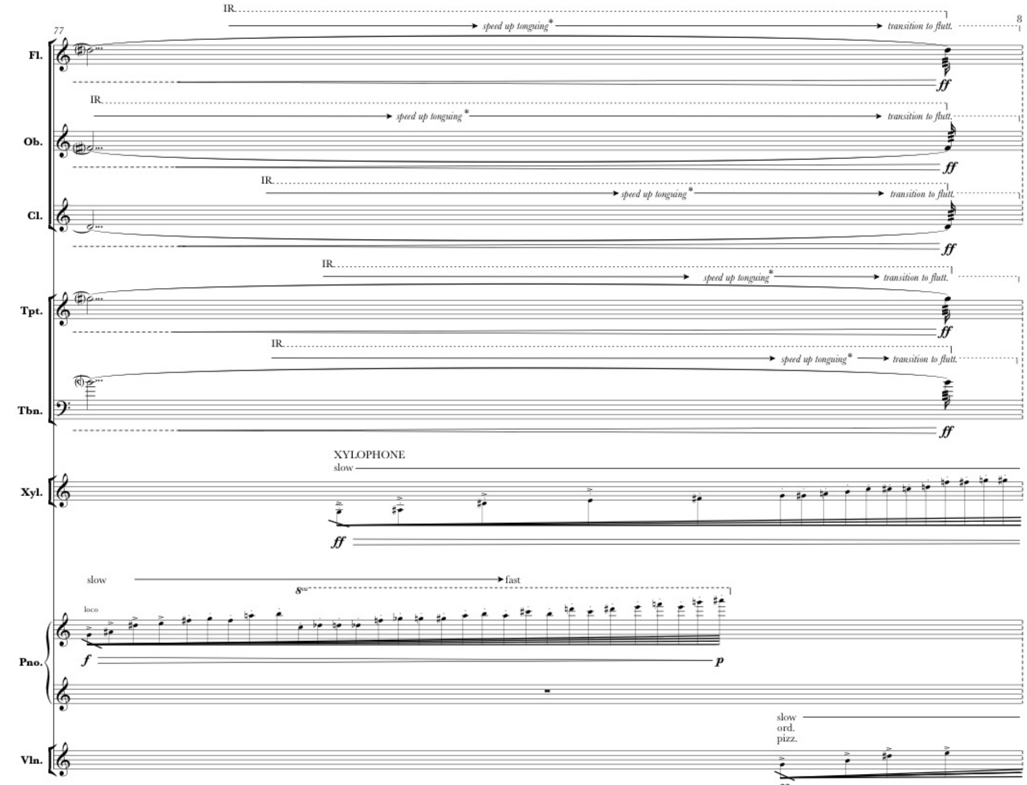

accel.
4 Alarm clock
♩= 100 (♪ = 200)
51
Cl.
Tpt.
Tri.
Glock.
Pno.
(breathe as needed)
con sord.
TO GLOCK.
irritating and insistent
GLOCKENSPIEL
l.v.
TO VIB.



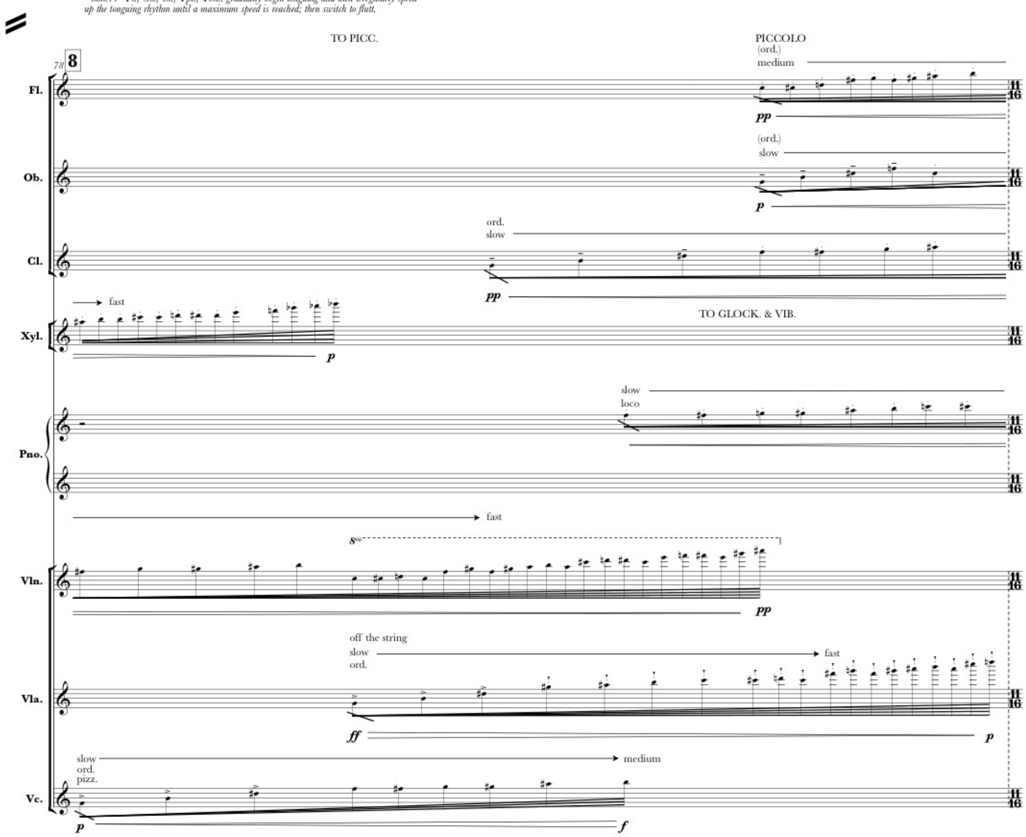
* mm. 62 - Vla.: as high as possible
* mm. 62 - Picc., Pno., Vla., Vc.: Irregularly vary dynamics, ranging from **ppp** - **p**.

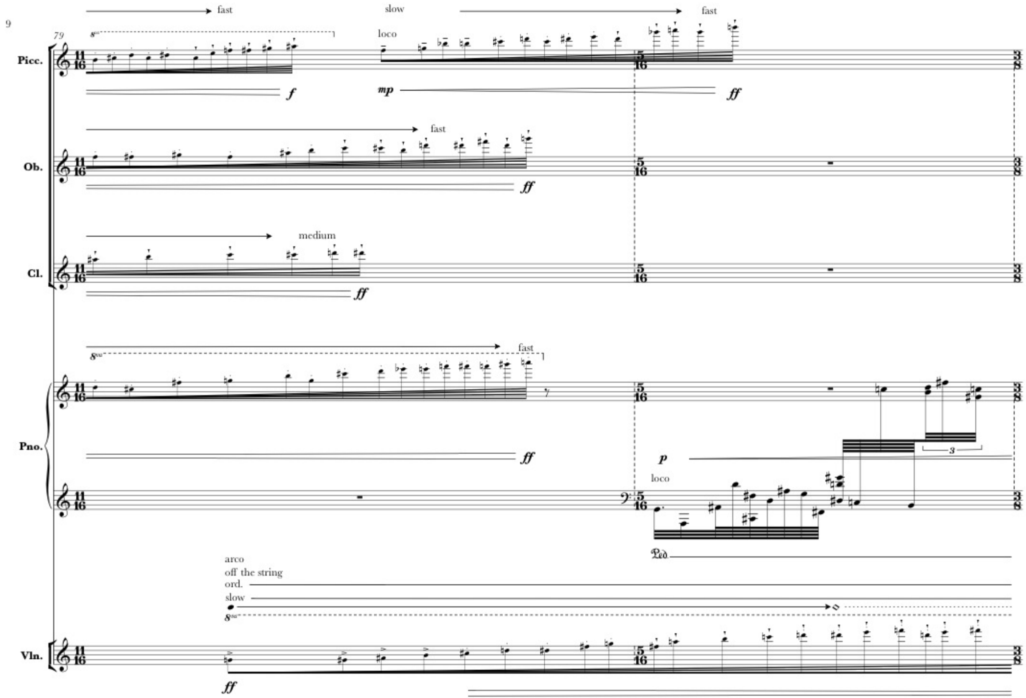
rit.
6
Fire alarm
♪ = 90 (♩ = 45)
6
63
Decrease density over time
and gradually elongate pitches
without corresponding to the new tempo
sim.
Picc.
Ob.
ppp
*
(breathe as needed)
Cl.
con sord.
Tpt.
mp
mf
p
mp
bow
TO XYL.
Vib.
ppp
Pno.
sim.
Vln.
Vla.
Vc.
* mm. 67 - Ob.: as soft as possible
68
Softly and irregularly fluctuate between 'niente' and 'pp'
pp
(breathe as needed)
mf
mp
mf
mp
mf
p
con sord.
Tbn.
p
mf
mp
mf

* mm. 76 All: This indication is meant to illustrate what is happening in the section, and should not be treated as a tempo marking



* mm.77- Fl., Ob., Cl., Tpt., Tbn.: gradually begin tonguing and then irregularly speed up the tonguing rhythm until a maximum speed is reached; then switch to flutt.

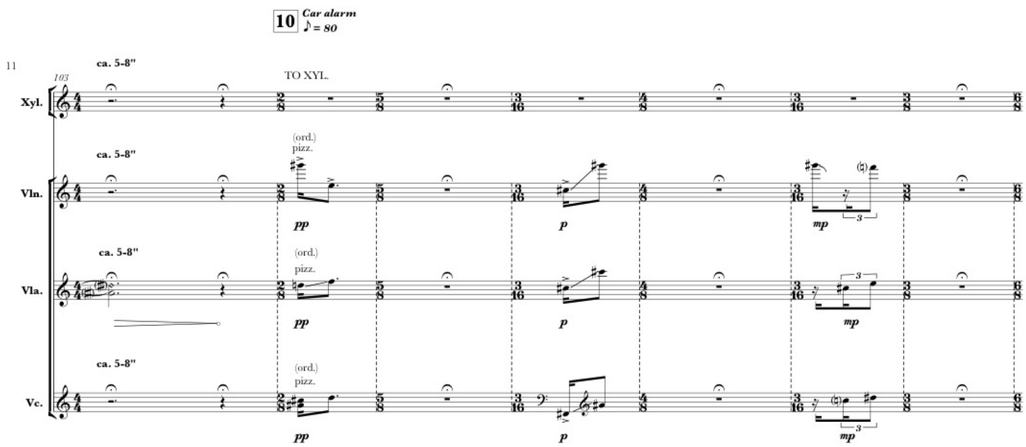


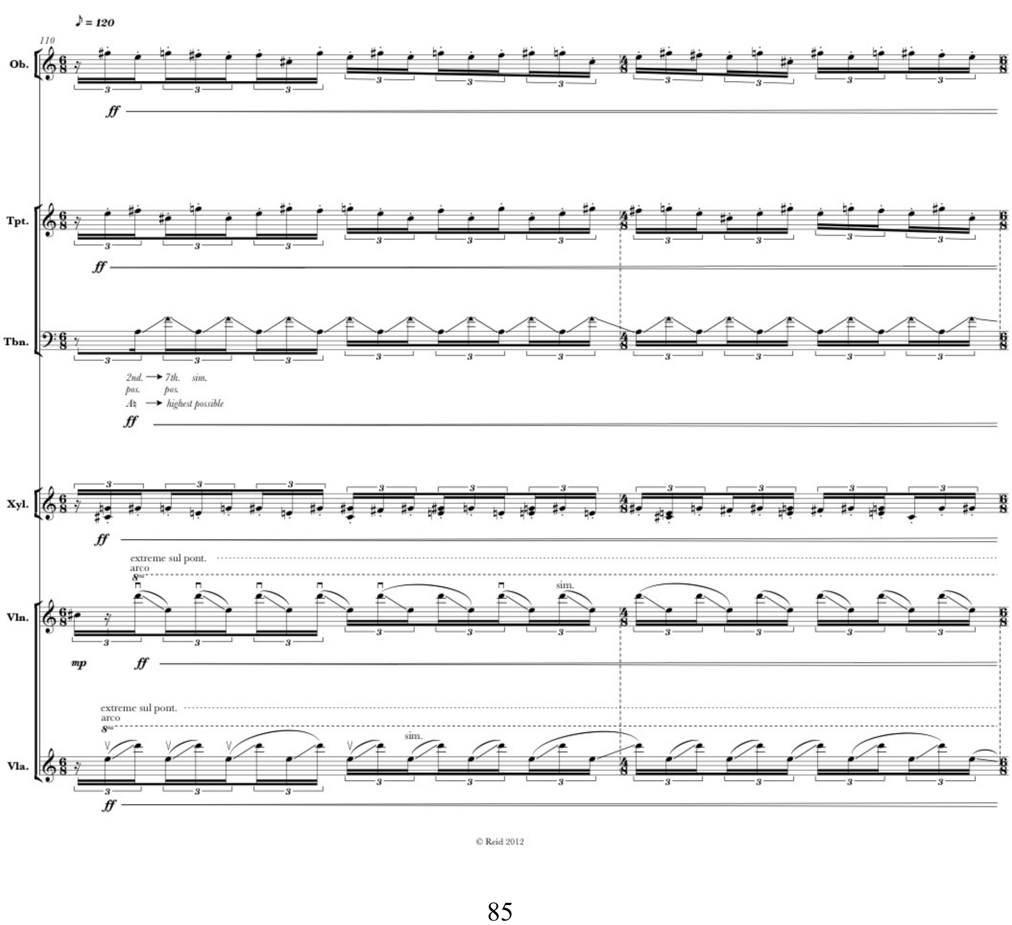


9
79
fast
slow
fast
loco
Picc.
f
mp
ff
fast
Ob.
ff
medium
Cl.
ff
fast
Pno.
ff
p
loco
Ped.
arco
off the string
ord.
slow
Vln.
ff

9
Wind Chimes
♪ = 42
accel.
81
Picc.
Ob.
Cl.
GLOCKENSPIEL
Glock.
VIBRAPHONE
Vib.
Ped.
Pno.
ff
sul pont.
fast
(8)
Vln.
p


89
Picc.
Ob.
Cl.
Glock.
Vib.
senza vib.
sul tasto
loco
Vln.
senza vib.
sul tasto
Vla.
arco
senza vib.
sul tasto
Vc.
♪= 80
molto accel.
♪= 120
97
Picc.
Ob.
Cl.
senza sord.
Tpt.
senza sord.
Tbn.
l.v.
Glock.
con rapid vib.
ord.
extreme sul pont.
P
Vln.
con rapid vib.
ord.
extreme sul pont.
P
Vla.
ord.
con rapid vib.
extreme sul pont.
P
Vc.


11
10
Car alarm
♪ = 80
103
ca. 5-8"
TO XYL.
Xyl.
(ord.)
pizz.
Vln.
pp
p
mp
Vla.
Vc.


♪ = 120
110
Ob.
ff
Tpt.
Tbn.
2nd. pos. → 7th. pos. sim.
A♮ → highest possible
Xyl.
extreme sul pont.
arco
8va
sim.
Vln.
mp
Vla.


accel. ♪= 158
12
112
Ob.
Tpt.
Tbn.
fff
TO WOOD BLOCKS
WOOD BLOCKS
slow
fast
W.B.
p
ff
Xyl.
fast
pizz.
slow
Vln.
mp
pp
Vla.
pizz.
Vc.
ff
11 Clock
♪= 200 (♩= 100)
accel.
TO WOODBLOCKS & RATCHET
115
light and percussive
Pno.
p
♪= 140
RATCHET
119
Rt.
sfzp
WOOD BLOCKS
mf
sub.pp
Ped.

* mm. 122 - Picc., Ob., Cl.: as fast as possible
mm. 122 - Tpt.: sweep up through the harmonic series as high as possible


125
Tpt.
Tbn.
S. D.
loco
arco
pizz.
Vla.
Vc.
accel.
127
Ob.
Cl.

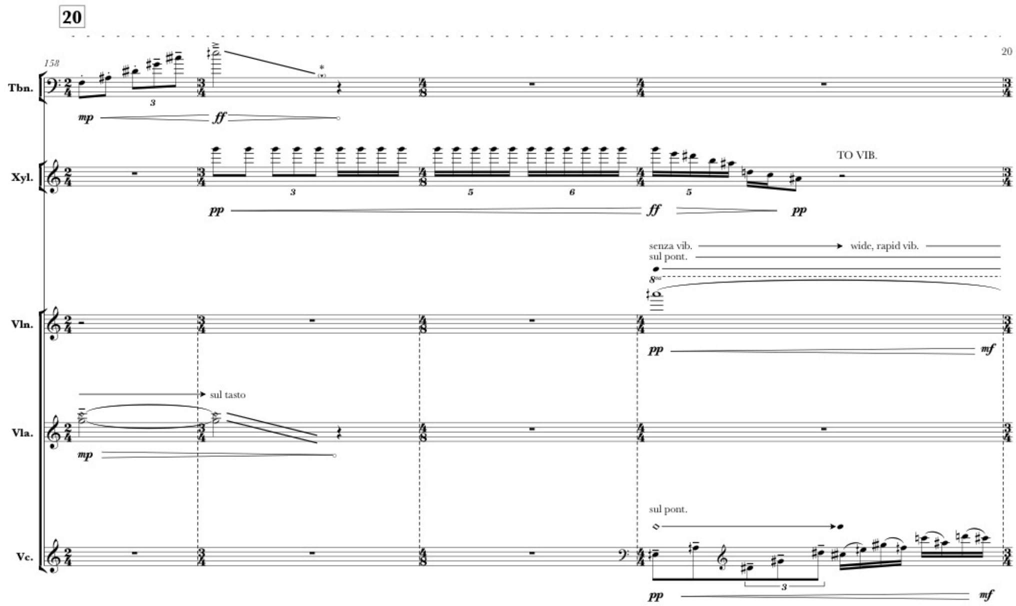

15
♩= 90
molto accel.
♩= 144
129
Ob.
Cl.
Tpt.
Tbn.
S. D.
slow
fast
Pno.
Vla.
Vc.
pizz.
arco
sub.mp
sub.mf
sub.f
sfzp


14 Alarm / Bell
15 Half Hour Chime ♩ = 110
131
Picc.
Ob.
Cl.
Tpt.
Tri.
Glock.
Vib.
Pno.
Vln.
TO OB.
Tpt.: If the D is too problematic, please play the following alternate.
con sord.
TO GLOCK., VIB., & TRI.
TRIANGLE
l.v.
GLOCKENSPIEL
VIBRAPHONE
pizz.
loco
135
rall.
♩ = 80
TO W.B. (& VIB.)

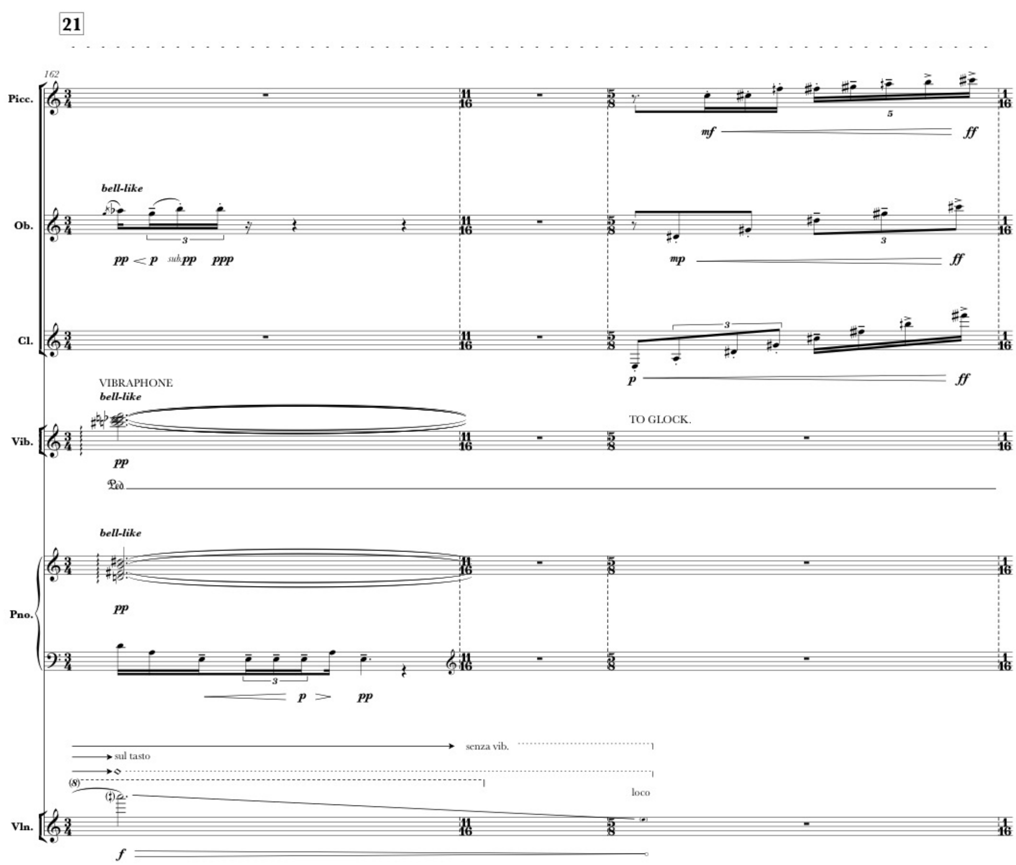

16
sub. ♩ = 180
molto accel.
17
137
Picc.
Ob.
OBOE
Cl.
Tpt.
Tbn.
WOOD BLOCK
W.B.
Glock.
TO W.B. & VIB.
VIBRAPHONE
Vib.
Pno.
arco
ord.
loco
sul tasto
(sul tasto)
loco
Vln.
senza vib.
con vib.
sul tasto
ord.
ord.
loco
Vla.
ord.
pizz.
(pizz.)
Vc.


17
18
142
Picc.
Ob.
Cl.
Tpt.
Tbn.
Xyl.
Pno.
Vln.
Vla.
Vc.
con sord.
TO XYL.
XYLOPHONE
TO GLOCK.
senza vib.
con vib.
rapid wide vib.
extreme sul pont.
sub. P
ord.
arco
146
flutt.
(con sord.)
GLOCKENSPIEL
Glock.
sul pont.
loco

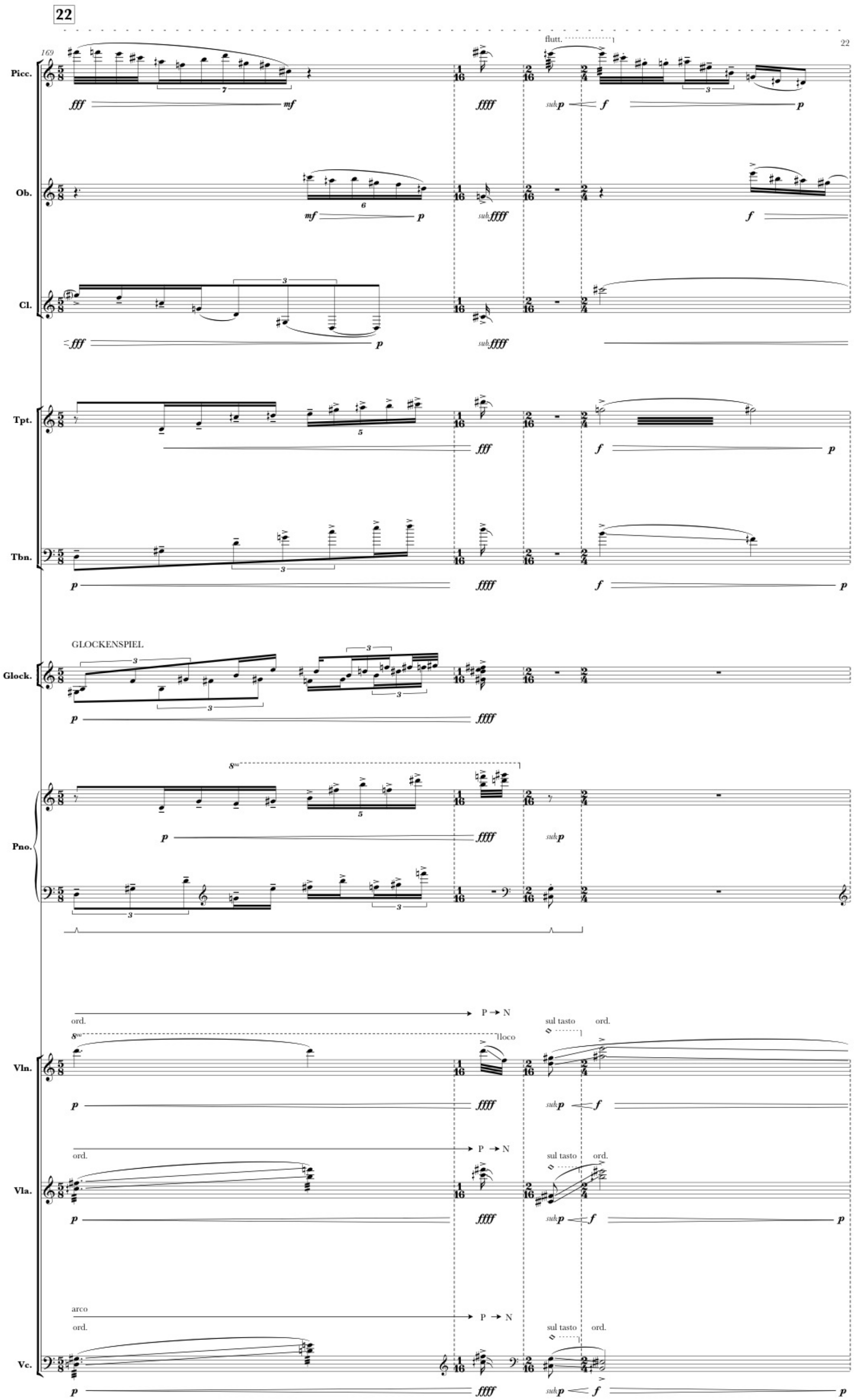

18
152
Picc.
Ob.
Cl.
Tpt.
Tbn.
Xyl.
Vln.
Vla.
Vc.
senza sord.
senza sord.
loco
XYLOPHONE
arco
extreme sul pont.
P
arco
extreme sul pont.
P
arco
(ord.)
19
155
senza vib.
con vib.
flutt.
Glock.
TO GLOCK.
GLOCKENSPIEL
sul tasto
loco
extreme sul pont.
sul tasto
loco
sul pont.



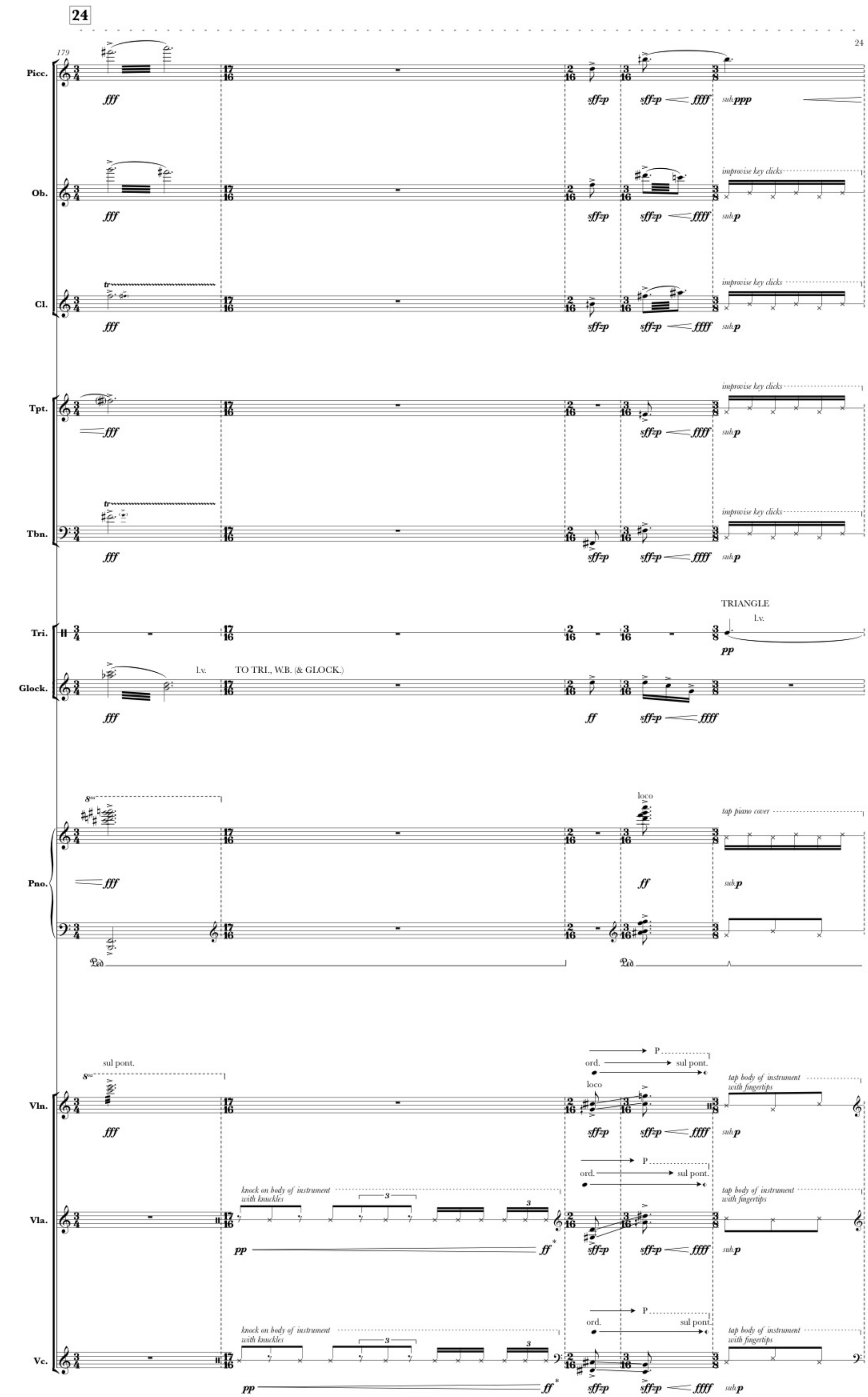
* mm. 159 - Tbn.: lowest possible note with smooth gliss.



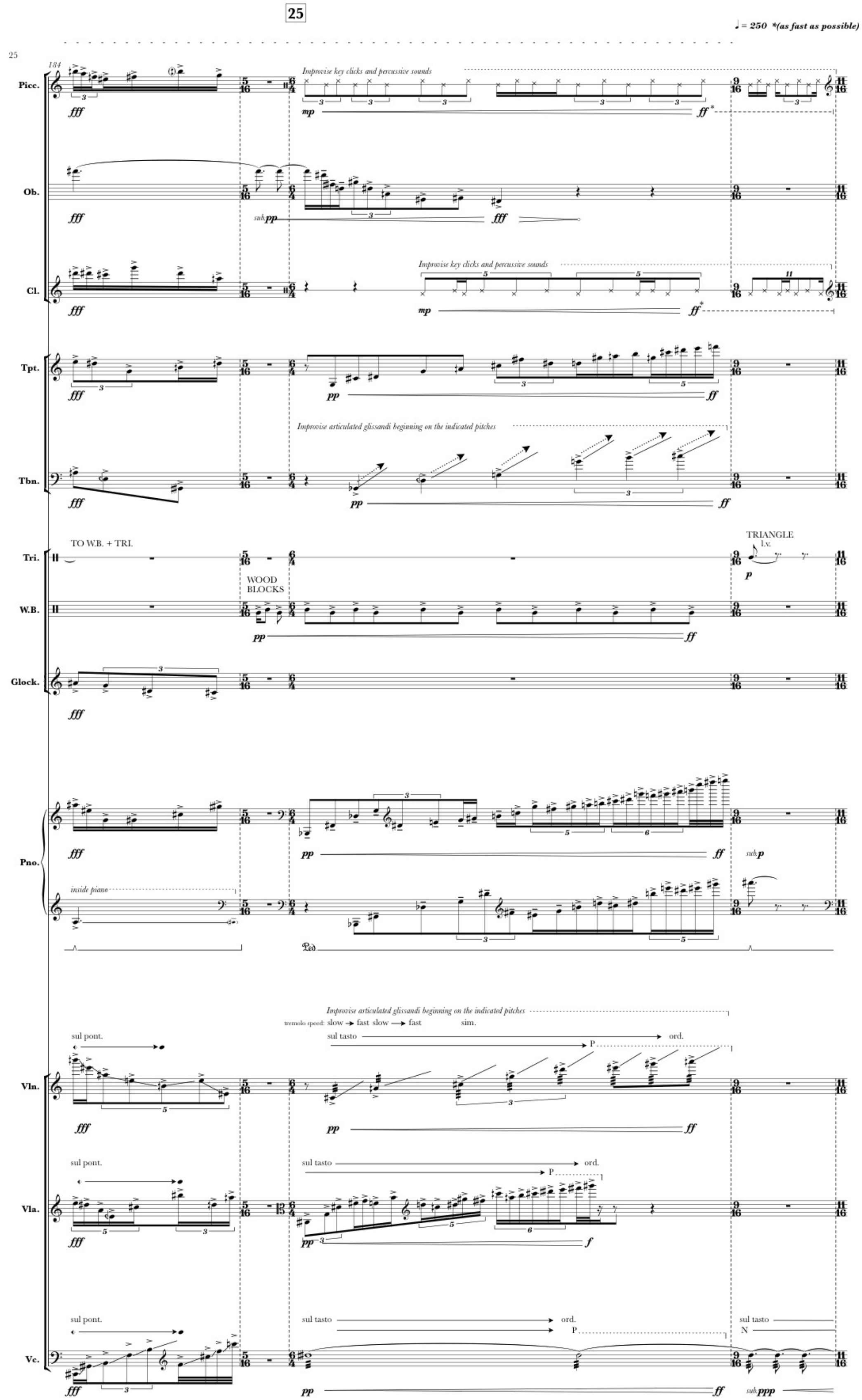

21
165
slow
fast
Picc.
sub p
ff
sfzp
fff
Ob.
Cl.
ppp
Tpt.
f
Tbn.
Vib.
Pno.
8va
Ped.
sul tasto
ord.
sul pont.
Vln.
Vla.
Vc.
pizz.


22
169
Picc.
flutt.
Ob.
Cl.
Tpt.
Tbn.
GLOCKENSPIEL
Glock.
Pno.
ord.
P → N
sul tasto
ord.
loco
Vln.
Vla.
arco
Vc.

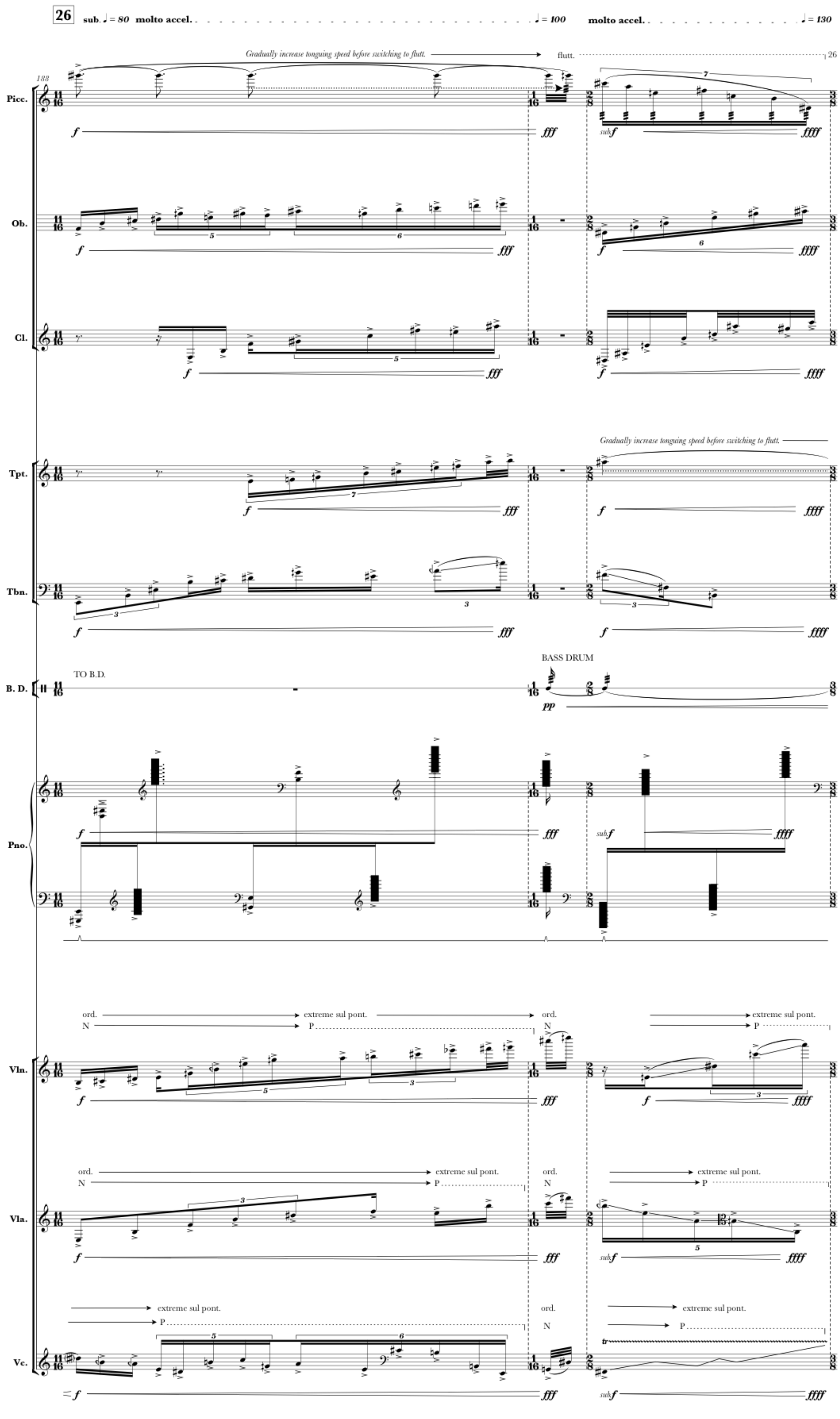

23
173
Ob.
Cl.
Pno.
loco
Vln.
Vla.
Vc.
sul tasto
sul pont.
176
Picc.
Tpt.
una corda
short and light
ord.

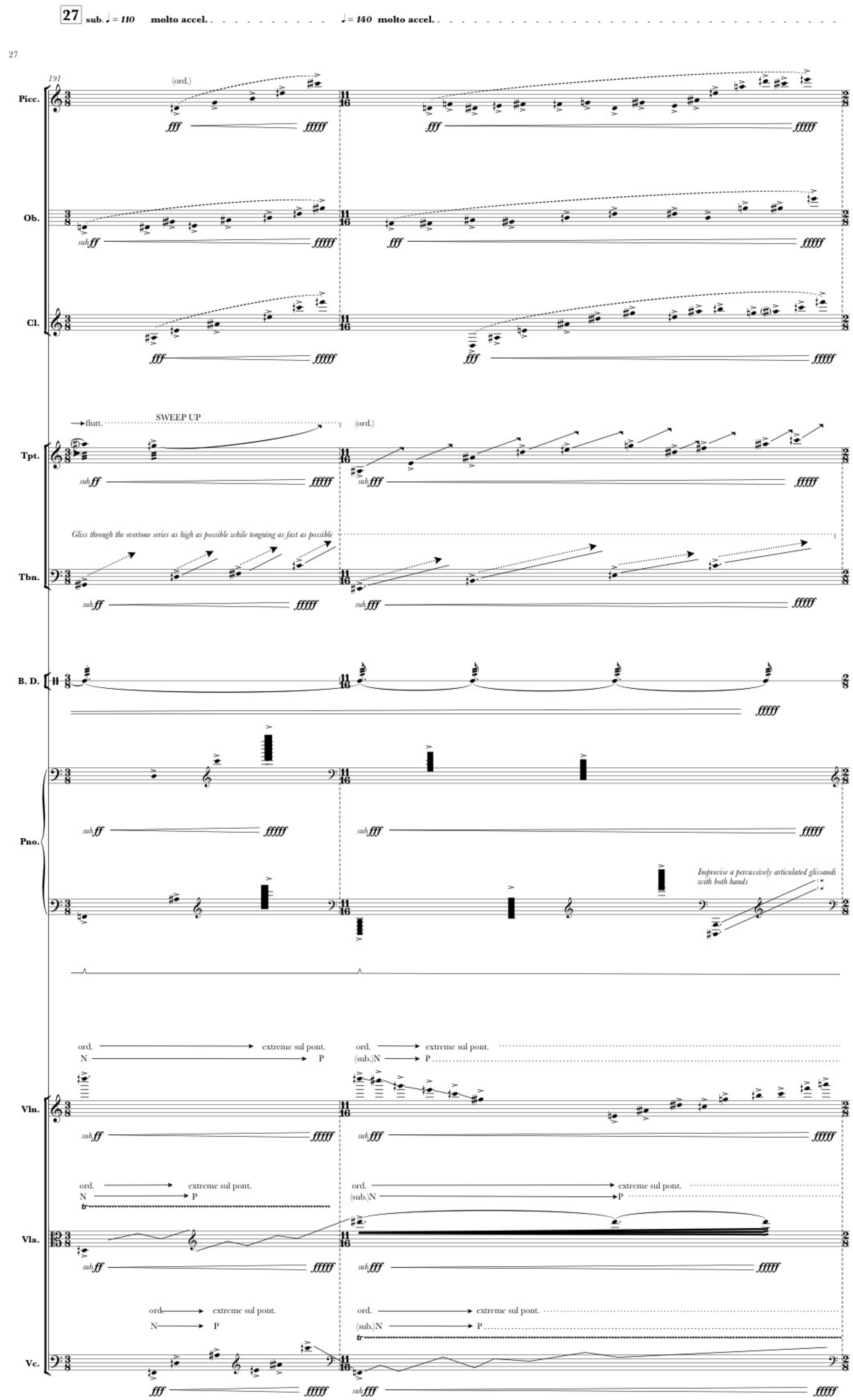


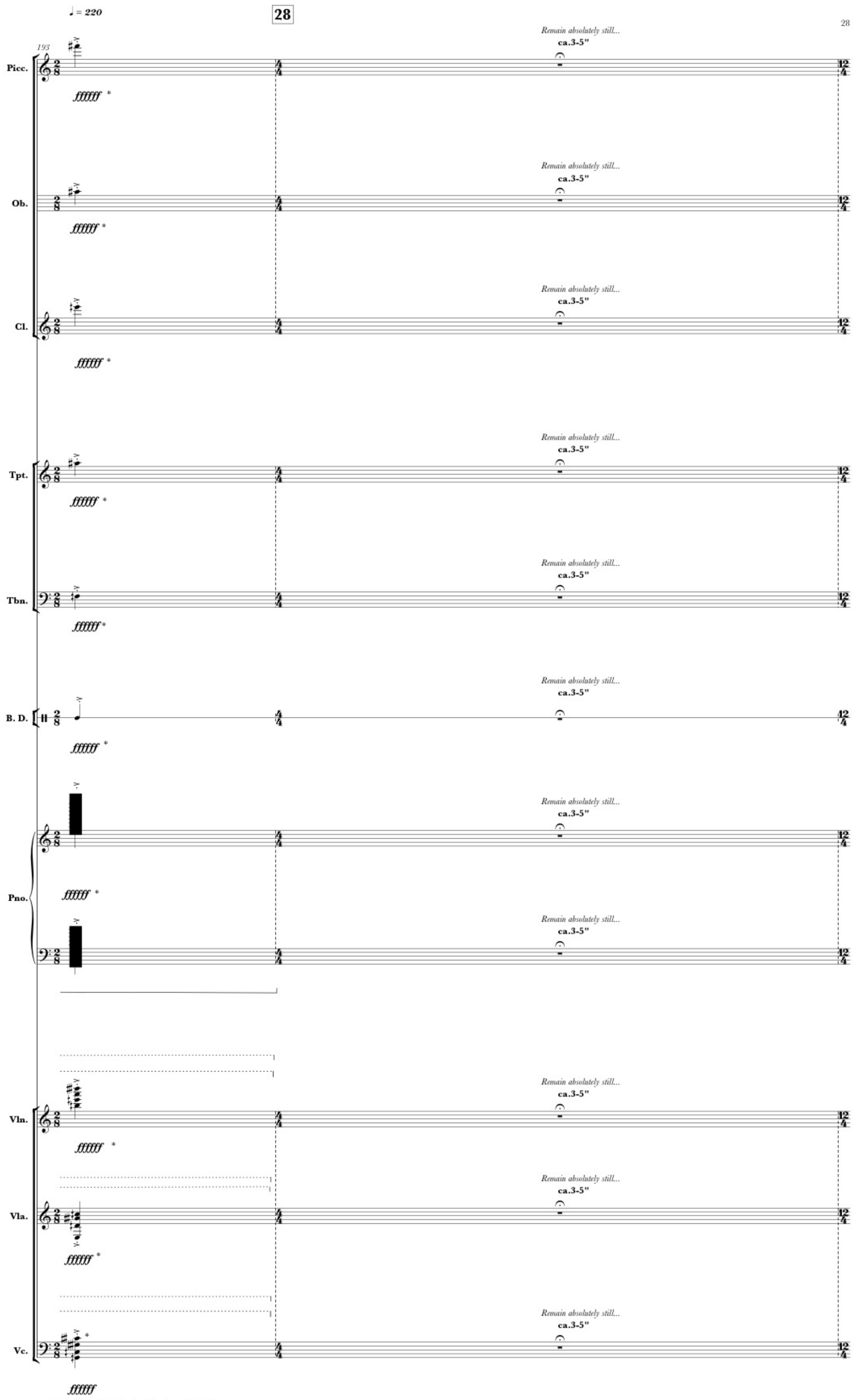
* mm. 180 - Vla., Vc.: as loud as possible (without damaging unstrument)



* mm. 186-187 - Picc., Cl.: as loud as possible

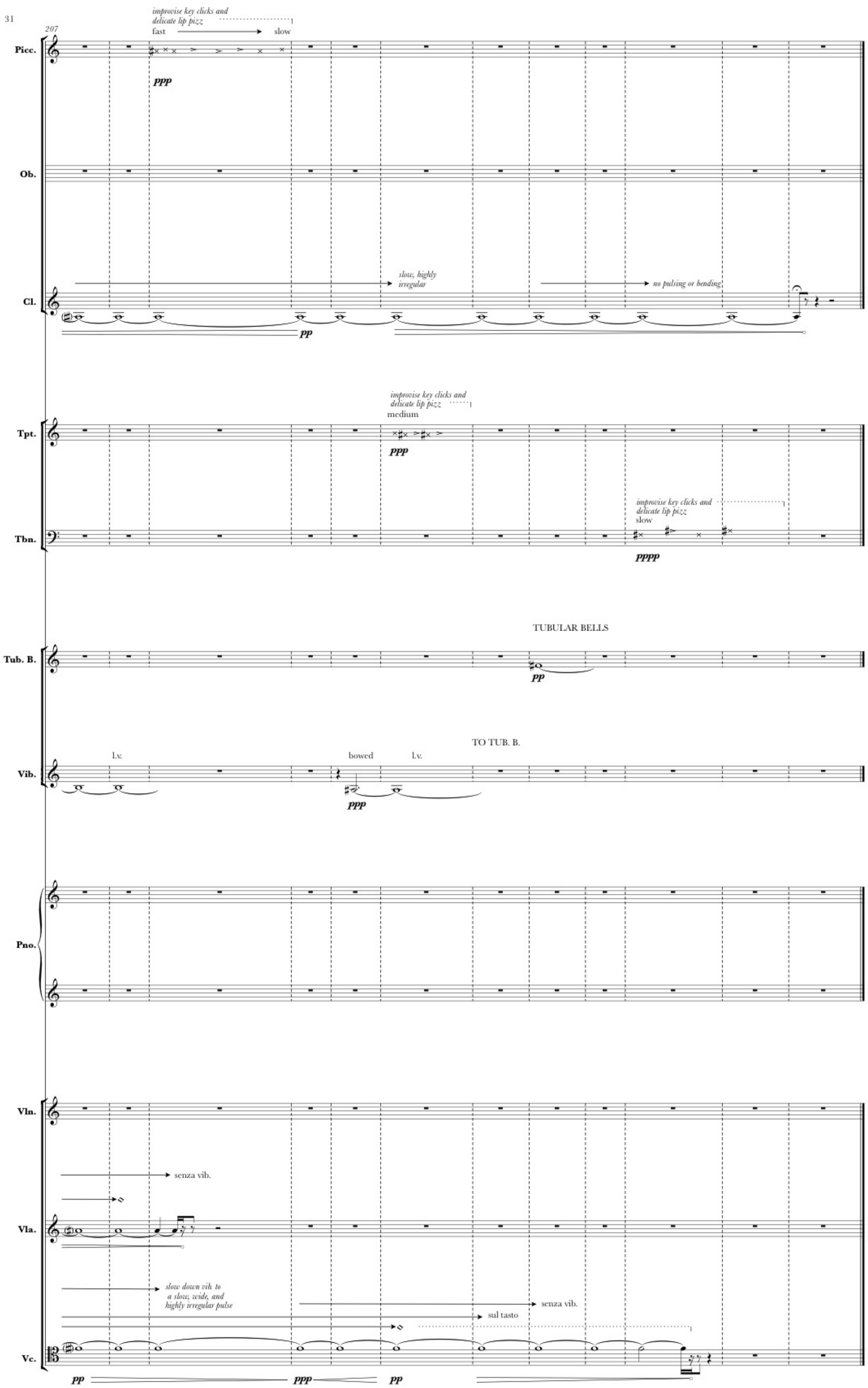

26
sub. ♩ = 80 molto accel. ♩ = 100 molto accel. ♩ = 130
188
Gradually increase tonguing speed before switching to flutt.
flutt.
Picc.
Ob.
Cl.
Gradually increase tonguing speed before switching to flutt.
Tpt.
Tbn.
TO B.D.
BASS DRUM
B. D.
Pno.
ord.
N
extreme sul pont.
P
Vln.
Vla.
Vc.


27
sub. ♩ = 110 molto accel.
♩ = 140 molto accel.
27
191
Picc.
(ord.)
fff
fffff
Ob.
sub. ff
fffff
Cl.
Tpt.
flutt.
SWEEP UP
(ord.)
Gliss through the overtone series as high as possible while tonguing as fast as possible
Tbn.
B. D.
Pno.
Improvise a percussively articulated glissandi with both hands
ord.
extreme sul pont.
N
P
(sub.)N
Vln.
tr
Vla.
Vc.


♩ = 220
28
193
Picc.
Ob.
Cl.
Tpt.
Tbn.
B. D.
Pno.
Vln.
Vla.
Vc.
Remain absolutely still...
ca.3-5"
ffffff *
ffffff
*mm. 193 - All: As loud and ferocious as possible


♩= 70
accel.
TO FL.
FLUTE
air
pitch
senza vib.
con vib.
TO PICC.
PICCOLO
195
Picc.
pppp
ppp
pp
Ob.
Cl.
con sord.
Tpt.
Tbn.
pppp
TO VIB.
TO GLOCK.
l.v.
Vib.
Pno.
on the bridge
sul tasto
Vln.
Vla.
Vc.


29
♩ = 120
199
30
Picc.
improvise key clicks and delicate lip pizz.
fast
slow
p
pp
Ob.
p
ppp
pp
Cl.
slightly pulse and bend the pitch up and down. Follow the directions for speed and regularity:
quick and regular
medium, slightly irregular
p
ppp
Tpt.
p
Tbn.
p
Tub. B.
TUBULAR BELLS
TO VIB.
pp
Glock.
l.v.
TO TUB. B.
p
pp
Vib.
VIBRAPHONE
bowed
ppp
Pno.
(8)
p
pp
molto vib.
slow down vib. to a slow, wide, and highly irregular pulse
senza vib.
sul pont.
ord.
sul tasto
Vln.
IV
p
pp
molto vib.
sul pont.
sul tasto
slow down tremolo
senza vib.
con sord.
molto vib.
slow down vib. to a slow, wide, and highly irregular pulse
loco
Vla.
p
pp
molto vib.
sul pont.
slow down vib. to a medium pulse that is slightly irregular and exaggerated
Vc.
p
ppp


207
Picc.
improvise key clicks and delicate lip pizz
fast
slow
ppp
Ob.
slow, highly irregular
no pulsing or bending
Cl.
pp
improvise key clicks and delicate lip pizz
medium
Tpt.
ppp
improvise key clicks and delicate lip pizz
slow
Tbn.
pppp
TUBULAR BELLS
Tub. B.
pp
l.v.
bowed
l.v.
TO TUB. B.
Vib.
ppp
Pno.
Vln.
senza vib.
Vla.
slow down vib. to a slow, wide, and highly irregular pulse
senza vib.
sul tasto
Vc.
pp
ppp
pp

6.3 Score for *Occupied Spaces*

The score for *Occupied Spaces* appears on pages 107-153.

Occupied Spaces

For Two Pianos and Percussion

By Leah Reid

Instrumentation:

Percussion I:

triangle
metal wind chimes
suspended cymbal
wood block
bass drum

crotales (lower and upper set, range: sounding 2 8ves higher)
tubular bells
marimba (4 1/3 octave)

Percussion II:

suspended cymbal
cowbell
gong
tam-tam
timpani (25")

glockenspiel (sounding 2 8ves higher)
xylophone (sounding 1 8ve higher)
vibraphone

Piano I:

grand piano
toy piano (range: C4-C6)

Piano II:

grand piano
celesta (sounding 1 8ve higher)

Additional Materials Needed:

Piano I:

2 e-bows
percussion mallets

Piano II:

2 e-bows
percussion mallets

General Notes to Performers:

Accidentals carry through the bar

all trills should be played a semi-tone higher

there are 4 types of barlines in the score:
- the solid barlines indicate the change / new presence of a 'room.'
- dashed barlines indicate that the room continues through the next bar
- double barlines mark sections
- (...and the final barline marks the end of the piece...)

Dynamics are relative, not absolute

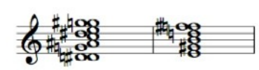
Notes to Percussionists:

all percussion instruments should freely vibrate unless the score indicates otherwise (i.e. no l.v. markings will appear in the score, but should be assumed)

Notes to Pianists:

in the last section of the piece, the pianists will play the piano strings with e-bows. Performers should use one e-bow per hand and the switch should be turned to the left (emphasizing lower harmonics). Depending on the beaming of the piano, pitches may have to be substituted. Some pitches may be possible by playing them down an octave using the e-bow switched to the right (emphasizing upper partials). If necessary, octave substitutions are acceptable. The following pitches should be marked in advance:

Piano I Piano II



pianists will also strike the piano strings with mallets where indicated

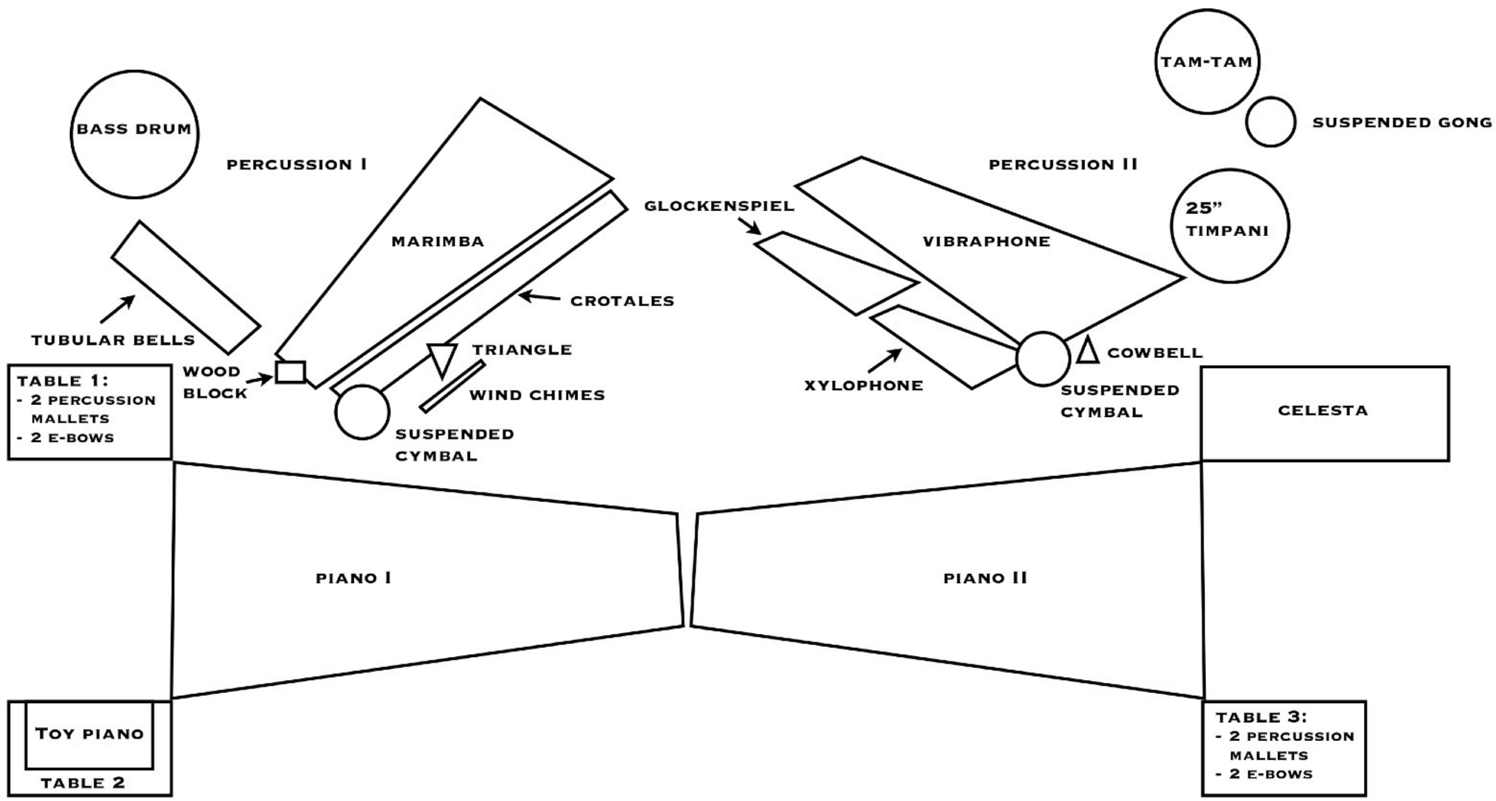
Notation Key:

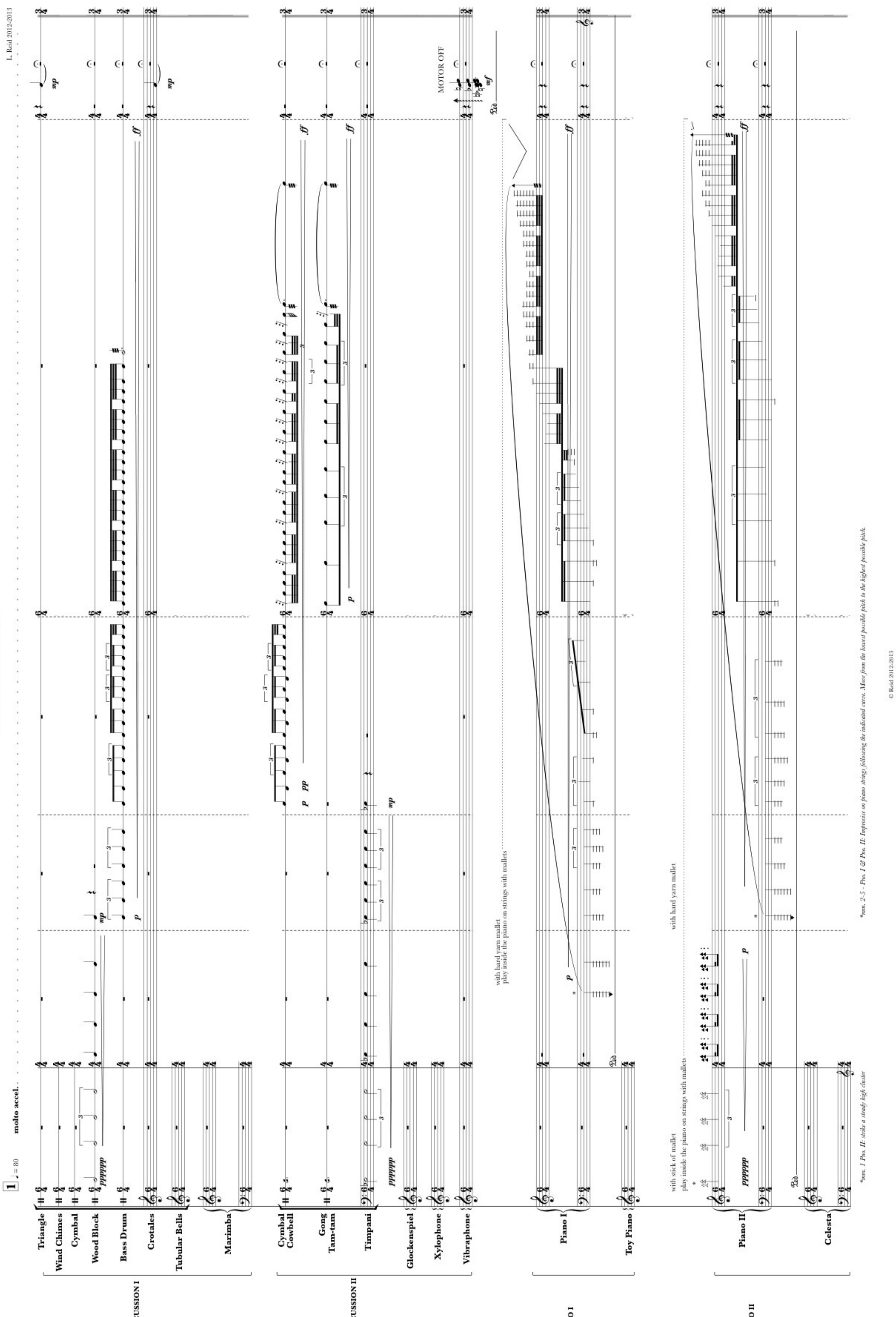
slow ⟶ fast - begin with a slow, steady pulse and gradually increase the speed to a tremolo

fast ⟶ slow - begin with a tremolo and gradually decrease the speed to a slow pulse

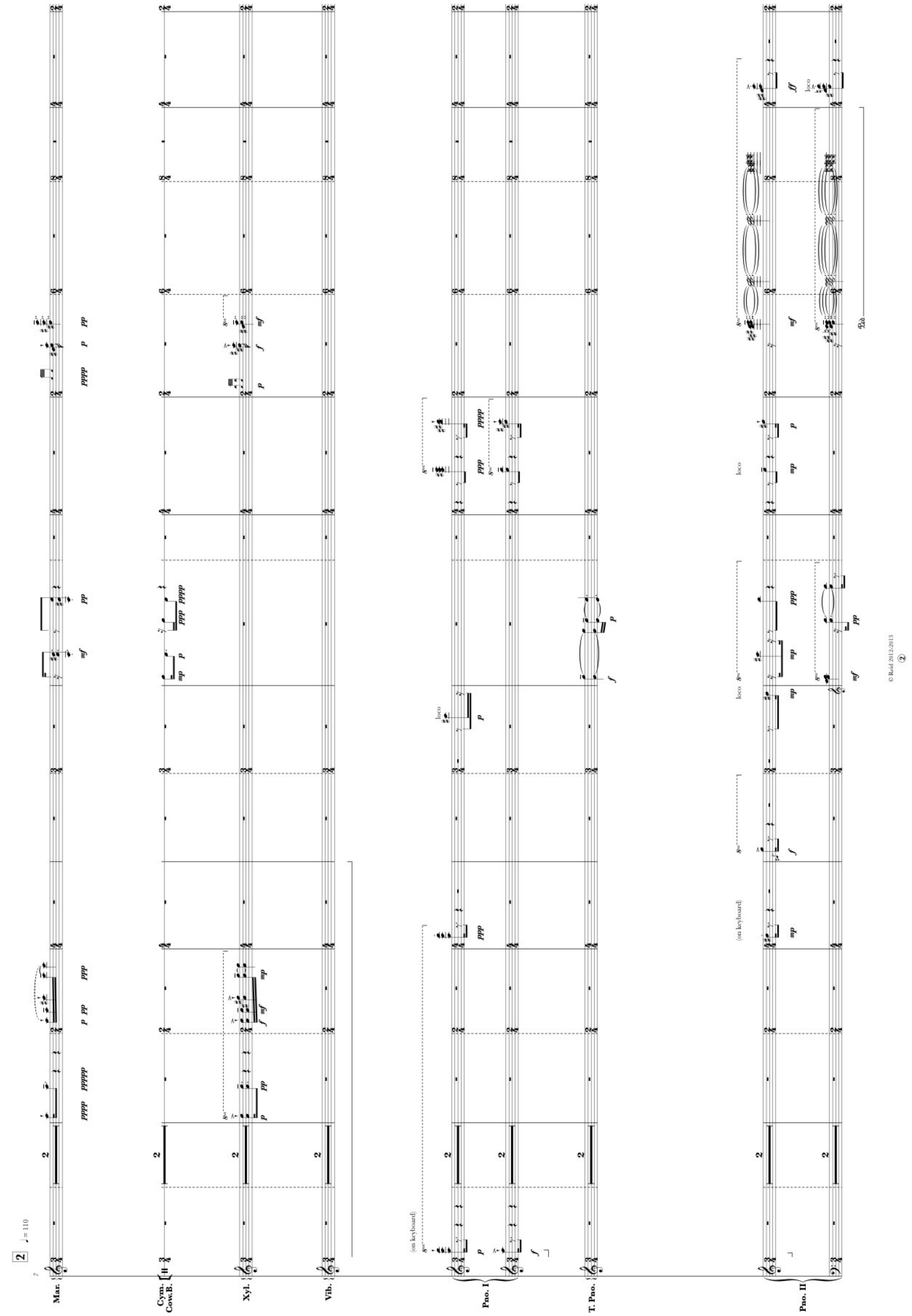
all other markings that are not self explanatory or standard are explained in the score

Suggested performance diagram:

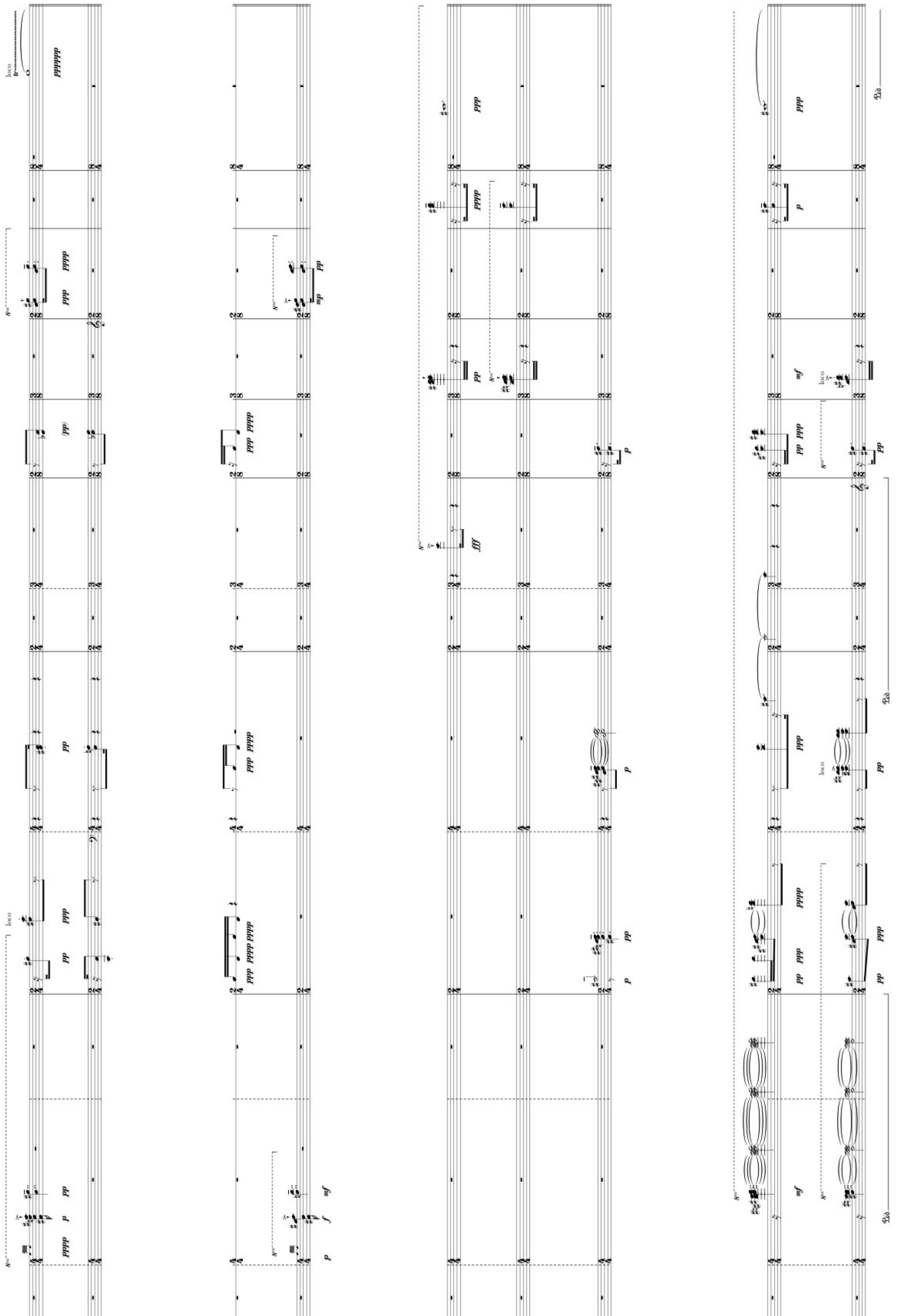


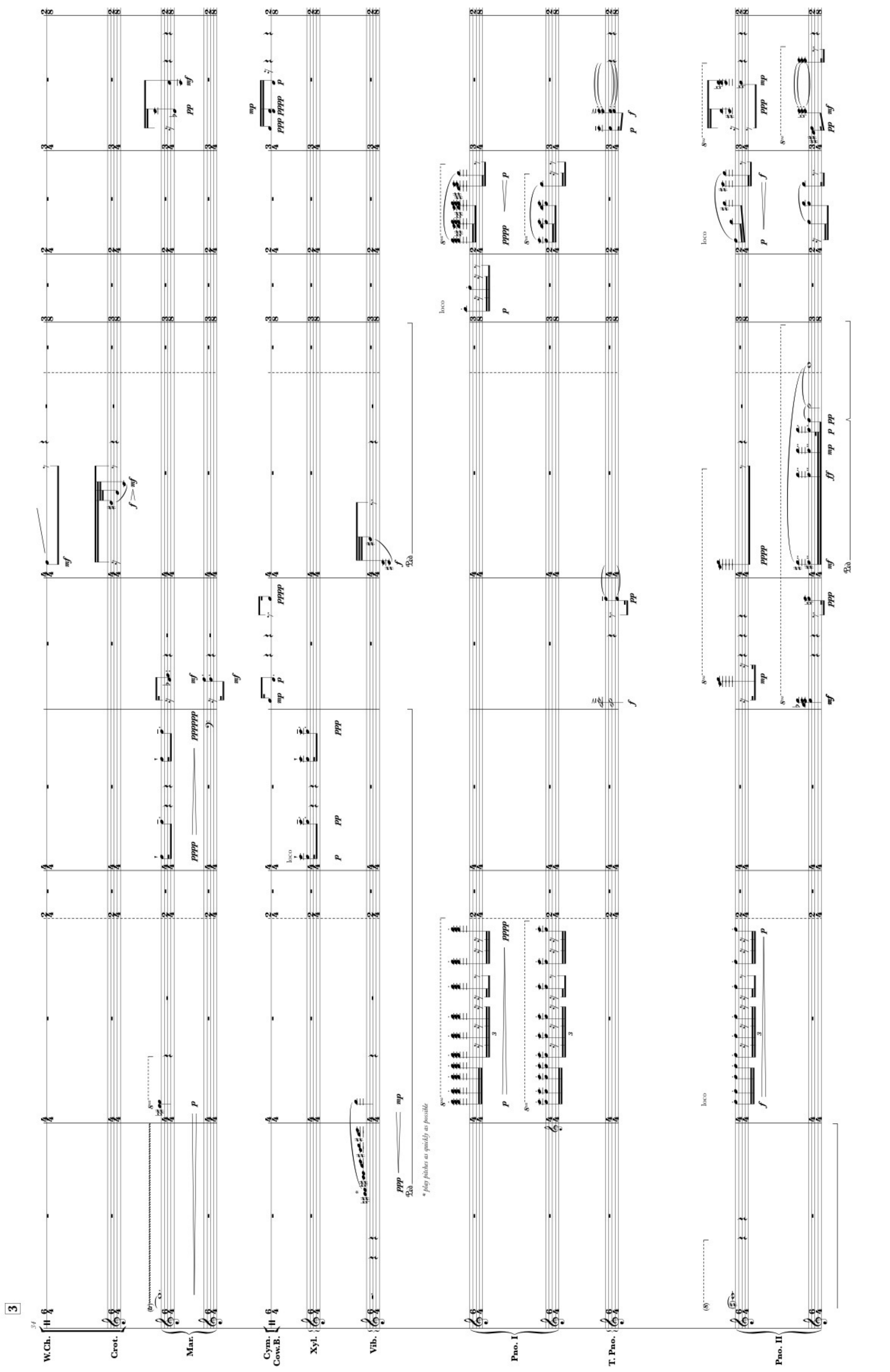


Occupied Spaces
L. Reid 2012-2013
molto accel.
PERCUSSION I
Triangle
Wind Chimes
Cymbal
Wood Block
Bass Drum
Crotales
Tubular Bells
Marimba
PERCUSSION II
Cymbal Cowbell
Gong Tam-tam
Timpani
Glockenspiel
Xylophone
Vibraphone
MOTOR OFF
PIANO I
Piano I
Toy Piano
with hard yarn mallet play inside the piano on strings with mallets
PIANO II
Piano II
Celesta
with stick of mallet play inside the piano on strings with mallets
with hard yarn mallet
*mm. 1 Pno. II: strike a steady high cluster
*mm. 2-5 - Pno. I & Pno. II: Improvise on piano strings following the indicated curve. Move from the lowest possible pitch to the highest possible pitch.
© Reid 2012-2013
1

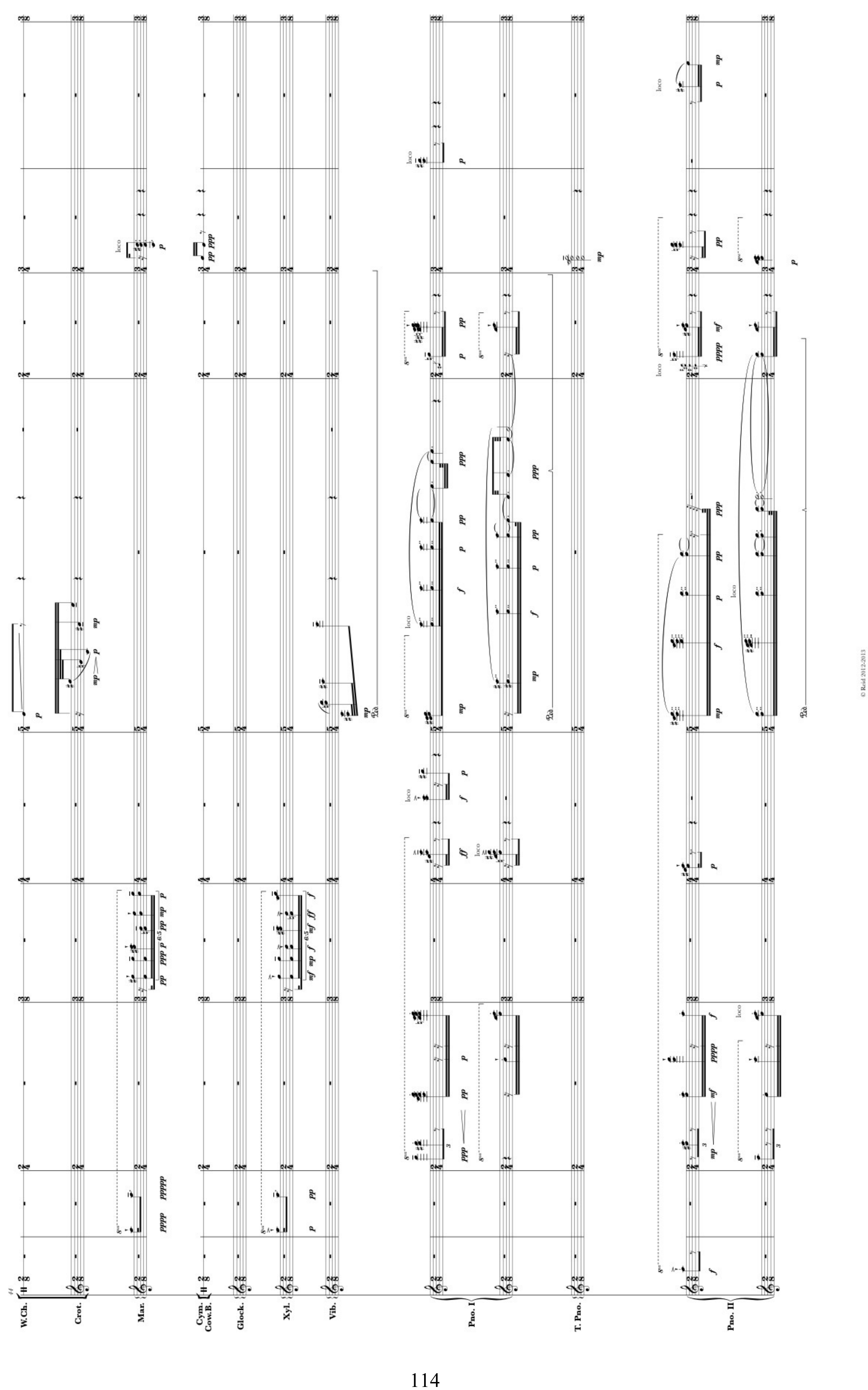


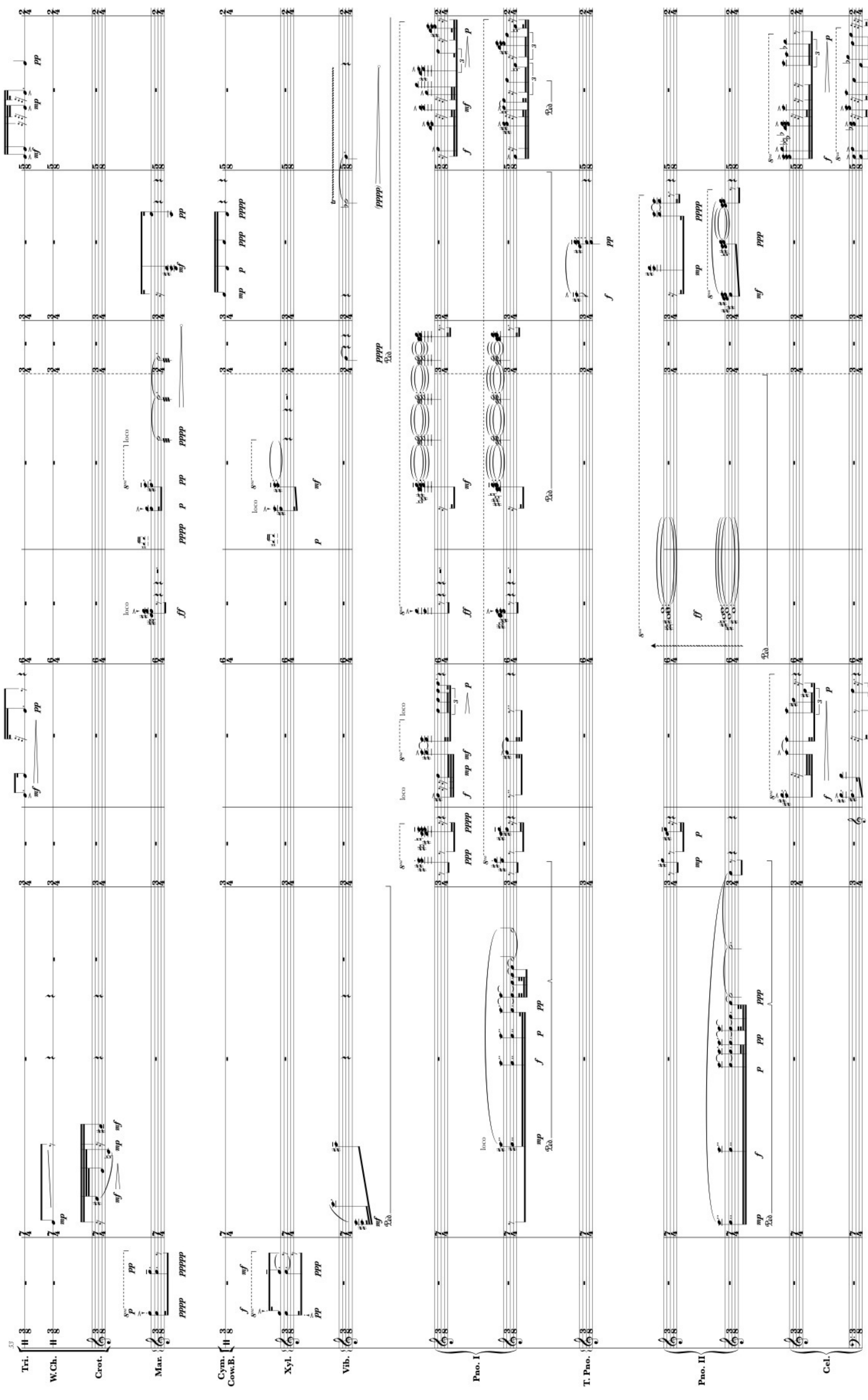
Mar.
Cym.
Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
(on keyboard)
loco
© Reid 2012-2013

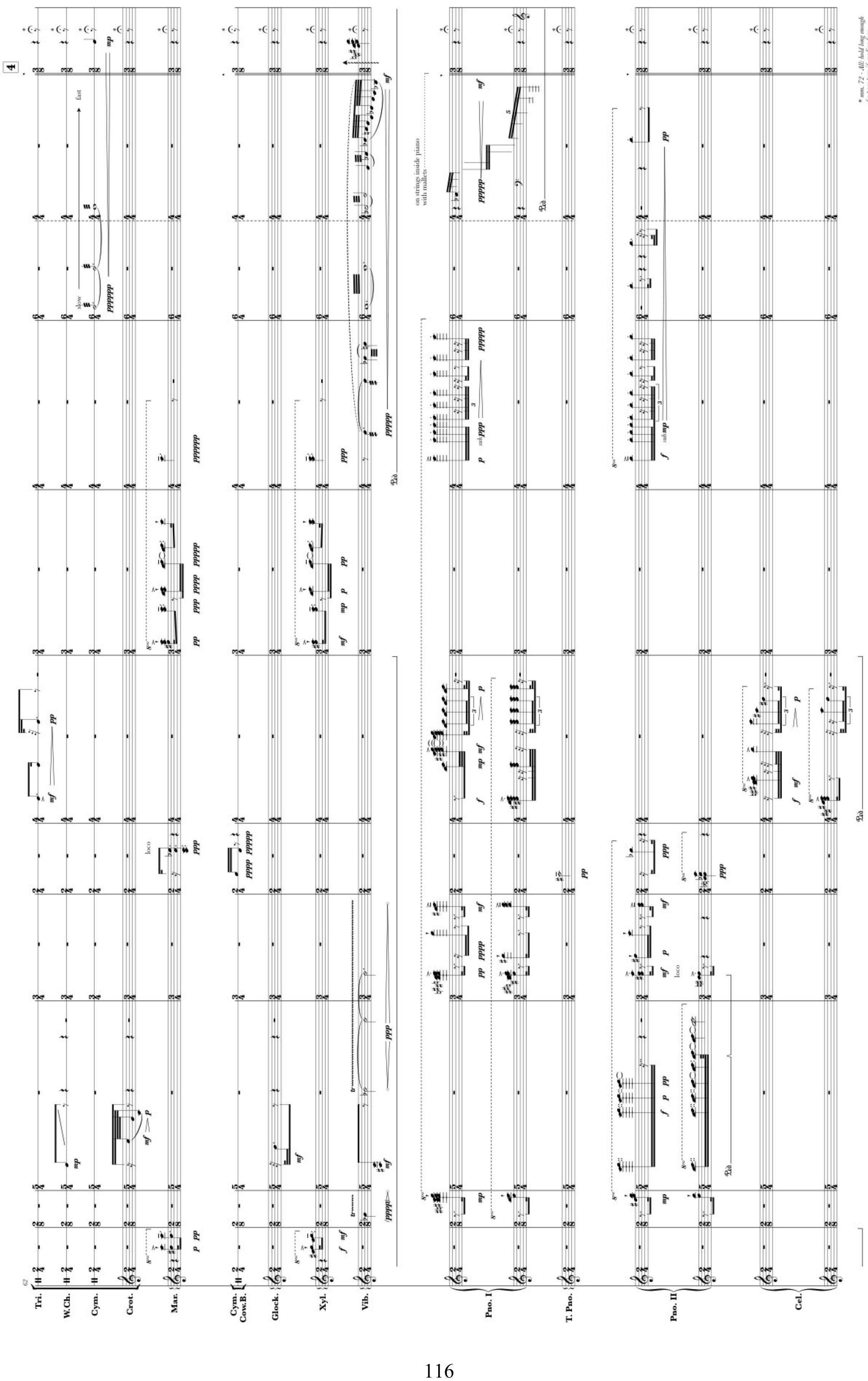

Mar.
Cym.
Cow.B.
Xyl.
Pno. I
T. Pno.
Pno. II
© Reid 2012-2013
3

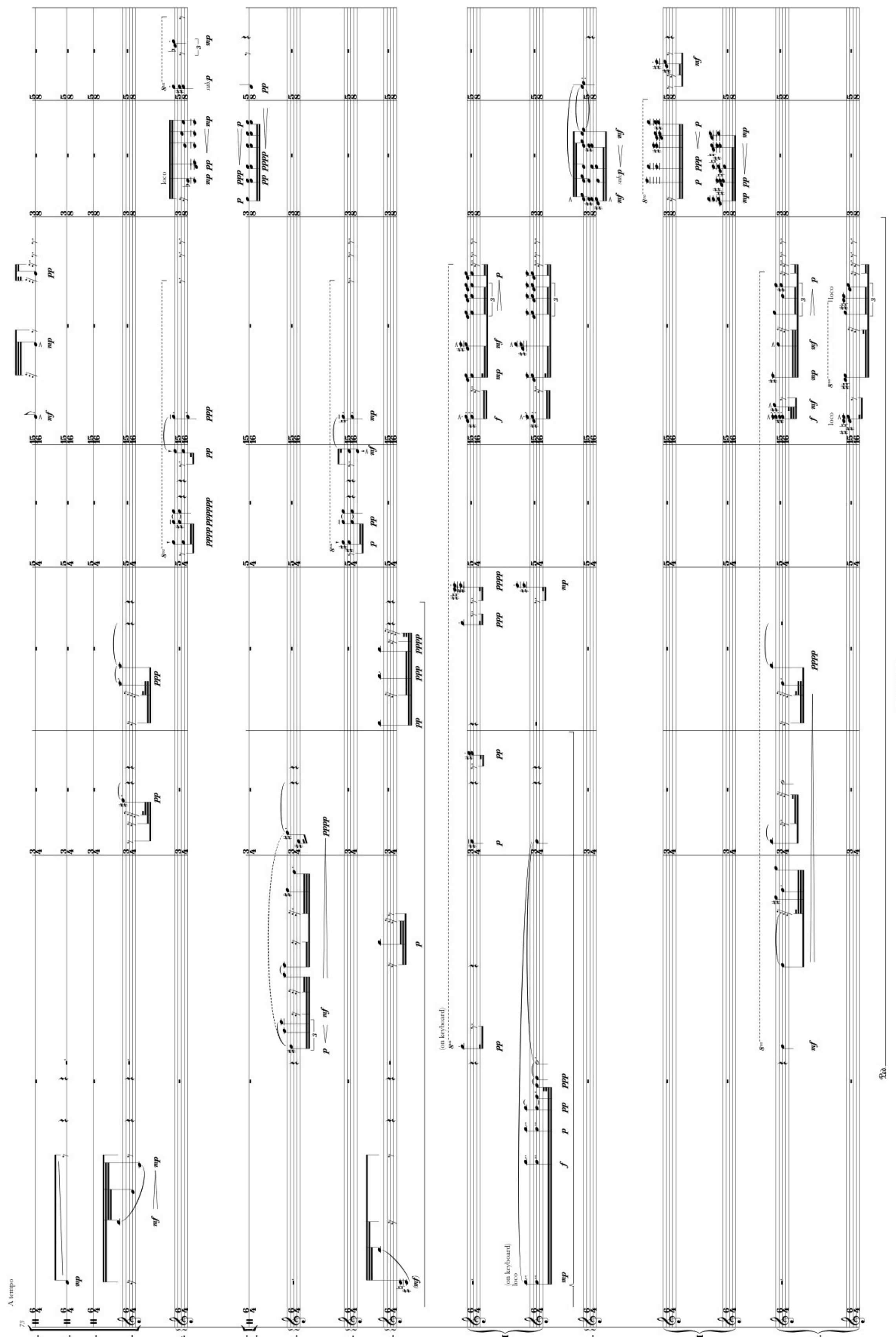

3
W.Ch.
Crot.
Mar.
Cym. Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
* play pitches as quickly as possible
loco

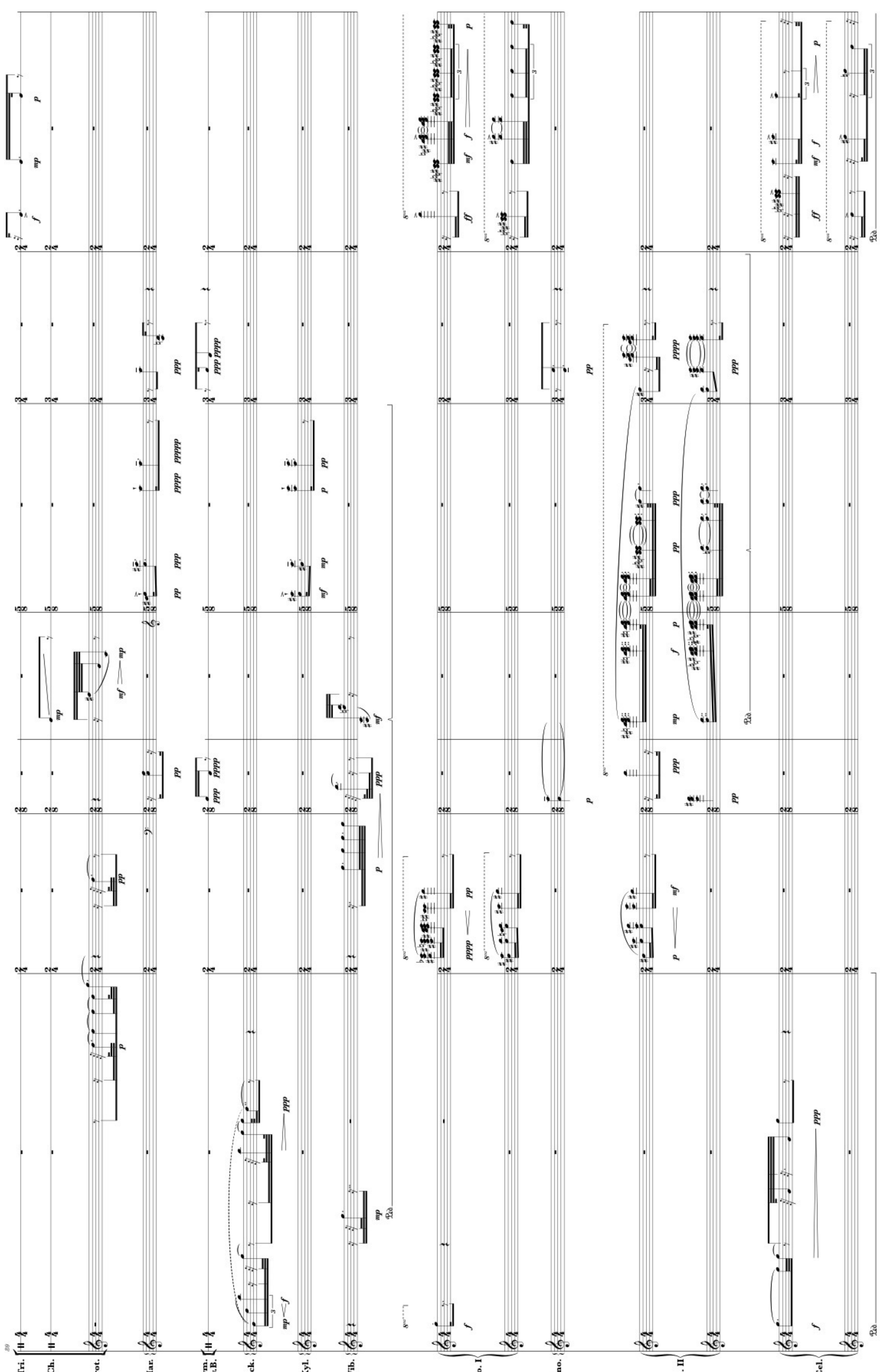
4

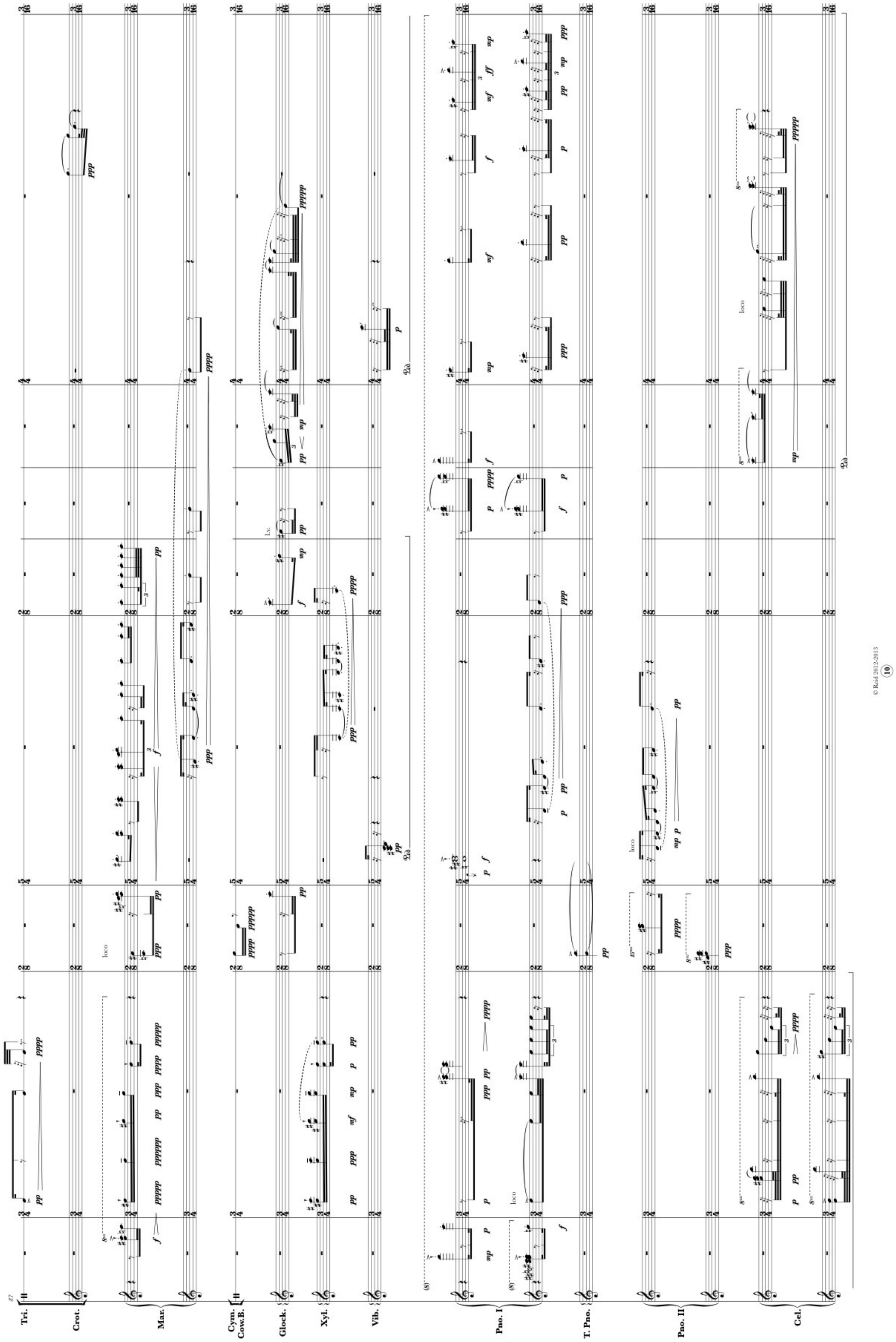

W.Ch.
Crot.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
© Reid 2012-2013

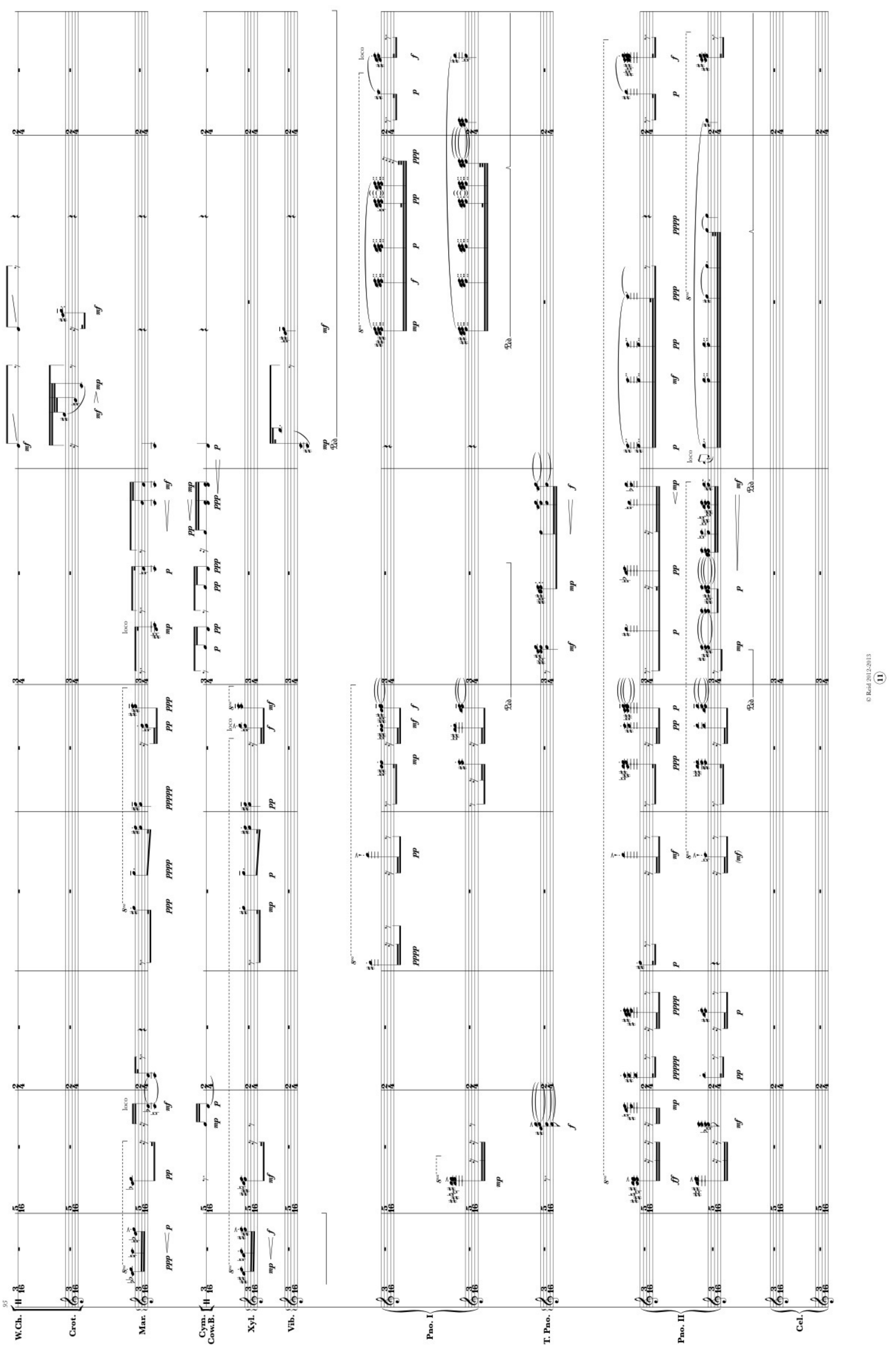

Tri.
W.Ch.
Crot.
Mar.
Cym.
Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
© Reid 2012-2013
6

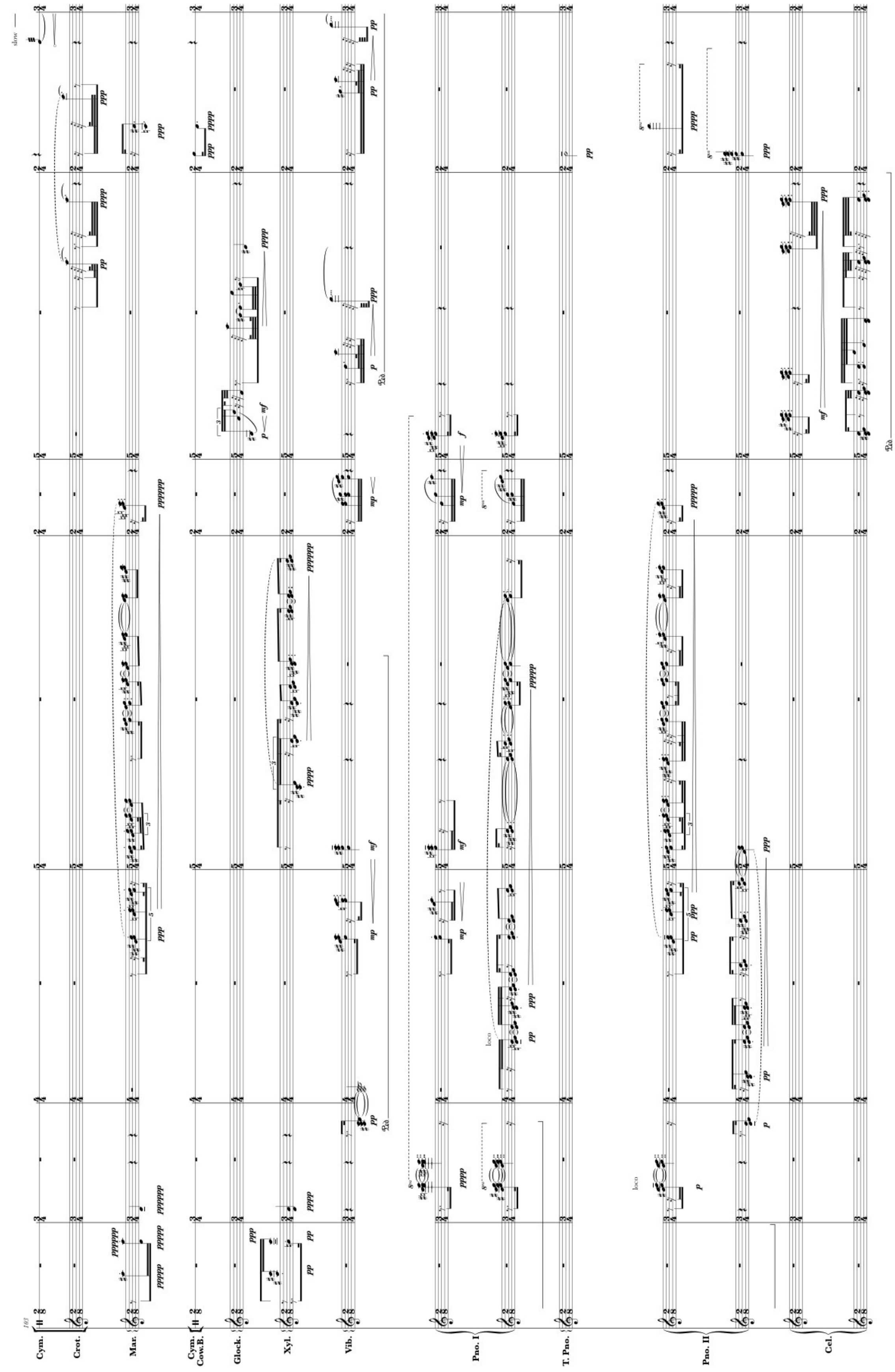

Tri.
W.Ch.
Cym.
Crot.
Mar.
Cym.
Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
4
loco
slow
fast
on strings inside piano
with mallets
© Reid 2012-2013
* mm. 72 - All: hold long enough for page turn if reading from the score


A tempo
Tri.
W.Ch.
Cym.
Crot.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
(on keyboard)
loco
© Reid 2012-2013
8

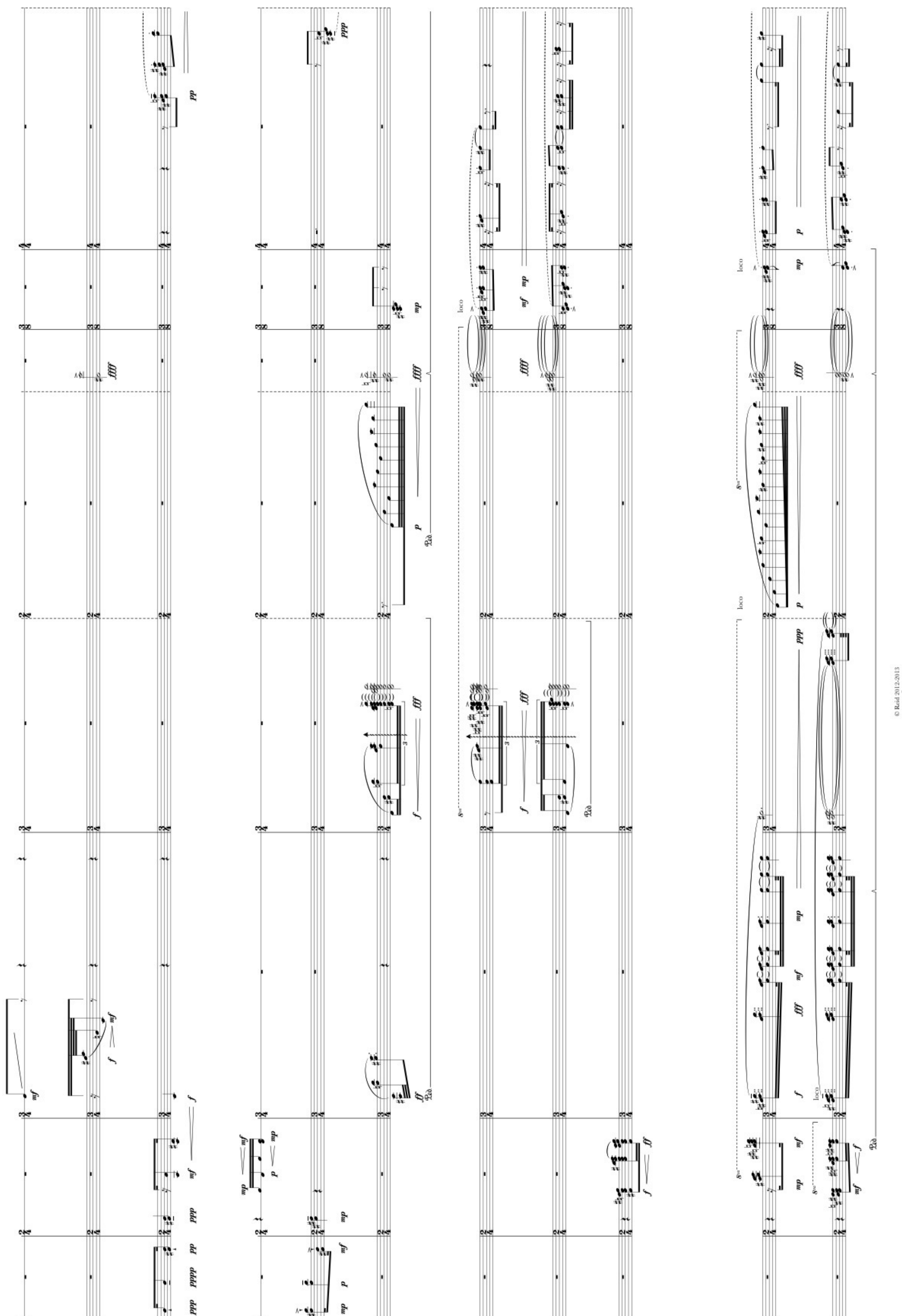

Tri.
W.Ch.
Crot.
Mar.
Cym.
Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
© Reid 2012-2013
9

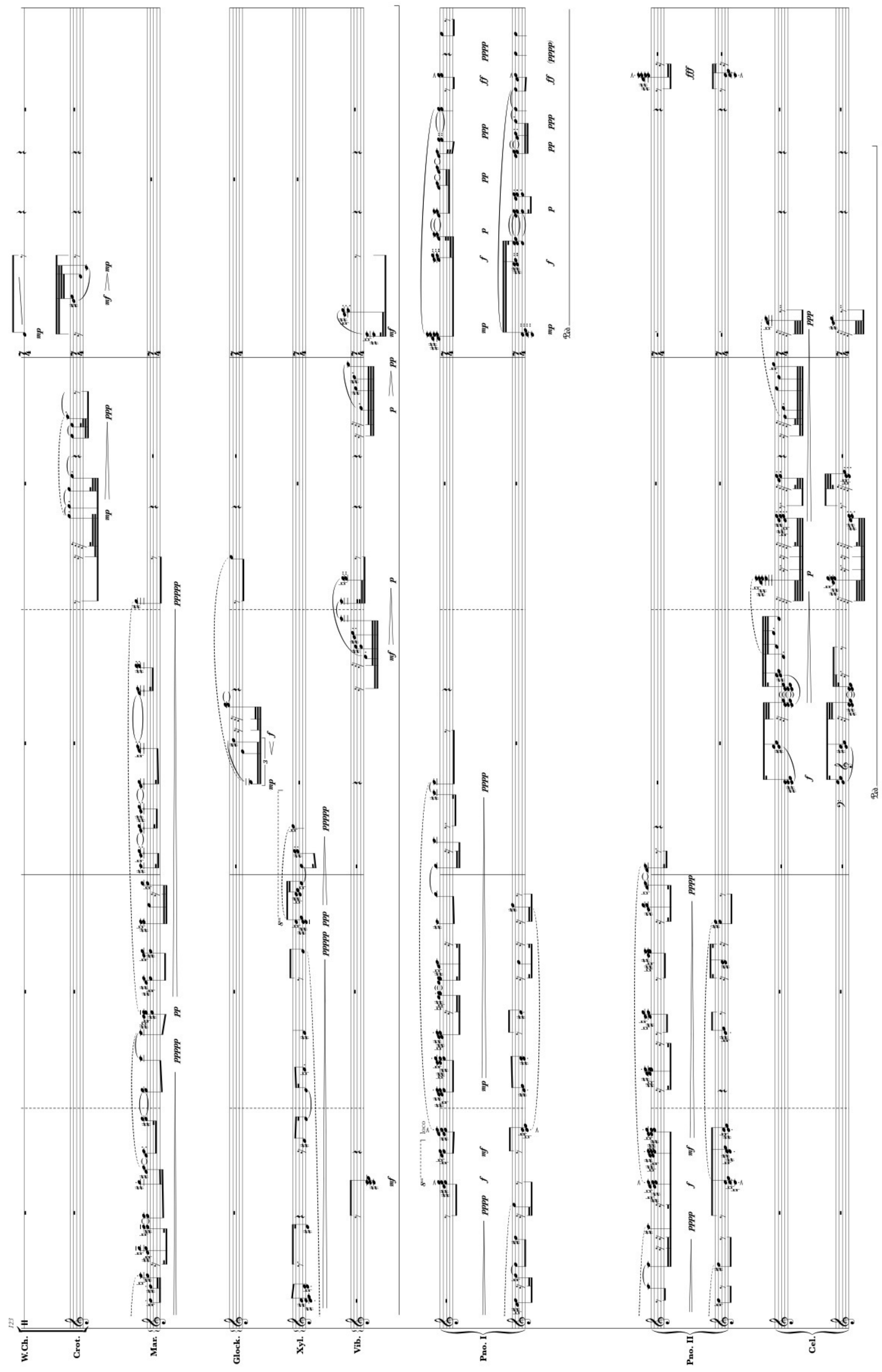

Tri.
Crot.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
© Reid 2012-2013
10

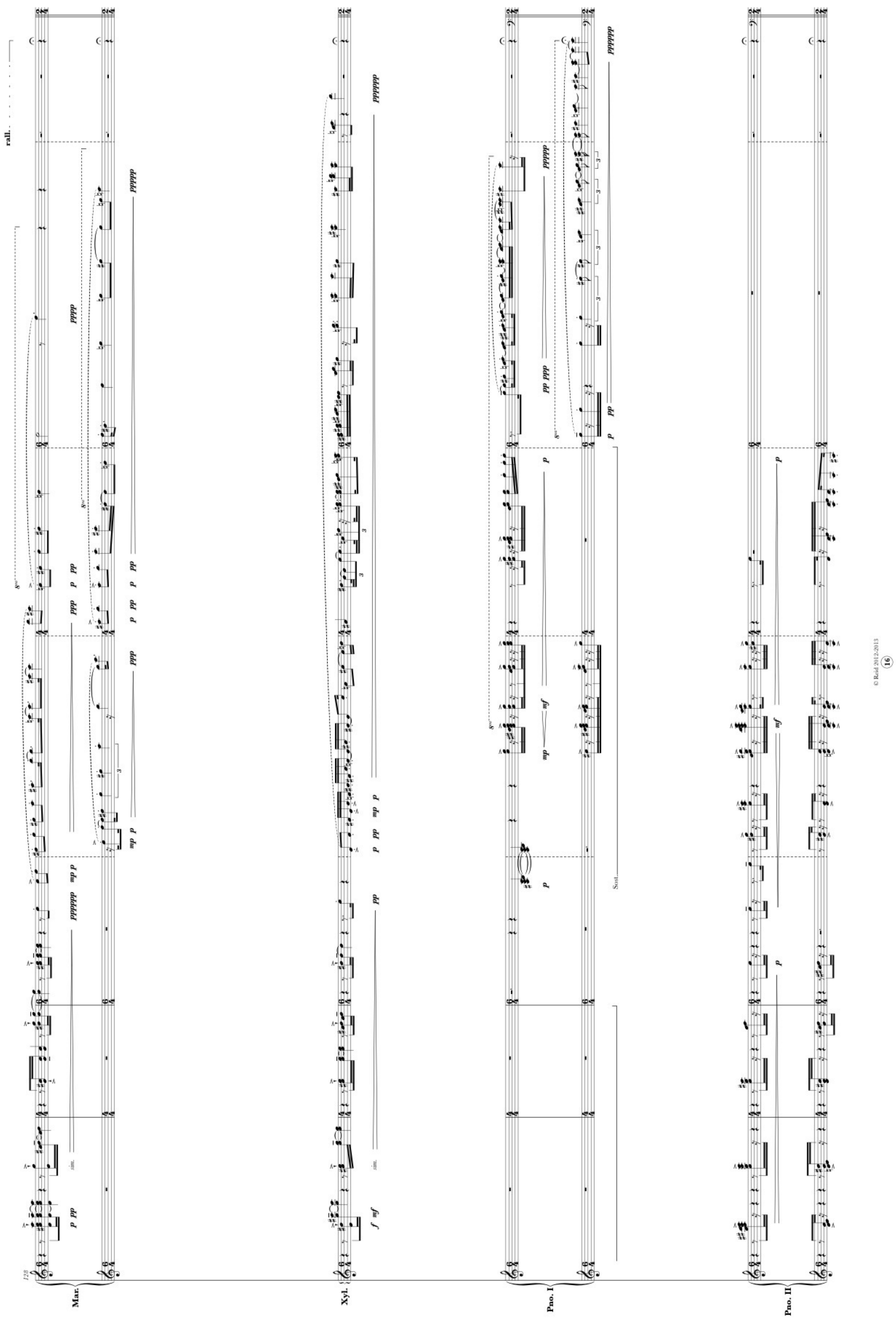

W.Ch.
Crot.
Mar.
Cym. Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
© Reid 2012-2013
11

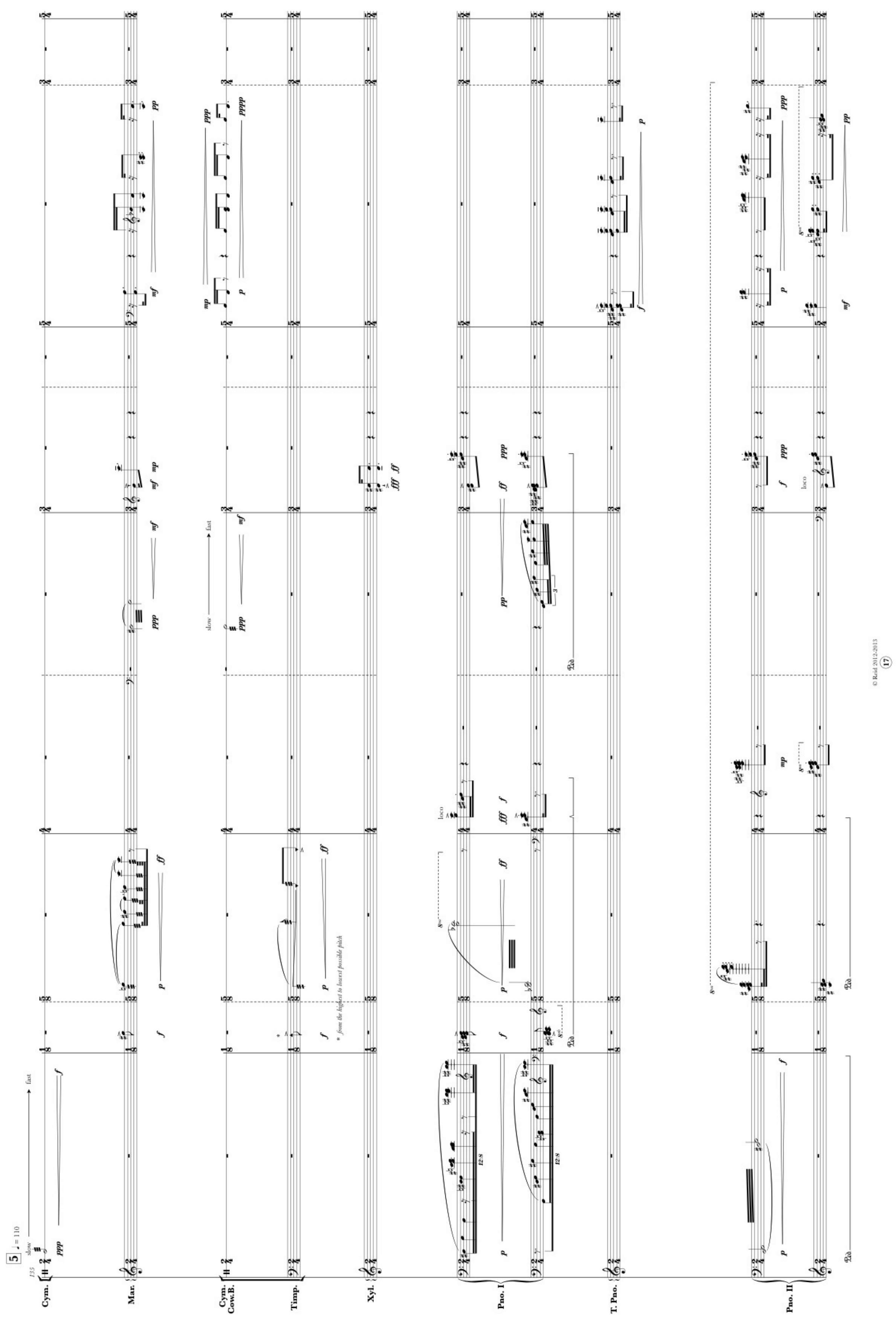

Cym.
Crot.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.

13

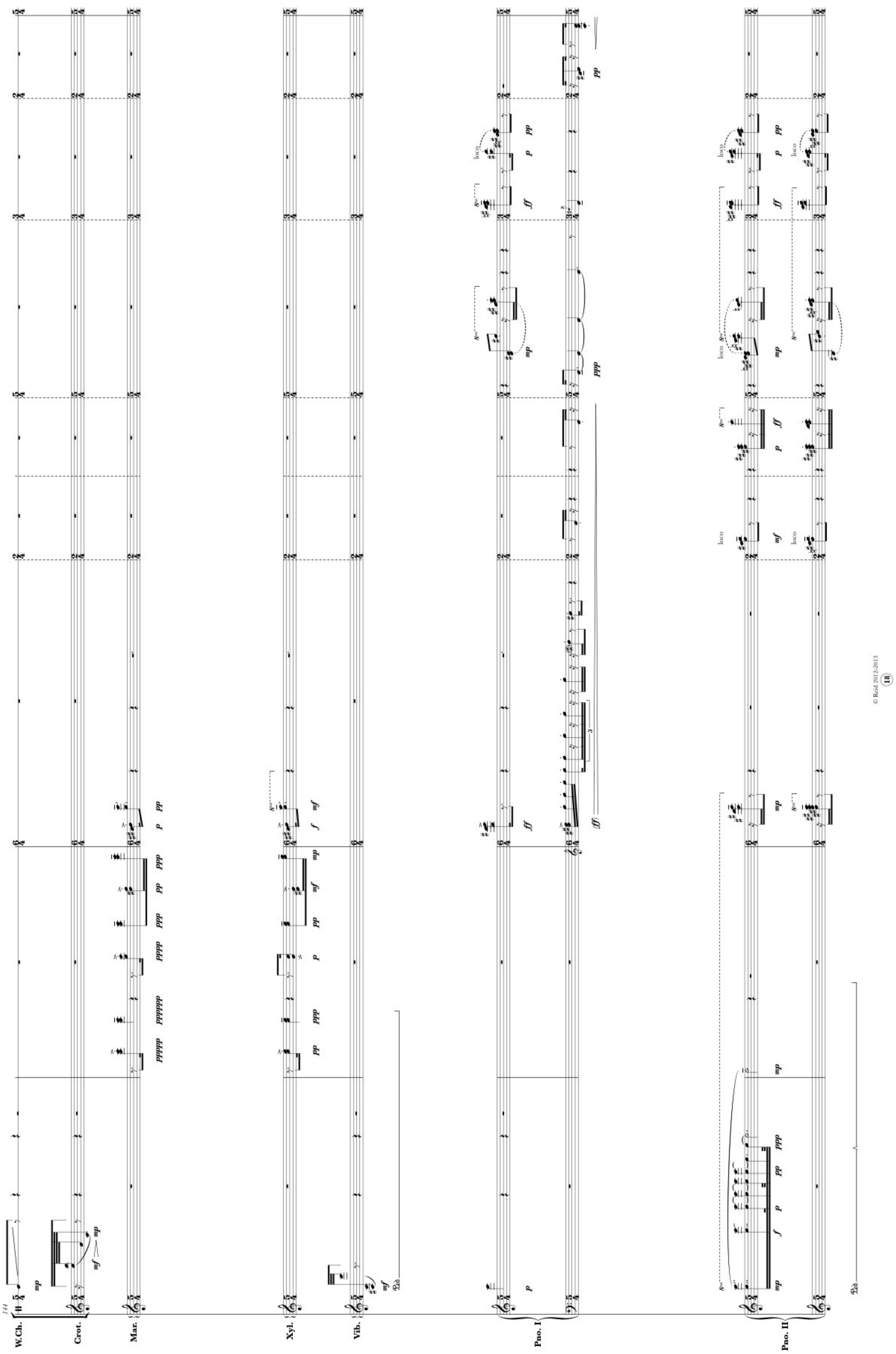

W.Ch.
Crot.
Mar.
Cym. Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
loco
© Reid 2012-2013
14

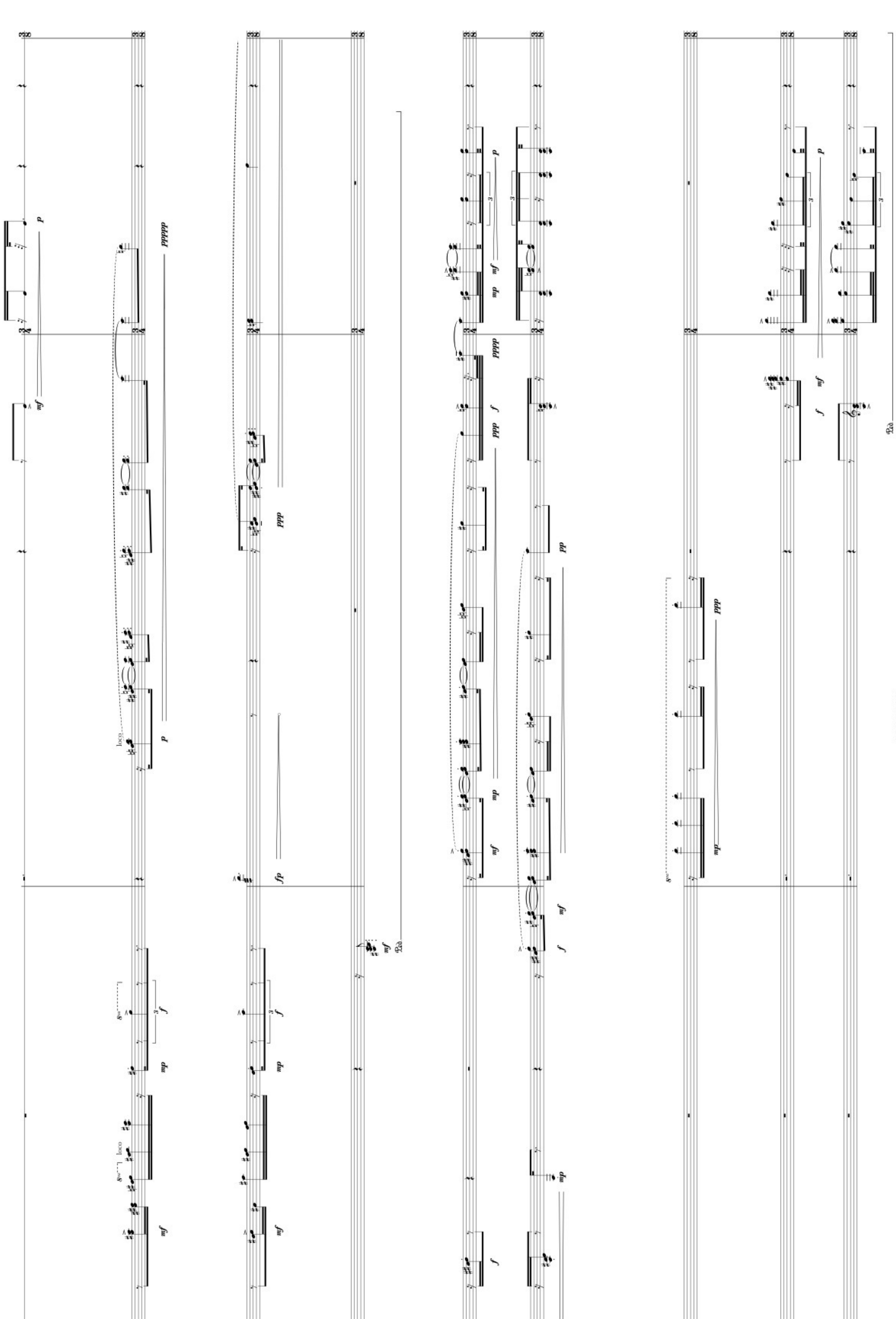

123
W.Ch.
Crot.
Mar.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
Cel.
loco
© Reid 2012-2013
15

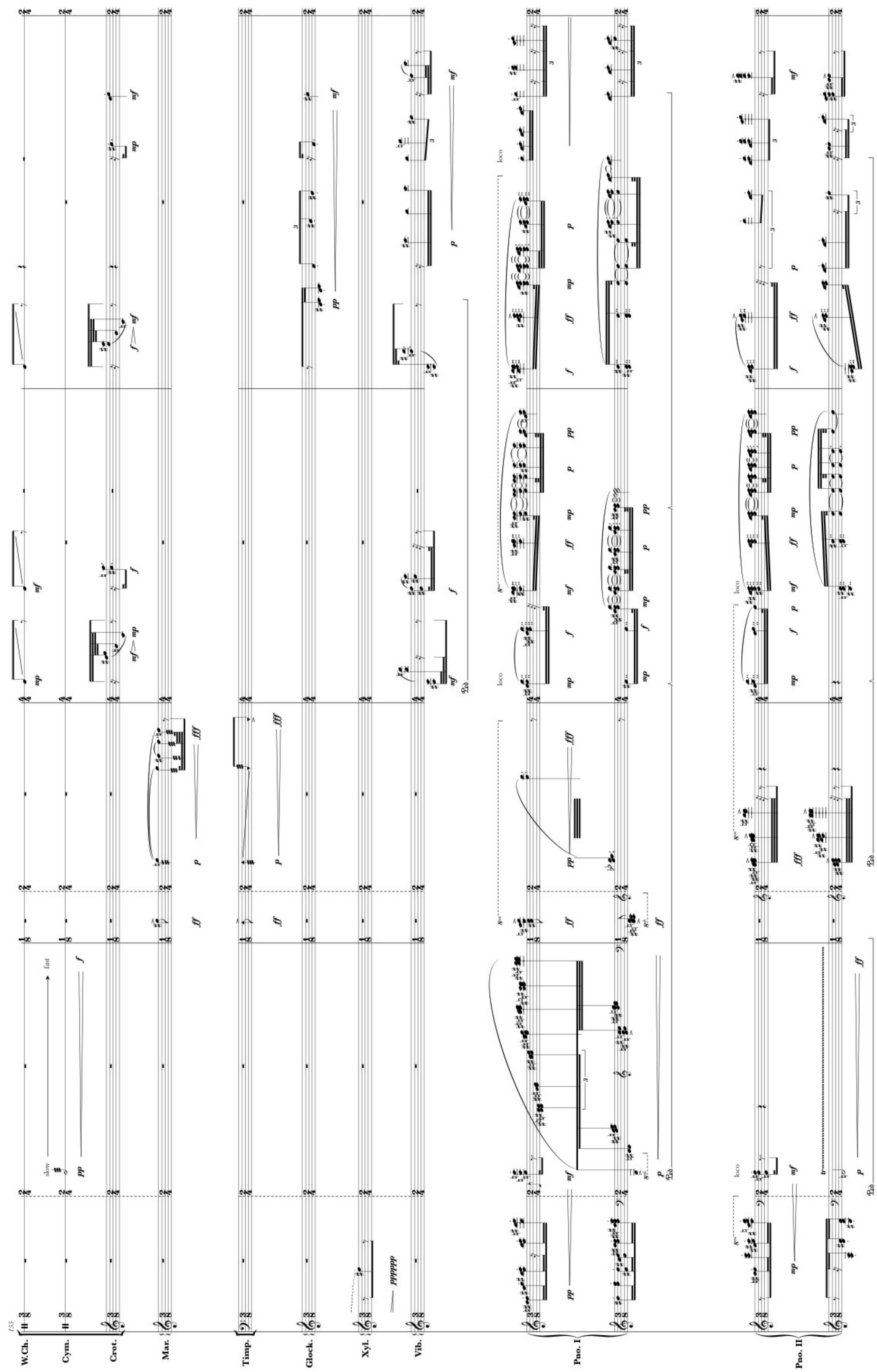

rall.
Mar.
Xyl.
Pno. I
Pno. II
Sost.
© Reid 2012-2013
16

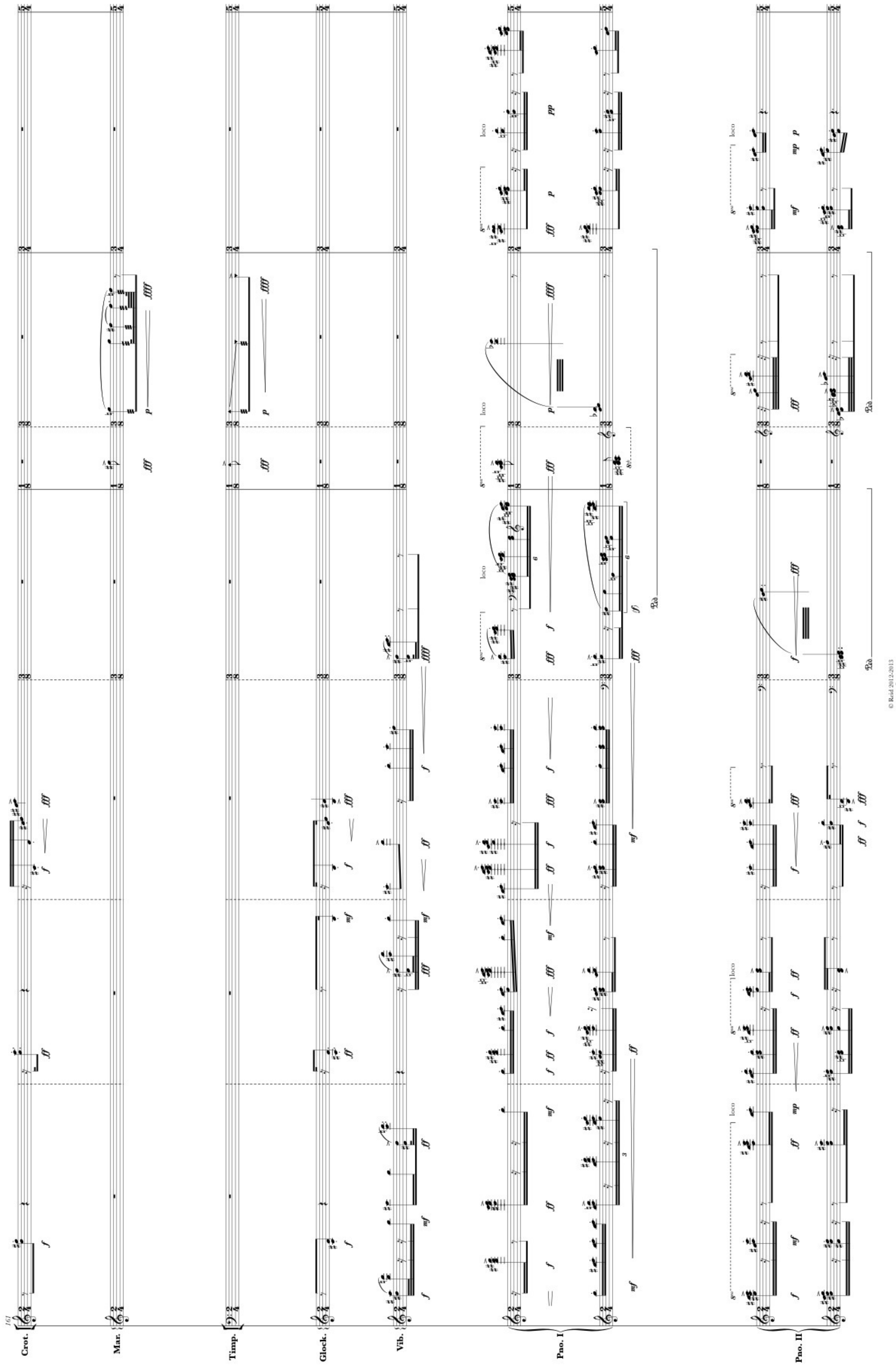


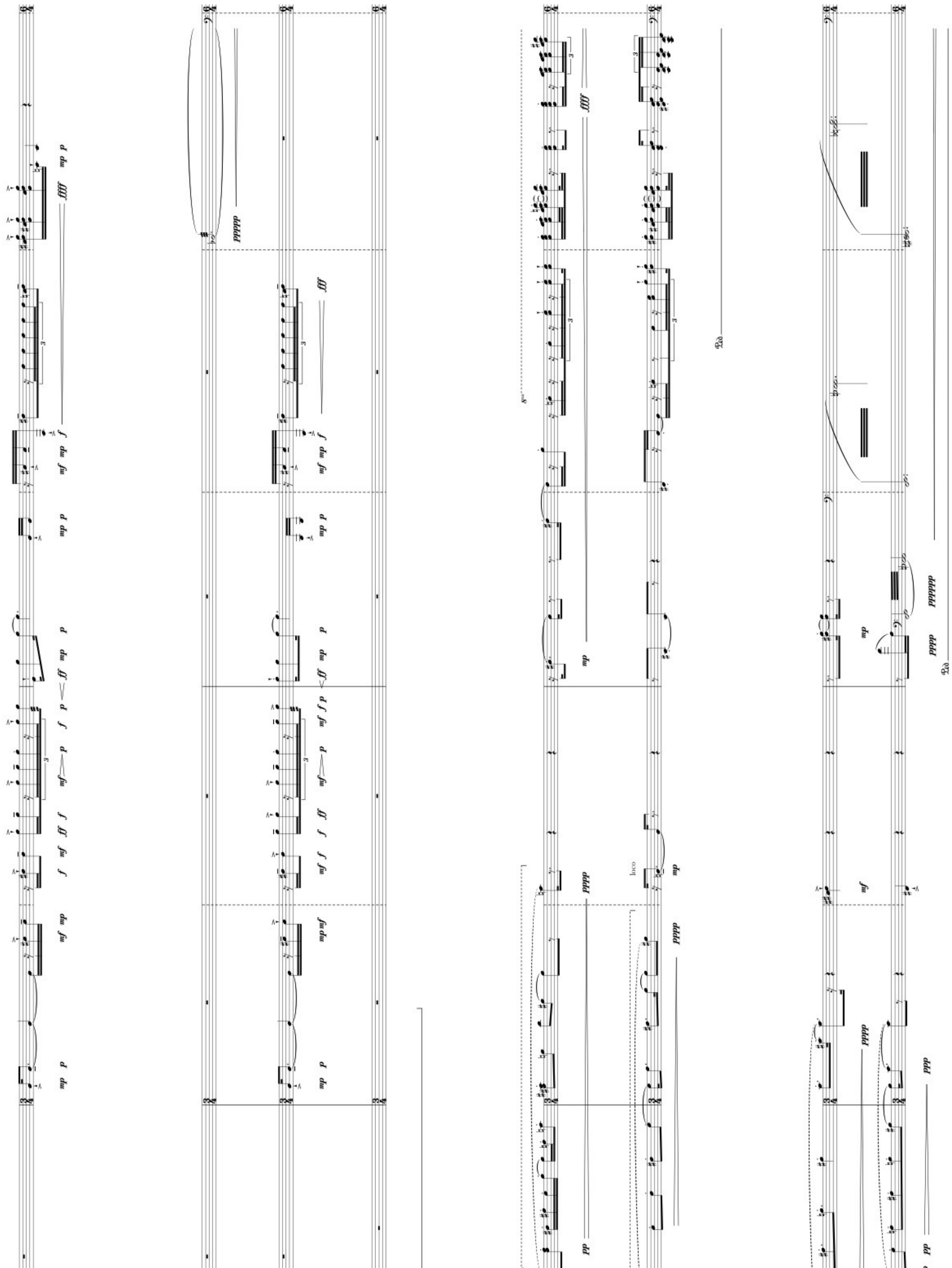
Cym.
Mar.
Cym.
Cow.B.
Timp.
Xyl.
Pno. I
T. Pno.
Pno. II
slow
fast
loco
* from the highest to lowest possible pitch
© Reid 2012-2013
17

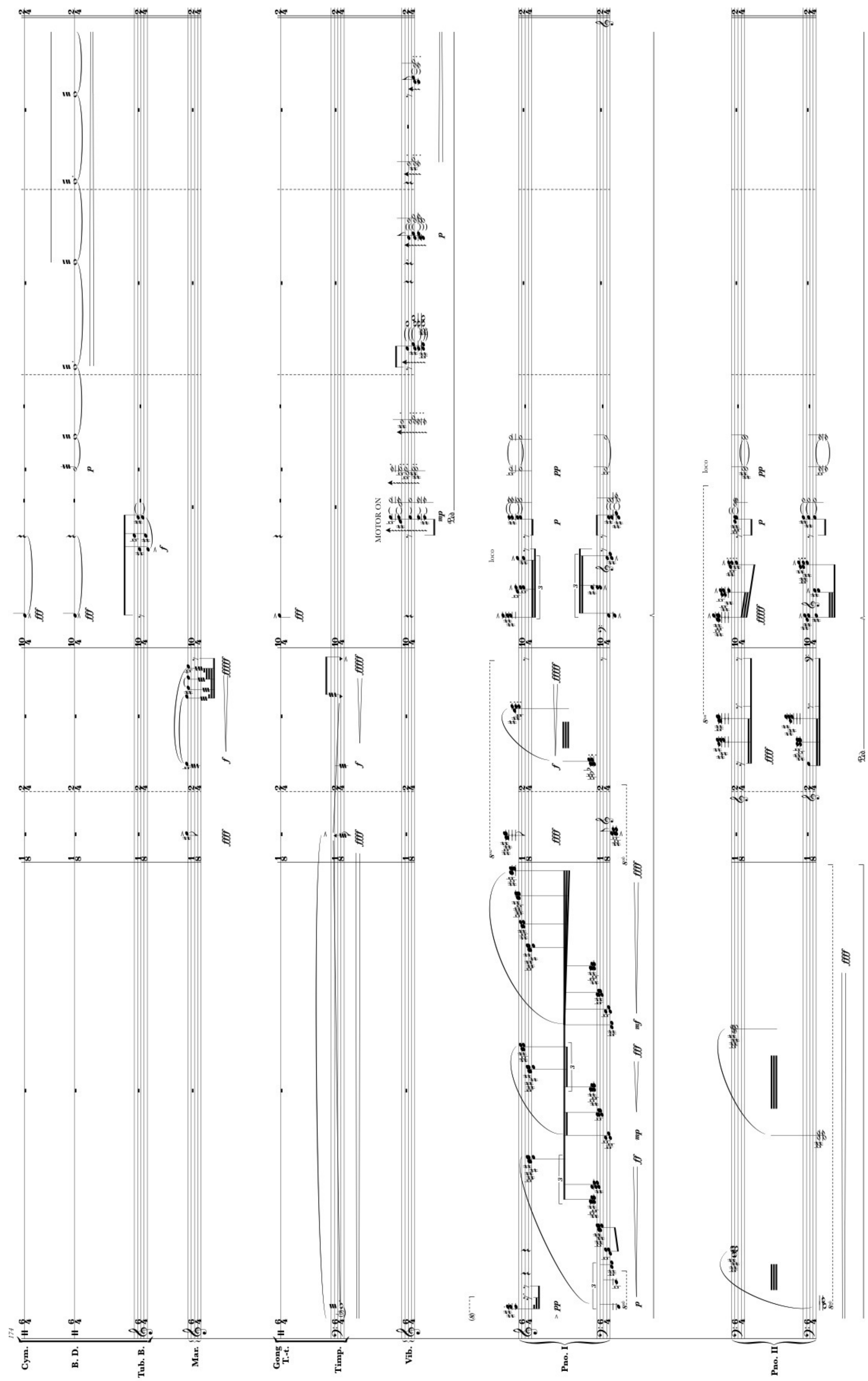

W.Ch.
Crot.
Mar.
Xyl.
Vib.
Pno. I
Pno. II
loco
© Reid 2012-2013
18

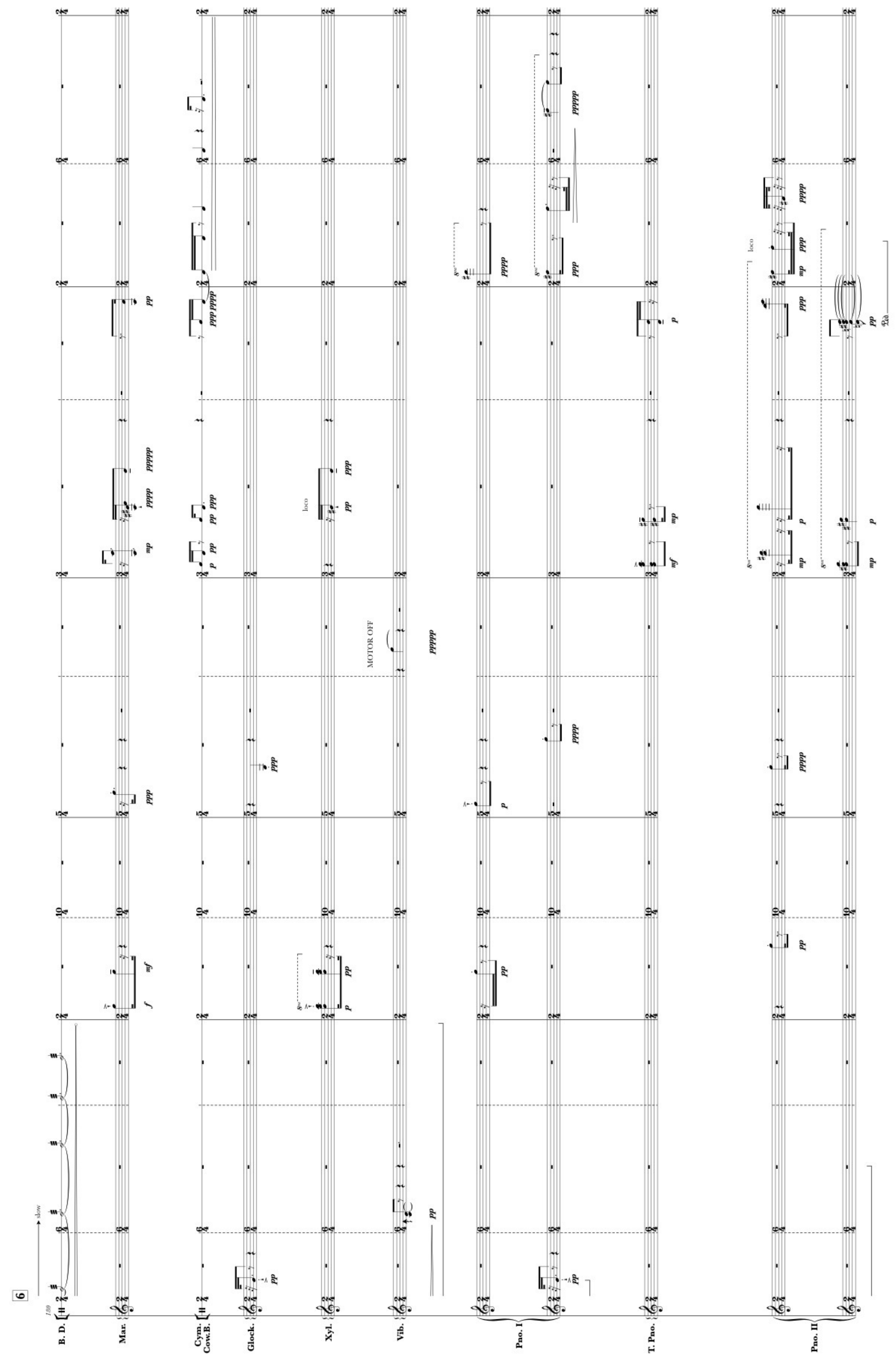

Tri.
Mar.
Xyl.
Vib.
Pno. I
Pno. II
Cel.
152
© Reid 2012-2013
19

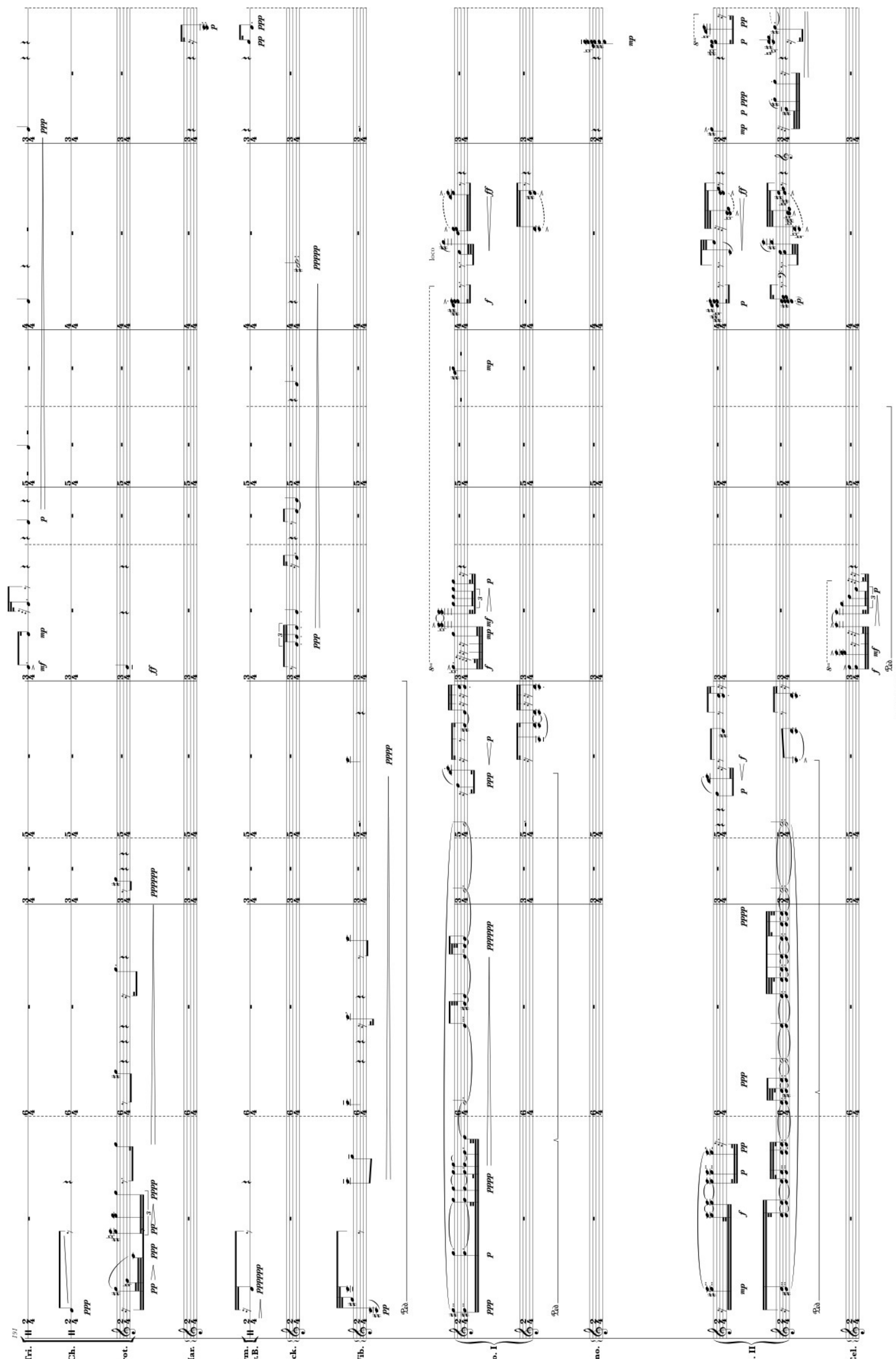

155
W.Ch.
Cym.
Crot.
Mar.
Timp.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
slow
fast
loco

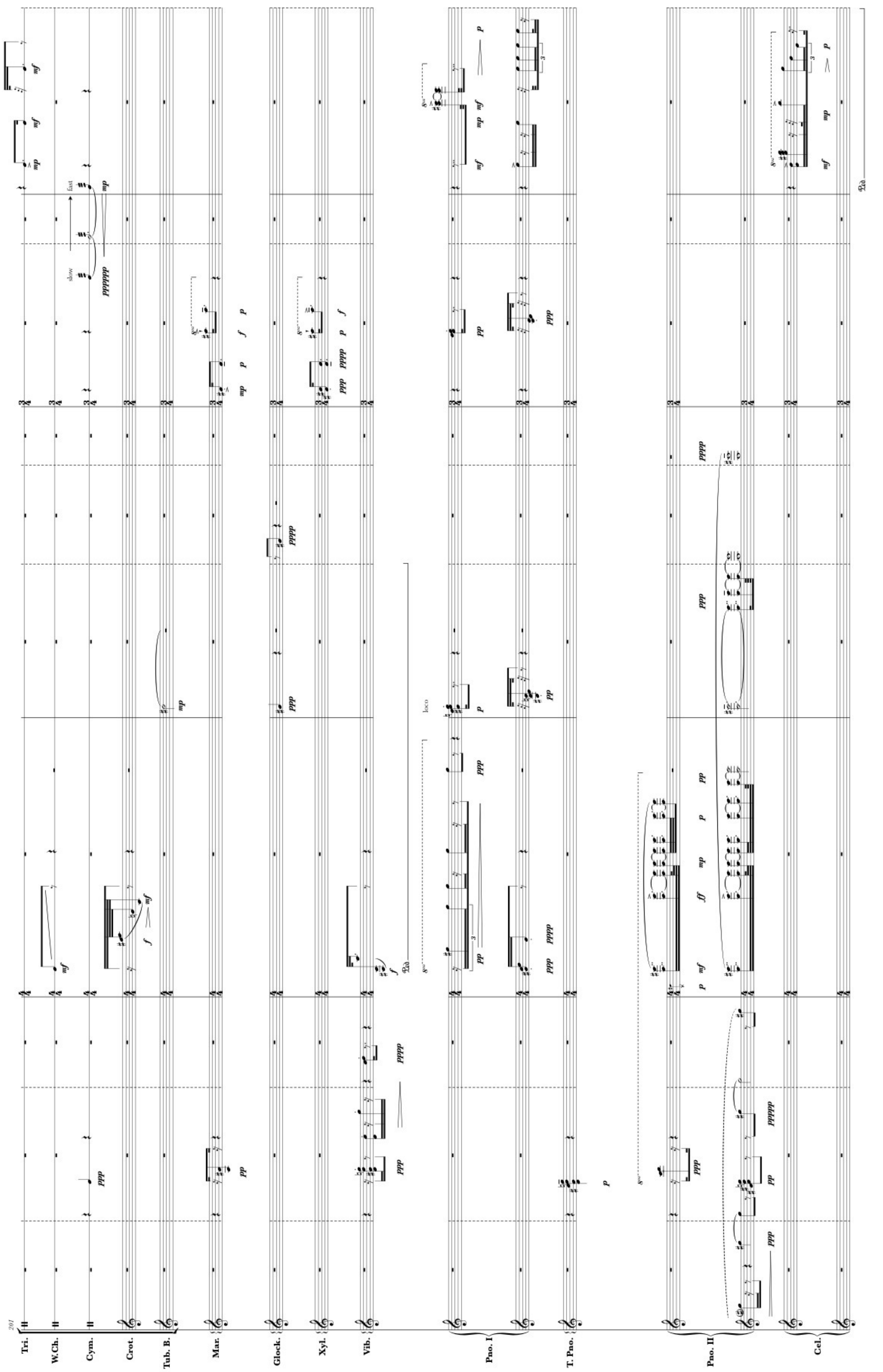

161
Crot.
Mar.
Timp.
Glock.
Vib.
Pno. I
Pno. II
loco
© Reid 2012-2013
21

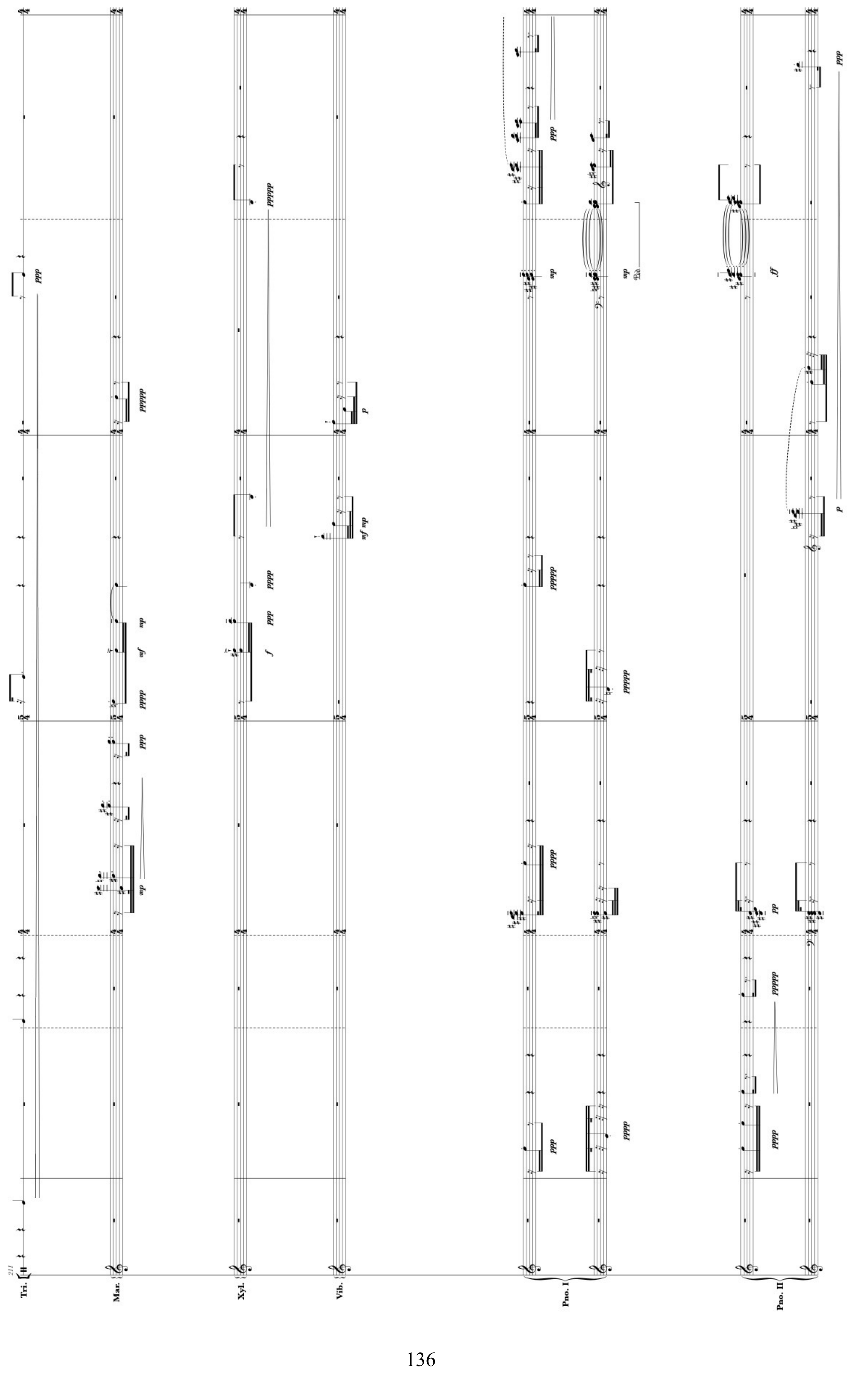

168
Mar.
Timp.
Xyl.
Vib.
Pno. I
Pno. II
loco
© Reid 2012-2013
22

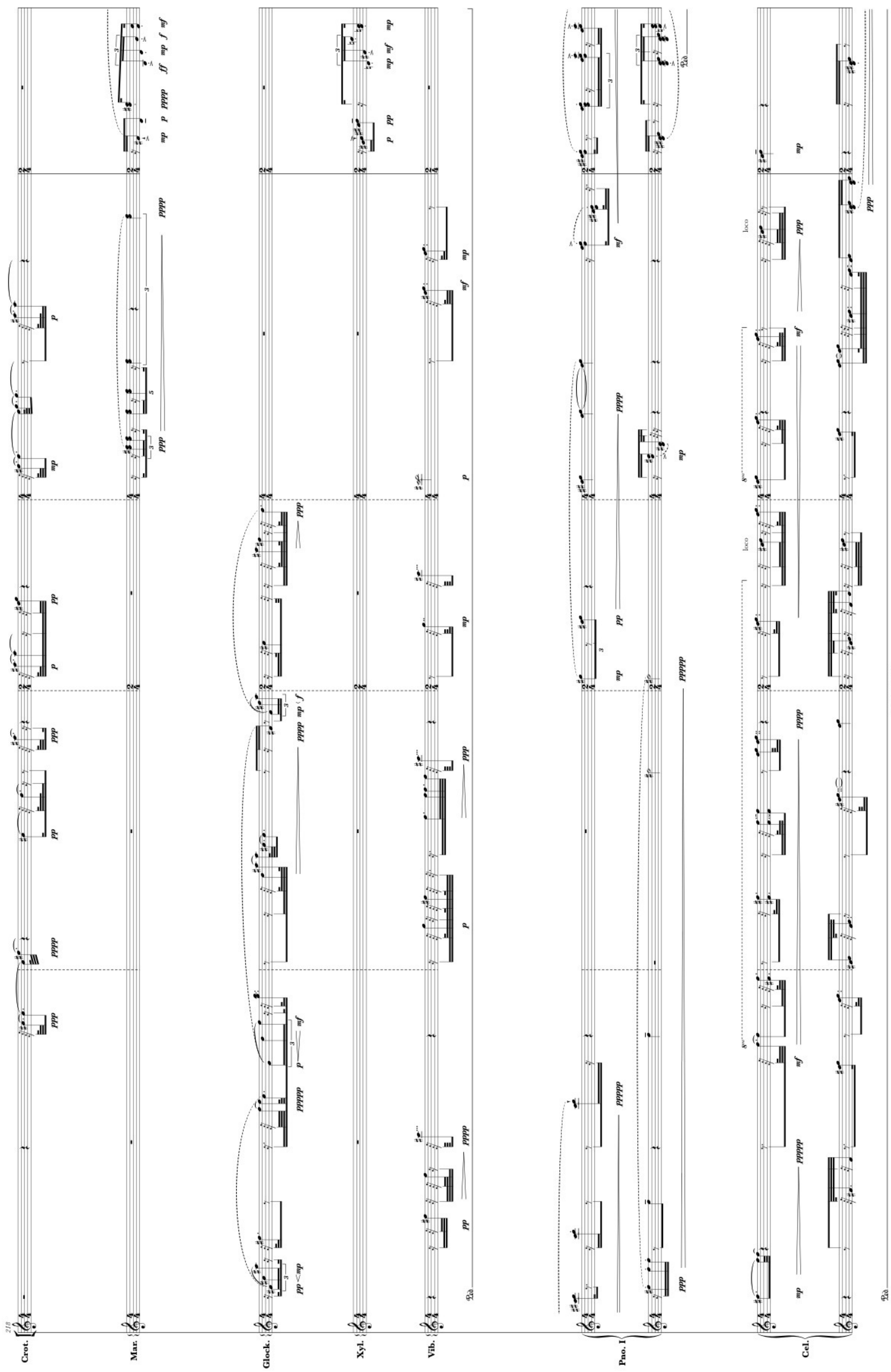

174
Cym.
B. D.
Tub. B.
Mar.
Gong T.-t.
Timp.
Vib.
Pno. I
Pno. II
MOTOR ON
loco
© Reid 2012-2013
23

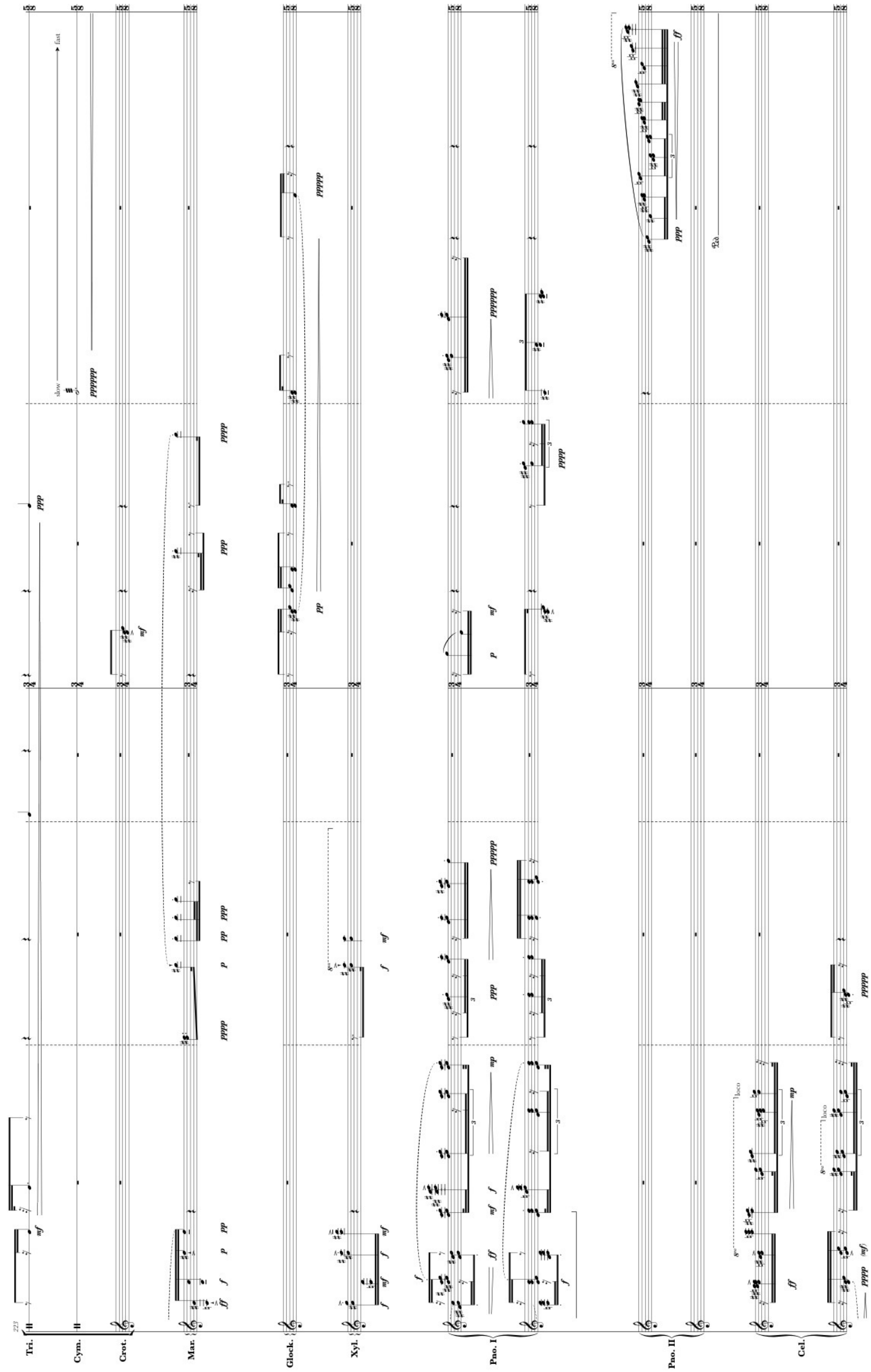

6
slow
B. D.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
loco
MOTOR OFF
© Reid 2012-2013
24


Tri.
W.Ch.
Crot.
Mar.
Cym.
Cow.B.
Glock.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
© Reid 2012-2013
25

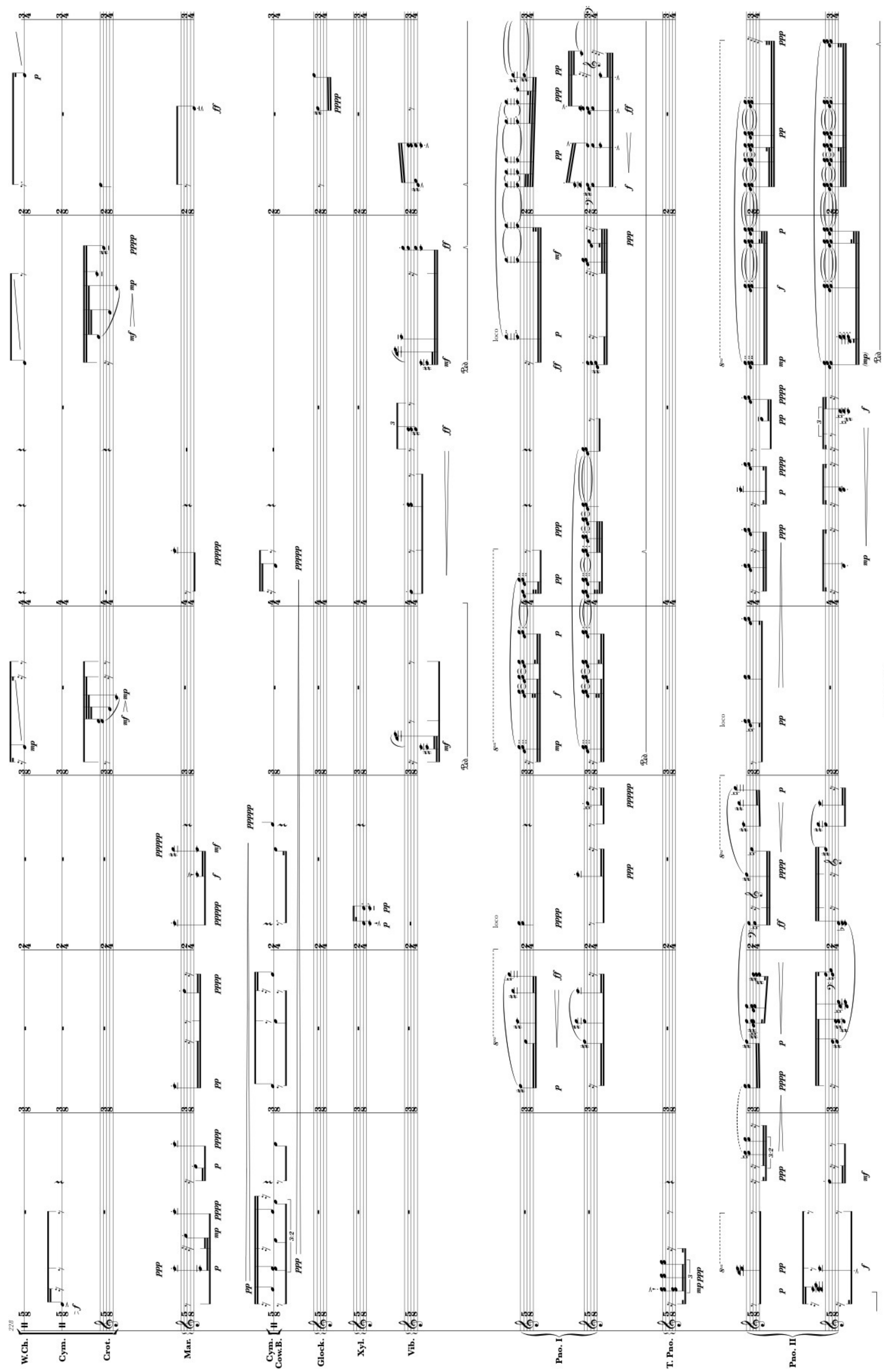

201
Tri.
W.Ch.
Cym.
Crot.
Tub. B.
Mar.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
slow
fast
loco

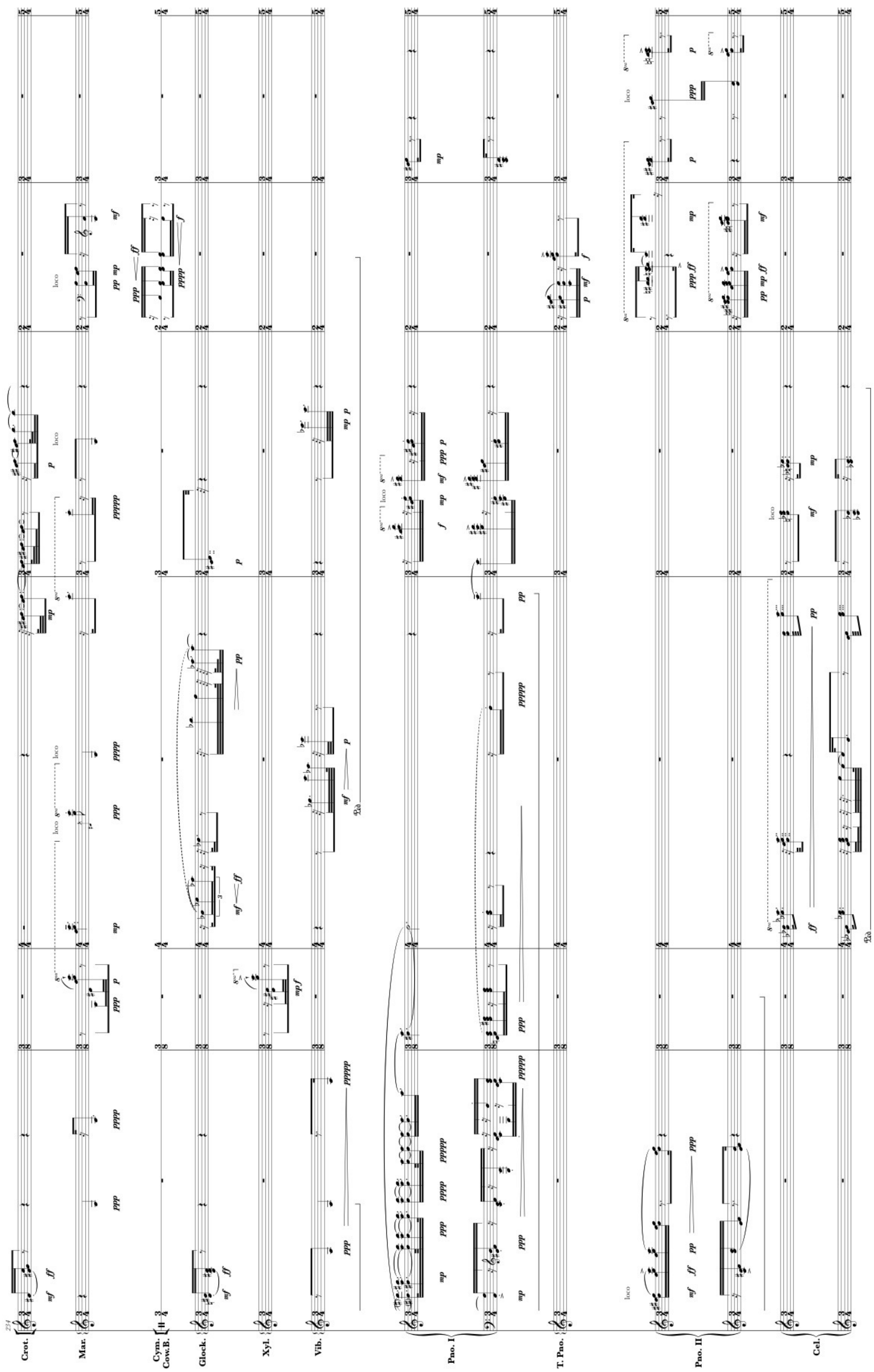

211
Tri.
Mar.
Xyl.
Vib.
Pno. I
Pno. II
© Reid 2012-2013
27

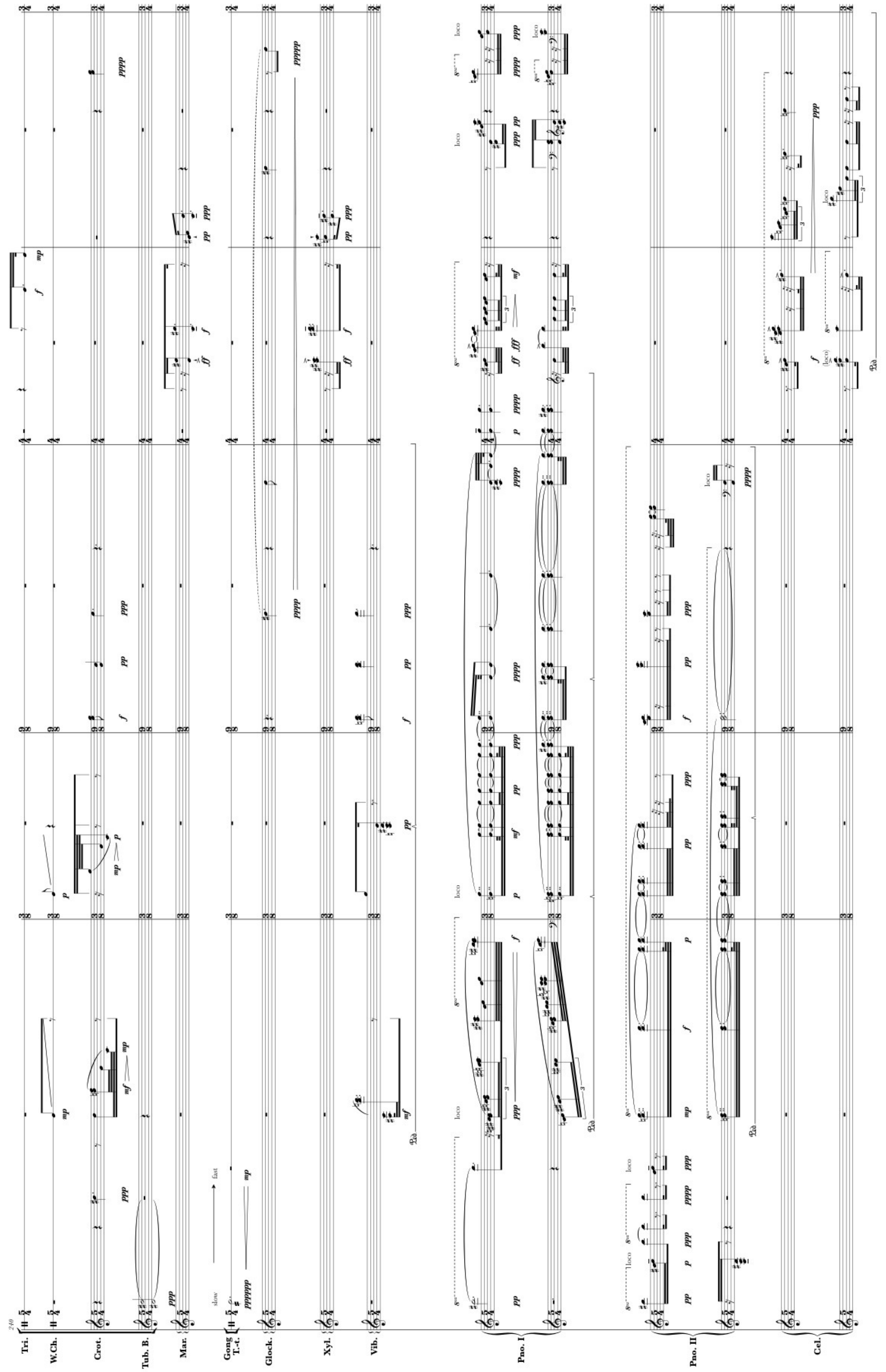

218
Crot.
Mar.
Glock.
Xyl.
Vib.
Pno. I
Cel.
loco
© Reid 2012-2013
28

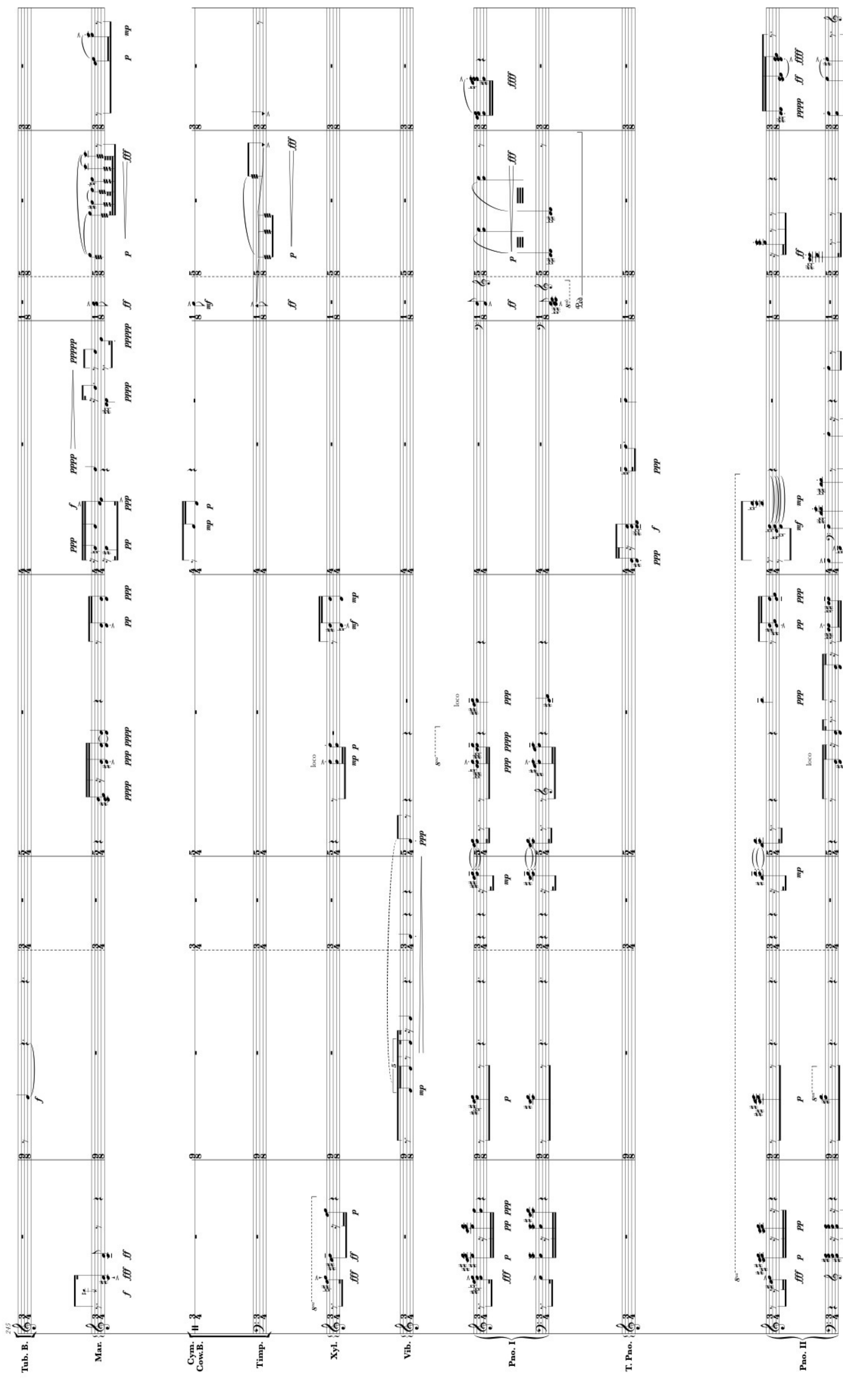

223
Tri.
Cym.
Crot.
Mar.
Glock.
Xyl.
Pno. I
Pno. II
Cel.
slow
fast
loco
loco

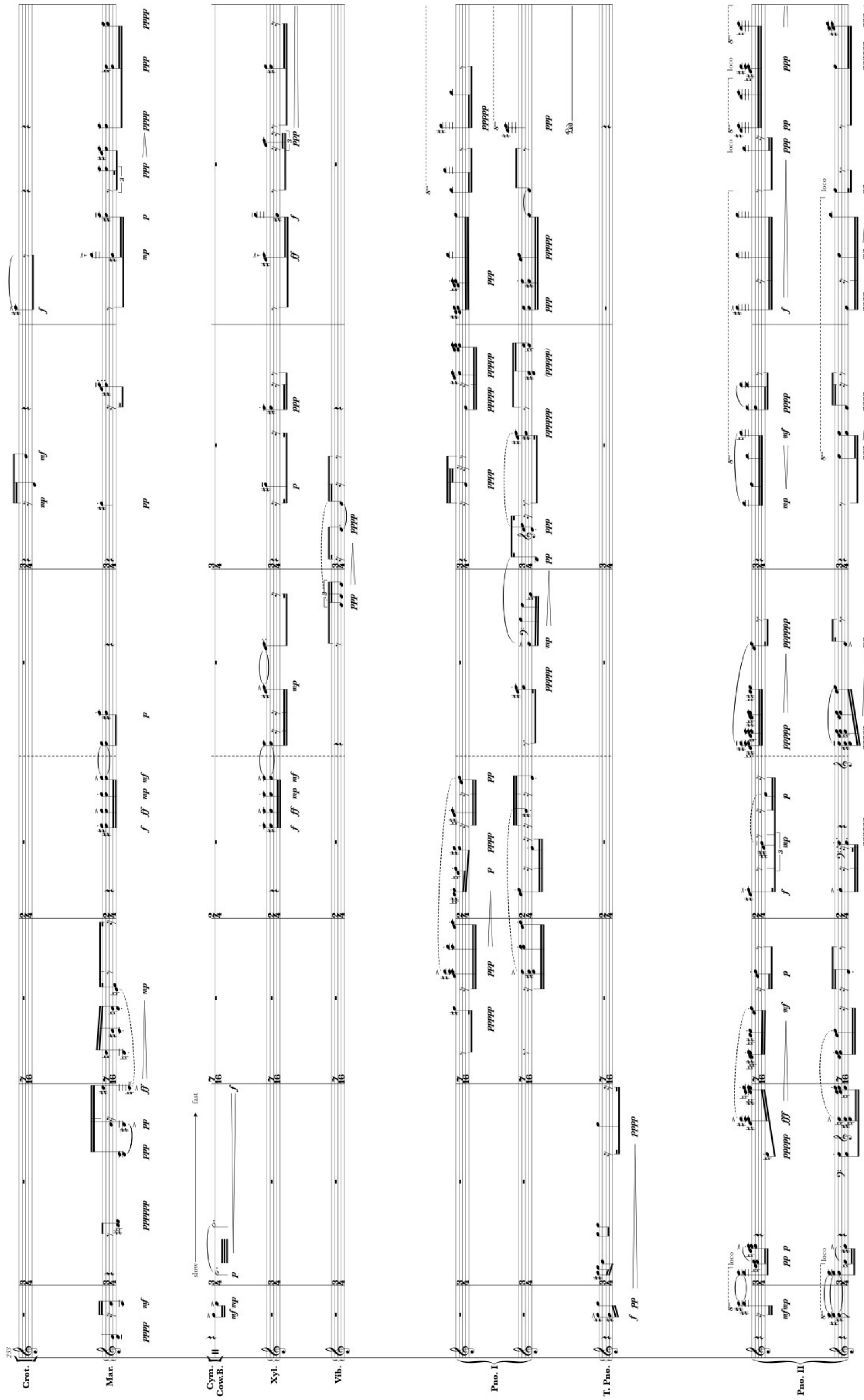
29

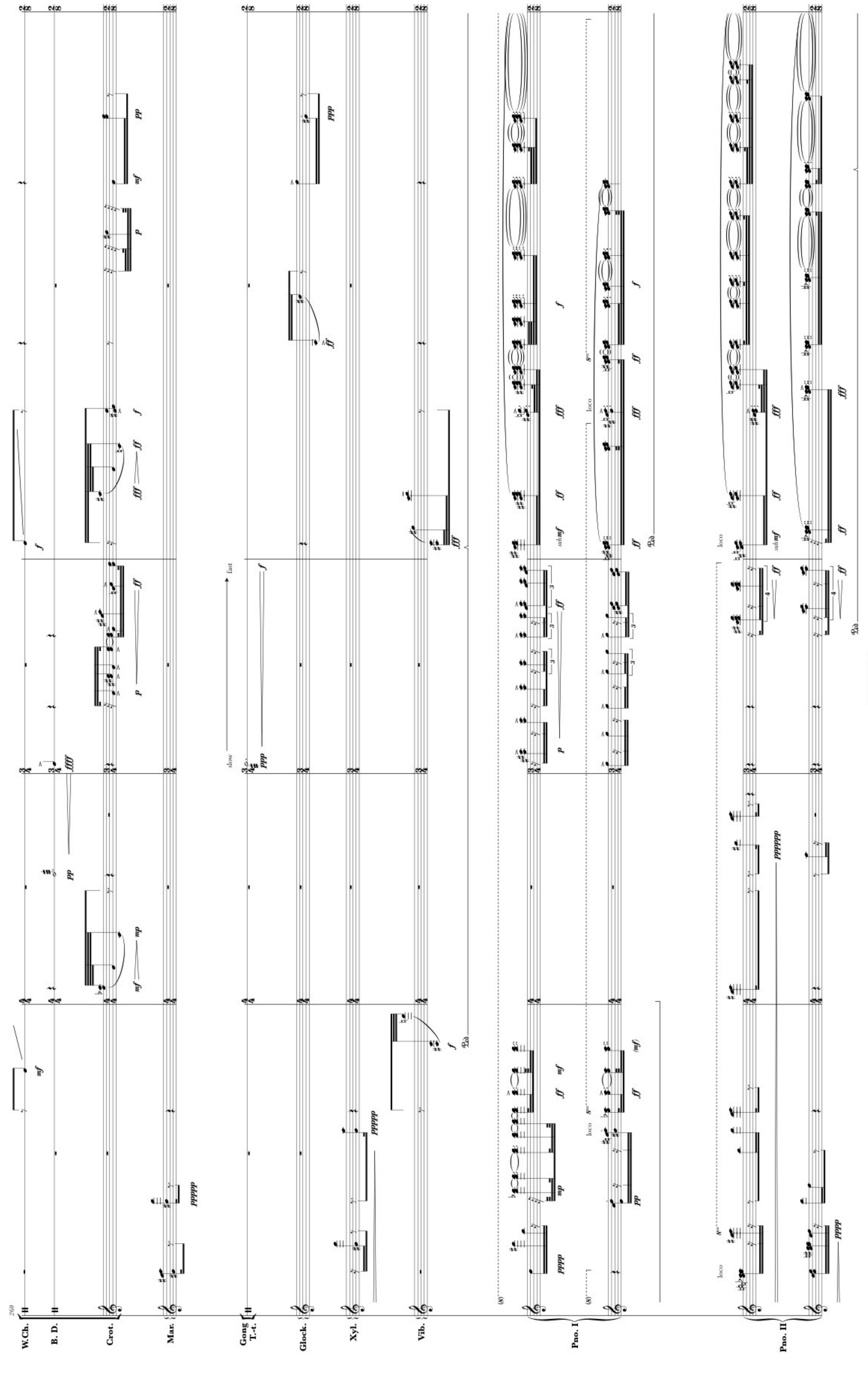

228
W.Ch.
Cym.
Crot.
Mar.
Cym.
Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
loco
© Reid 2012-2013
30


Crot.
Mar.
Cym. Cow.B.
Glock.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
Cel.
loco
© Reid 2012-2013
31

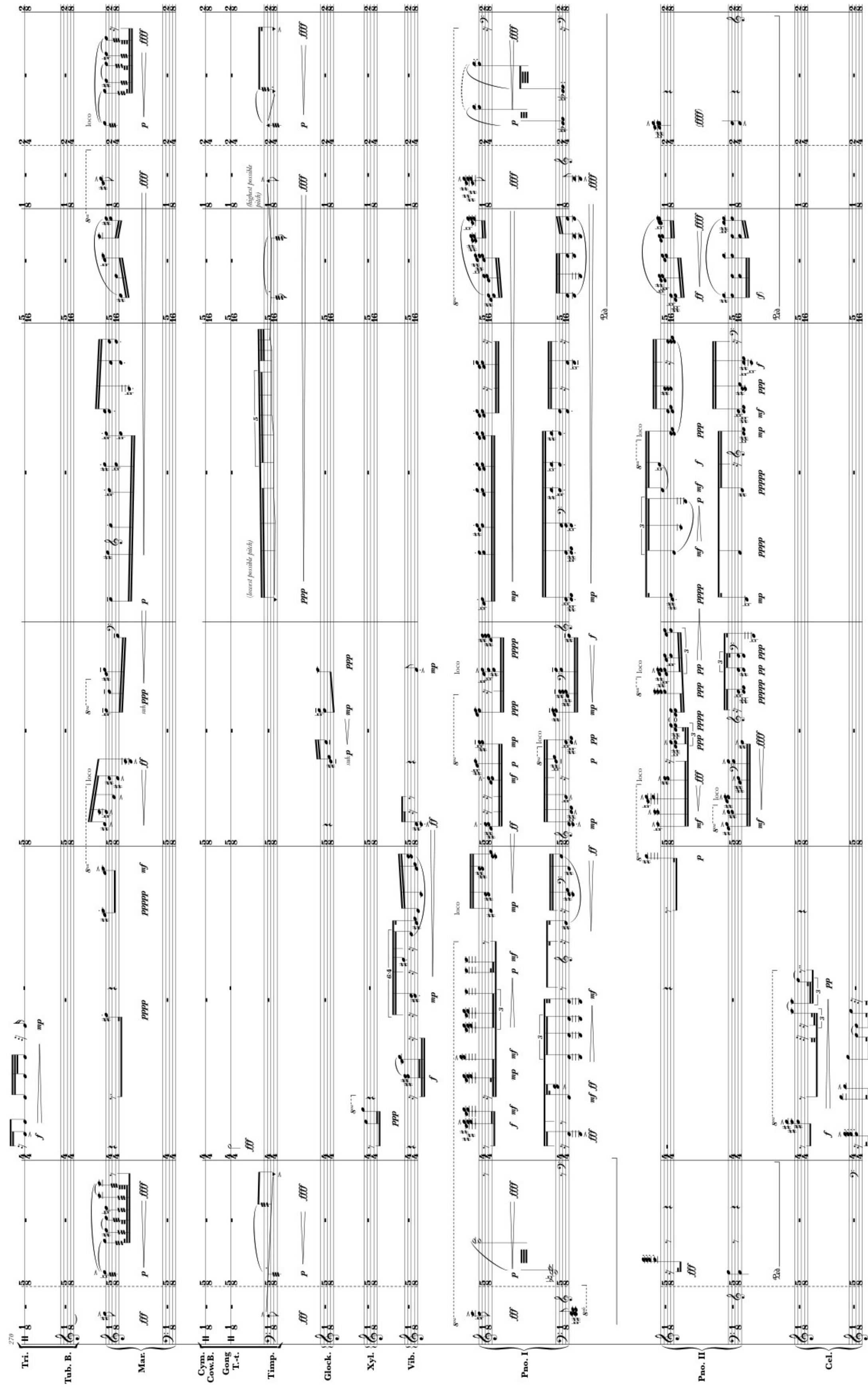

240
Tri.
W.Ch.
Crot.
Tub. B.
Mar.
Gong
T.-t.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
Cel.
slow
fast
loco
© Reid 2012-2013
32

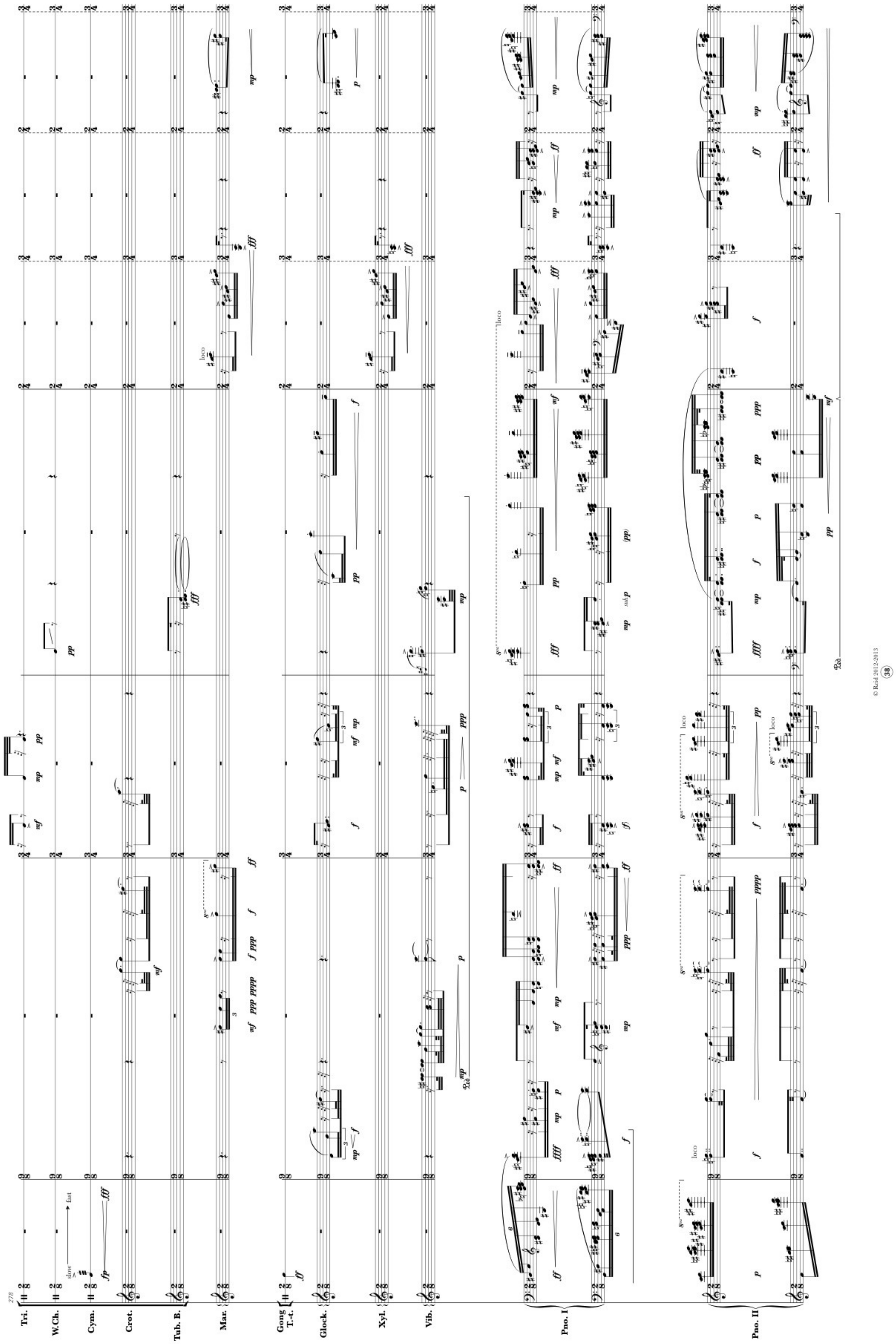

Tub. B.
Mar.
Cym.
Cow.B.
Timp.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
loco
© Reid 2012-2013
33

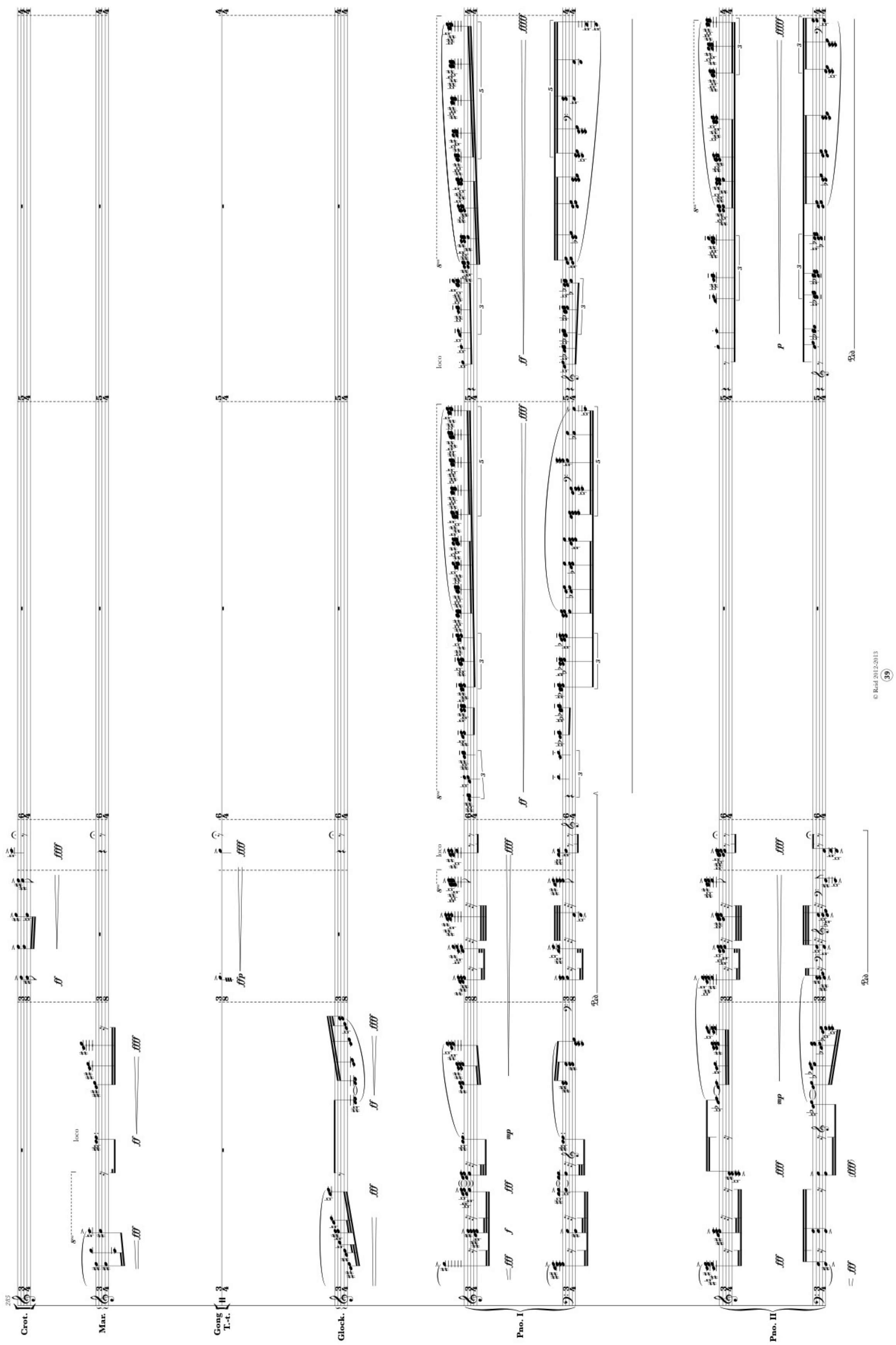

Crot.
Mar.
Cym. Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
slow
fast
loco
© Reid 2012-2013
34

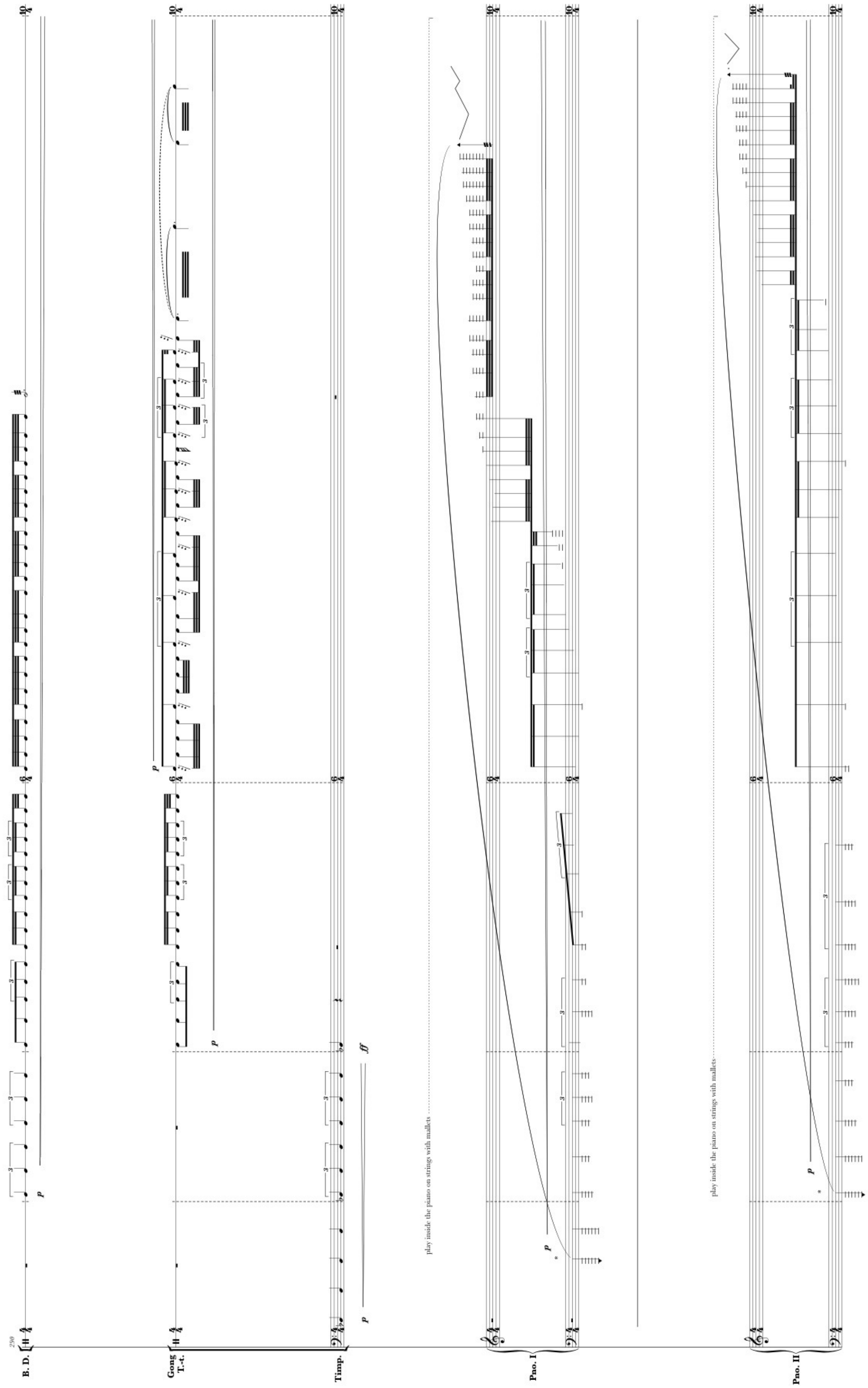

W.Ch.
B. D.
Crot.
Mar.
Gong T.-t.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
slow
fast
loco
© Reid 2012-2013
35


264
W.Ch.
Crot.
Tub. B.
Mar.
Cym. Cow.B.
Gong T.-t.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
loco
© Reid 2012-2013
36


270
Tri.
Tub. B.
Mar.
Cym.
Cow.B.
Gong
T.-t.
Timp.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
Cel.
(lowest possible pitch)
(highest possible pitch)
loco
© Reid 2012-2013
37

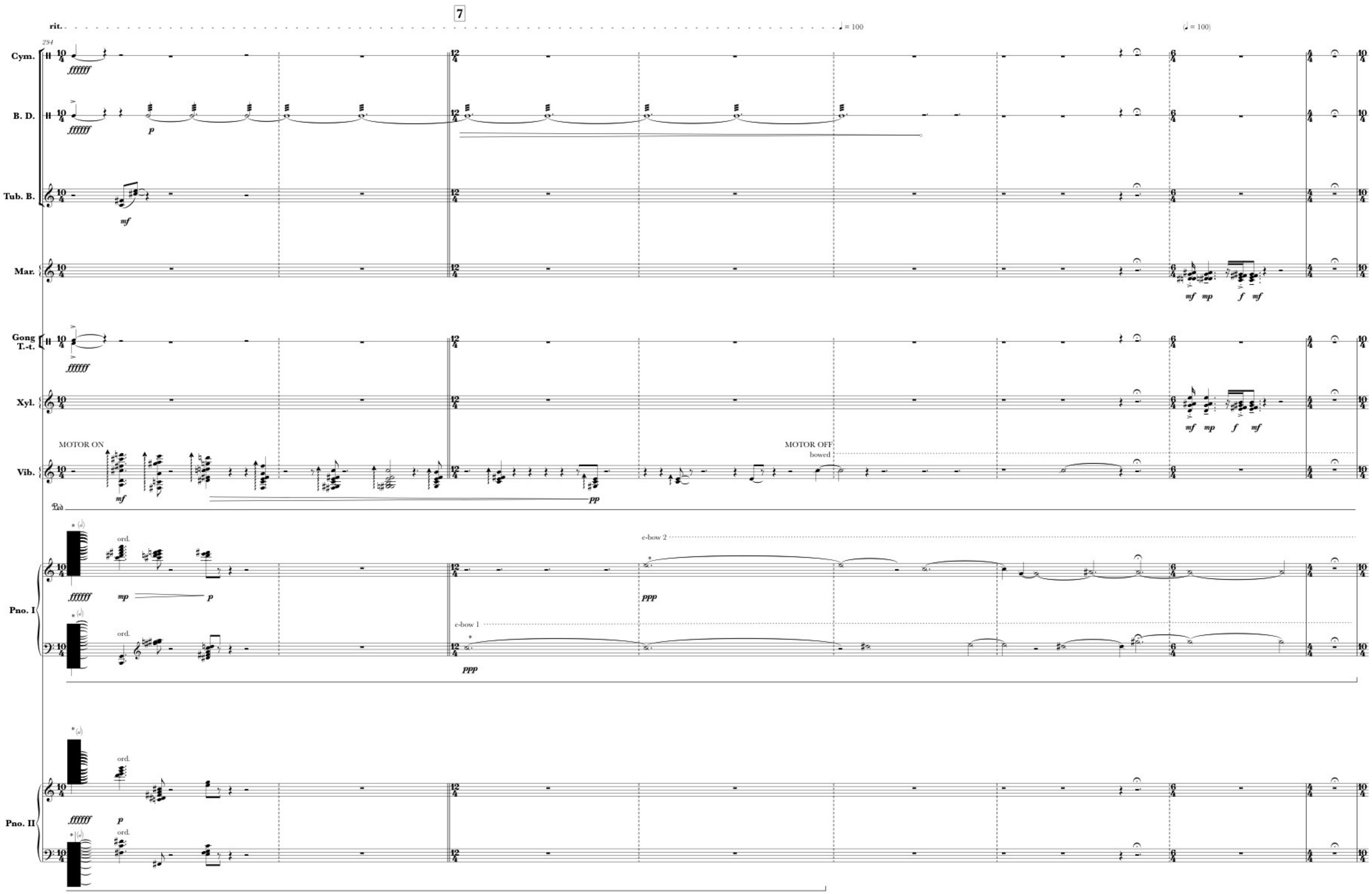

Tri.
W.Ch.
Cym.
Crot.
Tub. B.
Mar.
Gong
T.-t.
Glock.
Xyl.
Vib.
Pno. I
Pno. II
© Reid 2012-2013
38


Crot.
Mar.
Gong
T.-t.
Glock.
Pno. I
Pno. II
© Reid 2012-2013
39



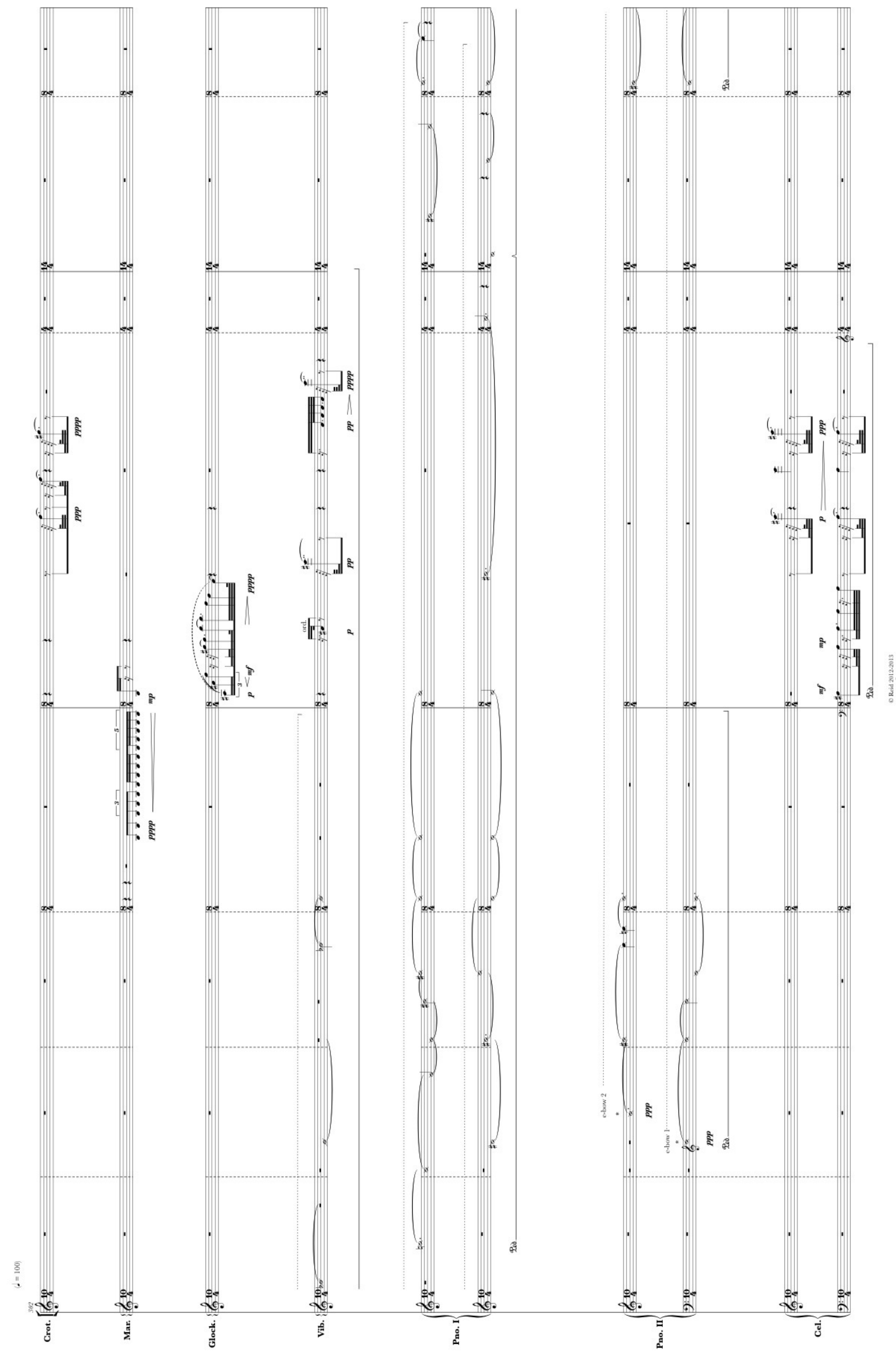
* mm. 290-293: Pno. I & Pno. II: Improvise on strings following the indicated curve. Begin with the lowest possible pitch and gradually move to the highest possible pitch

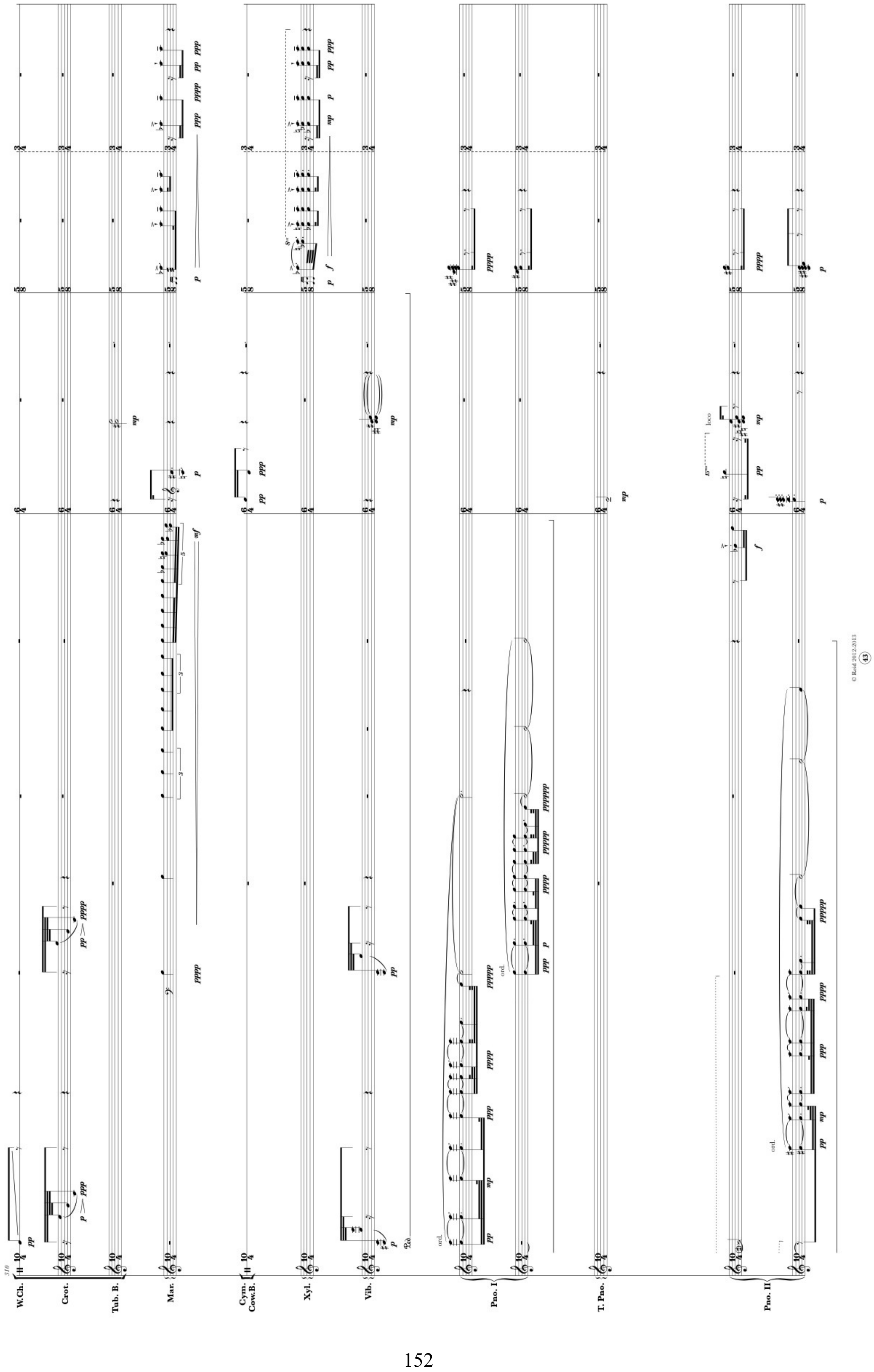
40

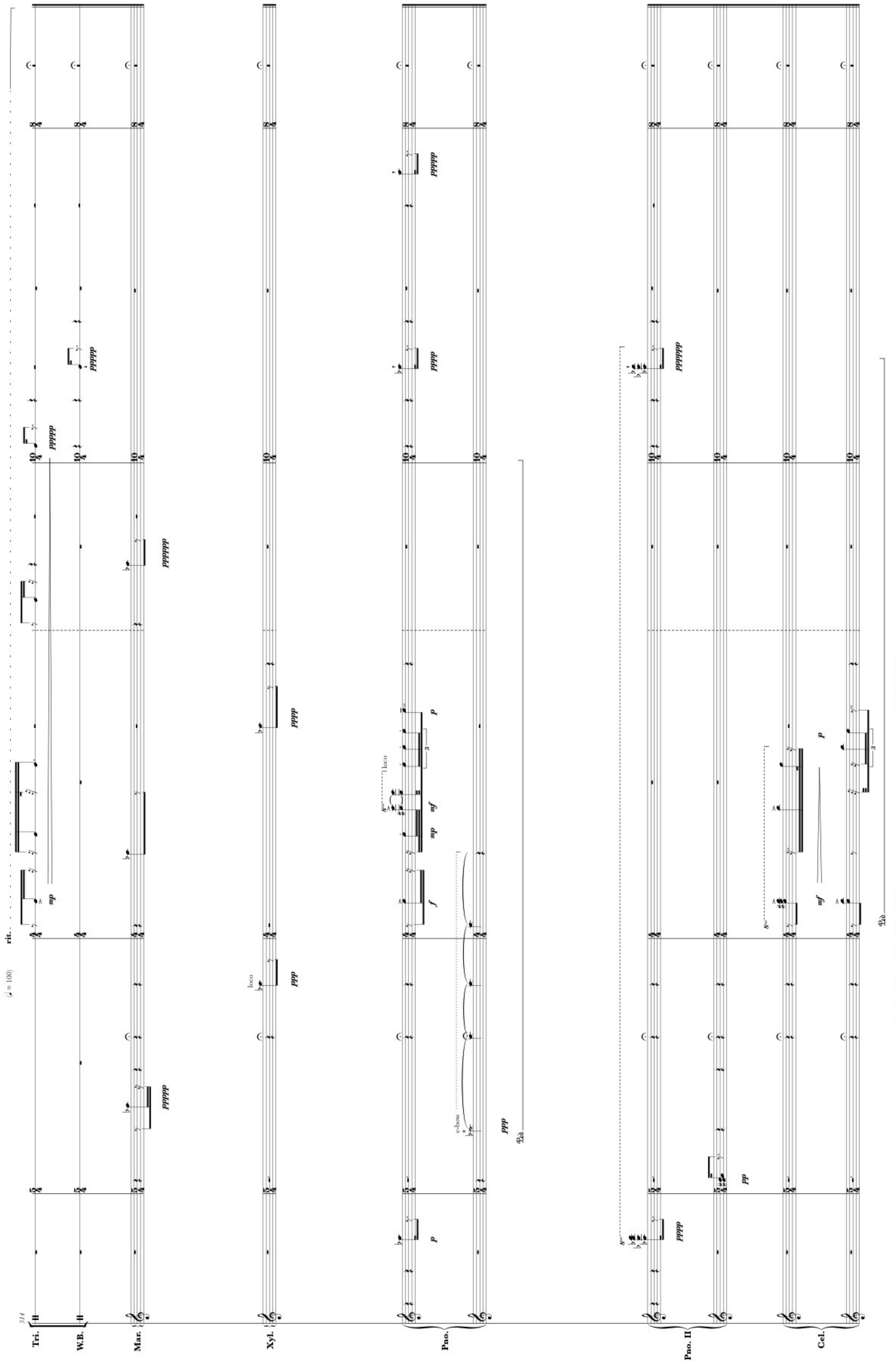


* mm. 294 - Pno. I & Pno. II: Still holding mallets - strike the keyboard with forearms for two beats - creating a giant ferocious cluster, then set the mallets down

* mm. 296-300, 302-306 and 308-309- Pno.I & Pno. II: The rhythms indicate the amount of time the e-bow should be on the strings. The pitches should continue to ring once the e-bow has been lifted from the string. Take additional time if needed to make the notes sound - all rhythms for the e-bow should be treated loosely


Crot.
Mar.
Glock.
Vib.
Pno. I
Pno. II
Cel.
ord.
e-bow 1
e-bow 2
© Reid 2012-2013
42


210
W.Ch.
Crot.
Tub. B.
Mar.
Cym. Cow.B.
Xyl.
Vib.
Pno. I
T. Pno.
Pno. II
ord.
loco
© Reid 2012-2013
43


314
(♩ = 100)
rit.
Tri.
W.B.
Mar.
Xyl.
loco
Pno.
e-bow
loco
Pno. II
Cel.
* mm. 315 - Pno.I: Allow enough time for the sound to fully emerge
© Reid 2012-2013
44

Bibliography

Abel, J. S., & Huang, P. (2006). A Simple, Robust Measure of Reverberation Echo Density. In *Proceedings of the 121st AES Convention,* 1–10.

Alberman, D. (2005). Abnormal Playing Techniques in the String Quartets of Helmut Lachenmann. *Contemporary Music Review*, *24*(1), 39–51.

Anderson, J. (2000). A Provisional History of Spectral Music. *Contemporary Music Review*, *19*(1989), 7–22.

ANSI, American National Standards Institute. (1960, (R1979)). 12.9 timbre. *ANSI S1.1.*

Aucouturier, J. (2006). *Ten experiments on the modeling of polyphonic timbre*. PhD thesis, L'Université Paris 6, Paris, France.

Bismarck, G. V. (1974). Sharpness as an Attribute of the Timbre of Steady Sounds. *Acustica*, *30*.

Bismarck, G. V. (1974). Timbre of steady sounds: A factorial investigation of its verbal attributes. *Acustica*, *30*, 146–59.

Blume, P. (2008). Mathias Spahlinger's *128 erfüllte augenblicke* and the Parameters of Listening. *Contemporary Music Review*, *27*(6), 625–642.

Boulez, P. (1987). Timbre and composition–timbre and language. *Contemporary Music Review*, *2*(1), 161–171.

Castanet, P. A., & Fineberg, J. (2000). Gérard Grisey and the Foliation of Time. *Contemporary Music Review*, *19*(3), 29–40.

Erickson, R. (1975). *Sound structure in music*. Berkeley: University of California Press.

D'Escrivan, J. (1989). Reflections on the poetics of time in electroacoustic music. *Contemporary Music Review*, *3*(1), 197–201.

Daubresse, E., Assayag, G., & Fineberg, J. (2000). Technology and creation — The creative evolution. *Contemporary Music Review*, *19*(2), 61–80.

Feron, F.-X. (2012). The Emergence of Spectra in Gérard Grisey's Compositional Process: From *Dérives* (1973-74) to *Les espaces acousiques* (1974-85). *Contemporary Music Review*, *30*(5), 343–375.

Fineberg, J. (2000a). Appendix I: Guide to the Basic Concepts and Techniques of Spectral Music. *Contemporary Music Review*, *19*(2), 81–113.

Fineberg, J. (2000b). Appendix II: Musical Examples. *Contemporary Music Review*, *19*(1975), 115–134.

Fineberg, J. (2000c). Spectral music. *Contemporary Music Review*, *19*(2), 1–5.

Fletcher, H. B. T. L. (1934). Loudness, Pitch and the Timbre of Musical Tones and Their Relation to the Intensity, the Frequency and the Overtone Structure. *October*, *6*(2), 59–69.

Gayou, É. (2007). The GRM: landmarks on a historic route. *Organised Sound*, *12*(03), 203–211.

Giordano, B. L., & McAdams, S. (2006). Material identification of real impact sounds: Effects of size variation in steel, glass, wood, and plexiglass plates. *The Journal of the Acoustical Society of America*, *119*(2), 1171–1181.

Grella-Możejko, P. (2005). Helmut Lachenmann—Style, Sound, Text. *Contemporary Music Review*, *24*(1), 57–75.

Grey, J. M. (1975). *An exploration of musical timbre*. PhD thesis, Stanford University, Center for Computer Research in Music and Acoustics, Report No. STAN-M-2.

Grey, J. M. (1977). Multidimensional perceptual scaling of musical timbres. *The Journal of the Acoustical Society of America*, *61*(5), 1270–7.

Grey, J. M., & Gordon, J. W. (1978). Perceptual effects of spectral modifications on musical timbres. *Journal of the Acoustical Society of America*, *63*(5), 1493–1500.

Grey, J. M. & Moorer, J.A. (1977). Perceptual evaluations of synthesized musical instrument tones. *The Journal of the Acoustical Society of America*, *62*(2).

Grisey, G. (1987). Tempus ex Machina: A composer's reflections on musical time. *Contemporary Music Review*, *2*, 239–275.

Grisey, G., & Fineberg, J. (2000). Did You Say Spectral? *Contemporary Music Review*, *19*(3), 1–3.

Hall, M. D., & Beauchamp, J. W. (2009). Clarifying spectral and temporal dimensions of musical instrument timbre. *Acoustique Canadienne, Journal of the Canadian Acoustical Association,* 37(1), 3–22.

Helmholtz, H. L. F. (Original German Edition in 1863, English translation in 1954). *On the Sensation of Tone*. Mineola, NY: Dover Publications.

Harvey, J. (1981). “Mortuos Plango, Vivos Voco”: A Realization at IRCAM. *Computer Music Journal*, *5*(4), 22–24.

Harvey, J. (2001). Spectralism. *Contemporary Music Review*, *19*(3), 11–14.

Heald, D. The Deutsche Bank Series at the Guggenheim Anish Kapoor Memory. Guggenheim. *2008*. Retrieved May 31, 2013, from http://web.guggenheim.org/exhibitions/kapoor/index2.html

Huang, P. and Abel, J. (2007). Aspects of reverberation echo density. In *Proceedings of the 121st AES Convention, Reprint 7163.*

Huang, P., Abel, J. S., Terasawa, H., & Berger, J. (2008). Reverberation Echo Density Psychoacoustics. *Audio Engineering Society Convention 125*. Audio Engineering Society.

Irino, T., & Patterson, R. D. (2002). Segregating information about the size and shape of the vocal tract using a time-domain auditory model: The stabilised wavelet-Mellin transform. *Speech Communication*, *36*(3-4), 181–203.

Iverson, P., & Krumhansl, C. L. (1993). Isolating the dynamic attributes of musical timbre. *The Journal of the Acoustical Society of America*, *94*(5), 2595–603.

Klein, W., Plomp, R., & Pols, L. C. (1970). Vowel spectra, vowel spaces, and vowel identification. *Journal of the Acoustical Society of America*, *48*(4), 999–1009.

Lakatos, S. (2000). A common perceptual space for harmonic and percussive timbres. *Perception & psychophysics*, *62*(7), 1426–39.

Lalitte, P. (2011). The theories of Helmholtz in the work of Varese. *Contemporary Music Review*, *30*(5), 329–344.

Ledoux, C., & Fineberg, J. (2000). From the philosophical to the Practical: An imaginary proposition concerning the music of Tristan Murail. *Contemporary Music Review*, *19*(3), 41–65.

Lerdahl, F. (1987). Timbral hierarchies. *Contemporary Music Review*, *2*(1), 135–160.

Malherbe, C., Fineberg, J., & Hayward, B. (2000). Seeing light as color; hearing sound as timbre. *Contemporary Music Review*, *19*(3), 15–27.

Manning, P. (2013). *Electronic and Computer Music*. Oxford University Press.

Manoury, P. (1984). The arrow of time. *Contemporary Music Review*, *1*(1), 131–145.

McAdams, S., & Cunible, J.-C. (1992). Perception of timbral analogies. *Philosophical transactions: Biological sciences, Processing of Complex Sounds by the Auditory System*, 336(1278), 383–389.

McAdams, S., Giordano, B., Susini, P., Peeters, G., & Rioux, V. (2006). A meta-analysis of acoustic correlates of timbre dimensions [Lecture slides]. Retrieved from McGill University: http://www.dafx.ca/slides/keynote3.pdf

McAdams, S., & Saariaho, K. (1985). Qualities and Functions of Musical Timbre. *International Computer Music Conference*, 367–374.

McAdams, S., Winsberg, S., Donnadieu, S., De Soete, G., & Krimphoff, J. (1995). Perceptual scaling of synthesized musical timbres: common dimensions, specificities, and latent subject classes. *Psychological Research*, *58*(3), 177–192.

Mirka, D. (2012). To cut the Gordian Knot: the timbre system of Krzysztof Penderecki. *Journal of Music Theory*, *45*(2), 435–456.

Murail, T. (2000). After-thoughts. *Contemporary Music Review*, *19*(3), 5–9.

Murail, T. (2005c). The Revolution of Complex Sounds. *Contemporary Music Review*, *24*(2-3), 121–135.

Murail, T. (2005d). Spectra and Sprites. *Contemporary Music Review*, *24*(2-3), 137–147.

Pasler, J. (1982). Debussy, "Jeux": Playing with Time and Form. *19th Century Music*, *6*(1), 60–75.

Peeters, G., Giordano, B. L., Susini, P., Misdariis, N., & McAdams, S. (2011). The Timbre Toolbox: extracting audio descriptors from musical signals. *The Journal of the Acoustical Society of America*, *130*(5), 2902–16.

Peterson, G. E. (1952). Control Methods Used in a Study of the Vowels. *The Journal of the Acoustical Society of America*, *24*(2), 175.

Plomp, R. (1976). *Aspects of tone sensation: a psychophysical study*. Academic Press.

Pollard, H. F., & Jansson, E. V. (1982). A Tristimulus Method for the Specification of Musical Timbre. *International Journal of Acoustics*, *51*, 162–171.

Poli, G. D., & Prandoni, P. (1997). Sonological models for timbre characterization. *Journal of New Music Research*, *26*(2), 170–197.

Pousset, D., Fineberg, J., & Hyacinthe, R. (2000). The Works of Kaija Saariaho, Philippe Hurel and Marc-André Dalbavie—Stile Concertato, Stile Concitato, Stile Rappresentativo. *Contemporary Music Review*, *19*(3), 67–110.

Pratt, R. (1976). A subjective rating scale for timbre. *Journal of Sound and Vibration*, *45*(3), 317–328.

Puckette, M. (2007). *The theory and technique of electronic music*. Hackensack, N.J: World Scientific Publishing Co.

Risset, J. C. (1994). Sculpting sounds with computers: music, science, technology. *Leonardo*, *27*(3), 257–261.

Risset, J. C. (2002). *Electroacoustic Music: Analytical Perspectives*. London, UK: Greenwood Press.

Risset, J. C., & Wessel, D. (1999). *Exploration of Timbre by Analysis Synthesis*. *The Psychology of Music*. San Diego: Academic Press.

Rose, F. (1996). Introduction to the pitch organization of French spectral music. *Perspectives of New Music*, *34*(2), 6–39.

Rose, F., & Kapuscinski, J. (2009). Japanese Traditional Orchestral Music: The Correlation between Time and Timbre. In *Proceedings from the Conference of Interdisciplinary Musicology,* 1–6.

Rossing, T. (1990). *The science of sound*. Reading, Mass.: Addison-Wesley Pub. Co.

Rossing, T.D. (2012). Pitch and Timbre. Lecture conducted from Stanford University, CA.

Saariaho, K. (1987). Timbre and harmony: Interpolations of timbral structures. *Contemporary Music Review*, *2*(1), 93–133.

Schaeffer, P. (1966). *Traité des objets musicaux, essai interdisciplines*. Paris: Éditions du Seuil.

Schubert, E., & Wolfe, J. (2006). Does Timbral Brightness Scale with Frequency and Spectral Centroid? *ACTA Acustica United with Acustica*, *92*(5), 820–825.

Stephenson, R. B., & Seiberling, C. L. (1994). *Jaffrey then and now: Changes in community character*. Jaffrey, N.H: Jaffrey Historic District Commission.

Singh, S., & Woods, D. R. (1971). Perceptual structure of 12 American English vowels. *The Journal of the Acoustical Society of America*, *49*(6), 1861–6.

Slawson, W. (1985). *Sound color*. Berkeley: University of California Press.

Smalley, D. (1997). Spectromorphology: explaining sound-shapes. *Organised Sound*, *2*(2), 107–126.

Spahlinger, M. (2008). This Is the Time of Conceptive Ideologues No Longer. *Contemporary Music Review*, *27*(6), 579–594.

Steenhuisen, P. (2004). Interview with Helmut Lachenmann—Toronto, 2003. *Contemporary Music Review*, *23*(3-4), 9–14.

Sundberg, J. (1977). Vibrato and vowel identification. *Arch Acoust*, *2*, 257–266.

Surianu, H., & Fineberg, J. (2000). Romanian spectral music or another expression freed. *Contemporary Music Review*, *19*(2), 23–32.

Terasawa, H. (2009). *A Hybrid Model for Timbre Perception: Quantitative Representations of Sound, Color, and Density*. PhD thesis, Stanford University, Center for Computer Research in Music and Acoustics.

Terasawa, H., Slaney, M., & Berger, J. (2005a). A Timbre Space for Speech. *Interspeech,* 4–7.

Terasawa, H., Slaney, M., & Berger, J. (2005b). Perceptual Distance in Timbre Space. *Eleventh Meeting of the International Converence on Auditory Display*, 5, 61–68. Limerick, Ireland.

Terasawa, H., Slaney, M., & Berger, J. (2005c). The Thirteen Colors of Timbre. *2005 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics,* 323–326. New Paltz, NY: IEEE.

Traube, C. (2006). Instrumental and Vocal Timbre Perception [Lecture slides]. Retrieved from the University of Graz Psychology of Music Performance Seminar: http://www.uni-graz.at/richard.parncutt/guests/2006/traube/Slides_CTraube_timbre.pdf

Traube, C., & Depalle, P. (2004). Phonetic gestures underlying guitar timbre description. *Proceedings of the International Conference on Music Perception and Cognition*, 658–661.

Vassilakis, P. N. (1995). Introduction to Psychoacoustics and Sound Perception—Timbre. Retrieved from http://acousticslab.org/psychoacoustics/

Wessel, D. L. (1979). Timbre Space as a Musical Control Structure. (C. Roads & J. Strawn, Eds.) *Computer Music Journal*, *3*(2), 45–52.

Wishart, T., & Emmerson, S. (1996). *On sonic art*. Amsterdam: Harwood Academic Publishers.