Compositional Outcomes of Audio Morphing Research

by

Darren Miller
BMus, University of Saskatchewan, 2005
MMus, University of Victoria, 2008

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of

Doctor of Philosophy

in the School of Music

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Abstract

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The following dissertation describes a personal course of research into audio morphing technology, with a primary focus on how such research might impact the composition of contemporary, research-based art music. These two primary concerns have been augmented through considerations of both: the broader literature of musical morphology, and selected analyses from the history of western art music that employ an idiosyncratic interpretation of audio morphing principles. I have attempted throughout to tightly focus these discussions through the lens of my own compositional activity, embodied by the accompanying dissertation composition for ten musicians/sound technicians (*for chelsea smith*) and its chapter-length analysis.

Therefore, following a terminological distinction between appearances and usages of the terms ***morphing*** and ***morphology*** in the existing literature (Chapter 1), the above materials will be organized in order of their importance to my compositional activity. As such, the analysis of my dissertation composition (Chapter 2) will be presented first. This will be followed by a summary of my technical research (Chapter 3), and three highly personalized interpretations of how morphing principles might be said to apply to works from the past repertoire of the western tradition (Chapters 4-6).

The morphing principles alluded to above include: the primacy of pure sound, the decomposition of complex sonic phenomena into simpler elements, the importance of continuous transformation, and the connection of disparate sonic entities through continua of new material. Such principles will not only inform my analyses of past music, but will also be revealed as central to my compositional perspective in *for chelsea smith*.

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On a personal level, the support of my friends and family has also been staggering. My parents (Phil and Betty), brother (Jordan), and sister (Jennifer), have all been invaluable resources throughout this process. This is doubly so for those closest to me on a daily basis, my wonderful co-devotees: Chelsea Smith and Annette Brosin.

I would also like to thank the pioneers from the field of audio morphing who have generously allowed the reproduction of many original diagrams for the clarification of Chapter 5. Finally, none of this could have been possible without the amazing performers listed in Chapter 6 who brought so much dedication and musicality to the preparation of an extremely difficult premiere.

Dedication

As is the case with the attached musical composition, the joint dedicatees of this written dissertation are two of the most amazing women that I am lucky enough to know. Both the namesake of the piece (Chelsea Smith) and my fellow PhD candidate Annette Brosin have supported me throughout this entire process, to a level that I would not have thought possible. Thank you both so much.

1 The Terminology and Literature of Morphing and Morphology

1.1 Introduction

The relatively recent opening up of a seemingly limitless soundworld will be mentioned frequently by many of the composers and thinkers cited throughout the following dissertation. It is primarily this aspect of contemporary practice that has motivated the following research. In the face of such vast material possibilities, the arrangement and above all ***interconnection*** of chosen materials takes on an added importance.

Audio morphing technologies – which by definition aim to connect two or more distinct sonic entities – constitute a particularly promising field of study in this regard. My own compositional outlook (as will be described at length in Chapter 2) has been impacted significantly by research into these technologies (to be summarized in Chapter 3). My preliminary assessment of the field also revealed a relevant body of literature dealing with a related term: ***musical morphology***. Because these two terms (morphing and morphology) are often found in close proximity to each other – despite an important terminological distinction – the present chapter will aim to clarify the language that surrounds them.

The personal, compositional, outcomes of this already broad conception of the topic were my primary concern. However, I have also included three chapters (Chapters 4, 5, and 6) on the re-assessment of older paradigms of musical organization (respectively: pitch, timbre, and form) in light of the principles described by the first three chapters. Once again, I have measured the value of these "historical" chapters in terms of their contribution to my present and future compositional thought.

As described above, the present chapter deals exclusively with the terminology of morphing and morphology, organized according to a loose chronology of the literature.

SECTION	TERMS/FIGURES CONSIDERED
I - Terminology	Morphing, Morphology
II - Sonic Morphing	Cook, Wishart, Caetano
III - Musical Morphology	Goethe, Wishart, Smalley, Raaymakers, Mahnkopf

Table 1: Overview of Chapter 1

As indicated in Table 1, brief preliminary definitions of both morphing and morphology will provide the necessary context for their respective appearances in the musical literature.

1.1.1 Terminology I – Morphology

Morphology and morphing are very closely related, yet essentially distinct terms. Throughout the following study, I will employ them in accordance with their usage by the various authors being considered. Outside the realm of audio morphing software, I will also occasionally adopt the use of the more general term: ***transformation***.

Because of the similarities between morphing and morphology however, it is important to first define both terms clearly. Musical morphology as a ***noun*** will henceforth be used in a very broad sense as an adaptation of the general, non-biological, definition of morphology from "the history of variation in form"[1] to "the history of variation in *musical* form"[2]. Due to the fact that both "variation" and "form" have specialized (and loaded) meaning in terms of music history and analysis, one might simply call musical morphology: "the study of how sound changes over time". This definition has the advantage of avoiding loaded terms such as "variation" and "form", while also opening the door to our contemporary sound-based musical practice. For instance, traditional tools of music theory such as Schenkerian analysis or set theory may be used to study how music (sound) changes over time (the course of a work) just as effectively as more recent technologically inspired methods. In terms of musical morphology, these older techniques are no less relevant (and depending on the repertoire, potentially more so) than those employed by Denis Smalley and Trevor Wishart (among others to be discussed later in this chapter).

1.1.2 Terminology II – Morphing

Following the precedent set by Perry Cook (to be discussed shortly), the ***verb*** morphing on the other hand, will henceforth refer exclusively to the illusion that one

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[1] "Morphology, n.", *OED Online,* Oxford University Press, accessed December 10th 2014, http://www.oed.com.ezproxy.library.uvic.ca/view/Entry/122369?redirectedFrom=morphology.

[2] The term appeared in biological discourse much earlier (early 19th century) than the general sense (late 19th and early 20th centuries). OED, "Morphology, n."

sound has continuously and seamlessly turned into another. As has been mentioned above, audio morphing is the aspect of my research that I consider to hold the most creative potential, and is therefore a primary focus of the dissertation as a whole. Audio morphing studies have helped to shape my compositional perspective, influenced how I look at music of the past, and brought to my attention the broader topic of musical morphology. All of these factors have influenced how I write music, in particular the attached dissertation composition (see Appendix A – *for Chelsea smith*). Based on these considerations, audio morphing is a fundamental concept behind my approach to musical composition.

It is important to note that this narrowly defined sonic phenomenon (morphing as a verb), is of course also a subset of the term musical morphology (as a noun) in that it represents a change undergone by sound(s) over time. As in all musical morphology, the specific sounds and transformations involved in a given sonic morph may also be more or less traditional, experimental, acoustic, or electronic in nature. The verb forms "morphed", "morphing", and "morph" therefore, do not *necessarily* imply the use of digital audio processing, though such will often the case. Due to this central role, and the added level of terminological difficulty associated with such processing techniques, the morphing of digital audio requires further discussion.

1.2 Audio Morphing

Chapters 4-6 will explore various examples of how my interest in musical morphing has influenced my reading of the (purely acoustic) canon of the earlier western tradition. |However, it is the emergence of electronic – and especially digital – audio resources that has made research into musical morphing possible as a compositional resource. The morphing of audio is the sonic equivalent of the ubiquitous digital video editing technique involving the distortion of both a departure and arrival image to resemble each other such that a switch from the first distorted image to the second distorted image appears to have been a totally continuous transformation. The following still-frames (see Figure 1) illustrate the video-based process[3]:

[3] Still-frame presidential example reproduced from: Marcelo Caetano and Xavier Rodet. "Sound Morphing by Feature Interpolation," *Proceedings of the ICASSP* (2011): 161-164. For one of the earliest and most well-known video examples, consider the music video for the Michael Jackson single "Black or White",

Figure 1 - Still Frames of a Video Morph (via Caetano)

While both visual and audio morphing employ computer software and occur over time, the similarities do not extend much further. While video morphing exists as a stable technology and universally understood effect, the phenomenon of audio morphing is much harder to define and implement. Certain digital audio techniques work extremely well in certain contexts – ie. using certain sonic materials – while failing to produce the desired effect in other situations.

Though the slippery sense of identity associated with audio morphing may pose difficulties for software developers, it is important to keep in mind the positive compositional consequences resulting from a multiplicity of potential techniques. During the composition of *for chelsea smith* (analyzed at length in the following chapter), I was able to draw compositional inspiration from multiple (often conflicting) definitions of the audio morph. Though the specific techniques and contexts will be addressed in subsequent chapters, it is sufficient at this point to note the diversity of compositional outcome represented by the following two examples (Figure 2 and Figure 3) of morphing-inspired composition.

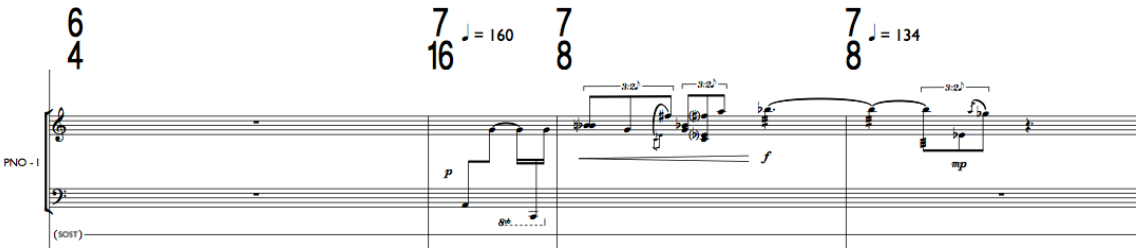

Figure 2 - Miller: for chelsea smith, mm. 71-4 (Piano 1)

where a sequence of moving faces are morphed into each other. See Michael Jackson, "Black or White," Youtube video, 6:22, directed by John Landis, accessed December 1st 2011, http://youtu.be/F2AitTPI5U0.

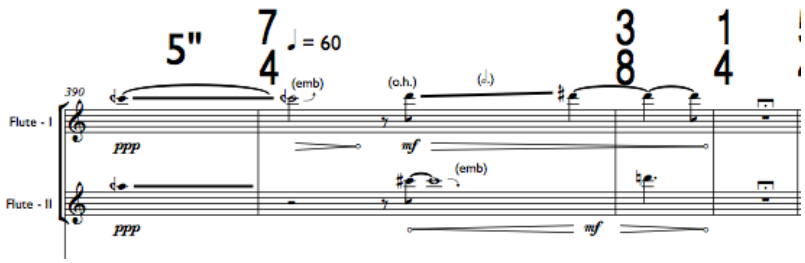

Figure 3 - Miller: for chelsea smith, mm. 390-3 (Flutes)

The basic concept is the same in both cases, where I have attempted to write music that embodies the principles behind audio morphing techniques. However, the striking differences between the respective morphing techniques that served as my inspiration are quite apparent when both excerpts are juxtaposed. Compare for instance the rapid, equal-tempered, and percussive activity of piano in Figure 2 to the slow, gentle, microtonal, gliding of the flutes in Figure 3. Such divergent textures result from the attempted translation of two morphing techniques with very different identities. The former was influenced by DFT or IR based cross synthesis, and the latter by techniques associated with spectral peak interpolation. More details regarding the nature of these techniques and their compositional influence on my work will appear in the following chapters.

For the time being however, it is sufficient to note that my present investigation – with its divided focus on both the software and compositional manifestations of sonic transformation – is both hindered and enriched by the less definable aspects of audio morphing. The following chronological survey of writings that have grappled with the identity of audio morphing technology begins with an especially complex case.

1.2.1 Defining the Audio Morph I - Perry Cook and Vocal Models

Princeton computer scientist Perry R. Cook's paper from DAFX 1998 (The 1998 Digital Audio Effects Workshop)[4], is a clear illustration of the difficulties involved in trying to establish a universal definition and/or technology for audio morphing. As the title ("Toward the Perfect Audio Morph? Singing Voice Synthesis and Processing") implies, Cook's perspective is that of a researcher interested in the electronic

[4] Perry Cook, "Toward the Perfect Audio Morph? Singing Voice Synthesis and Processing," *Proceedings of the Digital Audio Effects Workshop DAFX* (1998): 223-230.

manipulation of singing voices. These priorities have clear connections to Cook's background. Prior to obtaining three degrees in electrical engineering, Cook majored in vocal studies at the Kansas City Conservatory of Music, from which he obtained a Bachelor of Arts degree in 1986[5].

The specific techniques described by Cook in his 1998 DAFX paper will be taken up in Chapter 3. For now it is important to note the questioning tone of the title's first clause, and the fact that the paper is a technological survey of multiple techniques[6]. Cook concludes his summary of the various relevant techniques by pointing out that the phenomenon itself (audio morphing) is similarly without a singular identity:

> "The term "audio morph," has been applied to transitions between two instruments, between two vocal vowels, between two musical phrases, and even between the compositional styles of two composers. None of these are really equivalent to a morph in the graphics domain... perceptual categories, groups, and boundaries... challenge the notion of an ideal audio morph."[7]

Beginning this section with a deceptively simple question, Cook hints that the central difficulty might arise from mapping perceptual phenomena from one sense (in this case vision) onto another (in this case hearing):

> "What is an audio morph anyway? Is it appropriate to take a term, concept, etc. from one sensory modality (or media sub-discipline) and carry it directly into another?"[8]

Though Cook emphasizes the difficulty of searching for – and even questions the existence of – an ideal audio morph, he concludes that:

> "The profound linguistic nature of human perception, new knowledge of physical models of sound producing objects, and new studies of timbre in general, should all motivate the questions to be asked."[9]

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[5] Perry Cook, "Education," Curriculum Vitae, September 2013, accessed December 10th 2014, http://www.cs.princeton.edu/~prc/PRCVSept2013.pdf.

[6] See Chapter 3 for a complete breakdown of this paper's technical contents.

[7] Cook, "Audio Morph?," 7.

[8] Ibid., 6.

[9] Ibid., 7.

Thus for Cook the audio morph is not a distinct entity conforming to a single definition, but rather a field of possibilities. Cook reaches and substantiates this understanding through his survey of equally viable audio morphing techniques, and by tracing the origins of the term back to its visual roots, exposing the seemingly insurmountable difficulty of cross-modal (visual to aural) translation. Cook is not concerned with any single definitive answer, but rather "the questions to be asked". This emphasis on plurality and open-ended pursuit were particularly influential in my own compositional explorations, as will be described at length in the following chapter.

1.2.2 Defining the Audio Morph II - Trevor Wishart and Vocal Models

Another key figure to have employed vocal models while trying to define the audio morph[10] is composer, theorist, and audio software designer: Trevor Wishart. Born in Leeds in 1946, Wishart's compositional interests are directly related to both the voice and sound morphing technology, as described in his entry from *Grove Music Online*:

> "He has sought to extend the vocal repertory through the exploration of new vocal sounds (*Anticredos* and the *Vox* series) and pioneered the art of composing directly with sound…. employing sophisticated signal processing instruments of his own design to control the internal quality and the evolution of sounds themselves."[11]

Wishart agrees with Cook that cross-modality is problematic, in a 1996 description of an excerpt of his 1973-77 composition *Red Bird*:

> "It is interesting to compare these aural transformations with similar transformations which might be effected in visual space (for example in animated cartoons). First of all we should note that there is not necessarily any parallel in visual space of a transformation in aural space... What could be the visual equivalent of this transformation? [the beginning of the word listen turning into a flock of birdsong] Is it a mouth which changes into a bird or some representation of breath which becomes a bird. It soon becomes clear that seeking such a parallel is rather fruitless. Visual

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[10] Though Wishart uses the term transformations in the following citations, he has also used the term morphing interchangeably, and has even gone so far as to write public letters associating himself with the term. Trevor Wishart, "SoundHack. [letter to the editor]," *Computer Music Journal*, Vol. 21, No. 1 (Spring 1997): 10-11. As such, the following discussion will maintain the use of the latter term.

[11] Stephen Montague. "Wishart, Trevor." *Grove Music Online. Oxford Music Online*. Oxford University Press, accessed September 9, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/48593.

> transformation and aural transformation take place in different dimensions. Not only this, they have quite different qualities."[12]

The differences of quality and dimension cited by Wishart refer to characteristics of aural and visual media themselves. However, he also goes on to describe the differences in how these distinct entities are perceived by human subjects.

> "We normally have little difficulty in recognising a visual object, even at a glance. Rapid transformations between clearly recognisable objects are therefore quite simple to achieve in visual animation (speaking aesthetically rather than technically!). The whole process has a very 'concrete' feel, a certain definiteness. Aural images, however, almost always remain a little ambiguous. We can never be sure that we have made a correct recognition, especially where the transformation of sound-objects denies us the normal contextual cues. Transformation in aural space therefore tends to have a 'dreamlike' quality removed from the concrete, distanced and often humorous world of visual animation. At the same time, although transformations of abstract forms or between recognisable and abstract forms may be achieved in the visual sphere, these tend not to have the same affective qualities as time processes taking place in the domain of sound."[13]

As is clear from the above example, Wishart's writings (in three separate books) on morphing and morphology[14] involve much greater depth than Cook's conference paper on the same problem. As pointed out in *Grove Music*'s entry on Wishart: "his reputation among contemporaries is that of a radical innovator… his writings, particularly *On Sonic Art* and *Audible Design*, have helped to define the scope and craft of this new field." This level of detail (in addition to his creative output and contributions to software development[15]) make it difficult to classify his work as falling victim to any real technical or semantic difficulties. As such, Wishart's contributions will be taken up in more detail in Chapter 3 (dealing with audio morphing software), and in the final section of the present chapter (dealing with the literature of Musical Morphology as a noun). His

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[12] Trevor Wishart, *On Sonic Art* (East Sussex, UK: Psychology Press, 1996), 156-8.

[13] Ibid.

[14] The previously cited *On Sonic Art*, and the two following volumes: Trevor Wishart, *Audible Design* (York, UK: Orpheus the Pantomime, 1994); and Trevor Wishart, *Sound Composition*, (York, UK: Orpheus the Pantomime, 2012).

[15] Wishart's primary outlet as a software developer has been the Composer's Desktop Project. See: "CDP History", *The Composer's Desktop Project*, accessed December 10th 2014, http://www.composersdesktop.com/history.html.

fundamental influence on my own compositional work has resulted from the quantity and depth of these writings – but perhaps more importantly – from the high level of quality maintained in his musical output (in particular *Red Bird*, to be described at length, later in this chapter). Though Wishart's books are always substantially augmented through lengthy audio appendices, it is certainly his oeuvre as a composer that has constituted his most important illustrative body of sound examples.

1.2.3 Defining the Audio Morph III – Marcelo Caetano and Instrumental Models

The above-cited discussions from the 1990s approach audio morphing from a vocal perspective. However, a more recent figure has pursued the phenomenon of audio morphing technology from the other main performative tradition of western art music: instrumental sound[16]. Marcelo Caetano was born in Santos, Brazil in 1977. Though his studies have led to advanced degrees in electrical and computer science from the University of Campinas, he received instruction in piano performance and music theory for several years during his childhood[17]. The performance of electronic music that Caetano began during his teens was the first bridge between these two worlds. This link was further cemented with the 2011 completion of Caetano's IRCAM Doctoral Thesis: *Morphing Isolated Quasi-Harmonic Acoustic Musical Instrument Sounds Guided by Perceptually Motivated Features* (IRCAM: 2011)[18]. By far the most substantial technical document on the subject to date, this dissertation will be discussed on technological grounds in Chapter 3.

The introductory pages of Caetano's research are of interest for semantic reasons however. Despite the difference in orientation between Caetano and Cook (instrumental vs. vocal), both figures cite the same difficulties in terms of defining and implementing audio morphs:

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[16] Such is not to imply that instrumental models succeeded vocal models in any sort of teleological sense. The technical discussions of Chapter 3 will show not only that instrumental models have their own long history, but that source-filter separation (as discovered through vocal modelling) has a direct relationship to that history.

[17] Marcelo Caetano, "Biography", *IRCAM*, accessed December 10th 2014, http://recherche.ircam.fr/anasyn/caetano/bio.html.

[18] Marcelo Caetano, *Morphing Isolated Quasi-Harmonic Acoustic Musical Instrument Sounds Guided by Perceptually Motivated Features* (PHD Dissertation: 2011, L'Université Paris VI – Pierre et Marie Curie UPMC, L'École Doctorale Informatique, Télécommunications et Électronique EDITE, and L'Institut de Recherche et Coordination Acoustique/Musique IRCAM).

> "Not all of the transformations called sound morphing in the literature are conceptually similar... This lack of uniformity in nomenclature calls for the formalization of a theory of morphing, clearly defining which type of transformation can be considered morphing and allowing us to categorize them according to certain criteria. Defining precisely and formally the requirements of the desired morphing process has proved to be a difficult problem. On the other hand, describing the desired result is not any easier (partly so because more than one type of transformation is commonly called morphing)."[19]

For Caetano, the definition of audio morphing must address two independent problems: one technical, and the other perceptual. Thus does he address the same questions as Cook and Wishart, with slightly more precision (albeit within his focus on instrumental sound).

The division between "requirements" and "results" is characteristic of Caetano's methodology, with its dual emphasis on technical rigour and perceptual relevance. In terms of the latter, a great deal of psychoacoustic research accompanies Caetano's theoretical work. The inclusion of this data is important to Caetano's contribution in defining audio morphing, which for him can only be understood through the lens of human perception:

> "One important and difficult requirement we face when morphing sounds is that it is a perceptually related problem. That is, when we define the desired result, we usually do so by means of psychological dimensions of sound perception such as pitch and loudness; or dimensions related to timbre perception, such as sharpness of attack, brightness, onset asynchrony, spectral flux, roughness, among others."[20]

By emphasizing the "psychological dimension" of how humans perceive and describe music and audio of all kinds, Caetano establishes a critique of previous attempts towards the definition and implementation of sonic morphing techniques.

> "The classical approach to sound morphing is to interpolate the parameters of a model... However, when blindly following the interpolation principle, the perceptual impact of the interpolation of parameters depends largely on what type of parameters we chose to represent the sounds with. If the parameters of the model we used represent information that is not directly

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[19] Caetano, *Morphing*, 30.

[20] Ibid., 32.

> related to how we perceive sounds, the result of the interpolation of these parameters will very likely have very little perceptual significance."[21]

To ensure this perceptual significance, Caetano proposes the use of a new framework of interpolation, which may be non-linear in terms of the technical ***parameters*** generating the morph, while maintaining a linear scale (between 0.0 and 1.0) of perceived change to the sound's ***features***. This distinction is explained in a short summary of Caetano's PhD research co-authored with his teacher Xavier Rodet for the 2011 International Conference on Acoustics, Speech, and Signal Processing (ICASSP)[22].

> "In this work, parameter refers to coefficients from which we can resynthesize sounds, while feature refers to coefficients used to describe or identify a particular aspect of a sound. Usually, we cannot resynthesize sounds directly from feature values."[23]

This new framework of interpolation requires the introduction of a new variable, which Caetano calls the morphing factor (denoted by the symbol α in Figure 4 below). He describes the morphing factor as follows, and illustrates it with the visual example cited earlier:

> "α, called morphing or interpolation factor, as illustrated in Fig. 1 for images. Figure 1 shows that, ideally, we want the morphing factor α to control perceptually related features of the transformation, such that the morph should be perceptually halfway when α = 0.5, for instance."[24]

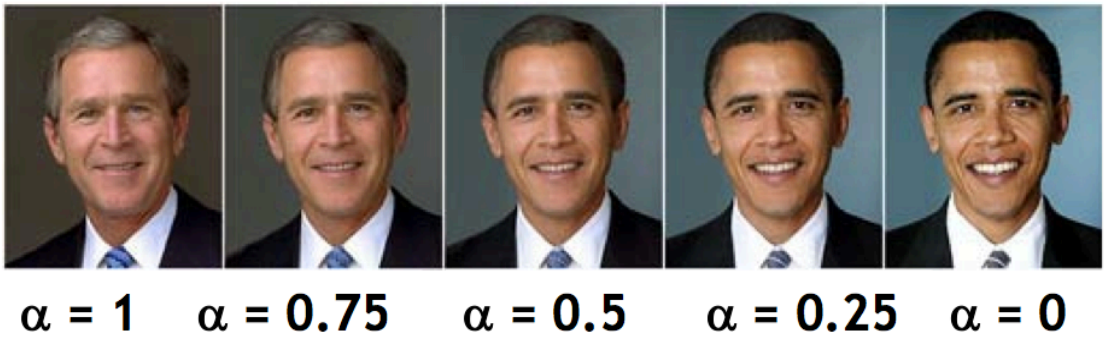

Figure 4 - Caetano's Morphing Index

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[21] Ibid.

[22] Caetano, "Feature Interpolation", 161-164.

[23] Ibid., 161.

[24] Ibid.

Though Caetano's work in the technical realm has been staggering, it is important not to lose sight of his contributions to the understanding of audio morphing on purely terminological grounds: the introduction of the morphing factor (α), and his emphasis on the phenomenological foundations of audio morphing. In fact, the concept of the morphing factor (α) is so useful in illustrating the nature and stages of a morphing process, that the following Caetano-inspired gradient bar (see Figure 5) will henceforth accompany all future examples in this thesis that describe morphing (or morph-like) transformations.

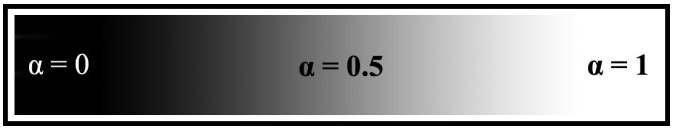

Figure 5 - Caetano Inspired Gradient Bar

Given my own emphasis on the perception of continuous transformation, these gradient bars will appear frequently in the final three chapters addressing this phenomenon in more examples of a more "historical" nature. In my own compositional work, Caetano's influence was perhaps most strongly felt through a similar emphasis on projected listener perception. In this case, the many theoretical adaptations of audio morphing principles to a purely musical context were constantly being re-evaluated based on such phenomenological concerns.

1.3 Musical Morphology

Before proceeding to examples from my own music, I would also like to consider the earliest appearances in the literature of musical morphology (as a noun). Again, this concept is distinct from morphing as a verb, in that its scope is much greater, encompassing the study of ANY change in (musical) form over time. Such a "zooming out" to the level of musical morphology broadens the scope of the present study to include essentially ***all*** musical transformation of any kind. Despite this potential unwieldiness, I regard such a decision as crucial to my compositional practice, in that the purely musical demands of a given work or passage are often quite amorphous and sprawling, necessitating an incredibly broad and open-ended perspective. In order to

fully embrace the fundamental principles of audio ***morphing*** in a compositional context, a less confined musical paradigm is useful.

As the suffix of the term Morpho***logy*** implies, it is a field of study rather than a phenomenological effect (as, on the other hand, the verb morphing denotes). Though now applied to various subjects (including music), botany was the area in which the discipline was first explored[25]. Furthermore, it is an odd twist of fate that the founder of morphology is not primarily remembered for his contributions to botany, but rather for his creative output as a cultural figure[26]. The discipline of morphology, that recent writers and composers such as myself have attempted to apply to music, was originally put forth in 1790 by Johann Wolfgang von Goethe[27]. Born in Frankfurt in 1749, Goethe is regarded as "one of the most important literary and cultural figures of his age", with a "many-faceted relationship to music"[28].

Agnes Arber, the author of a 1946 English translation of Geothe's *Metamorphose*[29], points out that the reception of Goethe's scientific writing has ranged from hostility (aimed at any activity that took time away from his artistic output) to the opinions of certain botanists - particularly W. Troll: "who maintains, in a fully reasoned

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[25] While the OED entry for Morphology cites Goethe's 1790 treatise as the first usage of the term in biological discourse, the first general usage of morphology does not appear until 95 years later in an article by C.F. Keary from the Numismatic Chronicle 3rd Series, Vol. V, 1885; as cited in OED, "Morphology, n.".

[26] Nicholas Boyle, "Johann Wolfgang von Goethe", *Encyclopedia Britannica*, accessed December 10th, 2014, http://www.britannica.com/EBchecked/topic/237027/Johann-Wolfgang-von-Goethe, has the following to say about Goethe's richly varied status as a cultural figure: "Johann Wolfgang von Goethe, (born August 28, 1749, Frankfurt am Main [Germany]—died March 22, 1832, Weimar, Saxe-Weimar), German poet, playwright, novelist, scientist, statesman, theatre director, critic, and amateur artist, considered the greatest German literary figure of the modern era."

[27] J.W. Von Goethe, *Versuch die Metamorphose der Pflanzen zu erklären* (Gotha: Carl Wilhelm Etttinger, 1790).

[28] Receiving his own entry in *Grove Music Online*, Goethe's contributions to western art music are considered in terms of major works of the choral, operatic, program music, and especially lied traditions: "The enduring fascination of his poems for song composers throughout the 19th century and into the 20th as far as Busoni, Schoeck and beyond resulted in a long line of compositions of extraordinary stylistic diversity. Arguably, Goethe's verse acted as a catalyst to the lied just as the poetry of Petrarch did to the 16th-century madrigal: the world of feeling and imagination unlocked by his poetry was explored and musically developed in many different directions." Philip Weller. "Goethe, Johann Wolfgang von." *Grove Music Online. Oxford Music Online*. Oxford University Press, accessed September 10, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/11358.

[29] Agnes Arber, "Goethe's Botany." *Chronica Botanica*, Vol. 10, No. 2 (Summer 1946): 63-126.

study of Geothe's morphology, that the centre and focal point of his whole mental life is to be sought in his scientific writings."[30]

Goethe's main contention is that plant growth and development can best be understood as an ongoing and seamless transition from state to state. Oddly enough, this description of botanical morphology (as a noun) has deep resonances with our previous topic of audio morphing (as a verb). A visual comparison of botanical morphology[31] to the Caetano-inspired morphing factor in Figure 6 serves to illustrate Goethe's understanding of the term.

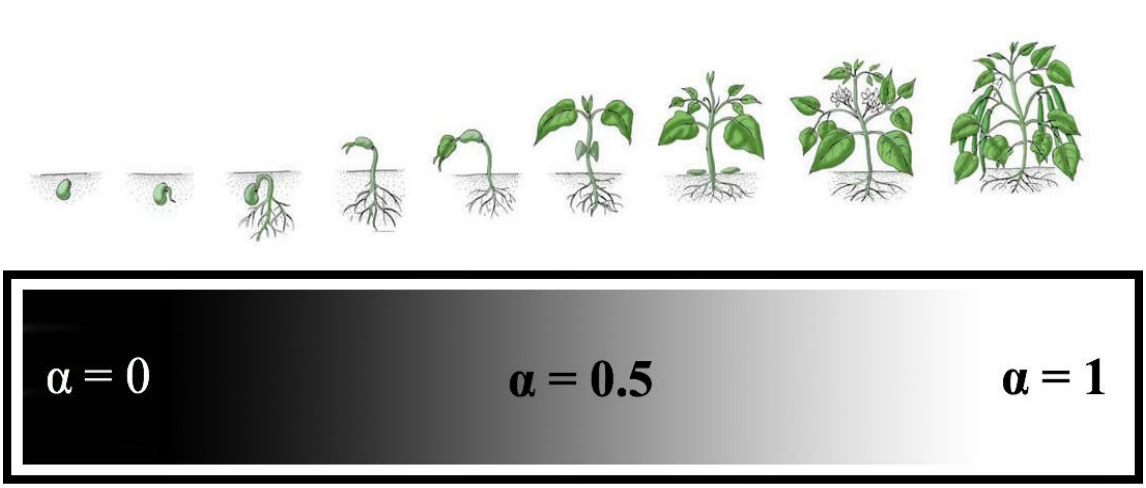

Figure 6 - Goethe's Morphology on a Caetano Gradient

A.K. Jensen's article on Goethe for the *Internet Encyclopedia of Philosophy*[32] describes this process with recourse to Goethe's own writings, and further explores the role of polarity.

> "Morphology reveals, "the laws of transformation according to which nature produces one part through another and achieves the most diversified forms through the modification of a single organ," (Goethe 1961-3, 17: 22)... The oppositional tension between the creative force and the compensatory limitations within all living things exemplifies the notion of 'polarity' or *Polarität.* In his 1790 essay, "The Metamorphosis

[30] Arber, "Goethe's Botany", 68.

[31] Source of plant images: "Plant Life Cycle", *Exploring Nature*, accessed December 10th 2014, http://www.exploringnature.org/graphics/plant_lifecycle_color72.jpg.

[32] AK Jensen, "Goethe" from *The Internet Encyclopedia of Philosophy*, accessed October 7th 2014, http://www.iep.utm.edu/goethe.

> of Plants," Goethe represented the intensification of a plant as the result of the interaction between the nutritive forces of the plant and the organic form of the primal leaf. *Polarity between a freely creative impulse and an objectively structuring law is what allows the productive restraint of pure creativity and at the same time the playfulness and innovation of formal rules*."[33] [emphasis mine]

While Goethe's involvement in the birth of morphology as a discipline is interesting in light of his cultural stature, it is the sub-topic of ***musical morphology*** that is the primary focus of the present investigation[34]. As such, the criteria for his inclusion among the following sources is an explicit (and pioneering) use of the term. Furthermore, the highlighted final sentence of the above citation will be seen to display particular creative resonance to my own practice in the following chapter's discussion of pre-compositional planning and structure in *for chelsea smith.*

1.3.1 Musical Morphology I – Ernst Lev

One of the first appearances of the term ***musical morphology*** in the literature is the 1980 reference book: *Musical Morphology: a Discourse and a Dictionary* co-authored by Siegmund Levarie and Ernst Levy[35]. As the subtitle implies, the bulk of this book is a dictionary, laying out definitions for commonly encountered musical terms. Most of these terms relate directly to questions of musical form, a link to morphology's botanical origins that this early text of musical morphology makes explicit in a number of instances.

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[33] Jensen, "Goethe", #H4

[34] Because the connections between Goethe's scientific writings (such as the *Farbenlehre* of 1810) and western art music are so implicit, there is a great deal of inference made by the secondary literature, such as: Angelika Abel, *Die Zwölftontechnik Weberns und Goethes Methodik der Farbenlehre. Zur Kompositionstheorie und Ästhetik der Neuen Wiener Schule* (Wiesbaden: Franz Steiner Verlag, 1982). Harry E. Seelig's 1986 book review of this volume in the *Goethe Yearbook* points out that (as is the case with Goethe's writings on morphology), such connections are implicit and must be deduced by the researcher: "Webern's lectures and letters, while they frequently mention the significance of Goethe's writings, do so only very generally and quite unsystematically; consequently Abel endeavors to provide the very system Webern's own utterances lacked." Harry E. Seelig, "Abel, Angelika, *Die Zwölftontechnik Weberns und Goethes Methodik der Farbenlehre. Zur Kompositionstheorie und Ästhetik der Neuen Wiener Schule* [Book Review]," *Goethe Yearbook*; Volume 3 (1986): 251-254. See also: Hans Moldenhauer, "Webern's Projected Op 32," *The Musical Times*, Vol. 111, No. 1530 (Aug., 1970): 789-792; and: Robin Maconie, "Message of 'Light': Goethe, Stockhausen and the New Enlightenment," *Tempo*, Vol. 58, No. 230 (Oct., 2004): 2-8.

[35] Ernst Levy and Siegmund Levarie, *Musical Morphology: A Discourse and a Dictionary* (Kent, Ohio: Kent State University Press, 1983).

The authors also attempted to tie their inquiry in to broader questions of contemporary society at the time. In this pursuit they saw an emphasis on fluidity and change emerging, and related their study of musical morphology to this perceived trend:

> "Morphology is the study of form. The concept of *form* points to something assumed to be stable—an entity, a type. One might object that there is no such thing, for everything changes continuously. This view is particularly popular today. In all fields the dynamic aspect of the world is stressed, and the paradox that "change is the only permanent state" has acquired near-official status. Yet nobody is really capable of negating form. What then is the relationship between fluidity and shape, becoming and being, change and type."[36]

The crucial relationship between fluidity and shape is one of the most compositionally relevant issues put forth by the co-authors. As with Geothe's invocation of polarity between generation and structure in plant growth cited above, the primary influence on my compositional practice is related to pre-compositional planning and structuring (to be described at length in the following chapter – in particular its discussion of form).

Furthermore, the Levy/Levarie description of change also calls to mind the morphing factor described in Caetano's dissertation being interpolated from 0 to 1, where a continuum of intermediate values bridges two entities of fixed identity.

> "It is also a world of change, but the change takes place between remembered forms... Change is thus understood as based on the unchanging."[37]

This connection can be illustrated through reference to the Caetano-inspired morphing index, as seen in Figure 7 below.

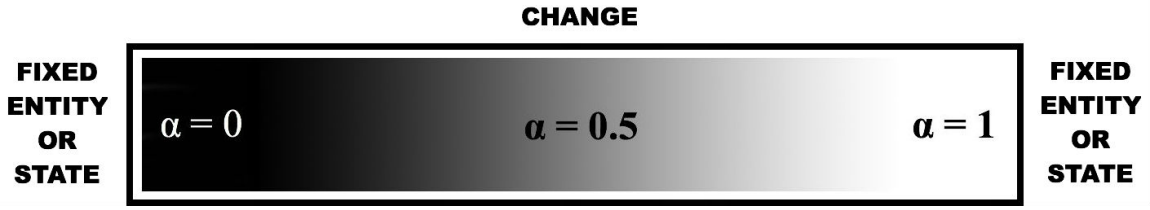

Figure 7 - Levy and Levarie's Notion of Change on a Caetano Gradient

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[36] Levy, *Morphology*, 3.

[37] Ibid.

Levy and Levarie then go on to describe all musical growth over the course of a form as resulting from a division in some sort of initial musical unity. They cite several examples from the modal and tonal repertoire to substantiate this assessment. While the scope of Levy and Levarie's study conforms tightly to the boundaries of the common practice period, their concepts have a much further reach. Particularly useful towards a definition of musical morphology are their notions of: form as a fluid relationship between multiple entities of a more fixed nature, and the importance of increased musical entropy over the course of a work.

1.3.2 Musical Morphology II – Trevor Wishart

While he interchangeably employs the term "musical transformation", important early appearances of the term musical morphology also occur in the work of English composer/author/developer: Trevor Wishart. As described above, Wishart is an expert in the field of audio morphing technology, as demonstrated through both his creative output (in particular, 1977's stereo tape composition *Red Bird*) and his activities in software development (The Composer's Desktop Project[38]). Through his efforts to elucidate audio morphing techniques to the lay - albeit musical - reader, Wishart employs highly accessible language. He also attempts to musical morphology as one of modern music's fundamental concerns. For this reason his contributions to the literature of musical morphology will now be examined, with his more concrete technical contributions being reserved for Chapter 3. Following a description of the philosophical foundation upon which Wishart discusses musical transformation, a brief analysis of *Red Bird* will be presented so as to anchor this theory in concrete musical terms.

The publication of Wishart's *On Sonic Art* in 1996 marks a clear and important milestone for the literature of musical morphology. For the first time the subject is treated explicitly in a full chapter (Chapter 9 – "Is there a natural morphology of sound?"), with recourse to many musical examples. Wishart's two other book-length publications deal primarily with pedagogical/technical (1994's *Audible Design*[39]) and

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[38] Composer's Desktop Project, "CDP History"

[39] Wishart, *Audible Design*.

analytical (2012's *Sound Composition*[40]) matters. The scope of *On Sonic Art* is more broad, encompassing most aspects of musical experience. Despite this increased breadth, the focus on musical transformation is tightened through its positioning as a foundation for the titular artform. Wishart describes musical transformation as the only viable response to the essentially limitless resources of the modern soundworld. The 2012 preface to *Sound Composition* describes these conditions in reference to the project of *On Sonic Art*.

> "To organise such sounds we cannot appeal to pre-ordained frameworks of pitch, or 'timbral consistency' to organise them. What we can do, however, is to establish relationships between them by the process of *transformation* of one sound into another. The special nature of this transformation space is discussed in *On Sonic Art*."[41]

Sixteen years earlier in the preface to *On Sonic Art* itself, Wishart had expressed this line of inquiry as an essentially philosophical matter.

> "This book is not about *how* to do it... Rather it is about *why*. Faced with all the new possibilities for structuring sound and sequences of sound-events thrown up by digital synthesis, analysis and control, what might be the effect of ordering sounds in one way rather than another, and what might be fruitful avenues for exploration?"[42]

This process of reflection is an important and explicit aim for Wishart, as he regarded it as lacking in the seminal research of the figures who most profoundly influenced his own development. One of Wishart's most important influences was the Groupe de Recherces Musicales (GRM)[43], founded in 1959 by the pioneer of electroacoustic music: Pierre Schaeffer. Born in Nancy in 1910, Schaeffer began musical experiments with recorded sound at the Studio d'Essai in the late 1940s. He was instrumental in the founding of several other organizations, culminating with the GRM in

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[40] Wishart, *Sound Composition.*

[41] Ibid., 5.

[42] Wishart, *On Sonic Art*, 3.

[43] For more on the GRM's influence on Wishart, see the foundational importance of the so-called "continuation types" described in Chapter 5.

its eventual home at Radiodiffusion-Télévision Française (RTF)[44]. In reference to his activities with the GRM at the RTF, one of Schaeffer's greatest contributions has been described as the elevation of all sound to the sphere of music.

> "Schaeffer's musical thought rests on the primacy of the ear over conventional aesthetic considerations. It is his view that recording has placed all sounds – whether music, noises, animal cries or whatever – on an equal footing, since all are experienced in the same manner. They may thus be treated as 'sound objects', distinct from their acoustic and notated sources."[45]

Wishart emphasizes throughout *On Sonic Art* that while he deeply respected the GRM's tendency to "rely exclusively on the ears and direct aural feedback, [he] would like to go a small step further here and attempt to theorise about these matters."[46] A great many words, technical analyses, and diagrams constitute this theoretical activity. However, it is far from an academic exercise for Wishart – rather, his concerns are purely compositional, evidenced both by his extensive creative oeuvre, and his assertion that:

> "With an understanding of various properties of the aural landscape, we can begin to build compositional techniques based upon transformations of the landscape."[47]

1.3.2.1 Musical Morphology IIb – Pre-Digital Morphing in *Red Bird*

Ironically Wishart's best known work to explore the phenomenon of musical transformation in an electronic medium (1977's *Red Bird*) was realized prior to the availability of digital audio tools. In his 2012 book *Sound Composition*, Wishart reflects on the technical limitations of the period.

> "At that time, the studio had few sophisticated technical tools. One could change the speed of most of the (stereo) tape-recorders over a continuous range of 2 octaves, edit the tape with a razor blade and splicing block, filter the sound using the EQ controls on the mixing desk and some

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[44] Francis Dhomont. "Schaeffer, Pierre." *Grove Music Online. Oxford Music Online*. Oxford University Press, accessed September 10, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/24734.

[45] Dhomont, "Schaeffer"

[46] Wishart, *On Sonic Art*, 4.

[47] Ibid., 155.

> limited analogue filters, and mix down from up to 5 tape-recorders (often using a group of helpers and a pre-timed mixing score)."[48]

While Wishart made use of such "mixing scores" during the recording of *Red Bird*, the only published score for the work (see Figure 8) is a much more abstract (and also much less detailed) listening/projection schematic included as an appendix to *Sound Composition*[49].

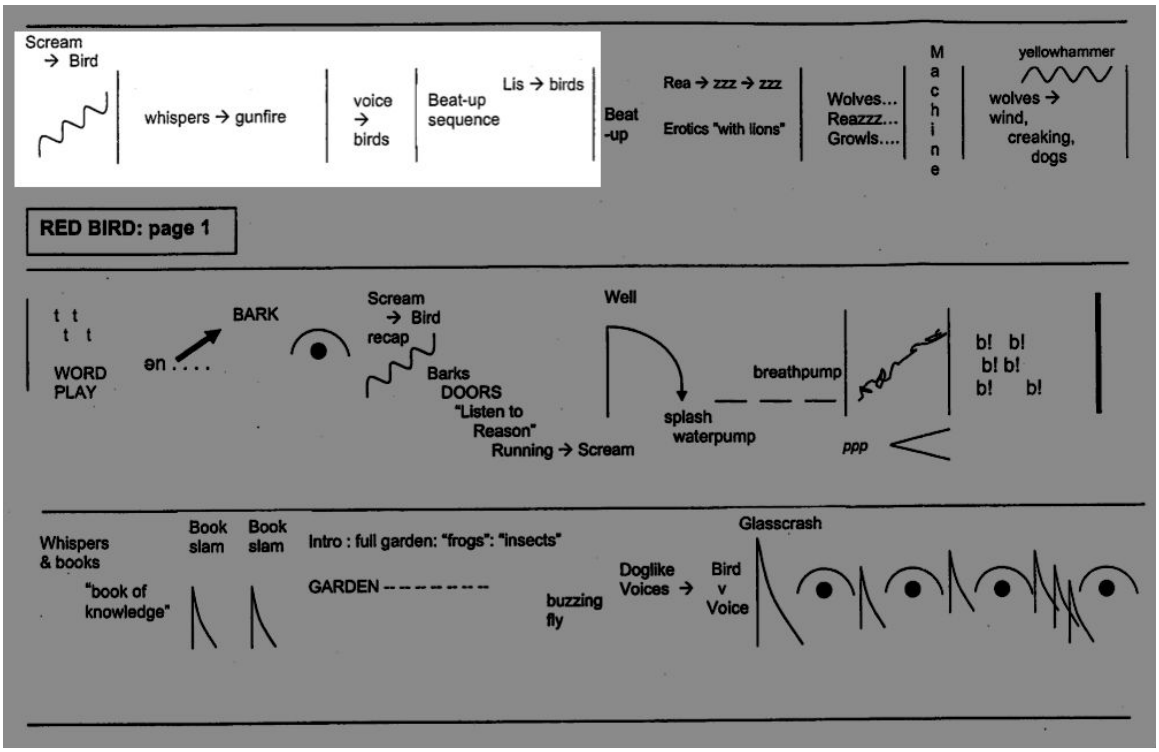

Figure 8 – Wishart: Red Bird (Listening Score, 0:00-1:42 Highlighted)

The highlighted section of Figure 8 represents the first minute and forty-two seconds of the work. It is a microcosm of the compositional concerns that motivate *Red Bird*. Referring to the early analogue techniques mentioned above, Wishart goes on to describe that:

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[48] Wishart, *Sound Composition*, 15.

[49] Trevor Wishart, "Red Bird," in *Sound Composition* (York, UK: Orpheus the Pantomime, 2012), 164.

> "After 4 years experience I had begun to master these simple techniques, knew how to get the best from them, and had a more developed idea of how to use environmental sounds in a sound composition. I therefore decided to embark on a more (technically) ambitious project, in which *sound transformation* or metamorphosis would be central to the workings of the piece."[50]

The "sound transformations" that make up the highlighted excerpt of Figure 8 above, are described with arrows by Wishart in the text of the "score". Caetano-inspired gradient bars reveal four separate transformations in the first four sections (see Figure 9 below).

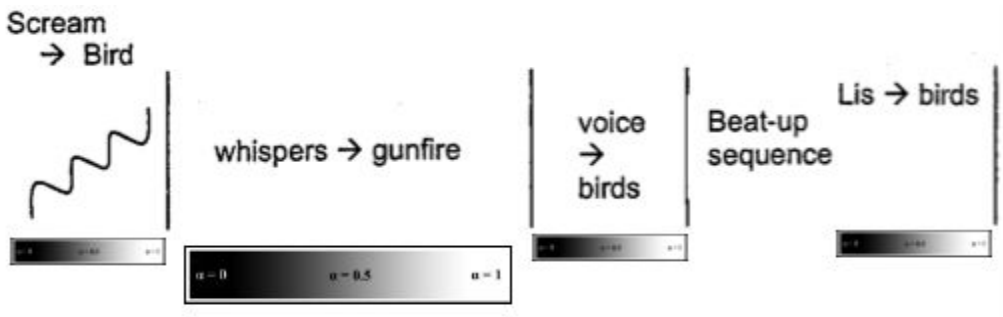

Figure 9 - Wishart: Red Bird (First Four Morphs, 0:00-1:42)

Thus are transformations (the "morphs" in Wishart's words) the generating principles, and primary compositional materials of the work. Much in the same way that these four transformations are representative of the work as a whole, a great deal can be learned by examining what Wishart describes as "the most successful continuous morph, the transformation *'Lis'> birdsong.*"[51], found at the end of Figure 9. Beginning at 1:26, this transition follows a non-morphing 'Beat-up sequence'[52]. The timings for each of these first four sections (or five if the 'Beat-up sequence' is considered independently) are shown below in Figure 10[53].

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[50] Wishart, *Sound Composition*, 15.

[51] Ibid., 25.

[52] The so-called "Beat-up sequence"s are characterized by rapid, narrow enveloped bursts of sound resembling the blows and vocalizations of a man being physically beaten.

[53] Trevor Wishart, *Red Bird Anticredos* (Albany, NY: Electronic Music Foundation, 2000), compact disc.

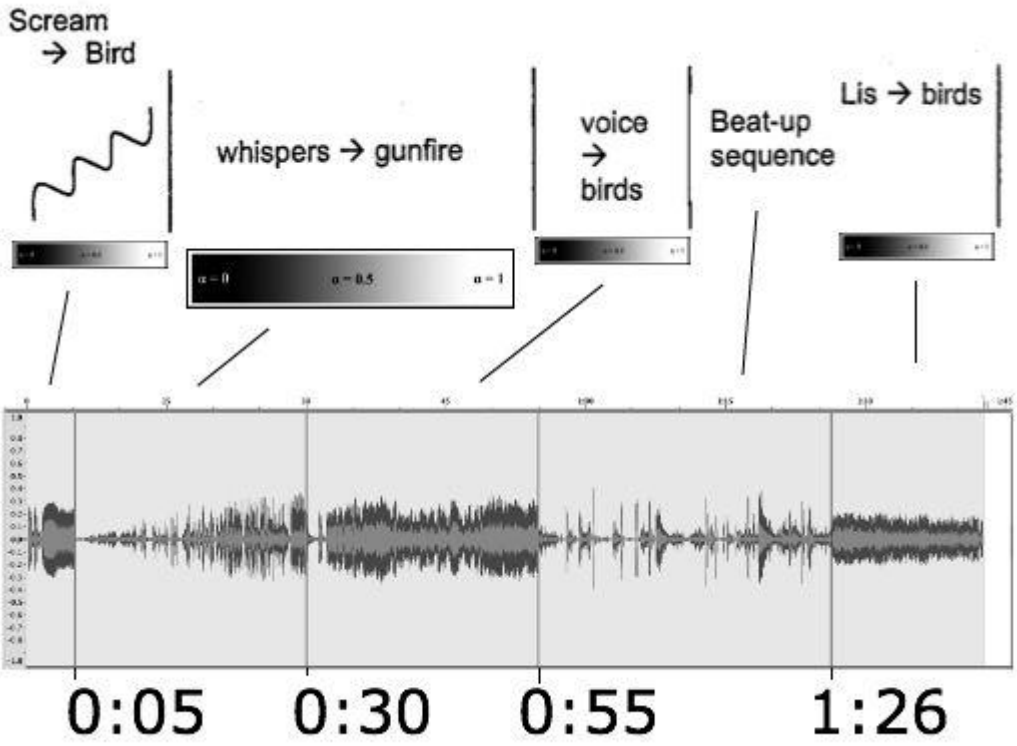

Figure 10 - Wishart: Red Bird (Waveform, 0:00-1:42)

Wishart describes the *Lis'> birdsong* transition in both prose and graphics (see Figure 11 below).

> "It begins with a vocal 'Lis' moving into sss-whistling with rapidly fluctuating pitch, vaguely similar to the rapidly bubbling line of the skylark into which it morphs. With a rapidly changing or complex source, a mix of several similar (but not identical) copies will blur the spectral details. We can then crossfade between such layered versions of our two matched sources and hope to fool the ear into accepting that a true spectral morph has taken place. The skylark source was chosen because it most closely matched the vocal whistling and it was adjusted in (average) pitch to match the vocal sound."[54]

[54] Wishart, *Sound Composition*, 25.

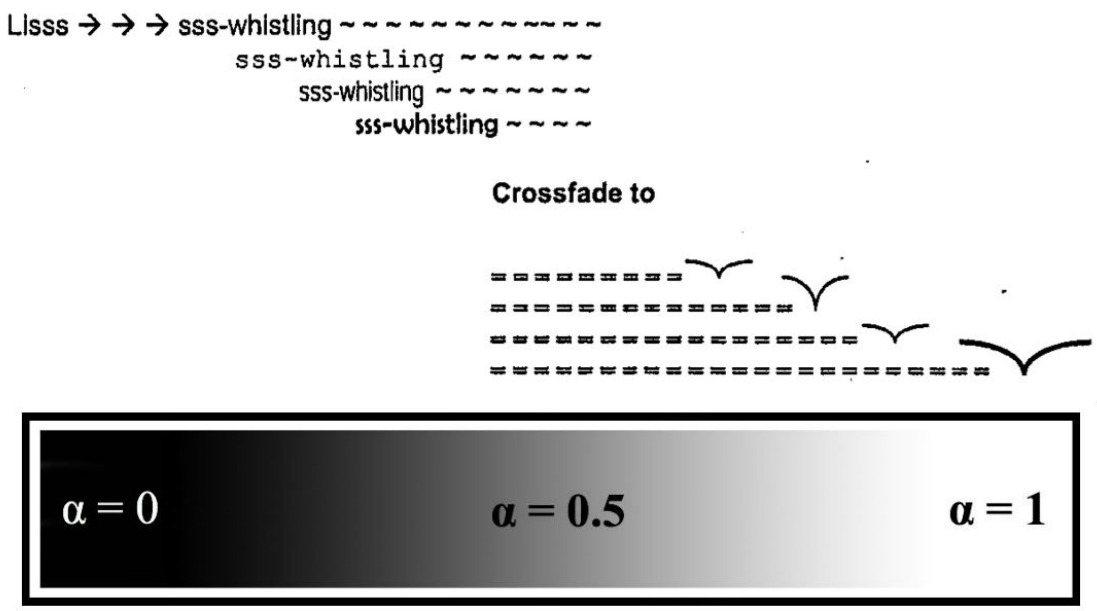

Figure 11 - Wishart: Red Bird (Lis>birdsong, 1:26-1:42)

By consulting a spectrogram of the *Lis'> birdsong* transformation, the forces described by Wishart are clearly revealed. Figure 12 shows the excerpt beginning at 1:26 (corresponding to 0 seconds in the spectrogram) with its frequency content plotted along the y-axis[55].

[55] For a more complete description of such representations, please consult the beginning of Chapter 5.

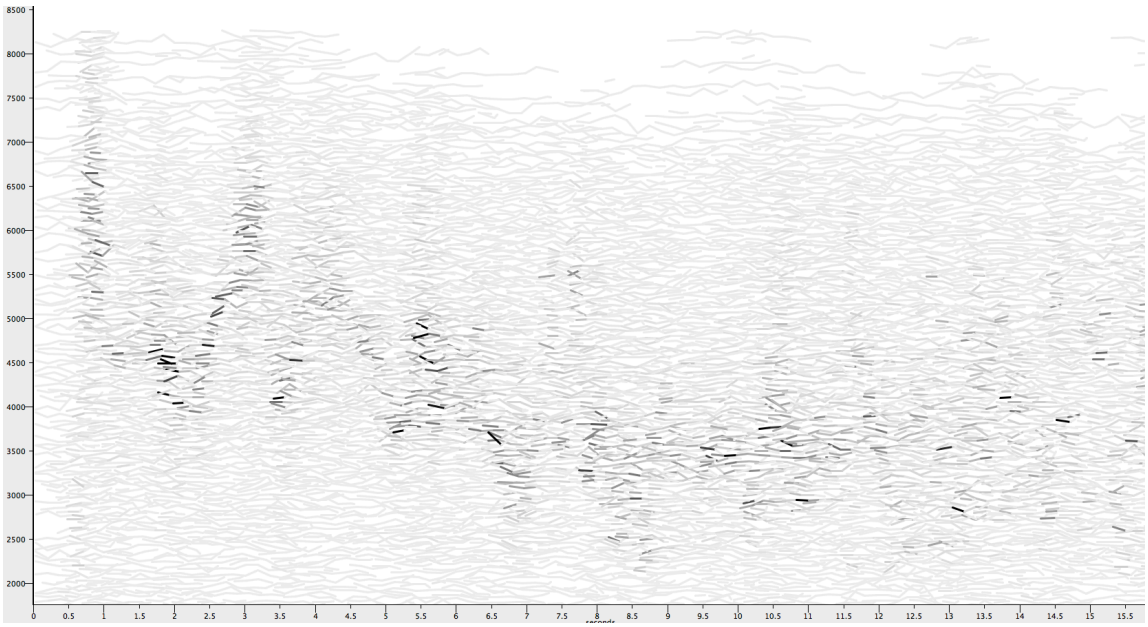

Figure 12 - Wishart: Red Bird (Spectrogram, 1:26-1:42)

What Wishart describes as the "sss-whistling with rapidly fluctuating pitch" can be seen in the first half of the graph, as a rising and falling pattern of dark lines (perceived pitch) surrounded by a field of gray (the white noise of the "sss" sound). At roughly the half-way point of the graph, the continuity of the rising and falling line dissolves into what Wishart describes as "the rapidly bubbling line of the skylark". While Wishart also describes this arrival material as "adjusted in (average) pitch to match the vocal sound", the overall descent of the first half of the graph to meet the second, looks (and sounds) as though the opposite were the case.

All the same, the principles behind this transformation – and the many other instances of morphing that make up the work – remain as described by Wishart above. The careful selection of materials that spectrally resemble each other are layered and subtly distorted to approach each other in spectral content (within the limitations of the human vocal apparatus and analogue technology) such that a cross-fade between the two creates the illusion of transformation.

Wishart's extensive philosophical, technological, and critical contributions will be taken up again in subsequent chapters. The present chapter however will continue on through the historical survey of appearances of the term morphology in a musical

context, with a closely related figure in the world of electroacoustic music: Denis Smalley.

1.3.3 Musical Morphology III – Denis Smalley

Like Wishart, Denis Smalley published important writings on computer music during the 1990's[56]. Furthermore, the principles underlying the transformations of *Red Bird* as described in the previous section (spectral analysis and interpolation) form the core of the field originated by Smalley: spectromorphology. The impact of these writings have been far-reaching. In a 2011 article[57], James O'Callaghan goes so far as to state that Smalley's "writings on spectromorphology have codified a formal taxonomy of the genre [electroacoustic music]"[58]. It is not surprising then, that the New Zealand born composer also has connections to the GRM with whom he studied in early 1970's, while also participating in courses at the Paris Conservatoire under Olivier Messiaen[59]. Following these studies Smalley pursued a doctorate from York University during the mid-1970's, concurrently with Trevor Wishart.

As with Wishart, new modes of composition suited to the contemporary soundworld are high on Smalley's list of priorities. According to Smalley in his influential 1997 paper on spectromorphology, it is imperative for modern composers to discover: "how to cut an aesthetic path and discover a stability in a wide-open sound world, how to develop appropriate sound making methods, how to select technologies and software."[60] This emphasis on the composer as one who reacts to virtually limitless sonic possibilities is extremely important to my own compositional outlook, as will be described at length in subsequent sections.

While Wishart's writings *actively* lay out an a-priori philosophical foundation on which to construct a contemporary compositional method, Smalley approaches the

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[56] See: Denis Smalley, "Spectromorphology: explaining sound-shapes," *Organised Sound*, Vol. 2, No. 2 (August 1997): 107-126; and Denis Smalley, "Defining Transformations," *Interface*, Vol. 22, No. 4 (1993): 279-300.

[57] James O'Callaghan, "Soundscape Elements in the Music of Denis Smalley: negotiating the abstract of the mimetic," *Organised Sound*, Vol. 16, No. 1 (April 2011): 54-62.

[58] O'Callaghan, "Soundscape Elements", 54.

[59] "Biography of Denis Smalley," *City University, London*, accessed September 15th 2014, http://www.city.ac.uk/arts-social-sciences/academic-staff-profiles/professor-denis-smalley.

[60] Smalley, "Spectromorphology", 107.

subject of musical morphology by *reacting* to the existing repertoire of electroacoustic music. This elaborate system of pattern recognition and classification is described most famously in the 1997 paper on spectromorphology mentioned above, in which he describes the discipline as a collection of:

> "...tools for describing and analysing listening experience. The two parts of the term refer to the interaction between sound spectra (spectro-) and the ways they change and are shaped through time (-morphology). The spectro- cannot exist without the -morphology and vice versa: some- thing has to be shaped, and a shape must have sonic content."[61]

Though such a project of classification may at first seem reminiscent of the dictionary building activities undertaken by Levy and Levarie, the language that Smalley employs to describe his target repertoire is in line with the "anti-lattice[62]" concept of morphology put forth by Wishart:

> "[Spectromorphology] is intended to account for types of electroacoustic music which are more concerned with spectral qualities than actual notes, more concerned with varieties of motion and flexible fluctuations in time rather than metrical time, more concerned to account for sounds whose sources and causes are relatively mysterious or ambiguous rather than blatantly obvious."[63]

My own compositional relationship to the above passage will be made explicit in relation to the structuring of both timbre and time in the following chapter. However, it is perhaps the final item mentioned by Smalley: "sounds whose sources and causes are relatively mysterious or ambiguous" that aligns most directly with my own compositional priorities. As will also be discussed in the following chapter, my concern with audio morphing is not manifest through some sort of pedantic "proof of concept" aesthetic employing chains of obvious sonic morphs linking sounds characterized by clear and unambiguous levels of auditory object perception.

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[61] Ibid.

[62] For a complete description of the lattice according to Wishart, see Chapter 2. In brief, the lattice describes the tendency of western music to arrange materials such that they might always be mapped onto an underlying grid of discrete steps of pitch (semi-tones) and additive rhythmic values (say, for example 32nd note units).

[63] Smalley, "Spectromorphology", 109.

Despite the many correspondences between Smalley and Wishart, it is important to note that Wishart's primary motivation is a compositional philosophy, while for Smalley such a theory would actually be the byproduct of spectromorphology's true project, to be "a descriptive tool based on aural perception. It is intended to aid listening, and seeks to help explain what can be apprehended in over four decades of electroacoustic repertory"[64] Though a byproduct it may be, a resulting compositional philosophy is by no means unimportant to Smalley, and is certainly something he was consciously aware of before embarking on the project of spectromorphology:

> "Although spectromorphology is not a compositional theory, it can influence compositional methods since once the composer becomes conscious of concepts and words to diagnose and describe, then compositional thinking can be influenced, as I am sure my own composing has been. In the confusing, wide-open sound-world, composers need criteria for selecting sound materials and understanding structural relationships. So descriptive and conceptual tools which classify and relate sounds and structures can be valuable compositional aids."[65]

Proposing a universal system of terminology for a diverse body of music written by so many composers in a large number of musical styles may seem slightly utopian. However, the basic principle of understanding works based on the morphology of their spectral content has gained traction in the wake of Smalley's writings[66]. The compositional utility of such an approach is also reflected in the sound categories of my dissertation composition as discussed in the following chapter.

The crossing of disciplines inherent in the translation of a visual phenomenon (morphology) into the aural realm (music), has also led to its consideration by figures more closely aligned with the visual arts. The following section will consider a figure who quite clearly straddles the line between these two disciplines.

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[64] Ibid., 107.

[65] Ibid.

[66] Smalley has also applied his taxonomic approach to sonic *morphing* (as a verb) via his 1993 paper "Defining Transformations" [Smalley, "Transformations"]. Again, the bulk of the paper is concerned with classifying various manifestations of sonic morphing according to generalized types, drawing heavily on the classics of the electro-acoustic repertoire. However, Smalley's closing statement again underscores the importance of potential compositional outcomes, while acknowledging the utopian nature of his project: "Although I have attempted to define it, suggesting categories and terminology, I have once more to stress that transformation is perceptually unstable. That, perhaps is part of its attraction. Music, after all, is not concerned with certainties." (Smalley, "Transformations", 296.)

1.3.4 Musical Morphology IV – Dick Raaymakers

One of the most interdisciplinary figures to have written about musical morphology is the Dutch composer and visual artist, Dick Raaymakers. In the Preface to a 2008 retrospective on the composer[67], editors Arjen Mulder and Joke Brouwer exclaim:

> "...what a diverse, poignant and highly complex oeuvre...! Dick Raaymakers (b. 1930) has, in fact, worked in six or seven different disciplines: electronic music – both autonomous tape music and "popular electronics" - performances, installations, music theater, essays and poetry."[68]

The four-hundred page volume prefaced by the above passage is testament to Raaymakers' multi-faceted practice, with its documentation of nearly fifty works in a huge variety of media.

Like Wishart and Smalley, Raaymakers also explored the phenomena of electronic musical morphology in his 2000 work: *Cahier-M*[69]. Given the fundamentally cross-modal (aural-graphic) origins of audio morphing discussed at the outset of this chapter, it is perhaps not so surprising that one of the only book-length texts dealing explicitly with morphology and music originated from an artist who so firmly straddles the line between audio and visual media. In fact, the project of *Cahier M* is explicitly audiovisual:

> "This investigation will not be restricted to aural sound, however; it will also delve into the morphological appearance of mechanised and electronified images. Sounds and images will not be discussed separately, but together based on their mutual relationship."[70]

The bridge between visual and aural media presented by Raaymakers is compelling, especially the large sections dedicated to the writings of Piet Mondriaan on electronic music. Mondriaan's prescriptions for an electronic music practice that extended his visual neoplasticism into the aural realm is historically significant both

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[67] Dick Raaymakers, *Dick Raaymakers – A Monograph*. Arjen Mulder and Joke Brouwer, eds. (Rotterdam: V2_Institute for the Unstable Media, 2008).

[68] Raaymakers, *A Monograph*, 10.

[69] Dick Raaymakers, *Cahier 'M': A Brief Morphology of Electric Sound* [2000], revised edition trans. Richard Barrett (Leuven: Leuven University Press, 2005).

[70] Raaymakers, *Cahier 'M'*, 1.

within Mondrian's output in itself, and also the broader context of electronic music history[71]. The intentionally diffuse and interdisciplinary nature of Raaymakers' inquiry generates a complex network of meaning around the concept of musical morphology, as suggested by the substantial list of definitions proposed for the M of the title: "morphology, 'mouvement', Marey, Mondriaan, and, of course, music."[72]

However, Raaymakers asserts that "*Cahier-M* is first and foremost about the morphology of artificial, electrified sound"[73], and though it does appear quite late in the work, he does present his own definition of morphology:

> "Morphology indeed refers to the way in which a given fundamental formula – a primary body, the initial pattern, the mother of all cells – is repeated."[74]

The central role played by repetition in Raaymakers' understanding of morphology relates to the second and third meanings of the letter M mentioned above: 'mouvement' and Marey. The nineteenth-century French chronophotographer: Étienne-Jules Marey, devised systems of photographing subjects sequentially at regular sampling intervals. Thus is the history of a form's repetition in time depicted graphically (see Figure 13), in order to study its 'mouvement' or morphology[75].

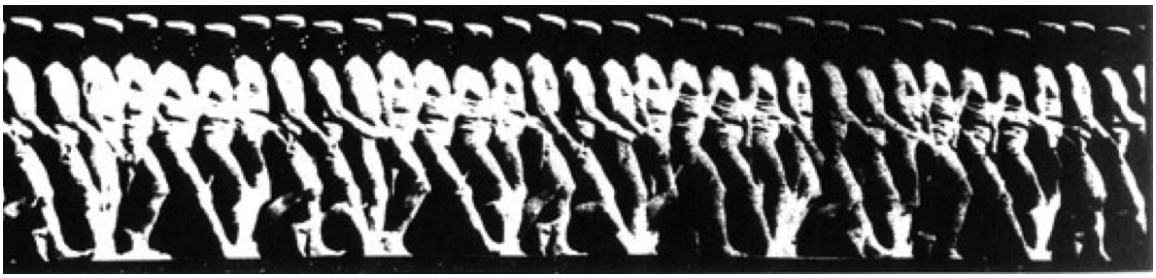

Figure 13 - Marey: Repetition of a Form (Man Walking) Over Time

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[71] Many of his statements regarding the balance of more and less perceptually pitched content echo the fourth of Stockhausen's famous Four Criteria of Electronic Music. Karlheinz Stockhausen, "Four Criteria of Electronic Music" [1972], in *Stockhausen on Music*, 88-111 (New York: M Boyars, 1989).

[72] Raaymakers, *Cahier 'M',* 1.

[73] Ibid.

[74] Ibid., 82.

[75] Image obtained from: "Walking Man," *Amazon Web Services*, accessed December 11th, 2014, http://classconnection.s3.amazonaws.com/565/flashcards/1998565/png/6-144AA2E0563348EE9FC.png.

Drawing a parallel to the composition of (especially electronic) music, Raaymakers cites the next step in a Marey analysis, wherein the most structurally important points of the form are isolated (see Figure 14) in order to more clearly describe the overall morphology[76].

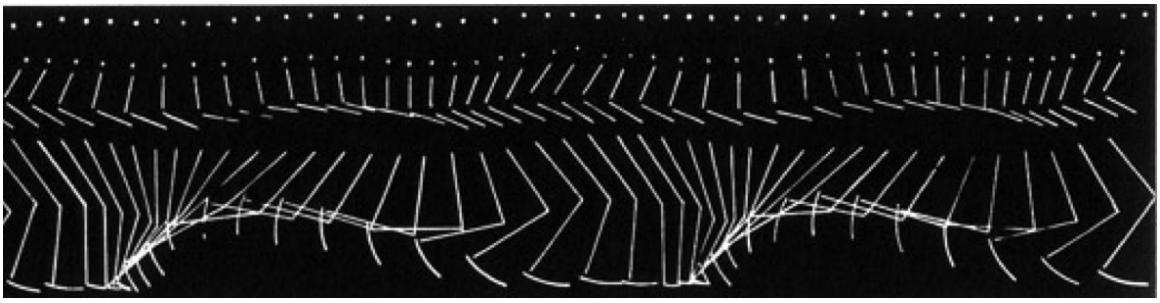

Figure 14 - Marey: Repetition of a Form (Man Walking) Over Time With Peaks

Thus is Raaymakers' definition of morphology inseparable from repetition and graphic depiction. As with Wishart and Smalley, defining morphology takes place fundamentally in the service of musical composition:

> "This extensive transformation can only be meaningful after performing a radical reduction of layered sounds to numeric (or digital) point structures... This is a necessary precondition for a workable and 'logical' system that allows one to study and 'compose' the morphology of sound."[77]

Not surprisingly – given the visual and methodological parallels – Raaymakers then goes on to present the work (both architectural and musical) of Greek composer Iannis Xenakis as a clear illustration of his Marey-influenced concept of morphology. Raaymakers explains the origin of Xenakis' plan for the 1958 Philips Pavilion as based on:

> "...the principle of a 'morphed' plane in all its simplicity and intelligibility. Based on the above about the principles that lie at the heart of sensible and correct morphological repetitions, such planes can be considered the result of repeating given basic patterns according to a plan and a more or less fixed repetition programme."[78]

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[76] Amazon Web, "Walking Man"

[77] Raaymakers, *Cahier 'M'*, 105.

[78] Ibid., 106.

The parallels between this piece of architecture, Marey's chronophotography, and Xenakis' 1953 composition Metastasis, are made explicit through a comparison of sketches related to each of the three works reproduced in Figure 15 below[79].

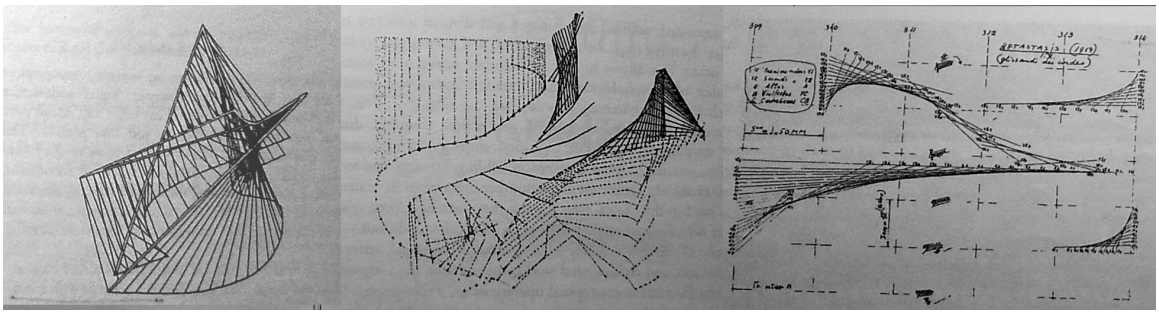

Figure 15 - Sketch Comparison: Philips Pavilion, Man Jumping, Metastasis

Such notions of morphology as the inherently graphic process of chronologically sampling movement over time and space, are reflected compositionally in Raaymakers' 1967-8 *Graphic Quartet* (see Figure 16). Here a system of tablature is employed to show the locations of a player's activity on the various parts of the instruments over time[80]:

> "A horizontal timeline is defined in minutes and seconds, and in the vertical direction there is a schematized cross-section of a violin, viola, or cello. Four horizontal lines divide the instrument into four sectors: the fingerboard, the part between the bridge and the fingerboard, the area around the bridge, and the area behind the bridge. The bridge line is drawn in bold; the three other, thinner lines run parallel to it. Within this system of coordinates, it is possible to depict the position as well as the action of the left and right hands in relation to the body of the instrument in the form of "routes"."[81]

[79] Ibid., 109-111.

[80] Raaymakers, *A Monograph*, 40.

[81] Ibid., 35.

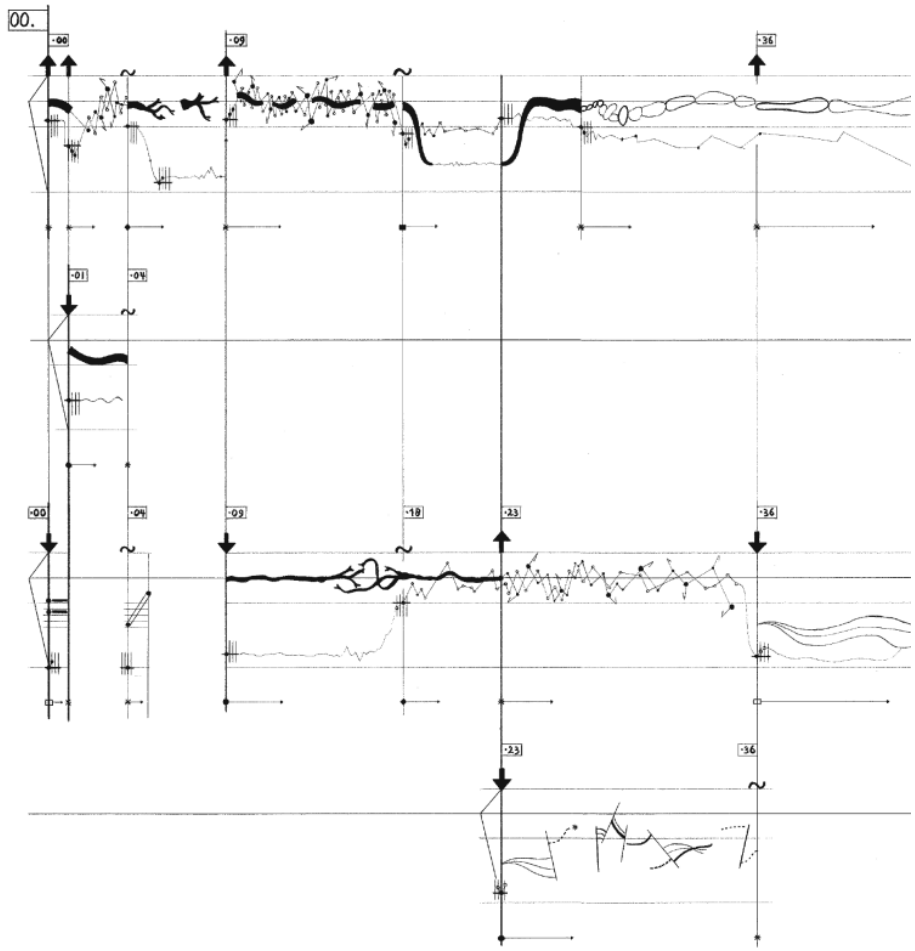

Figure 16 - Raaymakers: Graphic Quartet (Opening)

It is interesting to note that although Raaymakers subscribes to such a highly personalized concept of morphology, it is relevant not only to his own creative output, but also to the work of figures as diverse as Piet Mondriaan, Étienne-Jules Marey, Iannis Xenakis, and Helmut Lachenmann. These many divergent streams of thought and activity from these various artists all relate to the subject of musical morphology, with its vast scope and applicability.

1.3.5 Musical Morphology V – Claus-Steffen Mahnkopf

In keeping with such a scope, one of the most diverse collections of writings on the subject of musical morphology was published in 2004, as the second volume of *New*

Music and Aesthetics in the 21st Century, bearing the subtitle: *Musical Morphology*[82]. The concerns that motivated the assembly of the volume are outlined in a brief editors' statement:

> "While in common-practice music concepts such as theme or motive, phenomena such as line or melody, and systems of syntax and rhythm are generally taken to be self-explanatory, the question concerning corresponding means in post-traditional music (i.e., new music since 1945) – that is, sufficient to shaping the musical surface in a potentially meaningful manner – is rarely reflected upon and more commonly suppressed."[83]

The various individualized approaches to dealing with such expanded "post-traditional" means of contemporary practice, gives rise to "the difficult, but unavoidable basic questions concerning a musical typology of shapes."[84] in the present era. As a reflection of this vast and heterogeneous field of compositional activity, the editors chose to invite "an international group of composers... to consider the musical phenomenon of morphology in light of their own work[85]". Furthermore, because the vast majority of these composers[86] chose to deal with this issue in reference to a specific composition, the multiplicity of avenues through which musical morphology is explored becomes split off into ever smaller byways throughout the volume.

One of the few writers to explicitly mention musical morphology is chief editor Claus-Steffen Mahnkopf in his essay "On Musical Deconstruction"[87]. Borrowing a loaded term from the field of literary theory, Mahnkopf describes musical deconstruction as follows:

> "The aim of musical deconstruction is to bring to light contradictions, even *apriori* within the music (and the work), the construction, the form,

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[82] Claus-Steffen Mahnkopf, Frank Cox, and Wolfgang Schurig eds., *New Music and Aesthetics in the 21st Century, Vol. 2 – Musical Morphology*, (Hofheim: Wolke Verlag, 2004).

[83] Mahnkopf et al., *Musical Morphology*, 7.

[84] Ibid.

[85] Ibid.

[86] The complete list of contributors is as follows. Mark André, Aaron Cassidy, Sebastian Claren, Sidney Corbett, Frank Cox, Andreas Gürsching, Wieland Hoban, Claus-Steffen Mahnkopf, Chris Mercer, Giorgio Netti, Wolfram Schurig, and Steven Kazuo Takasugi.

[87] Claus-Steffen Mahnkopf, "On Musical Deconstruction," in *New Music and Aesthetics in the 21st Century, Vol. 2: Musical Morphology*, 9-21 (Hofheim: Wolke Verlag, 2004).

> the material, even the actual conceptual goals that have been set... The work of composing is itself—at least partially—directed against itself. "[88]

The emphasis on "conceptual goals" is paramount for Mahnkopf who asserts that "the most important deconstructivist method is the combination of divergent, even conflicting strategies of pre-compositional formal planning[89]". Thus not only is musical morphology a philosophical concept for Mahnkopf, but so too does even the act of composing itself take on a philosophical dimension:

> "The morphology of deconstructive music is constituted in such a way as to accomplish... the simultaneous positing of shapes and their critique... The subversive activity of the musical discourse (fragmentation, decomposition, motivic-thematic working à la Beethoven) no longer takes place in succession, i.e., as a form, but rather virtually simultaneously, i.e., as a fabric, a quality"[90]

Mahnkopf's definition of musical morphology - like Raaymakers' - is highly personalized when compared to the general taxonomies outlined by a figure such as Smalley. However it is by means of the rest of the volume, in which the eleven other authors each present similarly individualized concepts of musical morphology that the full breadth of the field of possibilities becomes clear. Such an amorphous notion of musical morphology is harmonious with Mahnkopf's own ideas about morphology: the simultaneity of positing and critique.

1.4 Conclusions

As seen at the outset of this chapter (during attempts to define the nature of audio morphing techniques), such a multiplicity of viable interpretation is unavoidable when dealing with a subject so intentionally open-ended and (ideally) universal. Mahnkopf et al's suggestion of an open field for the definition of musical morphology echoes Caetano and Cook's surveys of morphing techniques, Levy and Levarie's dictionary building, Wishart and Smalley's appeals to a vast repertoire of diverse compositions for generalized principles, and Raaymakers' multi-layered invocation of the letter M.

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[88] Mahnkopf, "Musical Deconstruction," 14-15.

[89] Ibid., 17.

[90] Ibid., 16.

Though presented in loose chronological order, the writings that mention musical morphology should also be regarded in this light – as a vast field of alternately overlapping and contradictory possibilities.

Such an interpretation was central not only to my understanding of musical morphology, but also to its implementation as a formative influence behind a musical work. The following chapter will describe how this understanding is manifest in the form and materials of *for chelsea smith*, followed by a discussion of the technical aspects of my research.

The remaining chapters will attempt to explain my understanding of morphing and morphology through several musical examples from the purely acoustic repertoire. There are many existing well known ways of interpreting historical materials and in no way does my more idiosyncratic personal interpretation suggest any kind of "proto-morphing" agenda on the part of their creators. However, I do believe in the creative value of observing them through such a lens, and aim to lay out this perceived value over the course of the following chapter.

2 Analysis of the Dissertation Composition

2.1 Introduction

The previous chapter highlighted a selection of the most important writings that my interest in digital audio morphing techniques revealed to me, at times branching out to include the broader topic of musical morphology. Because the pursuit of this background information was undertaken in service of a new composition (*for chelsea smith*) that work will now be discussed in full. Once my central concerns – those directly related to the compositional act – have been addressed by the present chapter, the remained of this document will deal with my technical (Chapter 3) and historical (Chapters 4, 5, and 6) influences in greater detail.

The following pages however, will explore the relationship between audio morphing techniques and technologically-influenced compositional aesthetics. The description of several purely musical concerns and characteristics will also be presented, as summarized by Table 2.

WHY?	WHAT?	HOW?
1) Conceptual Motivations	3) Orchestration	6) Electronic Morphing Techniques
2) Purely Musical Motivations	4) Materials	7) Acoustic Morphing Techniques
	5) Form	

Table 2: Overview of Chapter 2

2.2 Conceptual Motivations – The Virtually Infinite Soundworld

The primary ***conceptual*** motivation behind the writing of *for chelsea smith* was my attempt to understand the altered role of the composer in the early twenty-first century. Many composers have described our epoch as "post-traditional", due to the technological and aesthetic explosions of musical material (to be described in subsequent chapters). In particular, the writings of John Cage, Helmut Lachenmann, Tristan Murail, and Trevor Wishart have contributed to my awareness of our (virtually) infinite soundworld.

The most fundamental influence of these figures on the writing of *for chelsea smith* was my increased awareness of issues related to the arrangement of musical materials within a responsive large-scale form. This priority also motivated my research into audio morphing technologies – for in both cases – if any and all materials are available to the composer, then it is my position that the degree of interaction between them should be deeper and more meaningful than mere sequence or superimposition.

2.2.1 Conceptual Influence I – Cage and Acceptance

The genesis of ***all*** sound as musically viable material in the western tradition is often traced back to American composer John Cage[91]. In the 1991 Norton textbook: *Twentieth-Century Music*, Robert P. Morgan cites the "willingness to experiment with sound for its own sake, without consideration of accepted formal or technical practice"[92] as the definitive characteristic of twentieth century experimental composition in the United States.

The watershed work of this movement is certainly Cage's 1952 composition *4'33"*[93]. Though a great deal of Cage's work in the field of "sound for its own sake" involved audio recording, storage, and playback as performance media[94]; it is interesting to note that *4'33"* is a purely acoustic work[95]. This fact coupled with the radical

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[91] "Cage has influenced the development of music since 1950 more than any other American composer, possibly more than any composer of any nationality. Though perhaps more properly considered a musical philosopher than a composer, at least in any ordinary sense of that term (a view he himself appears to accept with complete equanimity), Cage's conception of what music can and should be has had a profound impact upon his contemporaries, including many who write music entirely different from his own." from Robert P. Morgan, *Twentieth-Century Music,* (Norton: New York, 1991): 364.

[92] Ibid., 296.

[93] John Cage, *4'33"* [1952] (New York: Henmar Press, 1960).

[94] Audio technology was employed by Cage as both sounds sources in live acoustic performances (such as in several of the *Imaginary Landscape* pieces) and also as both the content and storage/distribution/performance media of works such as the *Williams Mix*.

[95] While Cage later opened up the possible instrumentation of *4'33"* beyond the exclusive use of the piano (theoretically including performing forces such as silent loudspeakers: thus rendering it [arguably] no longer strictly acoustic), the 1989 composition *One3 = 4'33" (0'0") + [G clef]* is more accurately the "electronic" version of *4'33"*. The John Cage Trust works list describes it as follows: "Instrumentation: For performer amplifying the sound of an auditorium to feedback level. Comments: For any performance of this work, the player arranges a sound system so that the entire hall is on the edge of feedback." "*One3 = 4'33" (0'0") + [G clef]", The John Cage Trust*, accessed January 29th 2015, http://www.johncage.org/pp/John-Cage-Work-Detail.cfm?work_ID=299.

indeterminacy described in 2012 by Cage's friend and colleague Alvin Lucier, emphasize the important role of purely philosophical factors in Cage's validation of sound as music:

> "*4'33"* is a work in which no purposeful sounds are made. If no purposeful sounds are made, what constitutes the work? It's the showing of time and focusing attention on the sounds of the environment.... It's wonderful to learn to accept the sounds."[96]

Though the most probable sonic possibilities of *4'33"* are less than fully infinite (consider the finite possibilities of a silent performer in a concert hall), the significance of the work lies in the selection of sonic materials that reside wholly outside the pre-defined musical elements of traditional western art music. Also, the relinquishing of control over the work's specific sonic content illustrates the degree to which Cage's influence on my work might most accurately fall under the heading of philosophical or conceptual motivations.

A companion piece to *4'33"* was composed ten years later under the title *0'00"*[97], in which Cage explored the seemingly infinite aspect of the modern sound world even further. When one considers that "the idea of the piece is that you engage in an activity you have to do anyway and amplify it"[98] (as described again by Lucier in 2012), it becomes clear how much more open ended *0'00"* is than *4'33".* Given the diversity of potential activities that might have to be done by any given performer, almost any sound could potentially reach the audience. This acceptance and foregrounding (through literal amplification) of any sound that can be harnessed within the time and space of the concert hall, erases the aesthetic border between the musical and non-musical categories of sonic material available to the composer.

Such a dramatic paradigm shift has personal significance to me not only in the context of musical material, but also in terms of its presentation and combination. In the context of *for chelsea smith*, Cage's influence (via *4'33"* and *0'00"*) is most readily apparent through the integration of real-world (previously "non-musical") audio sources into musically meaningful contexts. Schaeffer and Russolo (the theories and music of

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[96] Alvin Lucier, *Music 109* (Middletown: Wesleyan University Press, 2012), 66-67.

[97] John Cage, *4'33" No. 2, 0'00"* (New York: Henmar Press, 1962).

[98] Lucier, *Music 109*, 44.

which will be described in Chapter 6) might also be cited as revolutionary in this regard. However, Cage is more personally relevant to my work due to: his experience as a composer in a wide spectrum of more and less traditional styles, the depth of his philosophical foundations, and the ***radical*** acceptance of his material aesthetic.

2.2.2 Conceptual Influence II – Lachenmann and Taxonomy

As described above, the contributions of Cage marked an intentional and radical departure from the overall vector describing material development in the western tradition. The coming chapters will show how these more mainstream developments occurred gradually, with a general trend of expansion and relative continuity[99]. Whereas Cage embodies a particularly dramatic rupture in this development, several composers who achieved equally radical results did so in a manner which constituted a conscious dialogue with the western tradition.

The performing forces, musical rhetoric, and theoretical writings of Helmut Lachenmann all illustrate a deep awareness and connection to the music of the past. However, his use of extended performing techniques (to be described in Chapter 6) have provided him with a palette of fundamentally new sounds. To this end however, Lachenmann still employs the specialized skills of trained musicians in the realization of scores consisting of enriched but essentially traditional notation. Furthermore, one can still identify the gestures, phrases, and architectural features of traditional western music through the surface of his materials.

On the level of pure sonic material however, Lachenmann's work bears an affinity to Cage's radical embrace of full acoustic experience. While his means of presentation have clear connections to previous practice, the soundworld explored by Lachenmann displays an ***exponential*** increase in sonic diversity. As with Cage, sound in and of itself becomes synonymous with music. However, it is important to note that Lachenmann is highly critical of music in which new or novel sounds are regarded as a compositional end product. Rather, Lachenmann has repeatedly stressed (as in following answer given during a 1999 interview with David Ryan) that his project is one of

[99] For an overview, skip ahead to the "conclusions" sections of Chapters 4-6.

contextualization, in which new arrangements of material should be the logical consequence of a more complete understanding of one's materials:

> "The fascination exerted by a musical effect per se has in the final analysis no significance: it is replaceable. Anybody, after all, can scratch with the bow behind the bridge; on the other hand every sound or noise, defamiliarized or not, familiar or unusual, draws its significance from the constructional development of the context."[100]

As described at length in Chapter 6, it is the grouping of new sounds into families or types that forms the basis of his 1966/1993 essay: "Soundtypes of New Music". At the start of this essay however, Lachenmann explicitly equates sound and music, again emphasizing this development's historical context.

> "An important achievement of musical development in our century has been the emancipation of acoustic sound from its comparatively minor role in the music of the past. Today, a key (though not yet central) point of musical experience is the direct application of acoustics and empiricism, in contrast to the traditional sound-view with its foundation of consonance, dissonance, and tonal relationship.[101]"

Thus, even for a composer such as Lachenmann who demonstrates clear ties to a tradition rooted in the past (through both his writings and his compositions), the fundamental characteristic of current practice is a revolutionary emphasis on sound as music "in contrast to the traditional sound-view".

Lachenmann's primary influence on *for chelsea smith* is not manifest through an abundance of extended instrumental technique (though such techniques are employed throughout). Neither is it displayed through any explicit allusions to the history of the western tradition. Rather, Lachenmann's greatest conceptual influences on *for chelsea smith* arise from his use of sound families and his above-cited "emancipation of acoustic[s]". For as will be discussed in the forthcoming section on musical material in

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[100] David Ryan "Composer in Interview: Helmut Lachenmann," *Tempo*, Vol. 3, No. 210 (1999): 21.

[101] "*Die Emanzipation des akustisch vorgestellten Klangs aus seiner vergleichsweise untergeordneten Funktion in der alten Musik gehört zu den Errungenschaften der musikalischen Entwicklung in unserem Jahrhundert. Anstelle der alten, tonal bezogenen, konsonanten und dissonanten Klank-Auffassung ist heute die unmittelbar empirisch-akustische Klang-Erfahrung zwar nicht in den Mittelpunkt, aber doch an den Schlüsselpunkt des musikalischen Erlebnisses gerückt*." Helmut Lachnemann, "Klangtypen der neuen Musik," in *Musik als existentielle Erfahrung: Schriften 1966 – 1995*, ed. Josef Häusler, 1-20 (Mainz: Breitkopf und Härtel, 1996): 1.

for chelsea smith, the "direct application of acoustics and empiricism" resulted in a work based on three primary sound families defined by acoustic features.

2.2.3 Conceptual Influence III – Murail and Technology

One of the writings that has contributed the most to my understanding of the present sound world's creative implications – and consequently influenced the composition of *for cheslea smith* – was written by French spectralist composer Tristan Murail. In 1980, well after the aesthetic openness pioneered by Cage and Lachenmann (among others) had become relatively well established, Murail presented a paper at Darmstadt entitled "The Revolution of Complex Sounds"[102]. This presentation was a retrospective assessment of what exactly had changed as a result of the exponential expansion of the modern soundworld, and an attempt to grapple with the altered role of the composer in this context.

Much like Lachenmann, Murail identified new compositional methods as the unavoidable consequence of a (virtually) infinite soundworld. And like Lachenmann, he also emphasized acoustic reality over traditional (in addition to more recent) systems of musical organization.

> "The most sudden and important revolution to affect the musical world during the recent past was based not on some type of reflection upon musical grammar (serial or other), but rather—more deeply—upon the world of sounds themselves: in other words, in the sonic universe that summons the composer. For any composer reflecting upon his place in music's evolution, this unprecedented opening of the world of sounds that we now recognize cannot fail to make itself felt in the compositional technique itself. More precisely: any attempt to integrate these new sounds that are above all, as we shall see, sounds of a 'complex' character, necessitates a profound revision of traditional compositional techniques"[103]

What Murail described as an "unprecedented opening of the world of sounds" involved many aspects. Factors of a Cageian/philosophical nature are identified:

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[102] Eventually published as: Tristan Murail, "The Revolution of Complex Sounds," *Contemporary Music Review*, Vol. 24, No. 2/3 (April/June 2005): 121-135.

[103] Murail, "Complex Sounds", 121.

> "The revolution of the world of sounds also took place within us. In effect, we are participating in a large-scale reappraisal of traditional listening.[104]

Similarly, the expansion of traditional performance practice to include extended techniques of the sort associated with Lachenmann are also mentioned. The "emancipation of acoustic sound" referred to by Lachenmann above, is described in terms of traditional instrumentation in the following statement by Murail (itself reminiscent of Lachenmann's descriptions of sound families cited in Chapter 6).

> "Along with the birth of new instruments, instrumental technique also renewed itself, giving the composer an entire category of sounds with previously unimagined characteristics—sounds that fall between two categories, paradoxical sounds, unstable sounds, complex sonorities that defy the traditional classification of harmony and timbre completely, inhabiting the unclaimed territory between them."[105]

The coming chapters will present an evolution of aesthetic enrichment within the western tradition, culminating in the creative use of audio recording devices. Murail also situates these technologies at the end of a long historical trajectory of enrichment.

> "The enrichment of musical material is not, in fact, new. It occurred slowly over the entire course of the 20th century, first with the development of percussion instruments, then with the appearance of electronic instruments... starting with work on analogue tape in the classical studios and ending with the computer"[106]

Murail's retrospective assessment of "work on tape" reveals consequences that reach far beyond the stylistic boundaries of *Musique concrète* as a genre. Specifically, Murail identifies Hungarian composer György Ligeti's 1961 orchestral composition *Atmosphères* as a consequence of audio technology.

> "It was inevitable that the development of electroacoustic techniques, and of our understanding of acoustics, would affect traditional compositional techniques. Indeed, electronic music produced a more or less deliberate proliferation of instrumental and orchestral music, which as a result proposed new schemes, new forms, new ideas as far as the use and

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[104] Ibid., 122.

[105] Ibid.

[106] Ibid., 121.

> combination of instruments, etc. It is obvious that we would not have Ligeti's *Atmosphères* without the development of tape music."[107]

It is this influence of audio technology on the composition of purely acoustic works that I recognize among my own motivating forces during the creation of *for chelsea smith*.

While the positive aspects of the landscape are Murail's primary subject matter, he does acknowledge the daunting nature of the compositional resources described above, citing the activities of composers who are intimidated by the wealth of new possibilities.

> "Despite this outpouring of new methods, of new concepts—or perhaps because of them—we are currently witnessing many composers performing a kind of turning backwards, a reversion to a maternal embrace, to a collective refusal of instrumental innovations, a refusal even of serialism or postserialism... Fear of the unknown, lack of imagination, or balking in front of the immensity of the task? This path is often disguised as a virtue"[108]

Murail's search for the missing "concepts permitting us to organize the new reality that, whether we like it or not, faces us"[109], veers primarily into the realms of timbre and harmony. Such an orientation is not surprising given the importance and interdependence of these two phenomena in spectral music.

> "It seems to me that the entire range of complex sounds can be integrated functionally within a musical logic, rather than used as a startling daub of colour, or only for expressive ends, for their anomalous or paroxysmal qualities. But on a more fundamental level they have an irreplaceable role in all processes of harmony and timbre. With their help, timbres are split into harmonies, harmonies fuse as timbres; without them, certain types of evolution that by definition require intermediate stages would prove impossible. They also demand that we open our musical horizons, and burst the traditional grids with which we have tried to imprison music... From this new reality of sounds should grow new methods of organization capable of embracing all categories of sound, past and future."[110]

Murail's directive to "burst the traditional grids" implies that a sonic/perceptual continuum is more befitting of modern musical practice. Such continua will be central to

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[107] Ibid., 123.

[108] Ibid., 122.

[109] Ibid., 123.

[110] Ibid., 135.

the discussions of both morphing software and "acoustic morphing" in subsequent chapters. Most significant in the context of the present section however, is the fact that continuous change was also a primary conceptual concern during the writing of *for chelsea smith*. This notion of *structural* continua is introduced by Murail in his description of formal principles that respond to a virtually limitless soundworld.

> "It will be an organization of energies, or paths—the path from pitch to noise, from smooth frequencies to rough ones, from periodic to random rhythms, etc. Musical form will no longer consist of frozen structures but of forces, and dynamisms. The old oppositions of container and content, of form and material will lose all meaning, since compositional process will have become an art of synthesis, born of a continuous movement from differentiation to integration."[111]

After describing these formal implications, Murail distinguishes them from the activity of past compositional schools. He does so by employing the imagery of construction and sculpting from the visual realm, though the dichotomy of additive and subtractive synthesis (described fully in Chapter 3) could also apply[112].

> "The true musical revolution of the 20th century lies here, in the fluctuation between abstract concept and aural perception that permits access into the depth of sounds, that allows us truly to sculpt sonic material, rather than piling up bricks or layers. One might speak of an opposition between the traditional compositional practice of amassing and compounding elements... and another method I designate as synthetic: the sculpting of music."[113]

While described above in terms of additive construction (composition), the treatment of actual musical phenomena as bricks of fixed dimensions also implies the

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[111] Ibid.

[112] American composer Roger Reynolds employs similar metaphors of construction and synthesis in his 1975 book *Mind Models*: "Historically, composers have achieved by additive construction. Their training has centred on the control of clearly characterized relationships that were built up according to prevailing values and techniques. It is no longer inconvenient to venture several steps beyond the use of a limited repertoire of given items. We can now begin with a surfeit. Our technological capacity for storing, synthesizing, and rapid sampling from diverse sources makes it possible to start off with a practically unlimited store of individual sound items or patterns, a selection as structured or random as one wishes. Such abundance is perhaps the most genuinely new resource with which we are faced. Now, in a demanding, clangourous environment, one may select rather than construct, sample differently rather than develop. In short, the composer's function might become essentially subtractive, rather than additive." Roger Reynolds, *Mind Models* (New York: Praeger, 1975): 158.

[113] Murail, "Complex Sounds", 123.

distortion of naturally amorphous "acoustical reality" into a brick-like mold. Murail describes the abandonment of this approach as a potentially generative force in the search for new organizational principles.

> "Musical structures of the past (tonal, serial, etc.) fail to account for intermediate categories because they force acoustical reality through inexorable sieves. We must, in fact, work with precisely those areas that have been neglected, and use their specific qualities, exploiting the imbalances of their internal energies and flowing dynamism, even drawing from them new structures of order that might apply to both the micro and the macro level of the score. We need, in fact, new organizing principles that do not exclude one or more categories *a priori*, but integrate the totality of sonic phenomena."[114]

As Murail points out, the rich inner life of even the most conventional of inherited musical elements is actually obscured by conventional schemes of organization: "the musical 'atom' is not the notehead written on staff paper. The musical atom is the perceptual atom"[115].

Among its many other contributions "The Revolution of Complex Sounds" establishes this deeper understanding of both new and inherited musical resources, and proposes their organization according to multi-dimensional structural continua. These two notions constitute another important aspect of Murail's writing that influenced the composition of *for chelsea smith*, as will be seen during descriptions of the work's material and form.

Similar concepts were also described by Trevor Wishart. While the many references to Wishart's writings throughout this document reflect its influence on my own creative work, the following section will address this connection explicitly.

2.2.4 Conceptual Influence IV – Wishart and Lattice Sonics

Terms and concepts such as Murail's: musical atoms, perceptual atoms, sonic continua, and additive vs. subtractive compositional paradigms, are echoed by English composer and computer scientist Trevor Wishart in his 1985 book *On Sonic Art.* In addressing the writings of French composer Pierre Boulez, Wishart introduces the

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[114] Ibid., 124.

[115] Ibid., 123.

concept of ***lattice sonics***. As the word "lattice" implies, Wishart's reading of Boulez describes a compositional paradigm based on discrete divisions and parameterizations: essentially the polar opposite of continua-based composition.

As late as 1952 even a figure as radical as Boulez – in one of his most extreme polemics no less – defined music as containing only "four sound-constituents: pitch, duration, intensity and attack, timbre."[116] In the same year, Boulez made these parameters compositionally explicit in *Structures I pour deux pianos*[117] (notably omitting the category of timbre through the use of a single instrument type for the duet), as seen in Figure 17 below[118].

ORMAP	0	1	2	3	4	5	6	7	8	9	A	B
PC	3	2	9	8	7	6	4	1	0	A	5	B
Duration	1	2	3	4	5	6	7	8	9	10	11	12
	𝅘𝅥𝅰	𝅘𝅥𝅯	𝅘𝅥𝅯.	𝅘𝅥𝅯	𝅘𝅥𝅯𝅘𝅥𝅰	𝅘𝅥𝅯.	𝅘𝅥𝅯..	𝅘𝅥	𝅘𝅥𝅘𝅥𝅰	𝅘𝅥𝅘𝅥𝅯	𝅘𝅥𝅘𝅥𝅯.	𝅘𝅥.
Intensity	*pppp*	*ppp*	*pp*	*p*	*quasi p*	*mp*	*mf*	*quasi f*	*f*	*ff*	*fff*	*ffff*
Articulation	>	⩥	·		norm	⌒·	·	*sfz*	⩥		⩦	⌒

EXAMPLE 1. *The series from* Structures 1a

Figure 17 - Lombardi: Boulez`s Series for Structures 1a

Thus even according to a composer for whom the negation of "a tradition that is now devoid of life"[119] was an explicit aim[120], compositional work consisted of the arrangement and manipulation of a fixed collection of inherited musical elements.

Wishart takes issue with Boulez's classification of acoustic materials in *On Sonic Art,* and cites such an understanding as the essence of lattice sonics. Wishart also mentions "the rejection by some musicians and musicologists of [his own] work on the

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[116] Pierre Boulez, *Notes of an Apprenticeship* (New York: Knopf, 1968): 275.

[117] Pierre Boulez, *Structures I pour deux pianos* [1952] (London: Universal Editions, 1955).

[118] Reproduced from: P. Lombardi, "Research notes: A Tesseract in Boulez's "Structures 1a"," *Music Theory Spectrum*, Vol. 30 No. 2 (2008): 339-359.

[119] Boulez, *Notes*, 182.

[120] Boulez states: "It seems that the present generation can now take leave of its predecessors; it has reached a self-definition sufficiently precise and explicit so that it need no longer accept sponsorship, need not suffer patronage." Boulez, *Notes*, 182.

grounds that it is not music'"[121], and cites the Boulez's categorization of musical phenomena as an unreasonably restrictive contributor to such assessments:

> "In some ways *On Sonic Art* can be viewed as a reply to Boulez's proposed limitations on the sphere of what constitutes music. Here is what Boulez has to say: *Pitch and duration seem to me to form the basis of a compositional dialectic, while intensity and timbre belong to secondary categories. The history of universal musical practice bears witness to this scale of decreasing importance, as is confirmed by the different stages of notational development. Systems of notating both pitch and rhythm always appear highly developed and coherent, while it is often difficult to find codified theories for dynamics or timbre which are mostly left to pragmatism or ethics [...].* (Boulez 1971:37)"[122]

These limitations imposed on musical phenomena outside the realm of pitch and rhythm by Boulez (as secondary categories) and "some musicians and musicologists"[123] (as non-music), are what Wishart describes as the boundaries of lattice sonics. A musical lattice can be defined as a two-dimensional grid with pitch on one axis, and durations on the other. The fact that it is a grid (as opposed to a continuous two-dimensional plane) is important, in that the distances between rhythmic values (greater or smaller fractions of beats) and pitches (more or less semitones) are discrete steps rather than continuous lines:

> "Conventional music theories, dealing with the organisation of pitch in finite sets, rhythms using summative notation and most usually in fixed tempi... I shall call lattice sonics. Everything from isorhythm through Rameau's theory of tonality to serialism comes under the general heading of lattice sonics"[124]

Wishart offers the following diagram (Figure 18)[125] to illustrate the concept:

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[121] Wishart, *On Sonic Art*, 4.

[122] Ibid., 6.

[123] Ibid., 4.

[124] Ibid., 8.

[125] Ibid., 25.

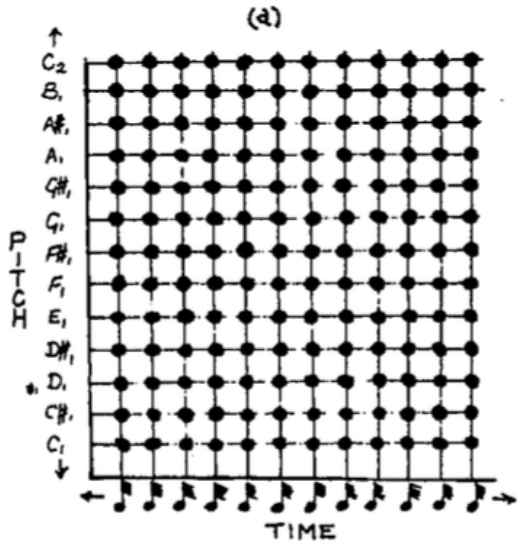

Figure 18 - Wishart: Pitch-Rhythm Lattice

Taking into account the orchestration of a given piece of lattice-based music will expand the lattice into a third dimension (Figure 19). Again however, movement in this dimension must also be achieved by discrete steps (one instrument cannot turn into another). Wishart also illustrates this three dimensional lattice in *On Sonic Art*[126].

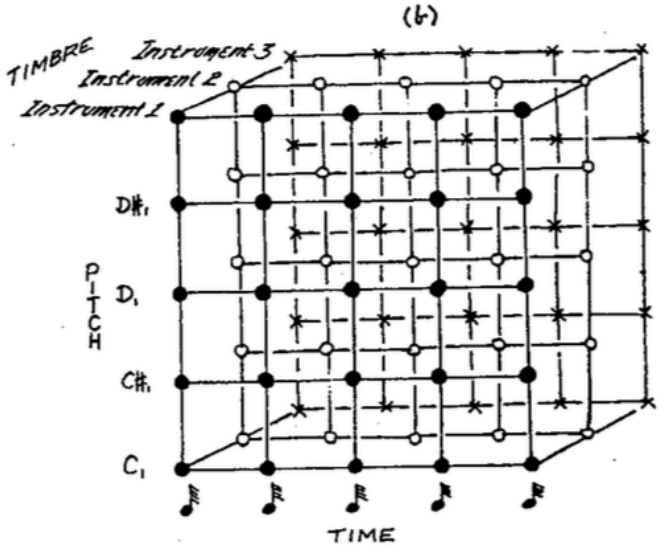

Figure 19 - Wishart: Pitch-Rhythm-Instrument Lattice

[126] Ibid., 26.

Wishart describes the problems of lattice sonics on two levels. First, subtle nuances of even the most traditional music (such as vibrato and tremolo) illustrate that "the lattice only remains an approximate representation of what takes place in actual sound experience"[127]. Wishart asserts that:

> "It is important to view sound-objects as totalities, or *gestalts*, with various properties, rather than as collections of parameters. The concept of a musical event as a concatenation of parameters arises directly from lattice-based musical thought"[128]

Thus, the persistence of lattice-based thought is not offensive to Wishart based on which parameters are plotted along any given dimension of the lattice (pitch, rhythm, and dynamics under Boulez). Rather, Wishart sees it as problematic in that discrete parametrization of actual sonic experience is considered possible.

Wishart's second criticism of lattice sonics is rooted in compositional practice. He contends that the internalization of lattice-based thinking is *the* major obstacle inhibitting the establishment of new musical paradigms based on sound's morphological qualities:

> "At least in our culture it seems extremely difficult to achieve a balance between morphological and lattice-based architecture. For many musicians, lattice structure is what differentiates music from non-music and morphological architecture will be perceived as either chaos and not architecture at all or at least of no concern to the musician."[129]

Thus, the abandonment of lattice sonics is the foundation of Wishart's concepts of musical morphology specifically, and music making in general.

In addition to the musical examples found throughout *On Sonic Art*, Wishart also refers frequently to human vocal production (though of course, the human voice is also Wishart's chosen musical instrument). The importance he ascribes to vocal/phonetic phenomena result from the central role of morphology in phoneme production and perception.

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[127] Ibid., 23.

[128] Ibid., 93-94.

[129] Ibid.,108.

> "Computer analyses of the sounds of speech show that the individual sound constituents (phonemes) are not spliced onto each other in a way one might achieve in an editing studio but in most cases elide into one another very rapidly in the course of the speech–act. Even more fundamental, as will be discussed later, many consonants are characterized by their morphology – the way in which they change form – rather than by their spectrum (their particular frequency or formant characteristics). All this relates very strongly to what I shall be saying about the architecture of music."[130]

Wishart's notion of all sounds as "totalities, or *gestalts*" rather than collections of discrete parameters as in Boulez[131], informs his methods of analysis, classification, and – most importantly – composition and morphology. In fact, these last two phenomena are essentially synonymous in Wishart's creative practice (as reflected by the central role of vocal morphology in both his live acoustic and pre-recorded studio works). Wishart's description and creation of music based on these criteria constitute his single greatest influence on the composition of *for chelsea smith*. The upcoming sections describing form and morphology in the work will reflect this influence.

Having thus described the conceptual motivations behind my dissertation composition, some purely musical influences should also be noted.

2.3 Purely Musical Motivations

My attempt to understand the state and implications of the contemporary soundworld was informed by the above mentioned composers. Their writings as excerpted above constitute some of the most important conceptual motivations behind the composition of *for chelsea smith*.

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[130] Ibid., 20.

[131] It should be noted that an additive or lattice-based approach is not inherently serial, as demonstrated through the example of Boulez's colleague Karlheinz Stockhausen. In the first part of his 1971 lecture: "Four Criteria of Electronic Music", Stockhausen describes how: "The Viennese School of Schoenberg, Berg, and Webern had reduced their musical themes and motifs to entities of only two sounds, to intervals." (Stockhausen, "Four Criteria", 89.) Though this development dramatically reduced (to the smallest possible plurality – a dyad) the inherited musical entities, such a compositional technique still involved—in the words of Murail—the "piling up" of musical "bricks" rather than the composer working to "truly sculpt" sound. Thus for Stockhausen, "It took a little leap forward to reach the idea of composing, or synthesizing, the individual sound" (Stockhausen, "Four Criteria", 89.). As Stockhausen points out, even the crafting of tone colour in traditional music is essentially additive in that it involves the assembly of "...timbres which the composer might choose, like a painter choosing colours to mix from. Classical orchestration is traditionally an art of mixing." (Stockhausen, "Four Criteria", 90.)

There were however several other motivations of a more purely musical nature. The first such musical motivation was a desire to explore meter in a meaningful way. Though my earlier compositions have employed time signatures, this feature has been treated primarily as a grid of one second increments (expressed as 4/4 with quarter notes at 60 bpm). The asymmetrical musical materials are laid on, in, and around this grid, with performers being instructed to ignore the metrical stresses (Figure 20) of traditional performance practices.

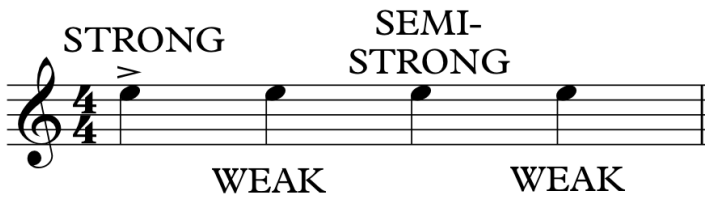

Figure 20 - Possible Implied Accentuation of Meter

Such a system still allows for materials of complex proportions (through the use of beat division and ties) and stress patterns (through accents, dynamics, and phrasing indications). Figure 21 from my 2008 string quartet *Ryan Pegg and Jessica Hoknes* demonstrates this phenomenon.

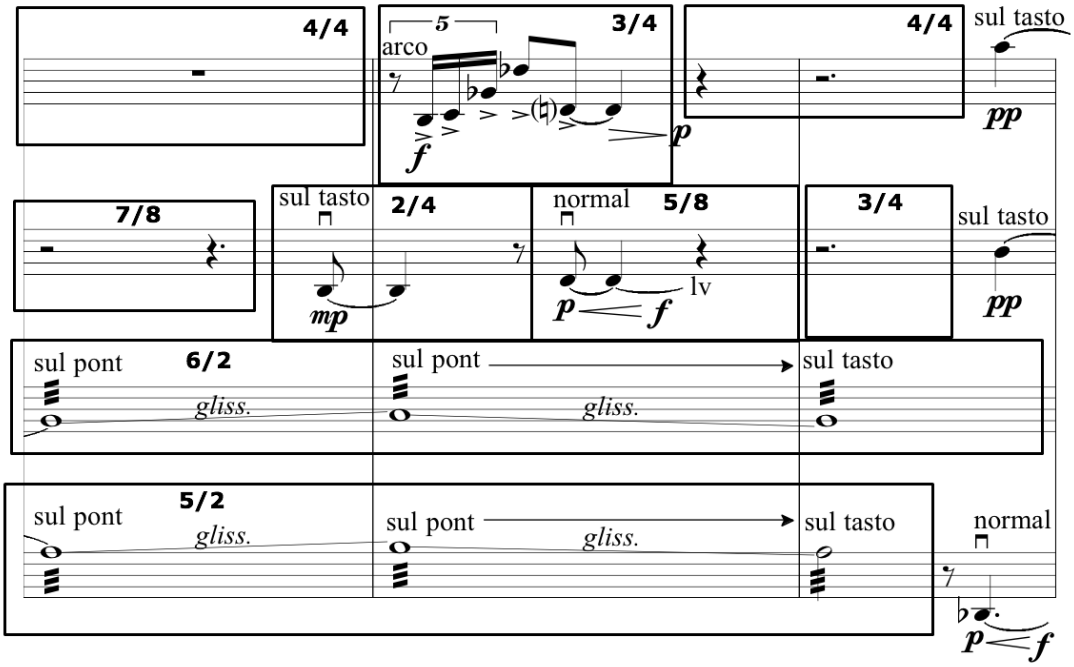

Figure 21 – Miller: SQ (Conflicting Temporal Materials in 4:4 Grid)

While clearly not tailored to the material, the use of a 4/4 metrical grid has yielded two very successful performances of this work. Given the lack of metric accent however, the desired rhythmic material of this passage could be expressed without measures, meter, or tempo. A true grid measured in seconds (without barlines or time signatures, as in Figure 22) could just as effectively indicate the passage of time[132].

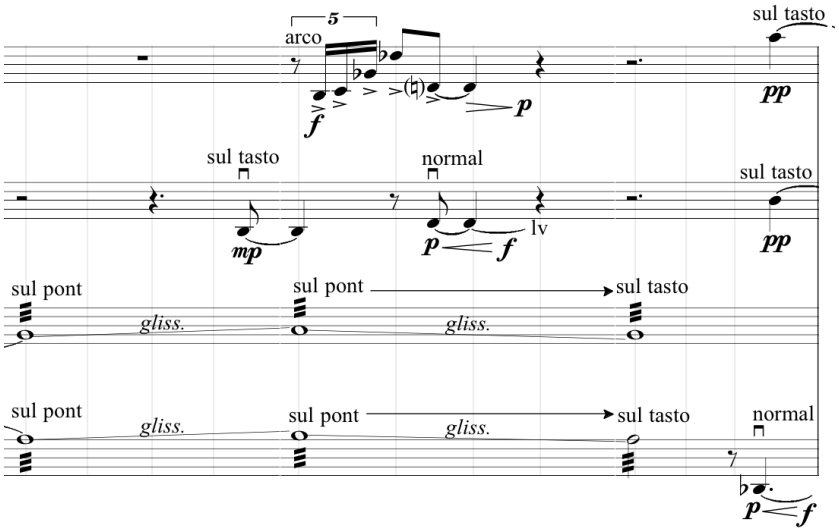

Figure 22 - Miller: SQ (Non-Metric Grid)

As suggested by the labels of the previous figure however, a score could be created in which meter (and tempo) might correspond to the exact dimensions of the musical material from moment to moment. In this scenario, the material could be said to generate the metric framework from the inside out.

The decision to pursue such schemes of metric organization was made pre-compositionally in the case of *for chelsea smith*. This decision also involved a much more purposeful fluctuation of tempi than I had previously employed in my work. While previous compositions had involved occasional deviations in tempo, these instances generally appeared as islands among a calm sea of 60bpm. The following excerpt

[132] The relationship between rhythm and meter has been discussed at length in the literature, especially in the second half of the twentieth century as cited at the outset of Chapter 4 of: Jonathan Kramer, *The Time of Music* (New York: Schirmer, 1988): 81. In addition to Kramer's survey (and original contributions) one might also consider the reframing of rhythm and meter according to the principles of process philosophy, as presented in: Christopher Hasty, *Meter as Rhythm* (New York: Oxford University Press, 1997).

(Figure 23) from my 2010 piano and fixed media electronics duet: *for will robbins*, constitutes only three of eight such measures (in which the tempo deviates from 60bpm) found in the entire work.

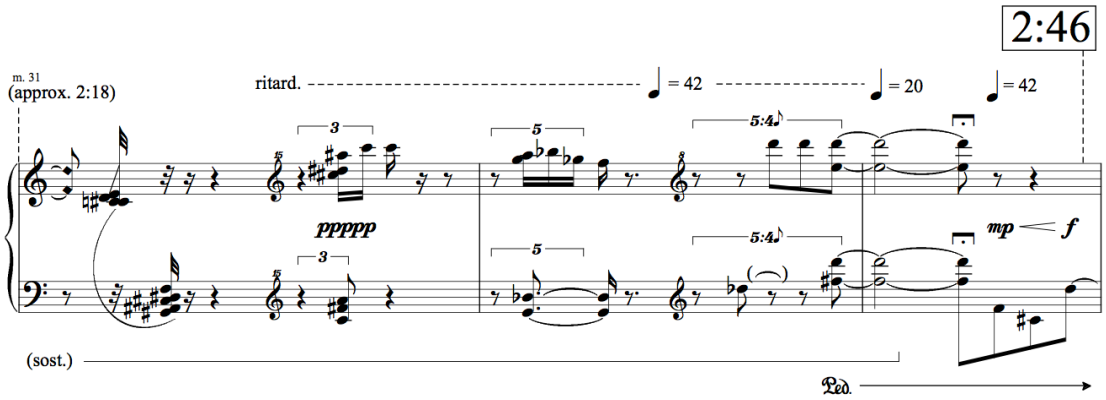

Figure 23 - Miller: for will robbins (mm. 31-3)

My transition to the use of wildly fluctuating meter and tempo in *for chelsea smith* was aided a great deal by the vast number of transcriptions that I performed to gather material. The sources of this materials were both field recordings of real-world audio, and improvised performances based on these recordings. Though the former will be discussed in the section of this chapter dealing with musical material, the latter brings up a second purely musical motivation behind the writing of *for chelsea smith*.

During a 2012 masterclass with Isreali composer Chaya Czernowin at the University of Victoria, I presented my 2010 percussion quartet: *for dylan and alisa.*

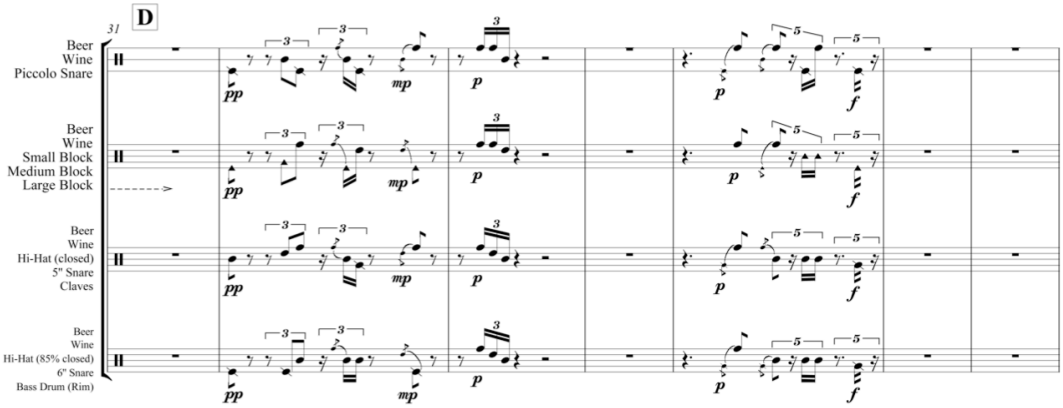

Figure 24 - Miller: for dylan and alisa (Rehearsal D)

During that meeting Dr. Czernowin commented on a sense of relative distance or impersonality in the work. The above excerpt with its many rhythmic unisons of relatively simple rhythms (Figure 24) was characteristic of this observation. While reassuring me that this did not constitute a complete failure of the work, Dr. Czernowin suggested that perhaps there might be more room for personal expression in my practice in general. Given that this was a facet of composition that I had been intentionally trying to suppress for many years, I thought that it might be a worthwhile challenge to embrace in my dissertation composition.

The relationship between my attempt at a more "personal" compositional practice, and the use of meter and tempo as derived from recordings may not be obvious at first. The unlikely connection results from the fact that my primary source of material in *for chelsea smith* is a pool of recordings that I made by performing either at the piano or on a live electronic setup. During these improvisations I attempted to both free myself from any imposed temporal framework, and also to perform in what I understood to be an "expressive" style (for which I have no formal definition). Specific examples of the transcription processes and recordings will follow during subsequent discussions of musical material in *for chelsea smith.*

2.4 Orchestration in *for chelsea smith*

The ensemble used to realize *for chelsea smith* was comprised of the following ten performers, conductors, and technicians.

INSTRUMENT	Performer at Premiere
Conductor	Alex Jang
Flute 1	Thomas Bauer
Flute 2	Thomas Law
Piano 1	Thomas Nicholson
Piano 2	Stephanie Taralson
Celesta	Liam Gibson
Percussion 1 (Vibraphone, Snare, Bass, Custom Tone Bars)	Aaron Mattock
Percussion 2 (Marimba, Snare, Cymbal)	Keenan Mittag-Degala
Technician 1 (Electronics Output Levels)	Annette Brosin
Technician 2 (Electronic Cues and Input Levels)	Darren Miller

Table 3: Instrumentation of for chelsea smith

The most obvious characteristic of this ensemble (Table 3) is the pairing (or tripling in the case of the celesta/percussion trio) of performing forces. The decision to group my instrumental resources in this way resulted from my first exposure to Italian composer Luciano Berio's 1972-3 *Concerto for Two Pianos*[133]. This work caused me to become very interested in the idea of an "acoustic hyper-instrument" resulting from the interplay of two soloists playing pairs of the same instrument.

My use of the term "hyper-instrument" in a context that does not (always) imply electroacoustic manipulation is a slight departure from the accepted usage of the term. In the sixth chapter of her 2012 master's thesis[134], Canadian computer scientist and musician Gabrielle Odowichuk describes her augmentation of a traditional vibraphone (the "Hyper-Vibraphone") as "combining natural acoustics with electronic sound and/or electronic control means, also called [a] hyperinstrument"[135]. While this accepted notion of hyper-instrumentation is abundant in *for chelsea smith*, I am also interested in a more general usage of the prefix hyper-, to indicate "the prepositional force of 'over, beyond, or above' (what is denoted by the second element)"[136]. While the use of live electronics is employed to this end in *for chelsea smith*, I also strove to overcome the physical limitations of a given instrument by writing for a pair (or more) of performers playing the same type of instrument.

As mentioned above, Berio's *Concerto for Two Pianos* (particularly its opening gesture) was extremely influential in this regard.

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[133] Luciano Berio, *Concerto for Two Pianos* (Milan: Universal Editions, 1973).

[134] Gabrielle Odowichuk, *Free-Space Gesture Mappings for Music and Sound,* Master's Thesis: University of Victoria, 2012.

[135] Odowichuk, *Gesture Mapping*, 48.

[136] "hyper-, prefix", *OED Online,* Oxford University Press, accessed February 2nd 2015. http://www.oed.com.ezproxy.library.uvic.ca/view/Entry/90273?rskey=k6uY9M&result=4&isAdvanced=false#eid.

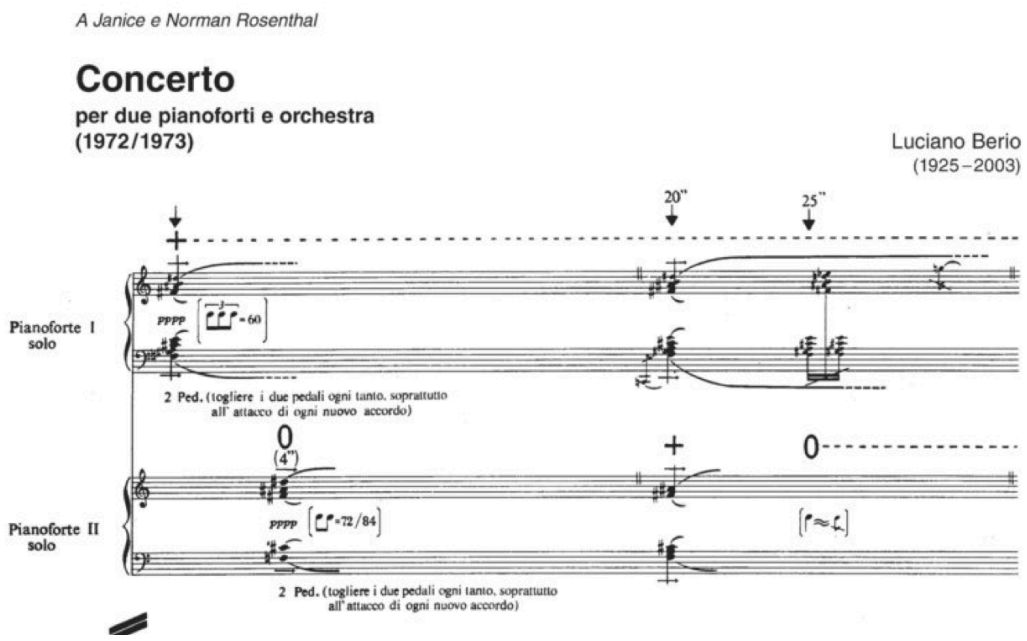

Figure 25 - Berio: Concerto for Two Pianos (m. 1)

In particular, the blending of both pianos during the opening system (Figure 25) suggested to my imagination many interesting possibilities inherent in such combinations. Berio's use of quiet poly-rhythmic rumblings from both instruments creates a blend of complex resonance and subtle pulsation not possible on a single instrument played by a single performer. And yet, the sound is quite cohesive. An attraction to this texture motivated my pairing of virtually all instruments in the ensemble with a complimentary instrument.

The passages most clearly influenced by this Berio composition are (not surprisingly) the passages in which the hyper-piano "solos" are foregrounded. In the example of measure 75 (seen in Figure 26 below), the independent tremolo figures in each piano excite the resonant contents of their respective sostenuto pedals.

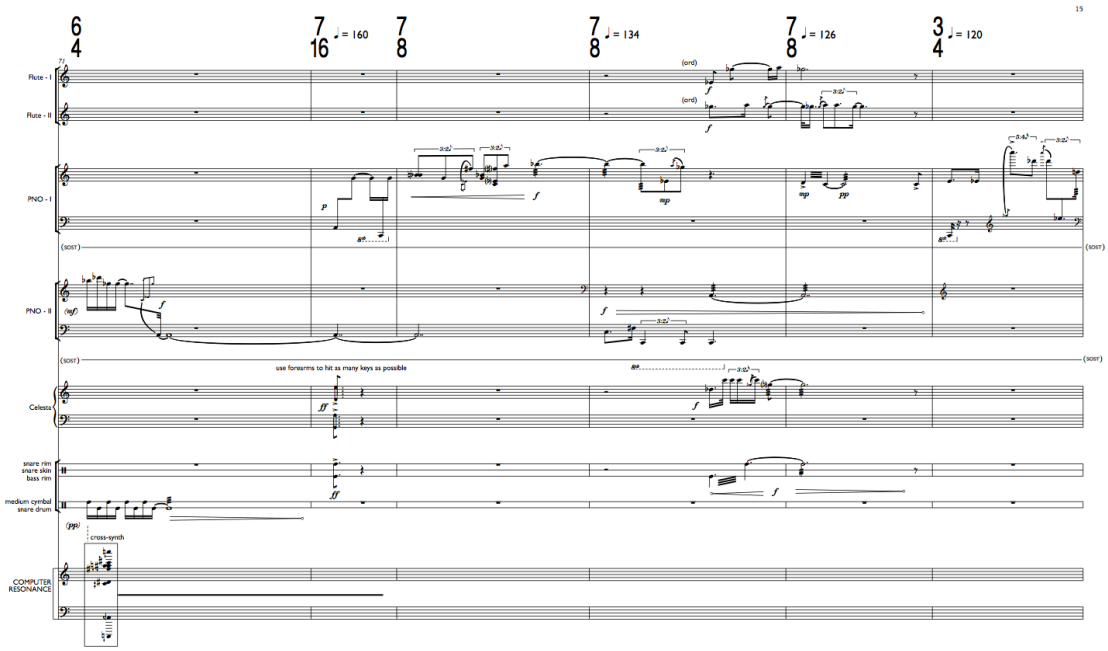

Figure 26 - Miller: for chelsea smith (mm. 71-6)

While both instruments are using the sostenuto pedal to lift the dampers on the same notes, the different pitches subject to tremolo at measure 75 and the varied pitch content of the attacks in the previous measures result in two highly distinct collections of piano resonance. Though this overall "aura" of resonance blends in acoustic space, producing a cohesive hyper-piano timbre, its respective components are more clearly defined than would be possible using only a single soundboard and set of strings on a single instrument.

A similar texture occurs at measure 20 of the work's slow introduction. Here both pianists are holding down a tritone in the bass register, while rapidly attacking the same noisily muted treble material. The resulting blends of distinct attacks and resonances are again more complex than the single-instrument version occurring two measures earlier. This relationship is mirrored by the flute based hyper-instrument, where a melody is performed first as a solo in measure 18, and then again in parallel quarter tone harmonizations at measure 20 (Figure 27).

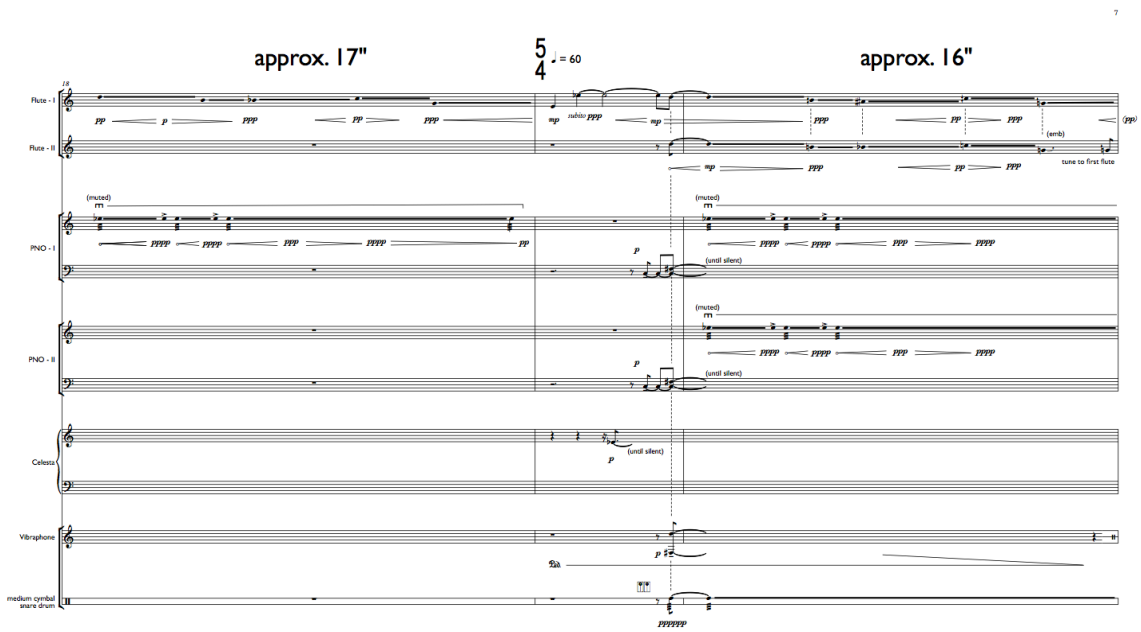

Figure 27 - Miller: for chelsea smith (mm. 18-20)

In the percussion section, this hyper-instrumentation occurs when both players are using mallet instruments (often with the celesta as well), such as measures 316-320 of Figure 28 below.

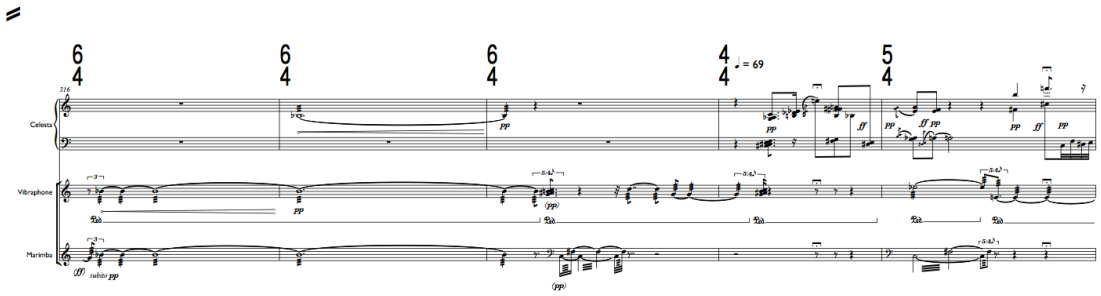

Figure 28 - Miller: for chelsea smith (mm. 316-20)

However it also occurs in the unpitched material of the drums and cymbals, as in measures 39-47 of Figure 29 below.

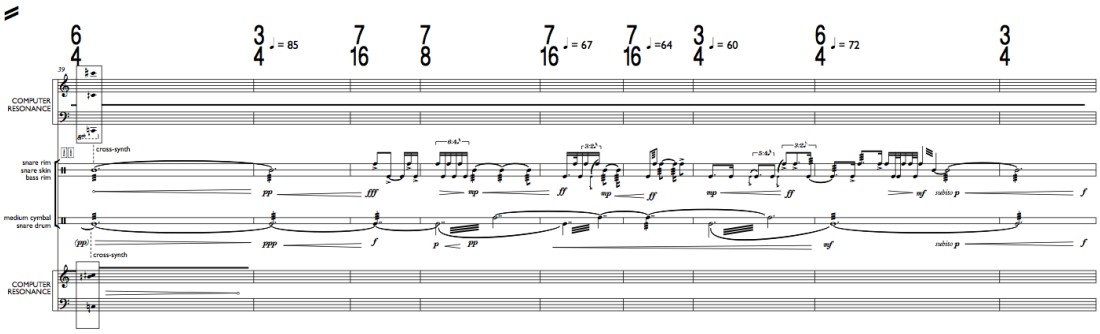

Figure 29 - Miller: for chelsea smith (mm. 39-47)

A final instance of acoustic hyper-instrumentation in the percussion section involves only a single player, and introduces the custom tone bars mentioned in the table of instrumentation (Figure 30). In order to realize the microtonal pitch content (to be described in the following section) on an equal tempered instrument such as the vibraphone, I built and tuned nine additional custom bars. In crafting these bars, I employed the same aluminium alloy used in the manufacture of commercial vibraphone bars. Aside from tuning, the principle difference between my bars and those on the conventional instrument was the fact that I did not hang resonators below my own. This lack of a resonating body necessitated careful control by the first percussionist in order to balance the timbre between both components of his hyper-instrument, such as during the extended trill at measure 290.

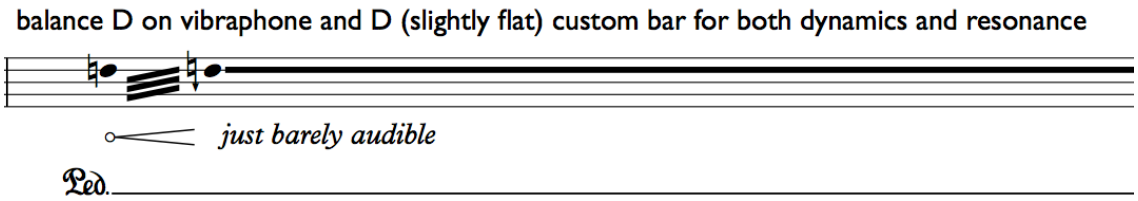

Figure 30 - Miller: for chelsea smith (m. 290)

The final pair of performers – technicians 1 and 2 – also relied on each others' activity to produce cohesive electroacoustic sound. However, it would be inaccurate to consider them as the respective halves of some virtual hyper-instrument in the same sense that the designation is used above. For while they were both performing on a single computer "instrument", the sonic characteristics of their respective activities differed

considerably. The details of this process will be discussed in the final section of the present chapter, which deals with both the acoustic and electro-acoustic morphing techniques found in *for chelsea smith*. For the time being however, it is worth noting that the technicians' augmentation of instrumental sound (through microphones placed on one of the pianos and both percussion setups) might come closer to the previously established definition of a hyper-instrument.

While questions of instrumentation (particularly those involving electronics) are related to musical material in *for chelsea smith*, the latter can also be considered in more abstract, pre-compositional terms. In particular, the relationship between material and form will be addressed in the following sections.

2.5 Musical Material in *for chelsea smith*

The origins of the musical materials that make up *for chelsea smith* are closely related to the conceptual and musical motivations described earlier. Conceptual motivations played a particularly important role, in that my desire to meaningfully connect materials (through compositional analogies to morphing and cross-synthesis) led to the selection of materials with distinct identities and high degrees of contrast. These two related priorities resulted in three quite general classes of material (see Table 4), which despite their generality, do not have a great deal in common with each other.

TYPES	CHARACTERISTICS
Resonant	narrow frequency bands responding to excitation by pink noise
Percussive	sharp, loud, rapid, and continuous bursts of complex rhythmic attacks
Lyrical	steady pitch(es) tracing a gentle and continuous curve through pitch space

Table 4: Three Principal Types of Material in for chelsea smith

The characteristics enumerated above can also be demonstrated through a pair of visualizations for each sound type (Figure 31). The frequency domain (top) best describes the nature of both the resonant and lyrical sound types, while the time domain (bottom) highlights the salient features of the percussive sound type.

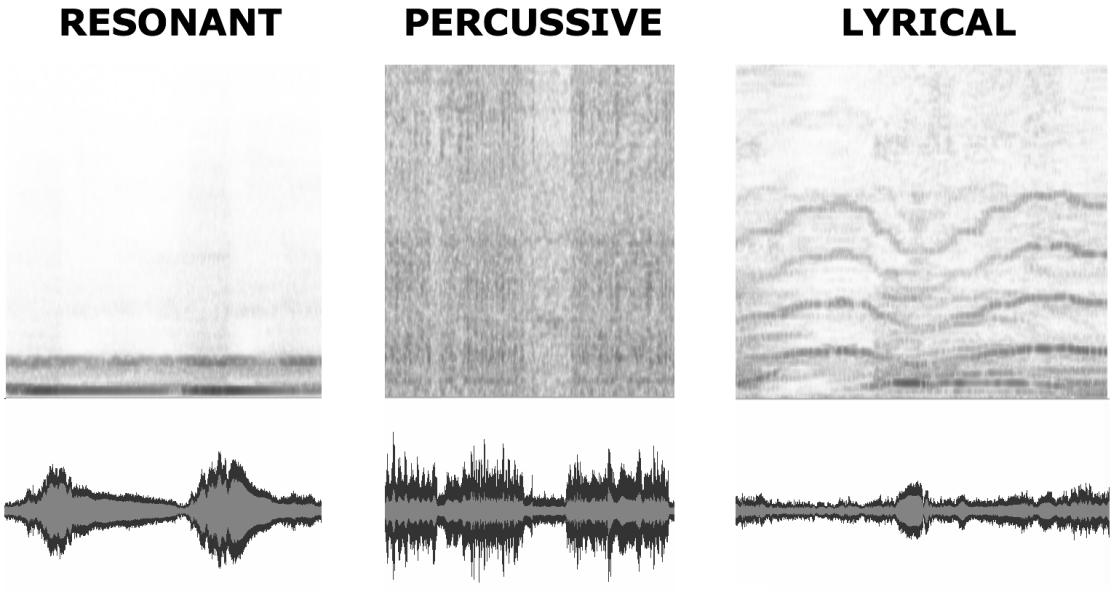

Figure 31 - Frequency and Time Domain Representations of Each Type

The foundational nature of these three particular types of material finds support in the ninth chapter ("Is there a natural morphology of sounds?") of Trevor Wishart's *On Sonic Art*. Citing the analytical contributions of the GRM, Wishart classifies all sound as having one of three kinds of temporal continuation.

> "In particular the category of *continuation* refers, as its name suggests, to the way in which a sound-object may be continued in time. Three basic categories emerge: the *discrete*, the *iterative* and the *continuous*. Discrete continuation describes such sounds as a single (unresonant) drum-stroke or a dry pizzicato on a stringed instrument. Iterative continuation applies to a single-note 'trill' on a xylophone (i.e. the sustainment of a sound which will be otherwise discrete by rapidly re-attacking it), a drum-roll or the impulse-stream of 'vocal fry' or a bowed note on a double bass string which has been considerably slacked off. Continuous continuation applies to a sustained note on a flute, a synthesizer or a bell."[137]

Though I was unaware of the above passage during the first stages of pre-composition, these three natural continuations of sound according to Wishart/Schaeffer, correspond quite closely to my own fundamental categories (compared in Table 5).

[137] Wishart, *On Sonic Art*, 177.

Miller	Wishart/GRM
Resonant	Discrete
Percussive	Iterative
Lyrical	Continuous

Table 5: Potential Correspondences Between Miller and Wishart

While Wishart states that discrete continuation is inherently non-resonant, his two examples (a drum-stroke and a pizzicato) are primarily distinguishable from each other based on the resonant qualities of their respective media (a drum and a string instrument). Furthermore, my own Resonant category is characterized by bandpass filters that only "resonate" when fed a signal: they have no inherent temporal dimension. Because I am employing the term to denote a clearly defined frequency response rather than any sort of temporal characteristic, the Resonant/Discrete pairing is actually much more unified than the respective terms might first suggest.

Unlike my pre-compositional desire for sound types of a specific character, Wishart's continuation types are based on empirical observation.

> "In the physical world, therefore, these three types of continuation imply something about the energy input to the sounding material and also about the nature of the sounding system itself."[138]

By emphasizing this corporeal foundation, Wishart is not blindly insisting that all modern musical materials adhere to these sorts of "naturalistic" laws. Rather, he is pointing out the unavoidable preconditions of aural perception that will affect how new sounds will be interpreted by a potential listener.

> "The mode of continuation (and attack-structure, articulation etc.) of a sound will tend to be read in terms of the physical categories I have described... We can, of course, transcend these categories of the physical experience of sound-events, but I would suggest that we do so in the knowledge that this background exists."[139]

[138] Ibid.

[139] Ibid., 179.

Such perceptual information can be useful in the effective crafting of new sonic materials. Wishart's following comparison of synthetic and acoustic in terms of continuation has direct relevance to the electroacoustic elements of *for chelsea smith* (to be discussed in more detail in a subsequent section).

> "Sounds undergoing continuous excitation can carry a great deal of information about the exciting source. This is why sounds generated by continuous physiological human action (such as bowing or blowing) are more 'lively' than sounds emanating, unmediated, from electrical circuits in synthesizers."[140]

As described by Wishart above, the temporal aspects and implied physical origins of my sound categories are their distinguishing features. I was primarily concerned with each sound type's existence over time, in short: its morphology.

Field recordings for each sound type were gathered. While their inherent morphologies determined their selection, spectral analyses of these field recordings also helped to generate characteristic pitch (or more accurately: frequency) materials. Through such analysis, nine peak frequencies were assigned to each group, for a total of twenty-seven frequencies. Because the resulting frequency collections were assigned to instrumental and electronic performing forces with varying degrees of control over pitch, three different frequency resolutions were employed. All nine combinations are presented below in Figure 32.

[140] Ibid., 180.

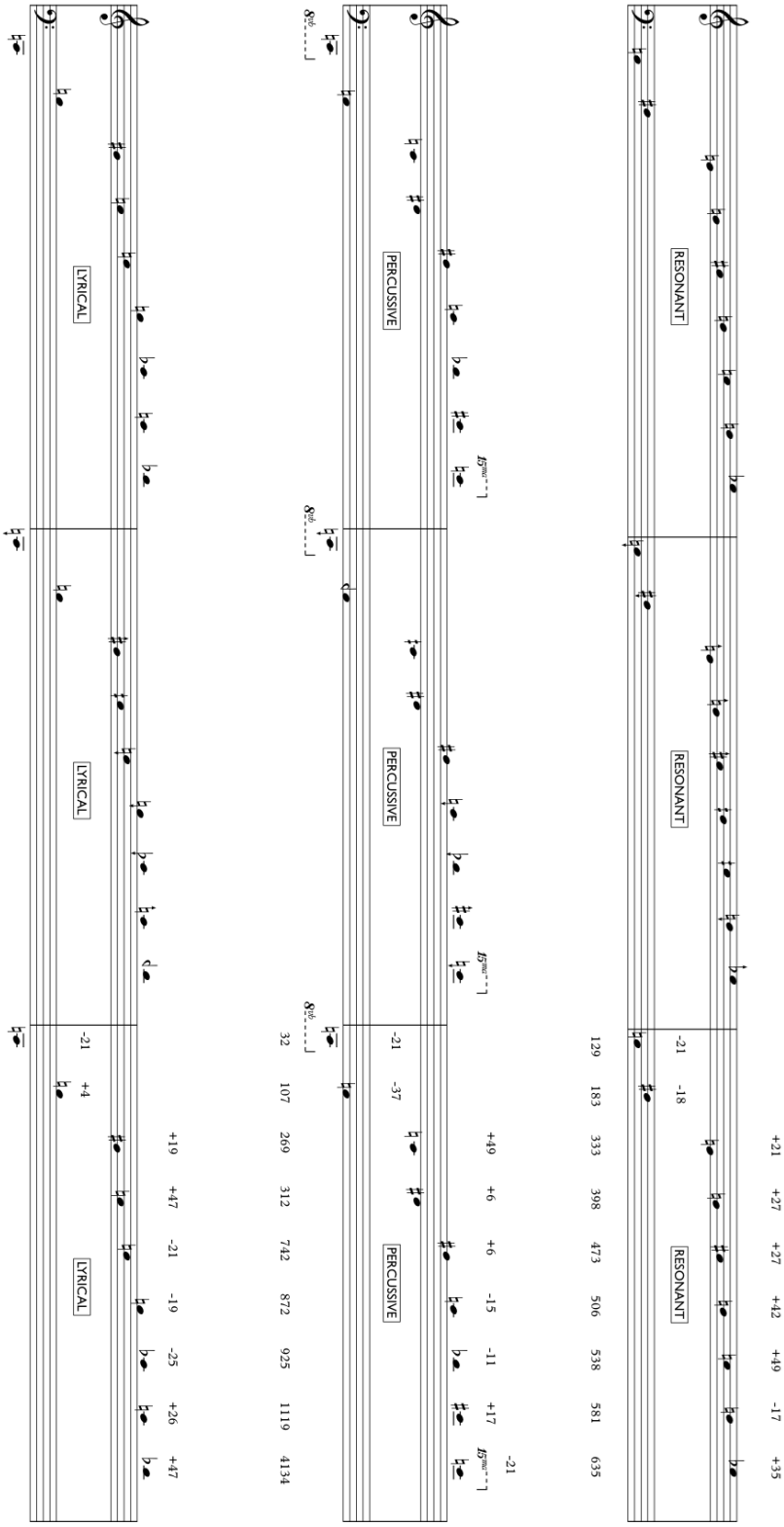

Figure 32 - Pitch Collections For Each Sound Type

The contrasts between material groups are also reflected in the contents of the three pitch collections. No two frequencies are duplicated amongst all three groups at the highest pitch resolution, and even at the lowest level of pitch resolution (the semi-tone) only C5, A5, and Bb5 appear twice.

In terms of register, the pitches associated with the resonant and lyrical groups are centred around the middle of the piano keyboard (C3-Eb5 and C2-Bb5 respectively), while the intervening percussive group spans a full six octaves (C1-C7).

While reducing these collections to sets of pitch-classes (employing octave equivalency) is somewhat misguided given the importance of register and tuning, the distinct identity of each group remains intact under such conditions. Two of the resulting sets contain six elements each, with one set of eight (the resonant sound type). Even a comparison of interval class vectors utilizing a six-dimensional cosine similarity measurement (Figure 33)[141] yields only moderate levels of similarity (Figure 34).

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

Figure 33 - Cosine Similarity

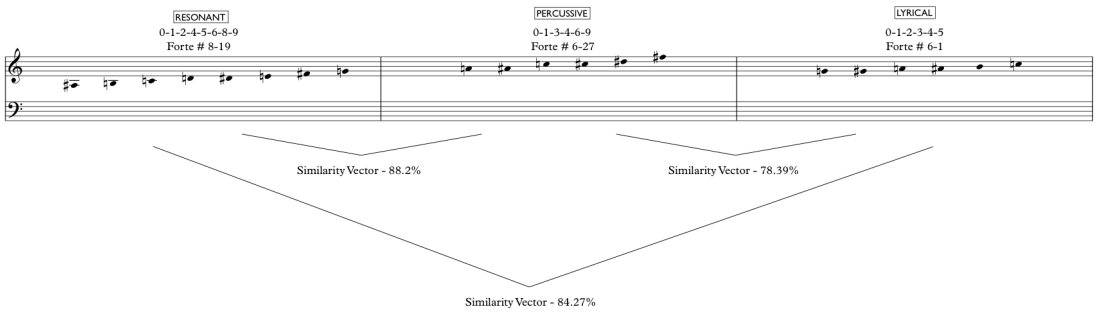

Figure 34 – Cosine Similarity of Pitch Materials as IC Vectors

[141] While I calculated the following values myself in Max/MSP, the image of the cosine similarity equation is taken from: "Cosine Similarity", Data Mining: Finding Similar Items and Users, accessed December 2, 2014, http://bionicspirit.com.

It is important to remember that such a comparison involves both the lowest levels of frequency resolution, and a disregard for the fixity of register that is so central to pitch organization in *for chelsea smith*.

Having thus emphasized the importance of material contrast in *for chelsea smith*, the specific qualities that generate these contrasts will now be described for each individual sound type. While these discussions will focus on material differences, the compositional use to which each field-recording was put remains essentially the same. In all three cases, a live electronic improvisation and a spectral analysis was performed on the field-recording. Transcriptions of both the live electronic improvisation and a piano improvisation informed by the spectral analysis were responsible for a significant portion of the work's material. As such, the content, derivation, and final manifestation of each soundtype's associated material will now be discussed in detail.

2.5.1 Musical Material I – Resonant Type

The field-recording responsible for the resonant soundtype was an approximately six second clip of a man's voice in a noisy room. The clip was spectrally averaged over its entire duration (Figure 35), resulting in a spectral envelope with high noise content and a few peaks corresponding to resonances of the speaker's voice, and the room in which he spoke.

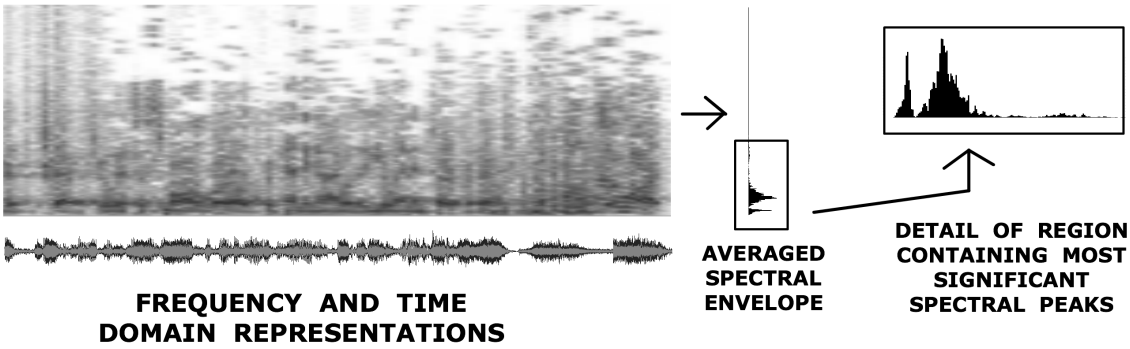

Figure 35 - Resonant Material Type Preparation

To generate material, this averaged spectral envelope (pink noise) was fed through a series of nine extremely narrow bandpass filters assigned to the top spectral

peaks of the analysis. The overall sonic result is a set of nine untempered quasi-sinusoids[142] being excited by pink noise via a custom Max/MSP patch.

In order to generate musical material, I assigned a slider to the gain level for each of the nine filters and one to the pink noise feeding the "instrument". I then performed and recorded a free improvisation in real-time utilizing this setup. This improvisation was the primary source material for the resonant sound type, and transcriptions of it were orchestrated across the ensemble in several passages (Figure 36).

[142] "Quasi-sinusoidal" in the sense that the filter bands were so narrow as to sound essentially like sine waves (ie. they are perceptually quasi-sinusoidal, not empirically quasi-sinusoidal).

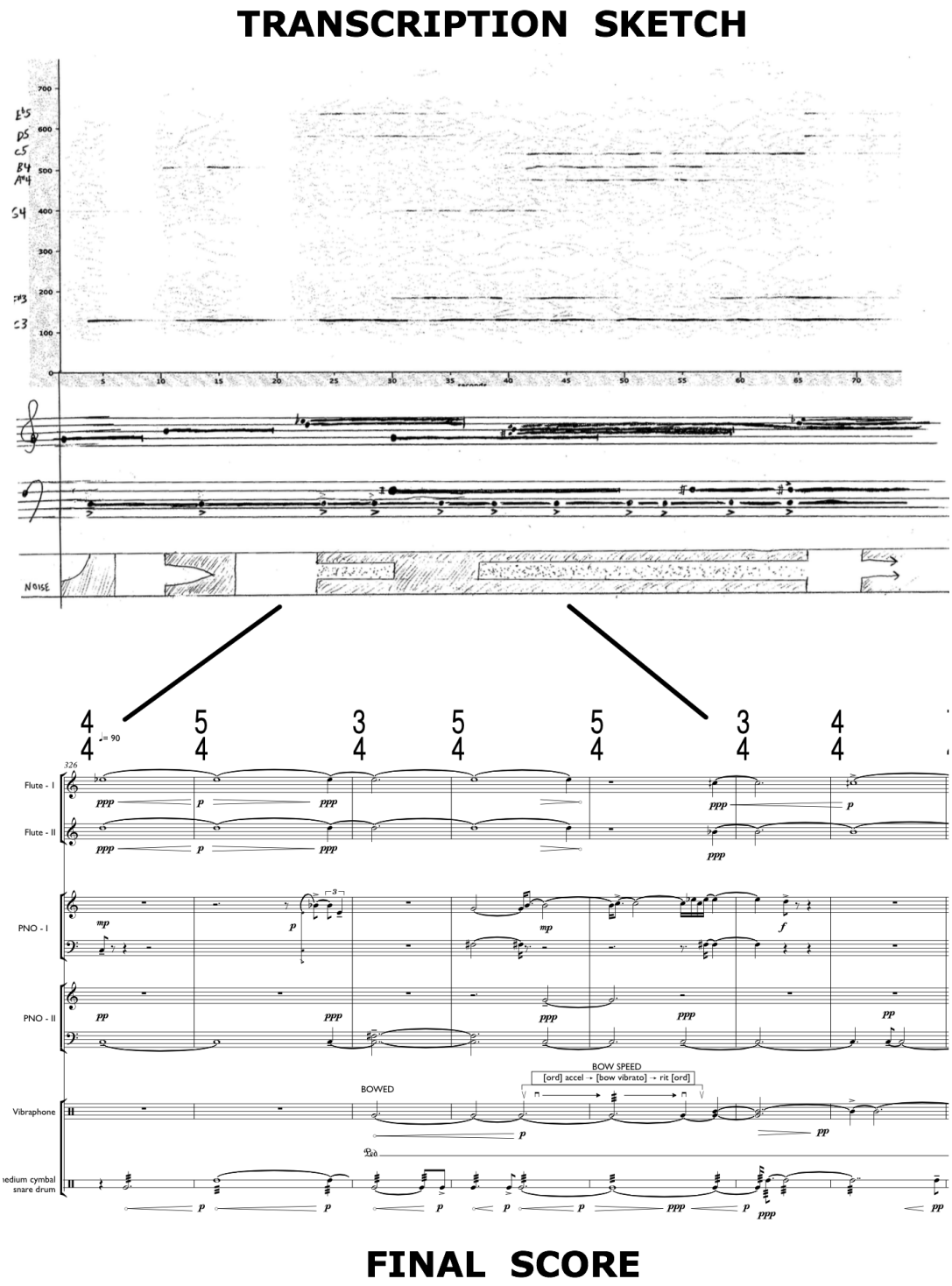

Figure 36 - Miller: for chelsea smith (Sketch and Score, mm. 326-32)

Although surface elaborations are present in the first piano, the highlighted section remains essentially recognizable. Slightly less obvious than the pitched correspondences, it is worth noting the accents and rolls of the second percussionist as reflections of the pulses and swells of the electronically generated pink noise (indicated in the lowest two systems of the transcription).

The piano improvisation based on the resonant sound type was also transcribed and employed as a reservoir of musical material for use in the composition (Figure 37). As noted earlier, the primary importance of these transcriptions was their inherent and spontaneous characteristics of tempo and meter.

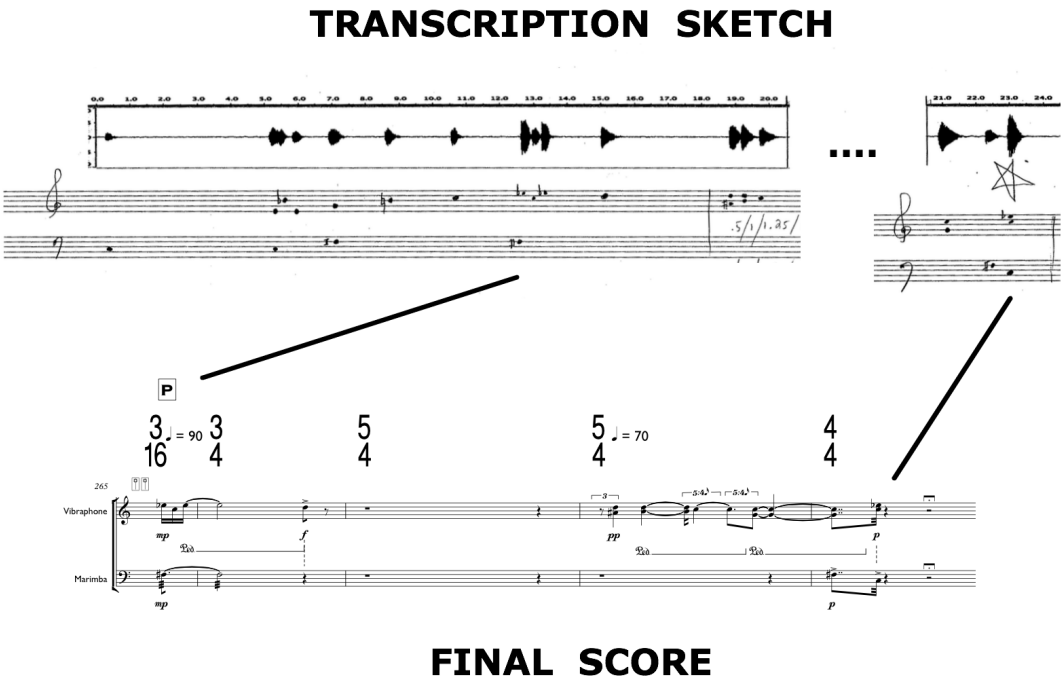

Figure 37 - Miller: for chelsea smith (Sketch and Score, mm. 265-9)

Note in particular the 3/16 measure and the use of 70 and 90 bpm tempi, both of which contribute to a feeling of inherent temporality for this material.

As described above, the three resolutions of frequency content associated with the resonant sound group were selectively employed depending on both the instrumental and musical contexts of a given passage. The coda (Figure 38) highlights a particularly striking instance of this phenomenon.

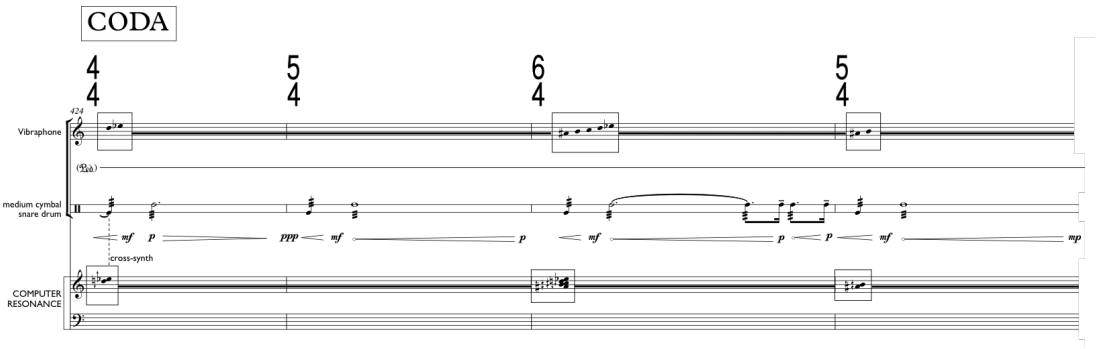

Figure 38 - Miller: for chelsea smith (Multiple Frequency Resolutions, mm. 424-7)

The precise cent tuning of the live electronics highlights the difference between maximum frequency resolution (the exact frequencies of the source material) with the semi-tone resolution of the commercial vibraphone.

Though the above discussion was rooted in materials of the resonant sound type, the same basic principles apply to materials associated with the other sound types as well. Transcriptions of both electronic and piano improvisations generated a significant portion of the work's material. Brief examples from the percussive and lyrical sound types will now illustrate this point.

2.5.2 Musical Material II – Percusssive Type

The field recording associated with the percussive sound group contained the sound of a tire being removed from a car through the use of a pneumatic impact socket wrench (or impact gun). Impact guns employ a two-stage process of storing and releasing the twisting force associated with normal drill action. By only releasing this stored up energy twice per rotation, each impact acting on (in this case) a wheel nut is much stronger than the average force of a continuously spinning drill.

When wheel nuts are sufficiently tight, this sound will have three characteristic components: 1) high clicks generated by the forward action of the socket hitting a fixed nut, 2) low clicks from the drill mechanism bouncing back again, and 3) the mid-range buzz of a freely spinning gun on a loosened nut. A spectrogram (Figure 39) reveals these three aspects, and the extremely short timeframe in which they occur.

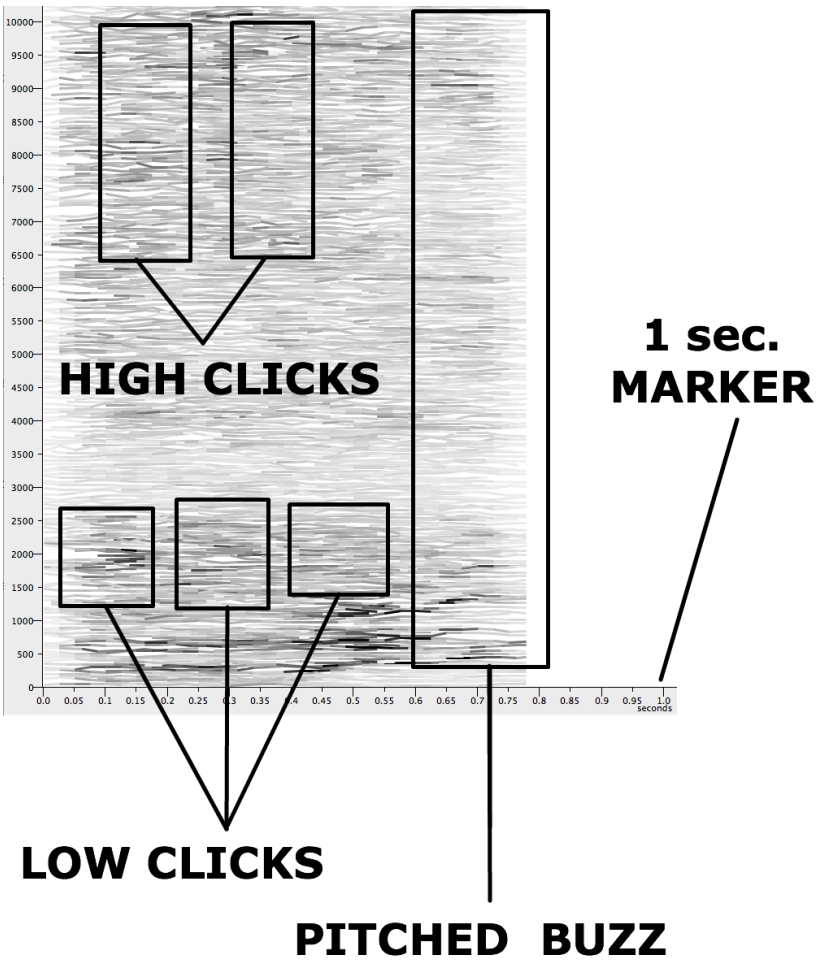

Figure 39 - Spectrogram of Impact Gun

Note in particular the short timescale of well under a second, wherein five clicks and a pitched buzz have occurred. These sounds are so fast and noisy that (with the exception of the semi-pitched buzz), few spectral characteristics are possible to perceive within so few DFT frames.

I employed a phase vocoder to explore the "dynamite of the split second"[143] to be described by Walter Benjamin in Chapter 6. As Benjamin points out, plastic (in the case of my compositional research, digital) recording media can be used to generate previously unknown materials through an examination of the seemingly commonplace at a new scale. To achieve this end, I assigned a slider to scrub through these field

[143] Walter Benjamin, "The Work of Art in the Age of Its Technological Reproducibility: Second Version," in *The Work of Art in the Age of Its Technological Reproducibility, and other writings on media*, edited by Michael William, 19-57 (Cambridge: Belknap Press, 2008): 37.

recordings at variable speeds, revealing and generating complex rhythmic textures in the process. The transcription of these electronic improvisations assisted me in the creation of the most rhythmically complex musical material in the work. One such transcription is compared to its actual appearance in the work below (Figure 40), where percussion instruments are used to simulate the low, high, and medium noise bursts.

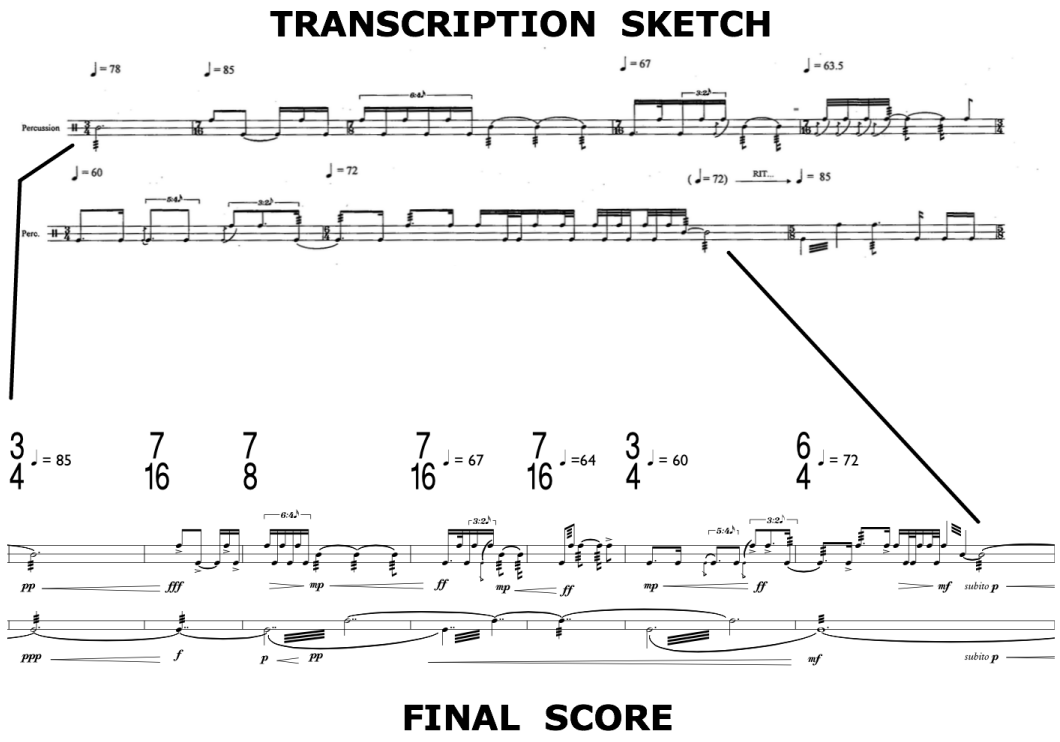

Figure 40 - Miller: for chelsea smith (Sketch and Score, mm. 40-6)

Slight simplifications of tempi can be found in the final score, where a second percussionist has also been added. Note for instance the differences between the "written out decelerandi" at: 67, 63.5, 60; and 67, 64, 60; quarter note beats per minute, respectively.

As suggested by its associated pitch collection, the piano improvisation based on the spectral analysis of this group is characterized by enormous leaps between peaks. The tiny (but challenging) piano cadenza at measure 204 (Figure 41) is the most dramatic and compressed illustration of this tendency.

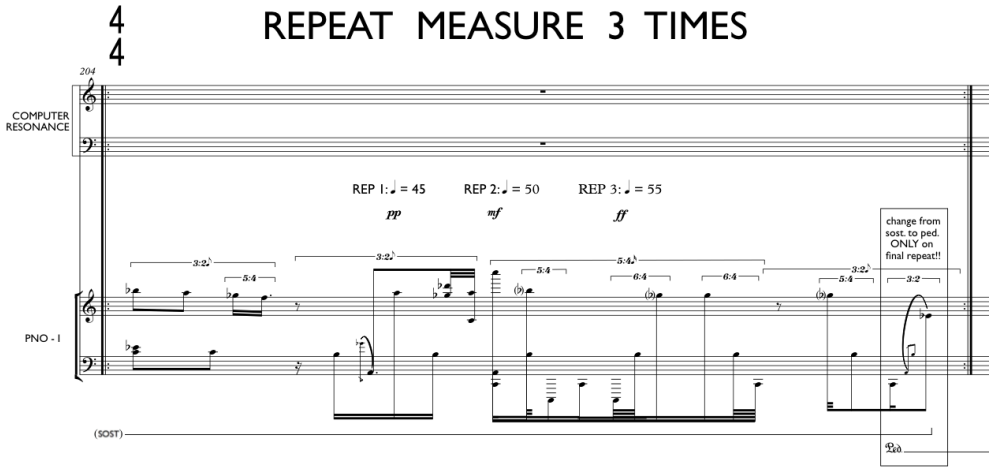

Figure 41 - Miller: for chelsea smith (m. 204)

While this excerpt involves multiple layers of material, the content of each layer is derived from the faithful transcription of pre-recorded piano improvisations as described above.

As was also the case in the resonant sound group, three frequency resolutions (hertz/cent, quarter-tone, and semi-tone) of the pre-compositional pitch plan are employed throughout the work, dependant on instrumental and compositional context.

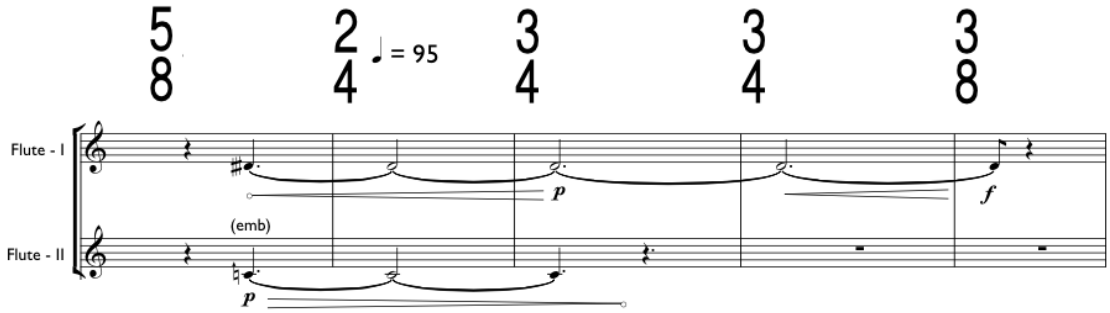

Figure 42 - Miller: for chelsea smith (mm. 345-9)

The level of frequency resolution at mm. 345-9 in the flutes for instance (Figure 42), corresponds to the middle gradation of pitch for this sound type; that which is characterized by the use of quarter tones and slight inflections to approximate the actual frequency values.

In the final category of musical material, such concerns of frequency vs. pitch are one of the most pressing compositional issues.

2.5.3 Musical Material III – Lyrical Type

The lyrical sound type in *for chelsea smith* was derived from field recordings of my pet dog Lupe yawning. These canine vocalizations are inherently lyrical, generally taking the form of a downward glissando over roughly half an octave. As in the case of the percussive sound group, I "performed" these short audio fragments (in Max/MSP) using a phase vocoder to stretch their fleeting glissandi into long continuous planes of moving pitch. In this way, a pre-recorded sample of only a few seconds in duration could be transformed into an unpredictable and non-linear (I would generally scrub both forwards and backwards, while constantly changing my speed) glissando lasting many minutes. Furthermore I doubled, tripled, and quadrupled the playback setup in Max/MSP so as to create a more dense network of moving voices. Finally, this dense electronic improvisation was also subjected to the frequent and randomized transposition of its constituent voices. The starting pitches of the time-stretched and pitch-shifted glissandi were chosen randomly among the twenty-seven total frequencies described thus far.

Because of their perpetual motion, the resulting transcriptions involved an infinitely more dynamic treatment of pitch than the fixed bands of the resonant sound group; and the low, mid, and high noise bursts of the percussive group. When executed acoustically (usually by the flutes), major accommodations needed to be made for instrumental limitations. For instance, continuous glissandi on the flute may only cross certain narrow distances (generally *well* under a minor third in size), and more importantly, all pitch materials assigned to the flutes are within the range of the instruments. Electronic presentations were of course able to transcend such limitations.

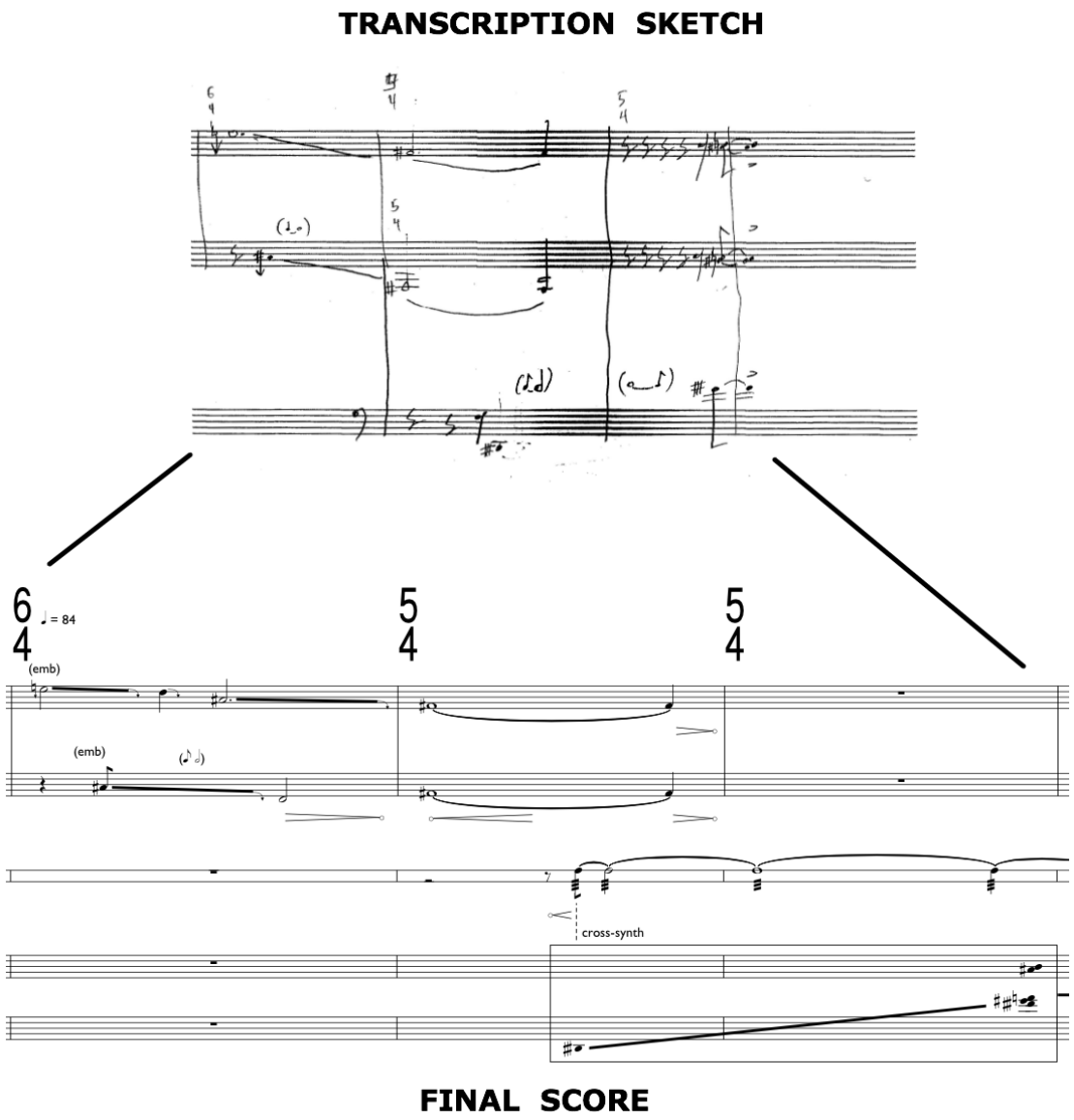

Figure 43 - Miller: for chelsea smith (Sketch and Score, mm. 372-4)

Measures 372-4 of Figure 43 reveal a substantial reduction in detail in the transcription that generated the two flute parts (shown on the top two staves of the final score). These approximations of the top two voices of the transcription sketch in terms of frequency, register, and gestural continuity, stand in sharp contrast to the fidelity of the cross-synthesized percussionist's material (shown on the bottom three staves of the final score). Again it is the overall *character* of each sound type that is of primary importance.

As described above, a piano improvisation using the nine semi-tone-rounded frequencies of the (in this case, lyrical) sound group's spectral analysis was recorded and transcribed as a pre-compositional source of musical material. Transcriptions of this improvisation were included in the work (Figure 44), again, primarily as a resource for "expressive" rhythmic material.

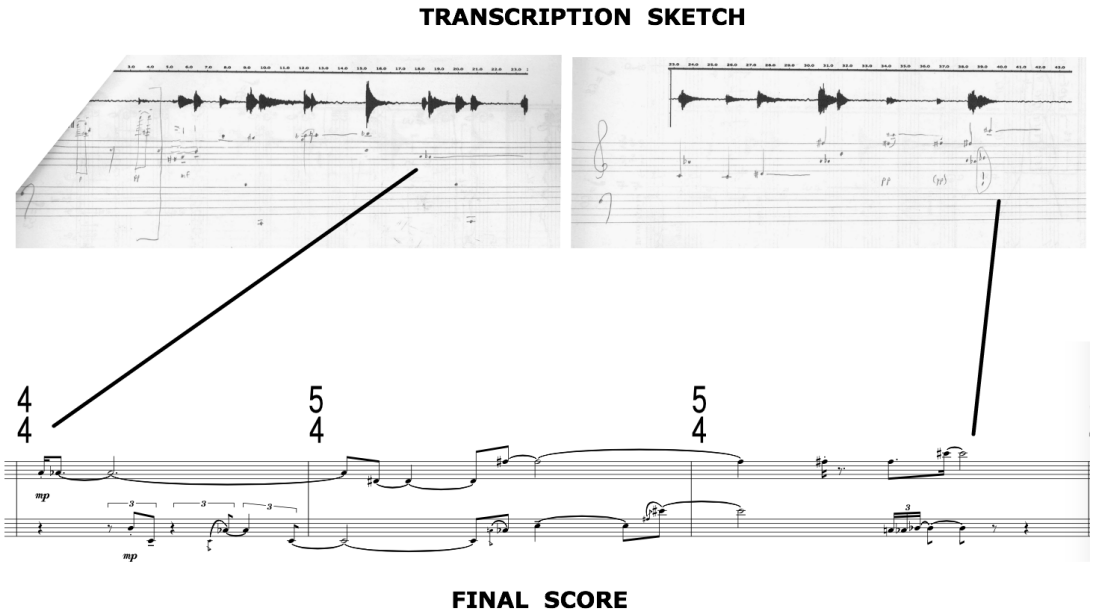

Figure 44 - Miller: for chelsea smith (Sketch and Score, mm. 411-3

Note that the instrumentation of this excerpt from mm. 411-3 is the pair of flutes. This assignment of materials from the "lyrical piano improvisation" to the two flutes completes a pattern begun with the two previous piano transcriptions. Each hyper-instrument has now been assigned a "hyper-solo" based on one of the three transcribed piano improvisations. These assignments are summarized in Table 6.

TYPE OF PIANO IMPROVISATION TRANSCRIPTION	INSTRUMENTATION
RESONANT Piano Improvisation Transcription	Percussion (+ Celesta)
RHYTHMIC Piano Improvisation Transcription	Pianos
LYRICAL Piano Improvisation Transcription	Flutes

Table 6: Mapping of Piano Improvisation Transcriptions onto Hyper-Instruments

The following discussion of form in *for chelsea smith* will draw heavily on this relationship between specific musical materials (in this case: written transcriptions of pre-recorded piano improvisations) and their generative effects on form (in this case through the "hyper-solos").

2.6 Musical Form in *for chelsea smith*

The importance of analyzing and classifying sounds according to type, family, or group will be emphasized in Chapter 6 as a reaction to the vast resources of the seemingly infinite sound world of today. As will be illustrated in this chapter, such activity often led to new concepts of form or musical logic.

In the case of *for chelsea smith*, almost the opposite relationship between material and form can be shown to exist. I say almost, because I *do* feel that form and material are interrelated to a previously unprecedented degree: both in the works mentioned in Chapter 6 and in my own work. However, whereas figures such as Schaeffer, Wishart, Murail, and Stockhausen (among others), proposed the generation of forms through the characteristics of material; my own desire to explore a form built on a foundation of sonic morphing actually ***necessitated*** certain types of material. A structure built using two identical or highly similar sound types for instance, would not satisfy my desire for a form that first and foremost emphasizes transformation.

Again, the use of the word "type" is important, as I was less drawn to specific sound sources, and more to sounds that were exemplary of certain distinct (resonant, percussive, lyrical) qualities. While I can demonstrate personal connections to all of the seminal sonic materials employed throughout the processes described above, they could just as easily have been replaced by any other sounds that satisfied the conditions of their type (again, resonant, percussive, and lyrical).

The interrelationship of form, material, and analysis is of primary importance in *for chelsea smith*. However unlike the works to be considered in Chapter 6, the trajectory of my creative process in *for chelsea smith* began with a consideration of form, which necessitated sonic analysis, and finally led to the treatment of specific musical materials. Musical material is still very important in *for chelsea smith* – the crux of the formal idea

is the interplay of materials. Again, it is the specific ***type*** of these materials that defines both their interplay, and the form which has called them forward.

2.6.1 Musical Form I – Pre-Compositional Plan

Developing and refining the above-mentioned form (based on the morphing of three distinct types of material), took place in three stages during the composition of *for chelsea smith*: during pre-compositional planning, during early stages of composition, and at the mid-point of composing the work.

The first stage of this three-fold evolution: pre-composition, was predictably the most general. Knowing that my main priority would lie in forming transitions between different types of musical material, I conceived of a musical form in which the central type of musical material would act as a sort of "gravitational centre" within the piece, with "departures" and "returns" giving the listener an experience of being "pulled away" from a place of orientation. As such, this central material type would receive disproportionate representation in the score. Because it was the most stable material type (lacking the rhythmic and melodic agitation of its counterparts), the resonant sound group was selected as the central axis around which the compositional morphing of the form would unfold. Figure 45 shows the visual abstraction of form that I referred to during the first period of composition. Note that the solid lines connecting each row constituted only a *hypothetical* unfolding of the piece.

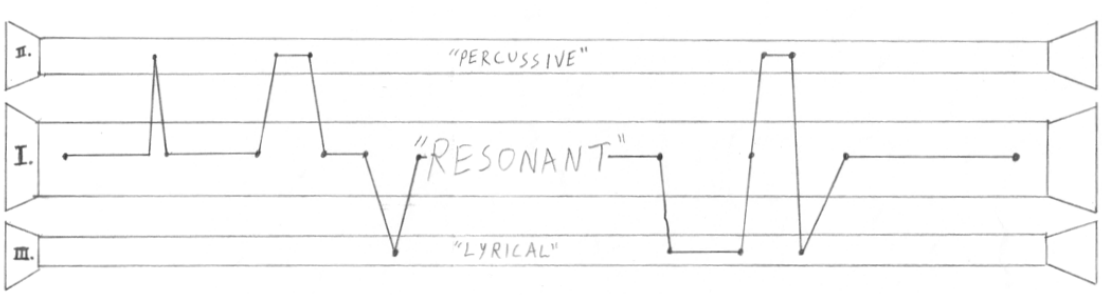

Figure 45 - Miller: for chelsea smith (First Sketch of Form)

The impetus to highlight a single material type as a perceptual core for the composition was influenced by my reading of Matthew Frederick's 2007 mini-textbook

of architectural design principles: *101 Things I Learned in Architecture School*[144]. Item 19 in Frederick's book is a suggestion to "Draw hierarchically."

> "When drawing in any medium, never work at a "100% level of detail" from one end of the sheet toward the other, blank end of the sheet. Instead, start with the most general elements of the composition and work gradually toward the more specific aspects of it. Begin by laying out the entire sheet. Use light guide lines, geometric alignments, visual gut-checks, and other methods to cross-check the proportions, relationships, and placement of the elements you are drawing. When you achieve some success at this schematic level, move to the next level of detail. If you find yourself focusing on details in a specific area of the drawing, indulge briefly, then move to other areas of the drawing. Evaluate your success continually, making local adjustments in the context of the entire sheet."[145]

While intense detail-based work had already occurred during the careful transcription of source materials, Frederick's notion of hierarchical composition enabled me to more effectively cope with the daunting collection of pages I had generated.

Concerns related to the effective proportioning of global form – perhaps according to some hierarchy influenced by Frederick – were at the forefront of my mind, due to my previously limited experience with large-scale forms. Given the inescapable time-based context of musical experience, concerns related to pacing took on an added dimension of importance. All the same, Frederick's suggestion to "evaluate continually" in a purely visual context, proved quite useful in the design of musical form.

2.6.2 Musical Form II – Early Compositional Revisions of Form

A first important revision to the formal design of *for chelsea smith* occurred during an early stage of compositional activity. While the formal figure included in the previous section depicted hypothetical tangents emerging from, returning to, and circling around a central vector; no specific order or frequency of travel was chosen. Furthermore, the decision to include "solos" for each hyper-instrument (both flutes, both pianos, and both percussionists with the celesta), based on the written transcriptions of pre-recorded piano improvisations had not yet been included. Figure 46 shows how both of these concerns were addressed.

---

[144] Matthew Frederick, *101 Things I Learned in Architecture School* (Cambridge: MIT Press, 2007).

[145] Frederick, *101 Things*, Item 19.

The material groups are labeled with the letters G (resonant), D (lyrical), and I (percussive) in reference to their original source materials. Lowercase letters represent the hyper-instrument solos based on the content of the piano transcriptions associated with that letter's sound type: g (resonant), d (lyrical), and i (percussive).

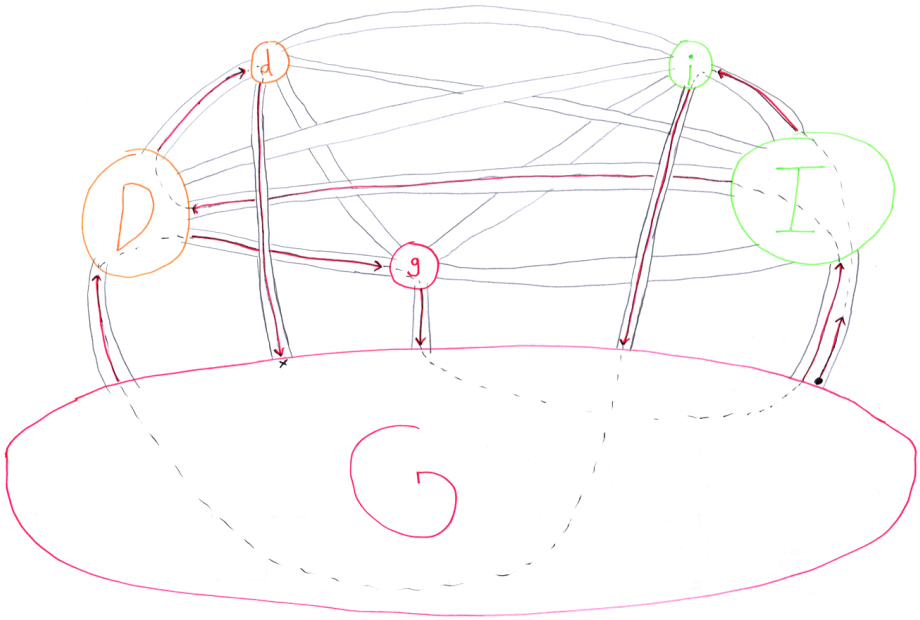

Figure 46 - Miller: for chelsea smith (Second Sketch of Form)

The decreasing sizes from G; to D and I; and finally to d, g, and i; reflect the fact that each material source is visited 4, 2, and 1 time(s), respectively. These proportions reflect the principles of the earlier, more general formal plan, while specifying explicitly how such emphases will be achieved.

The emergence of this design more closely resembling a "travel plan" occurred at the stage of composition corresponding to the "departure from I". At this point I had begun a "cross-synthesis inspired" transition from G to I (Figure 47), as found at rehearsal B of the finished score.

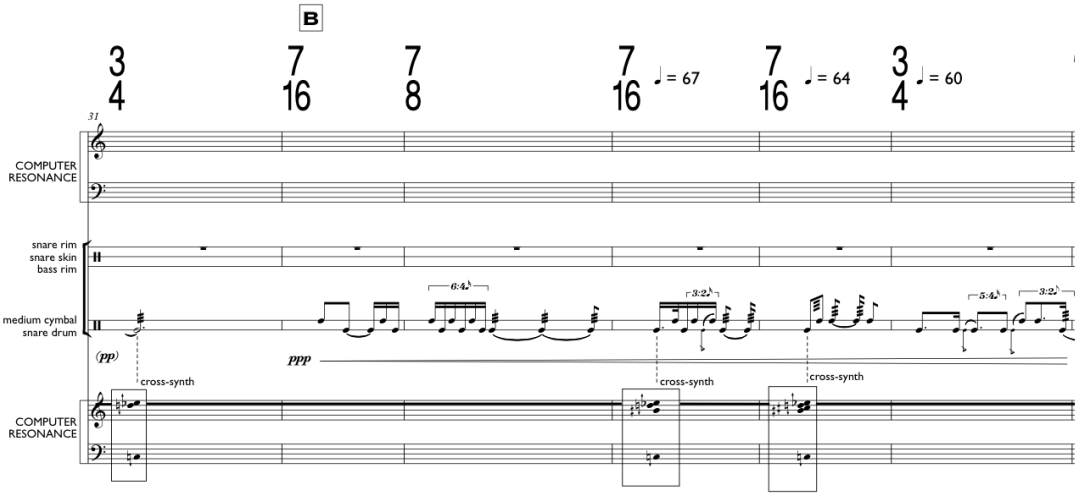

Figure 47 - Miller: for chelsea smith (Rehearsal B)

Here the rapid temporal activity of the rhythmic sound type is executed by the soft mallet percussion instruments associated with the resonant sound type. This "acoustic cross-synthesis" is complimented by the fact that these figures are also being electronically cross-synthesized with the pitch collection of the resonant sound type.

While embarking on the subsequent transition from I to i, it occurred to me that there were only a finite number of connections to be made between the various material types, and that their order should be an important determinant of form in a work emphasizing transformation. This realization led me to formally map out the frequency and order of the planned connections. It is these long thin paths from the previous diagram that are of primary importance: not the letters found at the various circular points of arrival.

The vast majority of these connections are achieved similarly to the G-I transition excerpted above. As noted, the primary inspiration is the audio morphing technique of cross-synthesis. In Chapter 2 it will be shown that cross-synthesis involves the manipulation of the impulse, magnitude, or source from one sound via the resonance, phase, or filter model of a second sound. While more detail will follow, it is sufficient for now to note that these processes yield very different results depending on which sound is providing which component of the signal. As such, I redrew Figure 46 to

indicate which sound would be supplying which component during each potential compositional cross-synthesis (Figure 48).

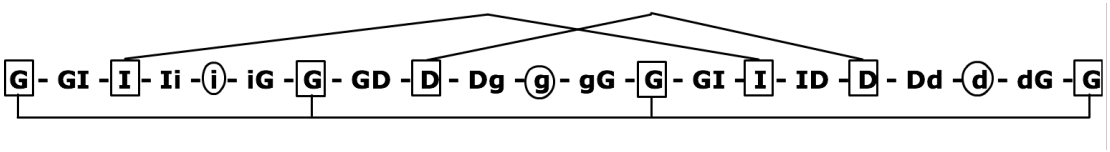

Figure 48 - Miller: for chelsea smith (Ordered Formal Sketch)

The first letter of each pair represents the origin sound and the second represents the destination. These orderings also indicate the impulse and the resonance components of each compositional cross-synthesis, respectively. For instance, the previous excerpt would be expressed as GI, and is found in the second position of the chain above. More details related to compositional cross-synthesis will follow, but first let us consider the final case in which the form of *for chelsea smith* underwent revision.

2.6.3 Musical Form III – Mid-Compositional Revisions

When I reached the exact mid-point of the above diagram (the appearance of the lowercase g), I analyzed the general proportions of the piece up to that point (Figure 49). This effort to "cross-check the proportions" (in the words of Frederick cited above) is represented by the following figure.

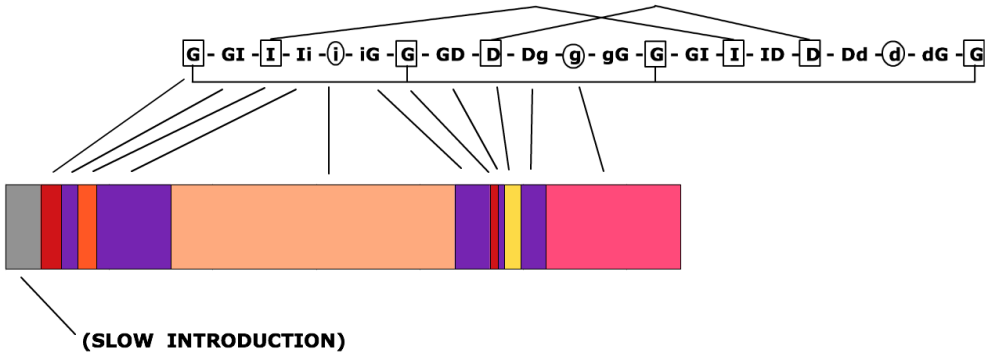

Figure 49 - Miller: for chelsea smith (Mid-Compositional Formal Analysis)

This analysis revealed an important formal characteristic. While I had designed a form in which the frequent recurrences of the resonant group outnumbered the appearances of the

other material types, I had done so in an atemporal manner. As such, there was nothing to stop the singular appearance of i (the piano improvisation based on the percussive sound group) from occupying more space in the above figure than all of the G or G based cross-syntheses combined.

Though this obvious discrepancy was surprising to me at the time, it was not terribly troubling. Despite the detail of my pre-compositional planning, I had purposely left sufficient creative space for a primarily intuitive compositional method. Furthermore, I was generally pleased with the proportions of the material as they stood. I decided therefore to maintain my intuitively composed proportions for the first half of the work. However, I also resolved to address both the temporal aspects of the formal plan for the second half of the work, and also the relative shortage of resonant type materials in the first.

In terms of the latter, rather than inserting measures into the existing form I elected to layer additional resonant materials onto passages that had previously struck me as perhaps overly sparse (see Figure 50). For instance, in mm. 60-3, I added four bars of resonant material in the flutes and percussion.

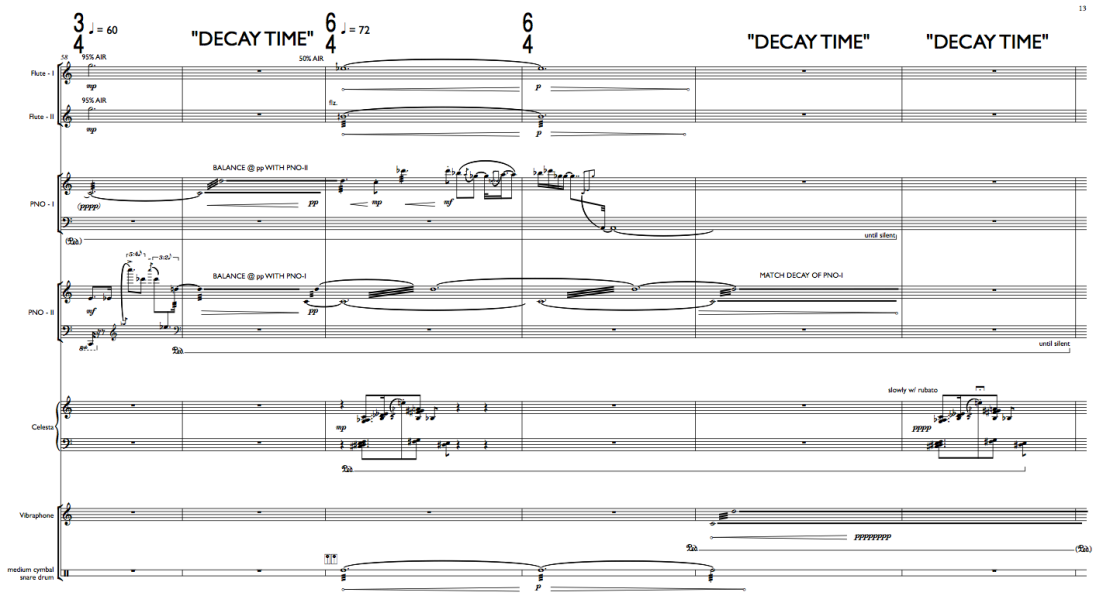

Figure 50 - Miller: for chelsea smith (mm. 58-63)

In terms of additional planning for the second half of the work, I chose to embrace the intuitive results that had struck me as the most successful in the first. Because I had been pleased with the overall proportioning of sections in the first half, I decided to map these ratios onto the proportions of the remaining sections. In reverse order, I duplicated these proportions for the projected lengths of the remaining sections (Figure 51).

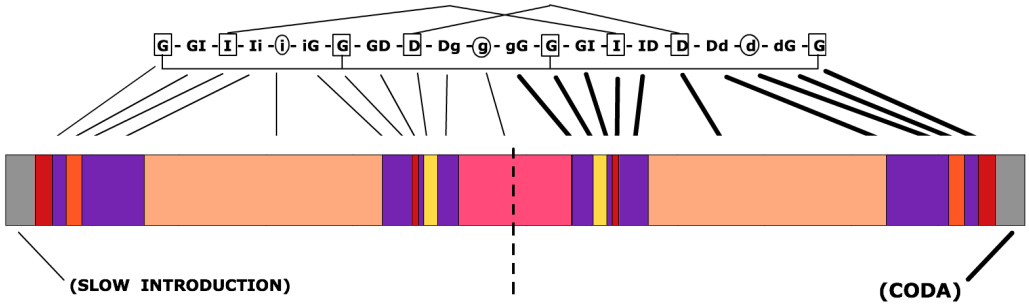

Figure 51 - Miller: for chelsea smith (Mid-Compositional Formal Projection)

Rather than measuring these proportions in a finite numbers of measures or seconds, I calculated them *as proportions*, and assigned percentages to each section.

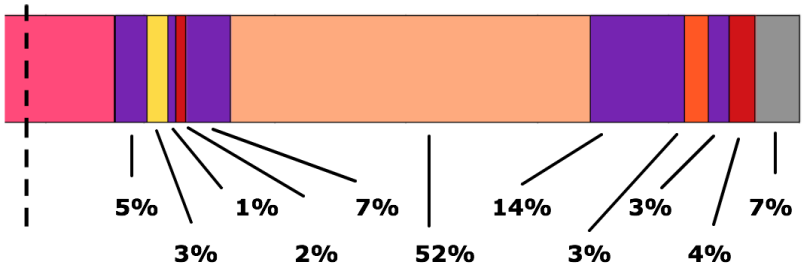

Figure 52 - Miller: for chelsea smith (Proportions as Percentages)

Through the use of percentages in Figure 52, I also scaled down durations for the second part of the form by a factor of just under one half. As such, the second half of the work contains an equal number of sub-sections, in a much shorter period of time[146]. As Figure 53 shows, the ratio between the first and second halves of the formal design is roughly 6.5 to 3.

[146] Because many bars were measured in seconds, given only approximate durations, or assigned wildly fluctuating numbers of beats and tempi, rough estimates in seconds were used in all calculations.

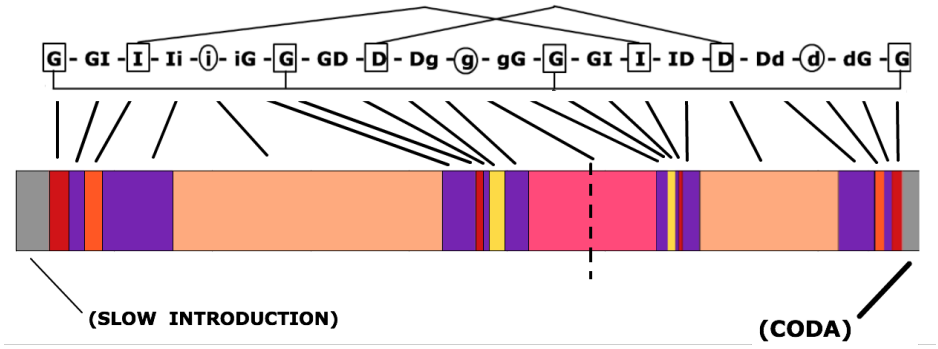

Figure 53 - Miller: for chelsea smith (Ratio of Two Main Formal Divisions)

Given that the second half of the form had just as many sub-sections to accommodate in much less time than the first; the process of layering in additional material of the resonant type was of even greater importance during the final sections. Figure 54 provides an example of this layering at Rehearsal O.

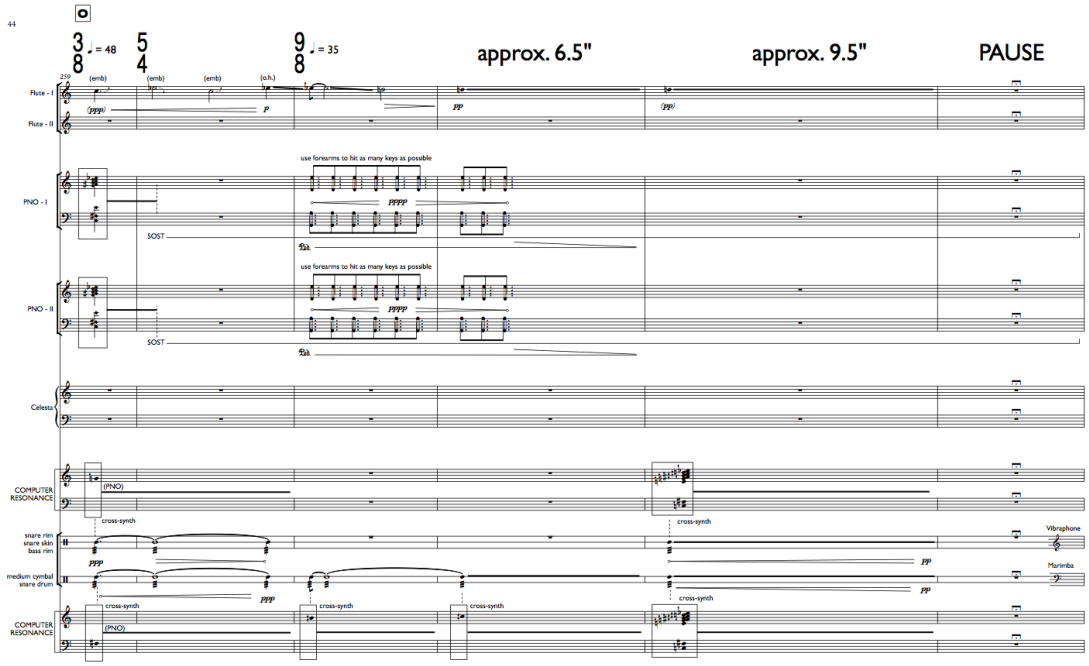

Figure 54 - Miller: for chelsea smith (Rehearsal O)

Here the otherwise lyrical material of the flutes is overlaid with additional content from the resonant sound group. Note the dense pedalled chords of the pianos and the complex computer resonances activated by the percussionists.

Given the ubiquitousness of such layerings throughout the work, the previous diagrams are capable of describing its form only in the most abstract sense. The ***actual*** form inhabited by – and generated through – the interpenetration of materials in *for chelsea smith* is perhaps too densely layered for abstract representations at a global level. At the local level however, much more analytical precision can be achieved.

2.7 Electronic Morphing Techniques in *for chelsea smith*

While global morphology in *for chelsea smith* is difficult to define, it is much easier to identify local transformations and to describe the techniques of sonic morphing employed; be they electroacoustic processes, or compositional methods influenced by such technologies. In terms of the former, three main morphing techniques from the pool of software solutions (to be described in the following chapter) were employed during the performance: 1) impulse response based cross-synthesis, 2) linear predictive coding based cross synthesis, and 3) analysis/re-synthesis based spectral peak interpolation.

2.7.1 Application of Electronic Morphing I – Impulse Response

The most ubiquitous electro-acoustic morphing technique in *for chelsea smith* is impulse response based cross-synthesis. For a complete description of this and other techniques as well as an introduction to acoustic terminology, please consult Chapter 3. In order to bridge the timbral or spectral gap between the two pianos and the two percussionists, a series of impulse responses were prepared containing notes and chords played traditionally on the piano. Both percussionists were equipped with spectrally rich instruments (the cymbal and drums) capable of producing broadband pink noise. A microphone on each percussion setup (see Figure 55) selectively fed these dynamic sources of pink noise through the impulse response buffers filled with the pre-recorded piano material.

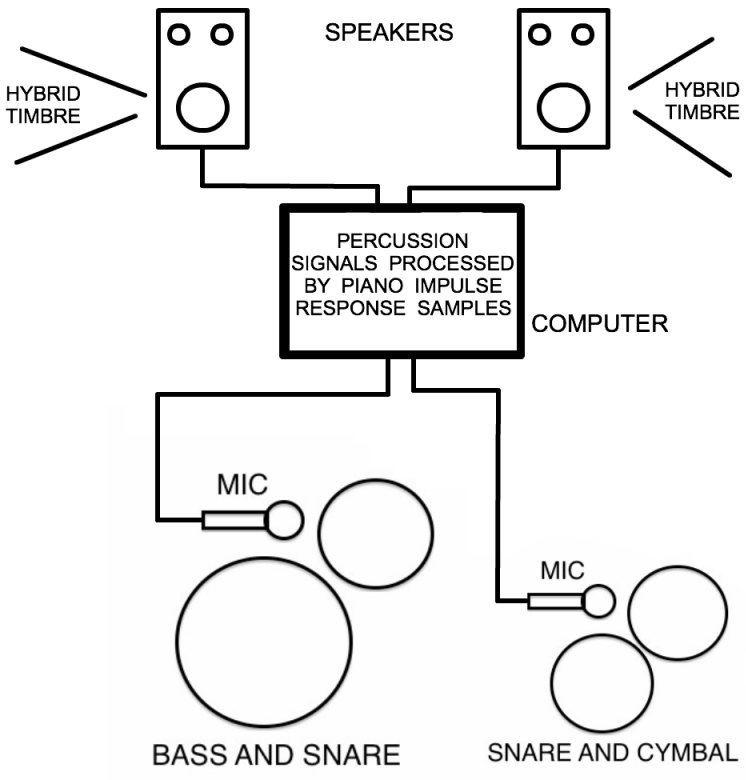

Figure 55 - Miller: for chelsea smith (IR Percussion Processing)

The resulting combination of live percussion playing and electroacoustic manipulation possesses a sort of hybrid timbre, wherein the attacks and sustained noise bands of the percussion instruments are given the pitched characteristics of various pre-recorded piano tones. These pitched resonances are notated in the score above or below the musical material of the percussion instrument being processed (Figure 56), joined by a dashed line labeled “cross-synth”.

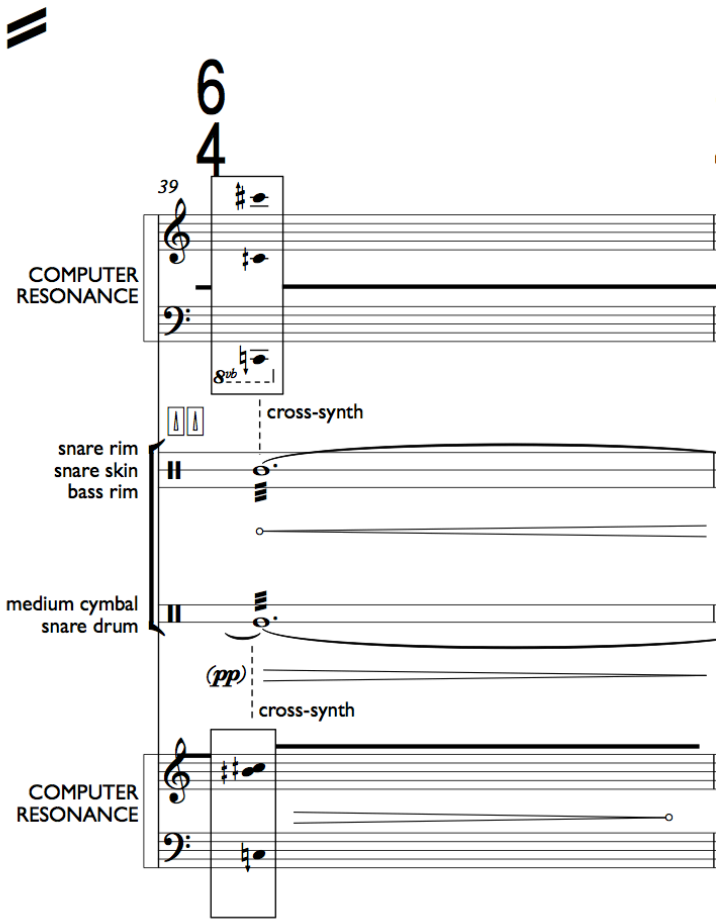

Figure 56 - Miller: for chelsea smith (m. 39)

The many pitch changes, crescendi, and decrescendi of these computer resonances were controlled by a (human) score-follower. This sound technician operated a single slider to tell the computer where in the score the live instrumentalists were. This information selectively gated the inputs to the impulse response cross-synthesis, and replaced the contents of the buffers whenever necessary.

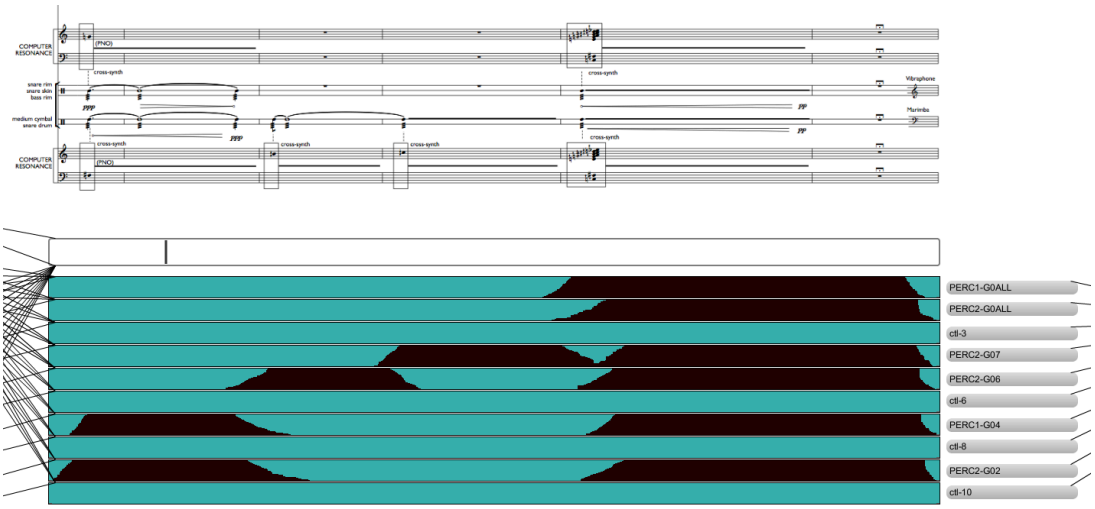

Figure 57 - Miller: for chelsea smith (Automated Gain Scaling)

The ten blue strips at the bottom of Figure 57 indicate the opening and closing of input gates. The gradual black slopes are scaled from 0. to 1. and are fed to input gain controls as needed. These ramps are all simultaneously controlled by the single white slider above them in the screen capture. An image of the actual score is at the top of the Max/MSP patch, by means of which the technician can follow the progress of the musicians with her slider. A second technician monitors the output levels to avoid feedback and maintain a desirable balance in the mix.

While these "hyper-sliders" can also be mapped to other parameters, the above arrangement was utilized for the majority of the work's electro-acoustic component.

2.7.2 Application of Electronic Morphing II – Linear Predictive Coding

Cross-synthesis achieved through Linear Predictive Coding on the other hand, was utilized as a *pre*-performance tool in *for chelsea smith*. While the results of this method were quite promising under highly controlled conditions (source and filter signals with very steady SINGLE pitches, high signal to noise ratios, no sudden dynamic changes, etc...) they were less successful in complex or unpredictable live situations.

In order to make use of such temperamental sounds in live performance, I prepared them ahead of time for later triggering and manipulation. In my experience, the most successful use of LPC based cross-synthesis occurred when a more complex,

pitched, source signal was filtered by a more simple, pitched signal. The order of spectral richness for the ensemble (minus the un-pitched percussion and celesta) was arranged according to the hierarchy outlined in Table 7.

DENSER SPECTRA	Piano – Flute – Vibraphone – Marimba	**SIMPLER SPECTRA**

Table 7: Spectral Richness of Ensemble

Because the piano was the most spectrally rich source of pitch in my ensemble, I chose it as the source signal in my LPC based cross-syntheses. I then prepared cross-fades of all four instruments in sequence to use as the filter signal. The result of the cross-synthesis was a steady tone of continuously changing spectrum that took on the characteristics of each instrument in the ensemble in sequence (Figure 58) – a sort of "all-timbre" pitch.

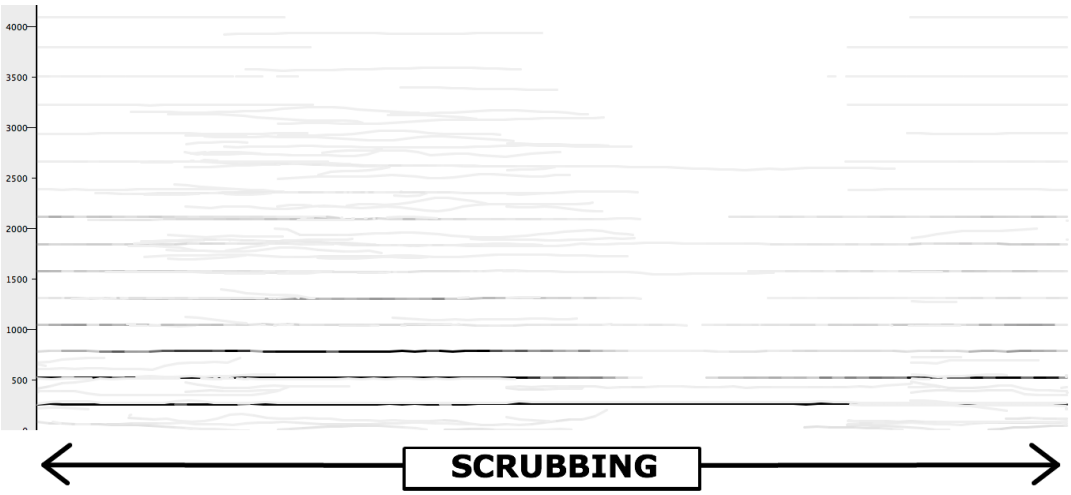

Figure 58 - Morphing Through Timbres of the Ensemble via Phase Vocoder

Because most of my instrumental sounds had such short steady states, I employed the Dudas/Lippe phase vocoder[147] to time stretch and repeatedly scrub through the most steadily pitched segments at irregular tempi. The result was a dynamic spectrum of a

[147] Cort Lippe and Richard Dudas, "The Phase Vocoder Part II," Cycling '74, accessed July 31, 2014, http://cycling74.com/2007/07/02/the-phase-vocoder-part-ii/.

steadily pitched nature, with no obvious loop points. The phase vocoder was also employed in performance, where I used the live percussion signal to gate a dynamically looping copy of the "all-timbre" LPC pitch seen in the above figure.

The following passage (Figure 59) comes from (the quite extended) measure 244. Here the score following slider is used to supply the Dudas/Lippe phase vocoder with pitch shifting data to generate the many precise glissandi of the looping/scrubbed "all-timbre" LPC pitch.

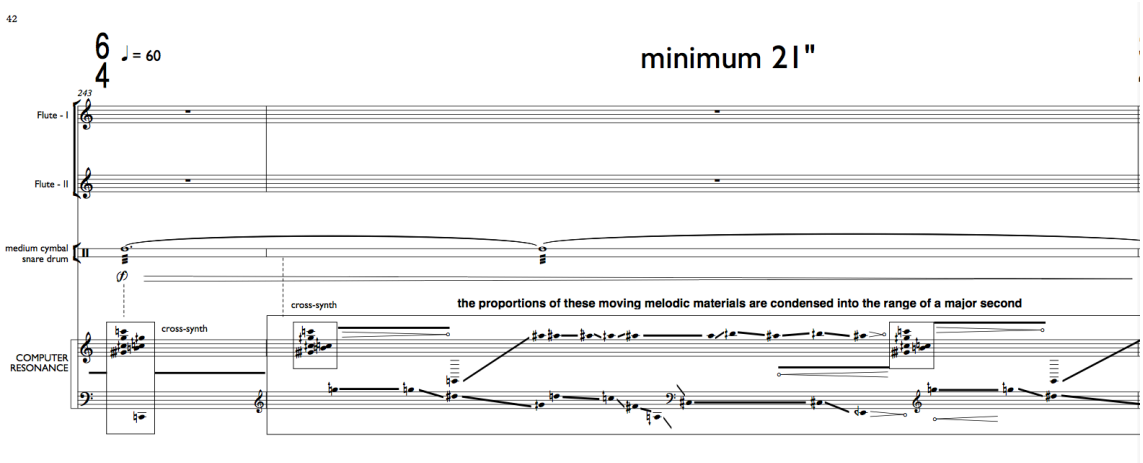

Figure 59 - Miller: for chelsea smith (mm. 243-4)

As with the previous gating of IR-based cross-synthesis, the many parameters of this passage are controlled globally through the movement of a single slider.

2.7.3 Application of Electronic Morphing III – Spectral Peak Interpolation

While the digital audio morphing techniques associated with the percussion setups have been described in terms of cross-synthesis above, a microphone was also placed on the first piano. This signal was used as the material for a very different sort of audio morph. As with the two previous techniques, a full description of spectral peak interpolation can be found in Chapter 3.

During the live performance, this technique employed a pitch tracking object: [sigmund~], designed by Miller Puckette[148]. This object provided a steady data stream of the strongest sixteen spectral peaks from the incoming piano signal.

[148] Miller Puckette, "Max/MSP Externals." Miller Puckette's personal website, accessed July 31, 2014, http://vud.org/max/.

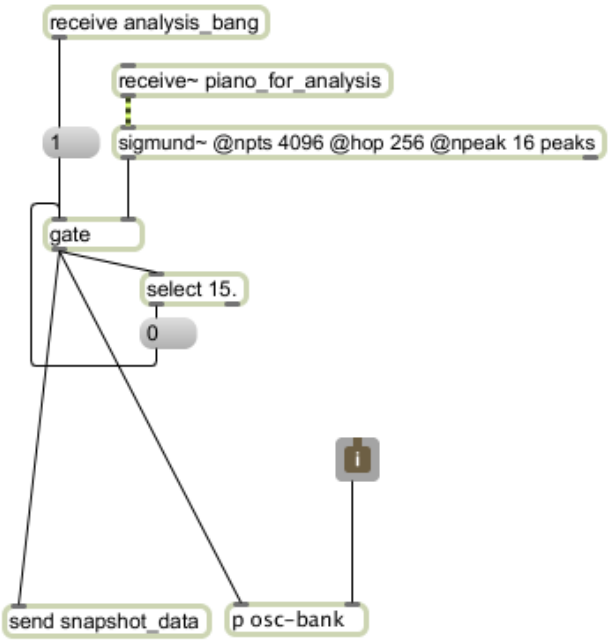

Figure 60 - Spectral Snapshot Module

The box labelled "receive analysis bang" at the top of the sub-patcher shown in Figure 60 was connected to a button housed on the same controller as the score following slider. When the score-following technician pressed this button, she could momentarily open a gate that held back the incoming stream of spectral data. These 16 peaks could then flow through to an oscillator bank, for a re-synthesis of the piano "snapshot", as indicated above.

A straightforward analysis/re-synthesis of this sort is indicated in the score with the label "sinusoidal sustain". However, when the spectral peaks are interpolated to those of a new sound (generally a previously recorded spectral snapshot of either piano or ensemble material), the label used is "sinusoidal morph".

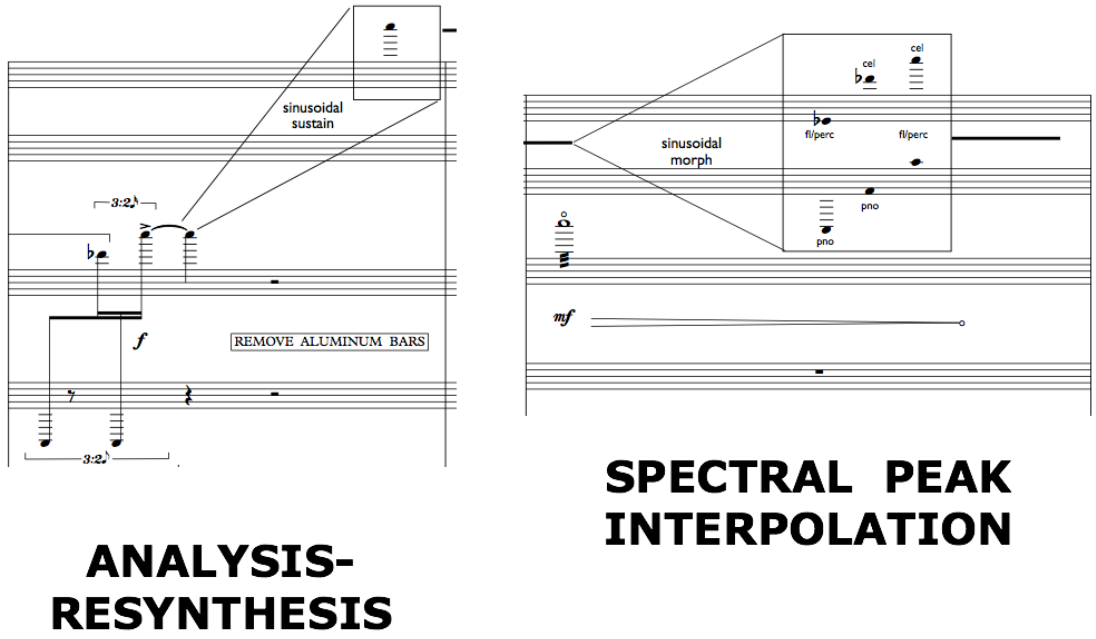

Figure 61 - Miller: for chelsea smith (mm. 123, 126)

Measures 123 and 126 (respectively) of Figure 61 illustrate this notational difference.

Again, the speed of the morph is flexible thanks to the (human) score follower. The score following slider is mapped onto the progress of the sinusoidal morph in passages such as measure 126 above. The morph found at measure 135 shows a 0.-1. transition on the first slider below the score. The loose temporal guideline of "FAST" reflects the rhythmic freedom given to the technician (Figure 62), and highlights the importance of listening by the conductor and other musicians.

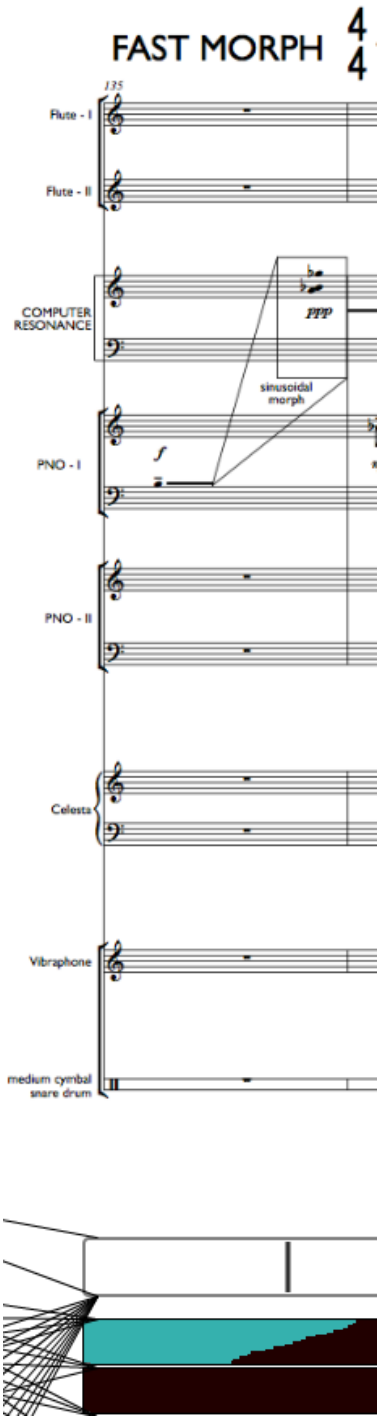

Figure 62 - Miller: for chelsea smith (m. 135)

Note the correspondence between the slider ramp and the shape of the sinusoidal morph lines in the score.

My primary interest in researching digital audio morphing techniques has been their implications for the development of present and future practices of musical composition. Such compositional activity may occasionally (or even exclusively) involve the use of electroacoustic media. However, as will be seen during the Chapter 6 discussion of form in twentieth century music, developments in audio technology can exert a far reaching influence over purely acoustic music composition as well. As such, it is primarily this aspect of audio morphing research that interested me on a creative level.

2.8 Acoustic Analogies to Morphing Techniques in *for chelsea smith*

My program note for the dissertation concert summarized this concern as follows.

> "Though some of the tools for audio morphing that I have researched over the past three years are heard over loudspeakers throughout the piece, I was primarily interested in taking the technical principles behind this software, and applying them to the composition of music for purely acoustic instruments."

The remaining sections of the present chapter will describe the compositional techniques that resulted from this project, primarily as they apply to the non-electronic instruments of the ensemble.

2.8.1 Acoustic Morphing Analogies I – Cross-Synthesis

As alluded to during discussions of form in *for chelsea smith*, acoustic or compositional cross-synthesis is by far the most frequently used transitional device in the work. Furthermore, a work which explores notions of musical transformation will by necessity possess many transitional sections. In fact, because transitions separate each material type, there are essentially as many transitions as appearances of structural material in *for chelsea smith*.

To apply principles of cross-synthesis to purely acoustic music, I generally tried to map the resonant or pitch content of one sound onto the impulse or rhythmic material of another. This technique is analogous to electronic cross-synthesis in which the LPC derived filter of one sound is applied to the source of another, the DFT derived phases of one sound are mapped onto the magnitudes of another, or an impulse response buffer containing one sound is applied to every frame of another (see Chapter 3 for more detail).

Though examples abound throughout the work, a particularly characteristic application of this concept can be found in mm. 253-6, seen below in Figure 63. Here the pitch resources of the resonant sound group are being mapped onto the temporal/impulse content of the lyrical sound group.

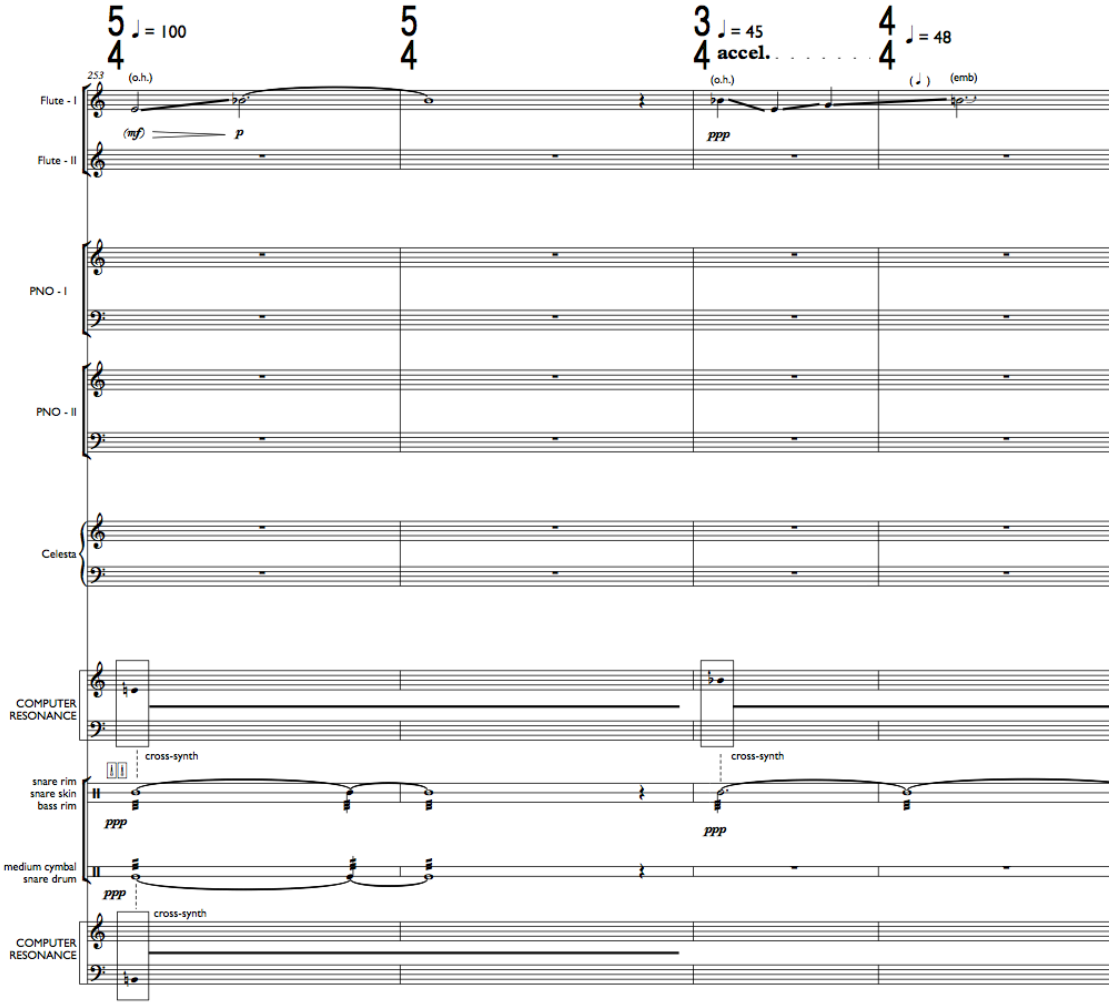

Figure 63 - Miller: for chelsea smith (mm. 253-6)

The origins of this cross-synthesis may be parsed out as follows (Figure 64).

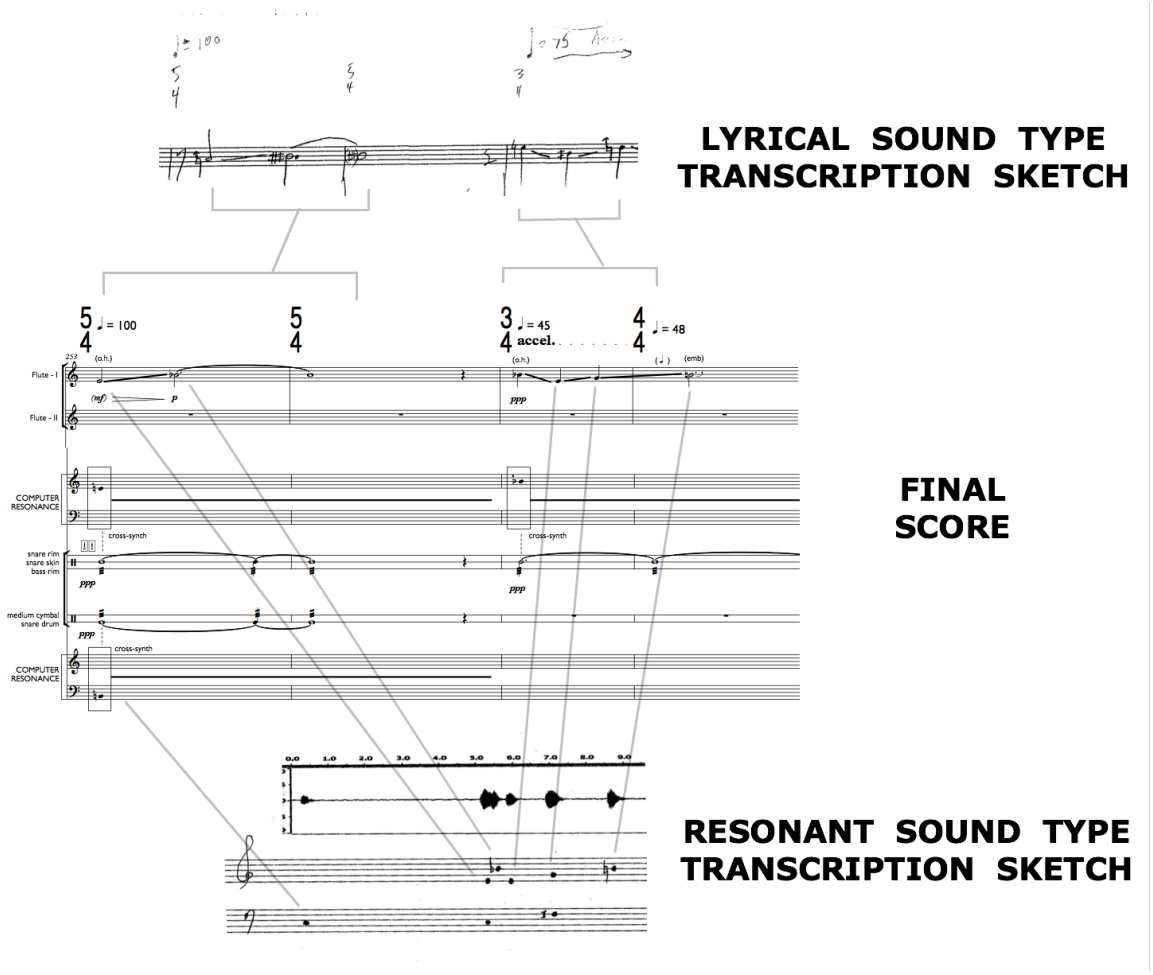

Figure 64 - Miller: for chelsea smith (Sketches and Score, mm. 253-6)

In addition to these loose approximations of electro-acoustic cross-synthesis utilizing conventional instruments, the conceptual foundations of DFT, IR, and LPC processing themselves were also a source of inspiration during the compositional process.

For instance, the separation of source and filter in LPC analysis revealed to me the previously unknown nature of vocal and instrumental sources. These noisy buzzing signals, stripped of their formant characteristics inspired the use of several analogous materials in *for chelsea smith.* For instance, the muting of piano strings with metal bars at mm.113-8 (Figure 65) might be considered a sort of analogy to the LPC residual of a normal piano tone.

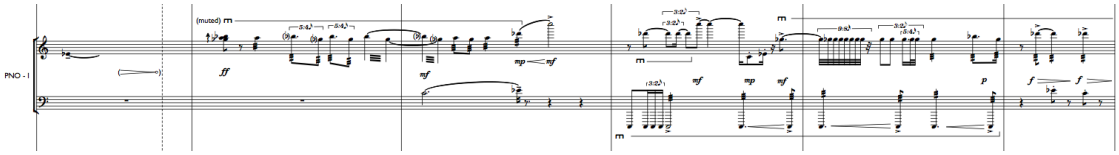

Figure 65 - Miller: for chelsea smith (mm. 113-8)

A similar example might be found in the frequent scraping of the snare drum's rim, quickly with a drumstick (Figure 66) as in mm.51-2.

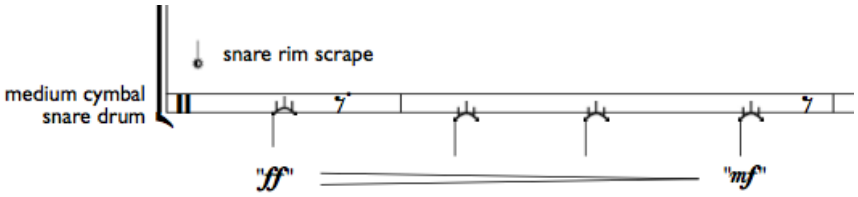

Figure 66 - Miller: for chelsea smith (mm. 51-2)

One might also consider the slow scraping of a low piano string with a plectrum (Figure 67). This gesture produces a low serrated sound on the border of pitch and rhythm, depending on the exact number of clicks per second. The following excerpt from measure 215 shows a particularly slow instance of this technique.

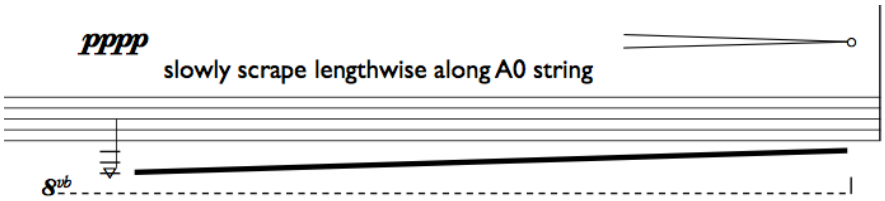

Figure 67 - Miller: for chelsea smith (m. 215)

Thus might notions of both cross-synthesis and source-filter separation be related to purely acoustic materials. However, additive techniques of digital audio morphing might also be regarded as an influence on the purely acoustic materials of *for chelsea smith* as well.

2.8.2 Acoustic Morphing Analogies II – Analysis/Re-Synthesis

The counterpart to cross-synthesis based morphing – at least in the context of *for chelsea smith*'s electronic component – is analysis/re-synthesis based spectral peak interpolation. The first stage of extending these techniques to the acoustic realm has already been discussed in terms of musical material in *for chelsea smith*. As noted earlier, the pool of nine pitches associated with each sound type was derived through a spectral analysis of its associated source recording.

A simple acoustic re-synthesis of this analysis could be said to occur in virtually every measure of the work, given that so many of the piece's materials originated through the transcription of source recordings. The ending of the piece is perhaps the most striking instance of this sort of material (Figure 68). Though I eventually decided to add some subtle live electronics to the Coda (beginning in measure 420 below), the original ending of the work was essentially an acoustic re-synthesis of the resonant sound group's electronic improvisation using only unprocessed percussion instruments.

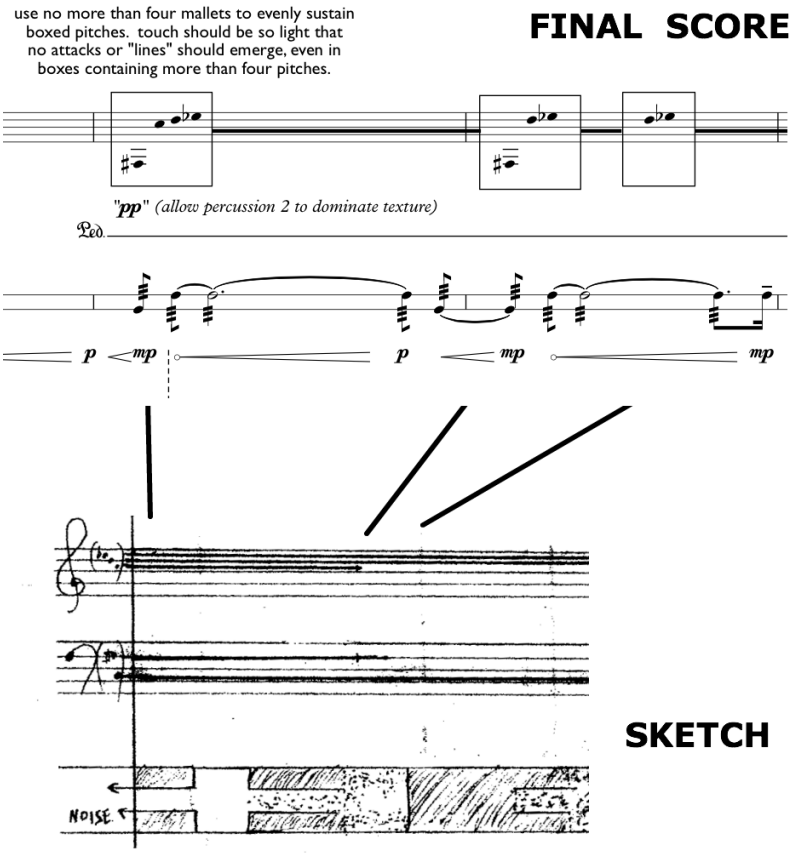

Figure 68 - Miller: for chelsea smith (Sketch and Score, mm. 420-1)

While the computer resonance has been omitted from the above excerpt, it should also be noted that the subtle dynamics, shared pitch content, and careful blending by the percussionists and technicians resulted in a texture dominated by the acoustic vibraphone. The extremely quiet contribution of the second percussionist's digital audio cross-synthesis (with pre-recorded piano resonances) served primarily to colour the timbre of the vibraphone trills with subtle microtonal and timbral inflections.

There was of course no true acoustic equivalent to the sixteen precise and agile voices of the re-synthesis oscillator bank, given that an overwhelming majority of its instruments hailed from the percussion family (drums, cymbals, mallet percussion, celesta, and piano). In creating the musical material for the flutes, I did occasionally attempt to emulate the textural sonorities of the oscillator glissandi characteristic of spectral peak interpolation. The spectral "purity" (relatively few harmonics) of a steady-state flute tone contributes a great deal to this effect. The passage beginning at rehearsal V (Figure 69) is one of the many examples of this texture being created by the flutes.

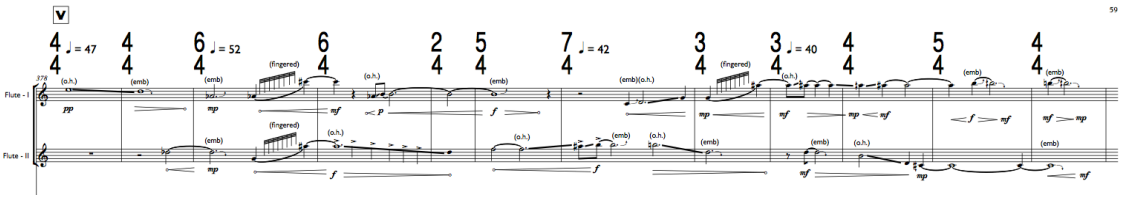

Figure 69 - Miller: for chelsea smith (Rehearsal V)

It is obvious from the above excerpt that the flutes are subject to many more physical limitations than the voices of an oscillator bank. The need to breathe, the limited range, and the imprecise (relative to a computer!) control of pitch are all examples of these limitations. However, it is perhaps the translation of these (and the previous) effects into a medium that is so inescapably human that holds the most interest for me as a composer and musician. As will be found in the purely technical discussions of Chapter 3, the success or failure of a given digital audio morphing technique is often dependent on its ability to transcend a certain "sterility" inherent in the medium. For instance, re-synthesis techniques relying on the precision of sine wave oscillators are found to be most satisfying only when said precision is intentionally disrupted by the introduction of subtle jitter in both frequency and amplitude. Such minute imperfections approximate

the conditions of real-world musical performance, rendering the results more convincing to human ears. Similarly the new, interpenetrating arrangements of material revealed through digital audio morphing technology can be rendered more *musically* convincing when their realization is entrusted to acoustic instruments and their highly skilled performers.

2.9 Conclusions

While *for chelsea smith* is intended to stand on its own as an autonomous musical work, it was also a by-product of the research described in the following chapters. Though a great deal of technical research underpinned both endeavours, my priorities have remained firmly oriented towards the creative activity of composing. The following investigations into the technical and historical backgrounds of various phenomena related to audio morphing should therefore be interpreted according to their influence on my activities of musical creation.

3 Morphing Software

3.1 Introduction

As the previous two chapters have mentioned, research into digital audio morphing technology has had a direct and tangible influence on the composition of *for chelsea smith*. Accordingly, they will now receive chapter-length treatment before several purely historical matters will be taken up in Chapters 4, 5, and 6. These final three chapters will deal with how my personal reading of sonic morphing might be applied to the acoustic repertoire of various European and North American composers.

In very much the same way, the present chapter will also present an idiosyncratic understanding of digital audio morphing technologies such as they relate to my own compositional practice (as outlined in the previous chapter). So as to orient the following discussion towards the general (musical) reader, certain fundamental terms and concepts will first be defined. Following these brief introductions to acoustics and digital audio manipulation, the various techniques of audio morphing will be discussed at length.

The technical and semantic difficulties described in Chapter 1 highlighted the fact that no single audio morphing strategy is definitive. Rather, there exists a field of possibilities, resulting from the impossibility of direct cross-modal translation between visual and aural morphs[149]. Various types of sounds are more or less successfully morphed utilizing a variety of different techniques. The current landscape of these techniques will be described in the following pages, highlighting the various strengths and weaknesses of each approach.

Finally, a selected overview of the literature on audio morphing technology will be presented in chronological order (of publication for several key writings). As such, the overall structure of the following chapter can be divided into three sections, with each new topic building upon the terminological foundation of its predecessors. These contents are summarized in Table 8.

[149] See the discussion of: Cook, "Audio Morph?" from Chapter 1.

I	II	III
An Introduction to Acoustics and Audio Manipulation	**The Techniques of Audio Morphing Software**	**The Literature of Audio Morphing Software**
Splitting the Sound, Sound Waves, Harmonics and Partials, Fourier Transforms, Additive vs. Subtractive Conceptual Frameworks	Analysis/Re-Synthesis (Peak Interpolation and Interleaving), Cross-Synthesis (DFT-Based, IR-Based, LPC-Based)	Early Acoustic Research, Compositional Context, Taxonomy, Algorithmic Refinement, Perceptually Motivated Features

Table 8: Overview of Chapter 3

3.2 Splitting the Sound

In his highly influential 1971 lecture *The Four Criteria of Electronic Music*, Karlheinz Stockhausen stressed the importance of considering sounds – not as indivisible and homogeneous units – but rather as a composite of many contributing parts.

> "If we understand that sounds can be composed, literally put together... if we can compose these sounds, in the sense of the Latin *componere* meaning put together, then naturally we can also think in terms—note the quotation marks—of the 'decomposition' of a sound. That means we split the sound... you hear this sound gradually revealing itself to be made up of a number of components."[150]

While the analog tools available to Stockhausen were much more rudimentary than their eventual digital descendants, they were still capable of yielding important acoustic data[151]. This information altered the compositional trajectory of several key works, most notably 1958-60's *Kontakte* (to which Stockhausen refers extensively throughout the lecture).

While the fruits of these early investigations then are quite clear, a radical advance occurred with the development of digital audio technology. In the introduction to his classic 1990 textbook: *Elements of Computer Music*[152], American author, musician, and computer scientist F. Richard Moore draws a sharp distinction between the pre- and post- computer eras of studying sound and music. Breaking down the etymological

[150] Stockhausen, "Four Criteria", 97.

[151] As described in Chapter 4.

[152] F. Richard Moore, *The Elements of Computer Music* (Upper Saddle River: Prentice Hall, 1990).

differences between astrology and astronomy, Moore suggests that the advent of digital audio will enable an important paradigm shift in the study of music.

> "Without mathematics, for example, the study of the stars is called *astrology,* derived from the Greek roots *astro,* meaning "star", and *logos*, meaning "word or speech." *Astrology* therefore signifies "what can be said about stars." The scientific study of stars, however, is called *astronomy*, from *astro* plus *nomy*, from the Greek *némein*, meaning "distribute." *Astronomy* therefore signifies the system of laws governing or sum total of knowledge regarding the stars... the *-logy* and *-nomy* suffixes distinguish neatly between the part of knowledge that can be expressed in words and the sum total of knowledge about a field."[153]
>
> "We still live in an age where the primary theory of music comes under the heading of "musicology." With computers we are gradually entering the age of "musiconomy."[154]

According to Moore then, the mathematical understanding of sound made possible by computation constitutes a fundamental change in how music can be studied[155].

The music and software associated with audio morphing reside at the intersection of Moore's scholarly pursuits, and those of a more compositional nature described by Stockhausen. Both the acts of developing and creatively employing such software rely on a splitting of the sound (as espoused by Stockhausen), made increasingly transparent under Moore's emerging paradigm of computer-assisted musiconomy. The specialized language required for such pursuits will be summarized in the following brief introduction to the terminology of acoustics and digital sound manipulation.

3.2.1 Sound Waves

Sound is both a physical and perceptual phenomenon of great complexity[156]. Given the focus of the present inquiry however, a dramatically simplified model of sonic

---

[153] Moore, *Elements*, 2-3.

[154] Ibid., 4.

[155] For more on historical "proto-musiconomy" surrounding 19th/20th century German figures Hermann von Helmholtz (1821-1894) and Hugo Riemann (1849-1919), see: Alexander Rehding, *Hugo Riemann and the Birth of Modern Musical Thought* (Cambridge: Cambridge University Press, 2003).

[156] For more on the perceptual aspects of acoustics (psychoacoustics), please see: David M Howard, *Acoustics and Psychoacoustics - 4th ed* (Oxford: Focal Press, 2009).

experience will be presented[157]. In very basic terms, sound is generated through physical vibration, that reaches the ear through the vibration of air molecules (Figure 70).

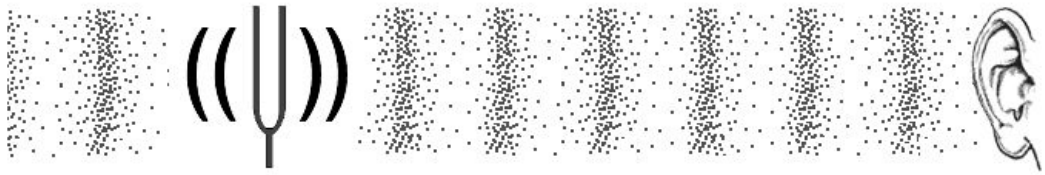

Figure 70 - Sound Propagating Through Air

Upon reaching the ear this acoustic energy causes the eardrum to vibrate, thus beginning a multi-stage energy transduction process, from acoustic (fluctuating air pressure), through mechanical (movements of the outer and middle ear), and hydraulic (fluid pressure of the inner ear), back to mechanical (stimulation of the "hairs" of the basilar membrane), and finally electrochemical (activity along the auditory nerve) before the brain begins to process the perception of sound[158]. See Figure 71 below.

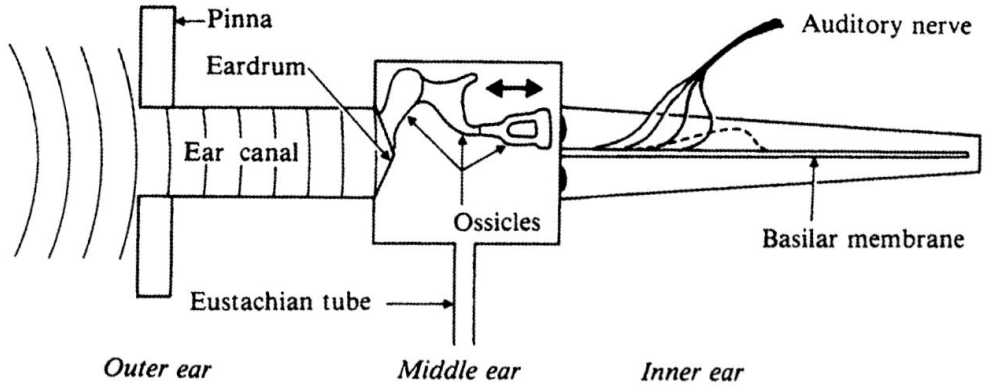

Figure 71 - Human Hearing Apparatus (via Rossing et al.)

Though the complexities of this perceptual apparatus are immense, the essential kinetic qualities of each stage in the induction chain remain fairly constantly a back and forth motion. The eardrum of a standing or sitting human embodies this fundamental motion in a side-to-side orientation, as depicted in Figure 72.

---

[157] For a more complete account, please consult: Thomas D. Rossing, F. Richard Moore, and Paul A. Wheeler, *The Science of Sound,* Third Edition (San Francisco: Addison Wesley, 2002).

[158] Rossing et al., *Sound*, 84.

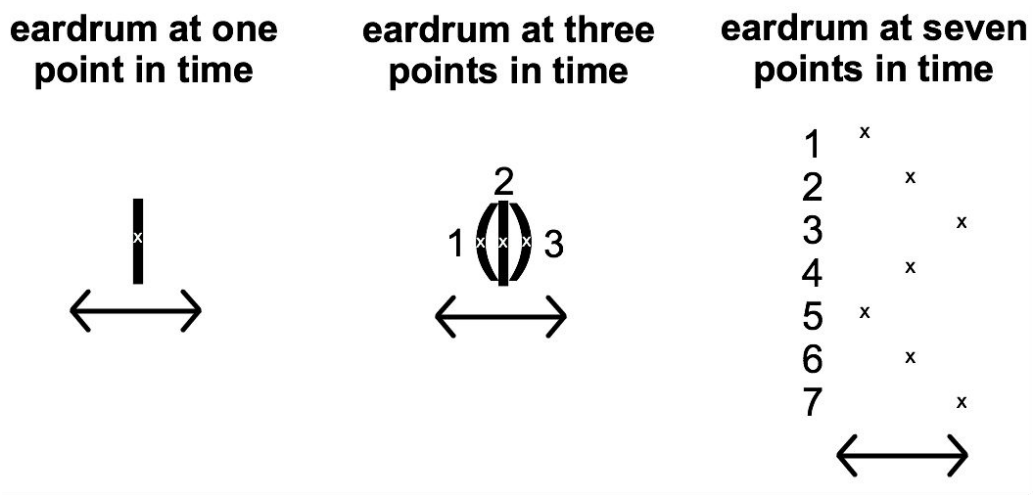

Figure 72 - Motion of Ear Drum Over Various Timeframes

If however, the hypothetical eardrum is turned on its side, and the resulting up-and-down motion is graphed over time (Figure 73), the unique pattern of fluctuations in air pressure resulting from a given sound can be graphed as a wave – a sound wave.

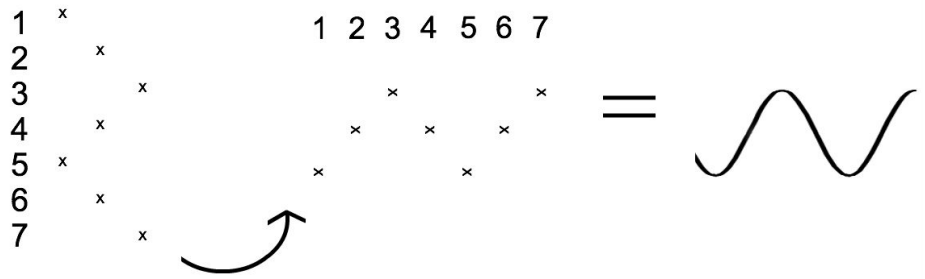

Figure 73 - Graphical Representation of Soundwave

When these fluctuations in pressure are packed together tightly in time, they are said to have a higher frequency as measured in cycles per second or Hertz (Hz). In musical terms, frequency corresponds to pitch. When they cause a greater displacement of the eardrum (or any other medium) they are said to have a greater amplitude, generally measured in Decibels (dB) relative to some reference level[159]. In musical terms amplitude corresponds to dynamic level. A summary is found in Figure 74 below.

[159] For more on Decibels, please see: Rossing et al., *Sound*, 99.

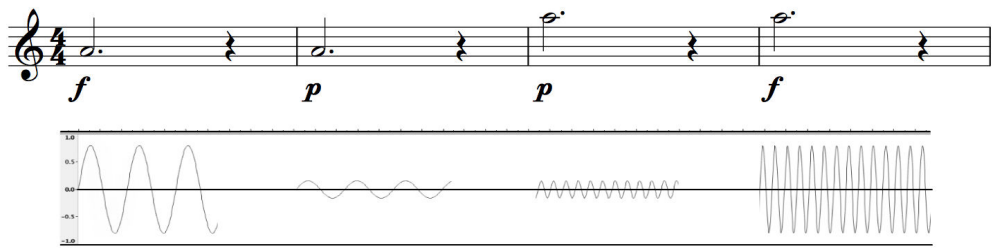

Figure 74 - Relationships of Pitch, Frequency, Amplitude, and Dynamics

The most perceptually relevant manifestation of sound waves for humans are of course the movements of their own eardrums, as highlighted above. The invention of the microphone is also of note however, given its mechanical mimicry of human hearing and its role in recording sound to plastic media. With microphones, the transduction and retention of sound waves leaves the confines of the listener's head, and moves into the more objective, spacious, and enduring storage media of cylinders, records, tapes, and digital files.

In technical terms, the content of such media is the quantification of a sound wave over time. Given the importance ascribed to human perception above however, one might also interpret it as a sort of "written history" of sound (or music). Theodore Adorno states as much in a 1934 article[160], with the assertion that "through the curves of the needle on the phonograph record, music approaches decisively its true character as writing"[161]. Adorno cites the physical embodiment of this link between sound and its graphic representation through the unique visual trace left by any given sound in the microscopic grooves of vinyl recordings (Figure 75)[162].

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[160] Theodor Adorno, "The Form of the Phonograph Record" [1934] *October,* Vol. 55 (Winter, 1990): 56-61..

[161] Adorno, "The Form", 59.

[162] Chris Supranowitz, "Record Grooves" SynthGear, accessed November 7th, 2014, http://www.synthgear.com/2014/audio-gear/record-grooves-electron-microscope.

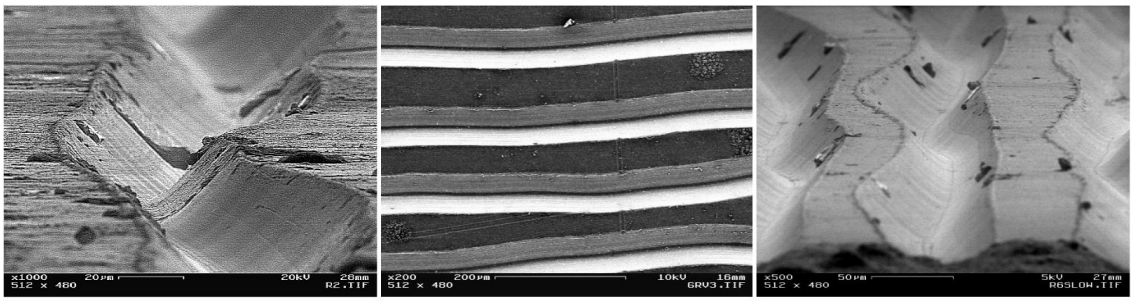

Figure 75 - Electron Microscopy of Record Grooves

The storage of such "writing" on various media enables the measurement, analysis, duplication, distribution, and even manipulation of the once-fleeting sound waves. In order to perform the analyses and manipulations at the heart of the present chapter however, more detailed information is required than is obvious from a simple record of amplitude over time. The necessary data comes from the entire spectrum of simultaneous frequencies at which a given sound source vibrates at any given moment. Therefore, the following sections will describe how one can derive and visualize such ***spectral*** data from recorded soundwaves.

3.2.2 Harmonics and Partials

The purest form of soundwave (ie. having energy at only one frequency) is called a sine wave or sinusoid, and corresponds to simple harmonic motion (motion in which restoring force is proportional to displacement[163]). In his 1983 textbook, *The Science of Musical Sound*[164], American engineer John R. Pierce states that:

> "Happily, our ears encounter pure tones (that is, sine waves) only in acoustical laboratories, or sometimes as the output of inferior or ill-used electronic musical synthesizers."[165]

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[163] Rossing et al., *Sound*, 22.

[164] John R. Pierce, *The Science of Musical Sound* (New York: Freeman, 1992).

[165] Pierce, *Musical Sound,* 41.

Thus, pure sine waves are essentially building blocks that can be used either in the measurement of real acoustic sounds with complex waveforms, or their synthesis. Early experiments conducted by Stockhausen (as described in the same 1971 talk cited above) employed this method.

> "To synthesize a sound you have to start with something more basic, more simple, than the sounds you encounter in daily life. I started looking in acoustic laboratories for sources of the simplest forms of sound wave, for example sine wave generators, which are used for measurement. And I started very primitively to synthesize individual sounds by superimposing sine waves"[166]

Thus for both acousticians and composers alike, the importance of sine waves lies in their mathematical relationship to real-world sound waves of a more complex nature. As Pierce summarizes:

> "The importance of sine waves lies not in their characteristic sounds, but in their inextricable association with the systems that produce and process actual musical sounds, systems such as vibrating strings, or columns of air, or bells and gongs, or drumheads."[167]

The relationship between sine waves and real sounds described above by Pierce, can be illustrated through a visual comparison of two sound waves which both have the same pitch. Consider for instance A=440Hz as performed by both a sine wave generator (top of Figure 76) and the author's singing voice (bottom of Figure 76).

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[166] Stockhausen, "Four Criteria", 90.

[167] Pierce, *Musical Sound*, 41.

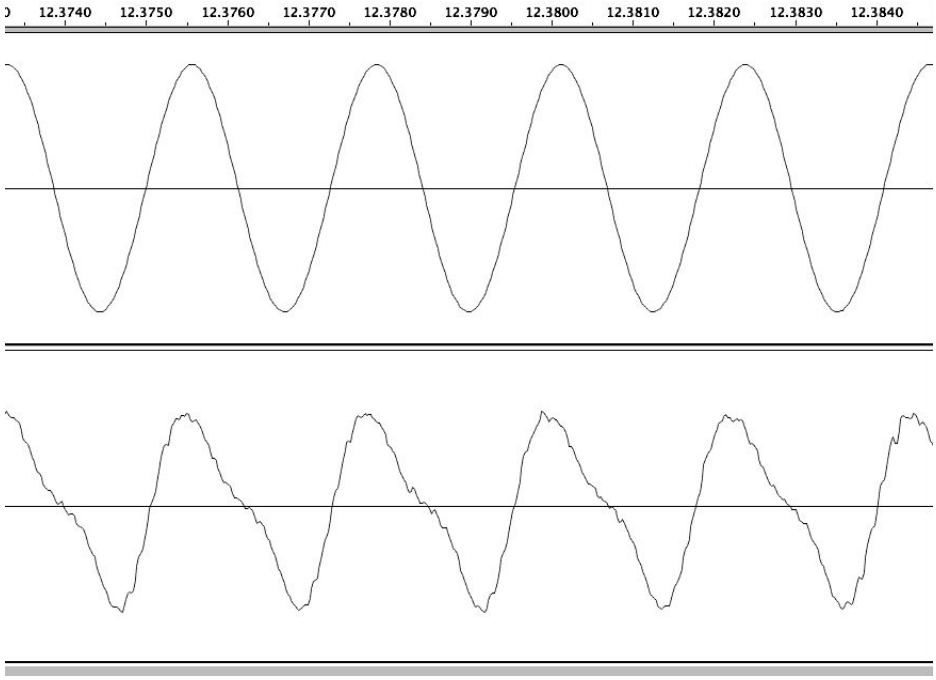

Figure 76 - A=440Hz (Sine Tone [top] vs. Author's Singing Voice [bottom])

The regular pattern of ridges on the bottom figure show – as Pierce describes – that real-world sound sources such as the human vocal apparatus vibrate at many frequencies simultaneously. The interference pattern that results from the superimposition of all of these simpler vibrations results in the unique waveform of a given sound[168], as seen in Figure 77 below.

[168] Image from: "Creating Table Functions for Additive Synthesis" from the Floss Manuals for CSound website, accessed November 7th, 2014, http://en.flossmanuals.net/csound/a-additive-synthesis/.

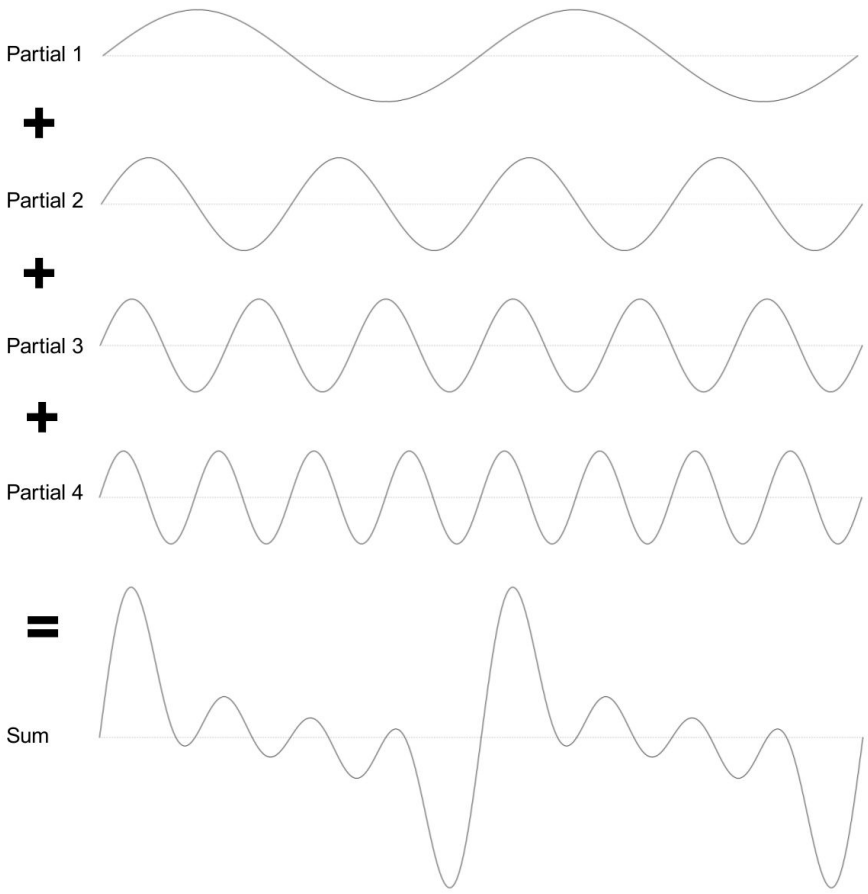

Figure 77 - Complex Waveform via Constructive and Destructive Interference

A complex sound is said to be ***harmonic***, if all of these partial vibrations occur at frequencies that are integer multiples of the fundamental (perceived pitch), and in this specific case the partials are also called ***harmonics***. However, partial vibrations can also occur at ***inharmonic*** frequencies – ie. non-integer multiples of the fundamental. The term ***partials*** therefore refers both to the component vibrations that make up harmonic and inharmonic sounds, while the term ***harmonics*** refers only to those specific partials which are integer multiples of the fundamental.

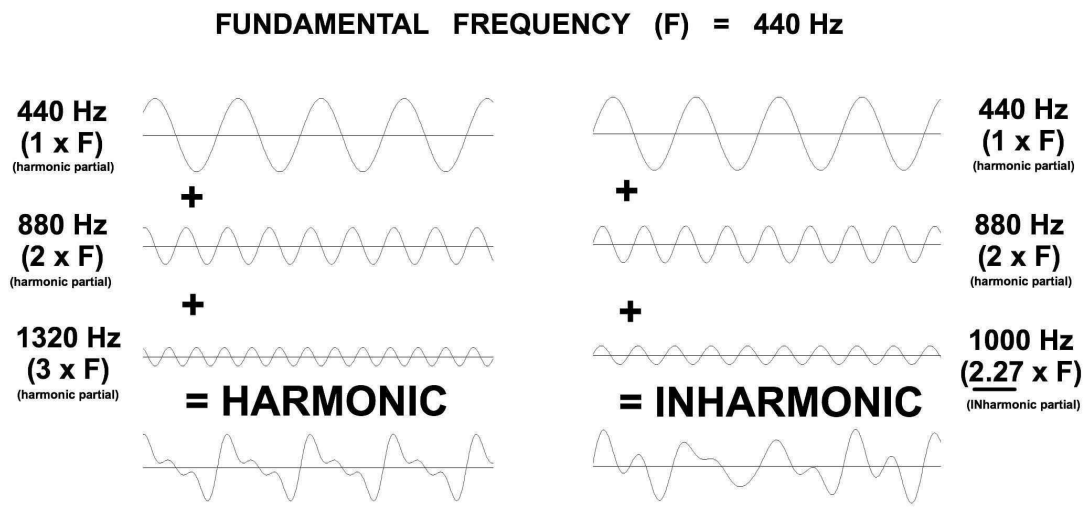

Figure 78 - Harmonic vs. Inharmonic Partials

As seen in Figure 78, waveforms obtained through the graphing of sound pressure over time may be useful in identifying whether or not a tone *has* harmonics/partials. However, it is also clear that they do not supply any useful information about ***how*** those partials are weighted, and which among them are harmonic. Such details are important when it comes to identifying for instance, different vowels being sung at the same pitch, or different instrumentals playing the same pitch. In short, they are a major determinant of timbre.

As such, this information is useful in the analysis, classification, and manipulation of recorded audio towards compositional ends. The following section will show how the additive relationship between sine waves and complex harmonic waveforms described above, may be exploited for an alternate visual representation capable of conveying such information.

3.2.3 Fourier Transforms

The history of visualizing the spectral information of complex harmonic waveforms is discussed in the 1990 F. Richard Moore textbook cited earlier:

> "The nineteenth-century mathematical physicist Jean-Baptiste Joseph Fourier made the remarkable discovery that *any* periodic waveform can be represented as a sum of harmonically related sinusoids, each with a

> particular amplitude and phase. In addition, Fourier derived a mathematical expression that transforms a waveform into its *spectrum*, showing explicitly the amplitudes and phases of the sinusoids that comprise it."[169]

This mathematical expression was devised by Fourier in 1822[170], long before digital audio technologies existed, and therefore dealt with continuous (analog) wave forms. The use of the Fourier transform within the context of digital audio is described by American author, composer, and mathematician Gareth Loy in the second volume of his 2007 textbook[171] on music and mathematics.

> "The age of digital audio has led to a need for a version of the Fourier transform that operates on sampled signals. The *discrete Fourier transform* (DFT) operates on discrete sequences of time and frequency. The *fast Fourier transform* (FFT) is a more computationally efficient version of the DFT."[172]

Given the reliance of audio morphing technologies on digital media, the abbreviations FFT and DFT will henceforth be used to indicate instances in which the spectrum of a sound is derived from its waveform.

The complete mathematics underlying the DFT are well beyond the scope of the present study. In presenting a concise version of this material in his 1996 textbook: *A Digital Signal Processing Primer*[173], American computer scientist Ken Steiglitz (born 1939) still required 149 introductory pages before presenting the transform itself. While the 1996 Steiglitz primer should be consulted for a definitive understanding of the DFT, the following highly simplified overview is intended to highlight those aspects of the transform most directly related to the composition of computer music containing spectral manipulation. Steiglitz presents the equation for the DFT (Figure 79) as follows[174]:

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[169] Moore, *Elements*, 61.

[170] Timothy Gowers, June Barrow-Green, and Imre Leader eds. "A Chronology of Mathematical Events," in *Princeton Companion to Mathematics*, 1010-1014 (Princeton, NJ: Princeton University Press, 2010): 1012.

[171] Gareth Loy, *Musimathics Volume 2* (Cambridge: MIT Press, 2007).

[172] Loy, *Musimathics Vol. 2*, 114.

[173] Ken Steiglitz, *A Digital Signal Processing Primer* (Menlo Park: Addison-Wesley, 1996).

[174] Steiglitz, *Primer*, 152.

$$X_k = \sum_{t=0}^{N-1} x_t e^{-jtk2\pi/N}$$

Figure 79 - Steiglitz: Definition of DFT

where a harmonic spectrum (***X***) can be described in terms of [a finite/discrete collection of] its harmonics (***k***) through the sum of each harmonic's real and imaginary components ($x_t e^{-jtk}$) as measured in radians at the fundamental frequency ($2\pi/N$).

This equation is relevant to the manipulation of spectral characteristics for two important reasons. The first is obvious: knowing the frequency, amplitude, and evolution of a sound's partials enables the analysis, classification, and – most importantly – manipulation of any sound that can be recorded or synthesized. Once a digital audio signal from the time domain has been converted to the frequency domain, its spectral data is completely open to creative alteration.

The second reason will become clear during subsequent discussions of DFT based cross-synthesis. For the time being however, it is sufficient to note the importance of the ***magnitude*** and ***phase*** data made accessible through the use of Euler's Formula ($e^{j\theta}=\cos\theta+j\sin\theta$). Though the specifics of DFT based cross-synthesis will be addressed later in this chapter, it is important to note that the technique is possible because this spectral data can be converted back into a time domain signal using the ***inverse-DFT*** (DFT^{-1}). The equation for the inverse DFT (Figure 80) is given by Steiglitz as[175] (with the terms as defined above):

$$x_t = \frac{1}{N} \sum_{k=0}^{N-1} X_k e^{jtk2\pi/N}$$

Figure 80 - Steiglitz: Definition of the Inverse-DFT

[175] Ibid.

How then does one represent such complex information in an intuitive and musically meaningful way? The following figure (Figure 81) contains highly simplified visual representations of both the DFT and DFT^{-1}.

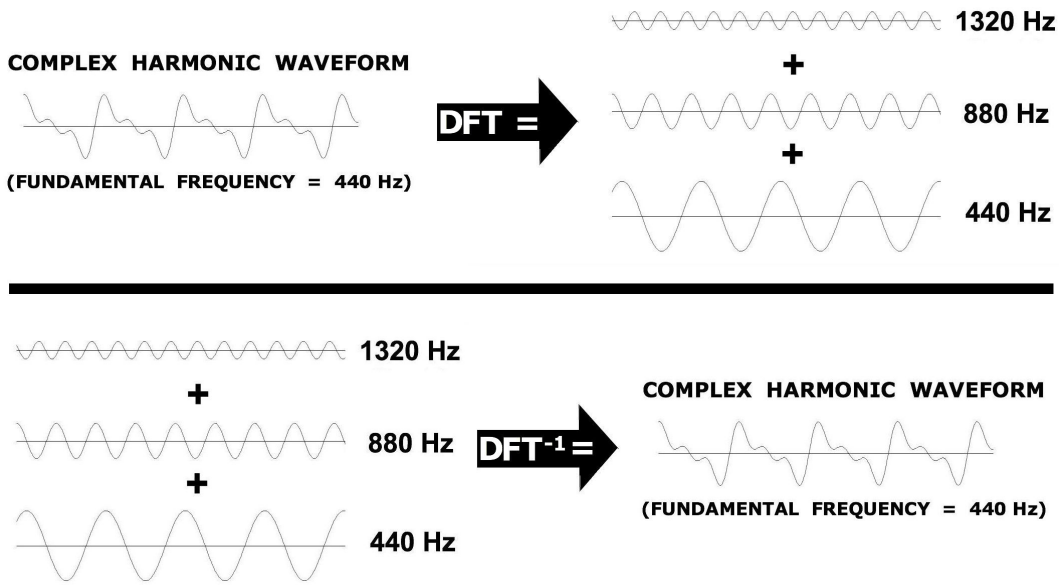

Figure 81 - Visual Representations of DFT and DFT-1

It is also possible to graph the spectrum of these frequencies horizontally along the X-axis, with their amplitudes rising vertically along the Y-axis. Because time is no longer depicted in such graphs, they represent a sound's harmonic content for a single moment in time only (specifically, the time that passes during the number of samples being used to calculate the DFT – which would ideally also correspond to the number of samples in one period of the sound wave's fundamental frequency). These differences in how the X-axis is labeled distinguish between graphs of a sound's ***time domain*** (waveform) and ***frequency domain*** (spectrum), and are compared in Figure 82 below.

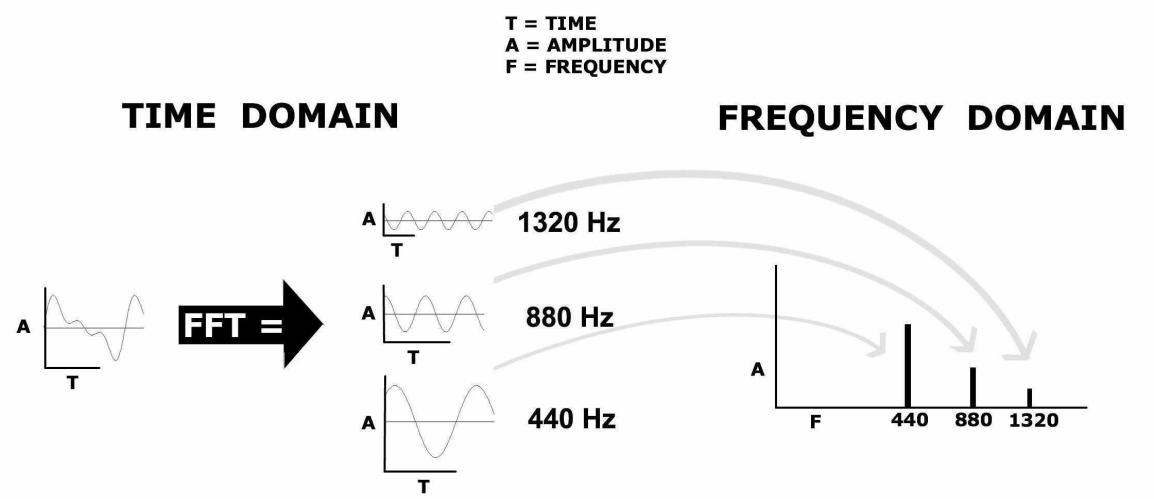

Figure 82 - Time Domain vs. Frequency Domain Representation

As alluded to earlier, frequency domain representations tend to provide more useful information about the timbre of a given sound. Consider for instance how easily one might identify the three following instruments (Figure 83) producing the same A=440Hz tone.

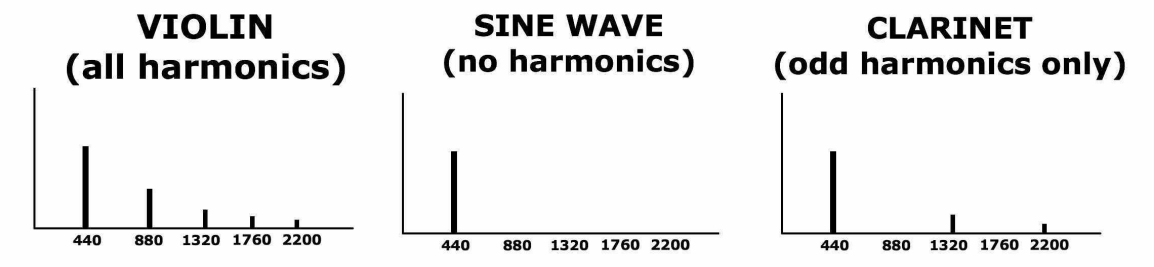

Figure 83 - Timbral Differentiation in the Frequency Domain

These plots of magnitude over frequency for a given DFT frame are referred to as the ***spectral envelope*** of a sound.

Two practical difficulties associated with DFT visualizations are immediately apparent when dealing with real-world, dynamic sounds: 1) the importance of visualizing time, and 2) the unpredictability or outright lack of a fundamental frequency or pitch in a given sound. The documentation that addresses the FFT functionality of the popular audio programming environment *Max/MSP* describes these difficulties and alludes to their solution:

> "Typically the Fourier transform is used on a small 'slice' of time, which ideally is equal to exactly one cycle of the wave being analyzed. To perform this operation on 'real world' sounds — which are almost invariably *not* strictly periodic, and which may be of unknown frequency — one can perform the [DFT] on consecutive time slices to get a sense of how the spectrum changes over time"[176]

To graph the evolution of a sound's spectral content over time (also referred to as its dynamic spectrum), these consecutive DFT frames can be shown on a single graph by bringing the Z-axis into play and graphing the passage of time from front to back, with frequency and magnitude measurements remaining on the X and Y axes (respectively). Figure 84 was generated using the "waterfall display" function of the open source application: *SndPeek*[177]

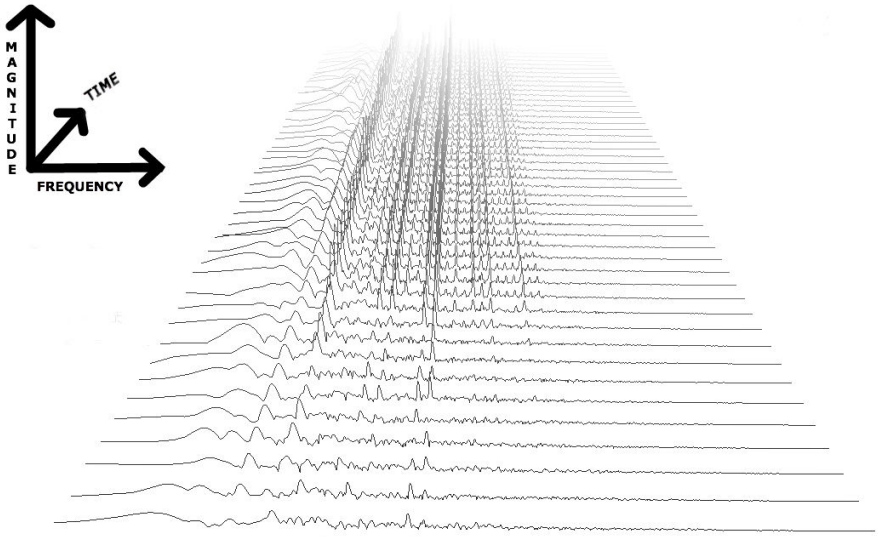

Figure 84 - Waterfall Style Visualization of DFT Data

[176] "MSP Tutorial 25: Using the FFT," *Users guide for Max/MSP 5.1.9,* (San Fransico: Cycling '74, 1990-2008).

[177] Ge Wang, Perry Cook, Ananya Misra, and George Tzanetakis. "*SndPeek* Software," Soundlab website, accessed February 15, 2015, http://soundlab.cs.princeton.edu/software/sndpeek/.

Another tactic involves returning time to the X-axis, moving frequency to the Y-axis, and indicating relative strength through the darkness of the point or line. The above-mentioned *Max/MSP* software was used to generate Figure 85, utilizing the sonogram mode of the [spectrograph~] object.

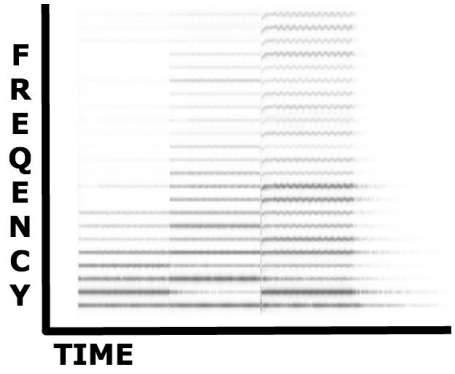

Figure 85 - Sonogram Style Visualization of DFT Data

While the two previous strategies address the ever-changing *temporal* aspects of real-world sound, the unpredictability or absence of a fundamental frequency must also be considered. In order to obtain a useful level of frequency resolution for any sound, one must calculate an DFT using a relatively high number of samples. This longer (hypothetical) period length means a lower fundamental frequency, which in turn ensures that there will be more frequencies at which the hypothetical harmonics (***DFT bins***) are present to register data.

Figure 86 shows the spectral content of three complex instrumental tones in black, with fundamental frequencies located at 20Hz, 50Hz, and 70Hz respectively. The same information is reproduced in a second diagram to the right. The only difference between these two illustrations is the resolution of the hypothetical DFT analyses, indicated in both cases by evenly spaced, horizontal, grey lines. These lines show the locations of the ***centre frequencies*** for each DFT bin generated through analyses corresponding to 100Hz and 10Hz fundamentals, respectively.

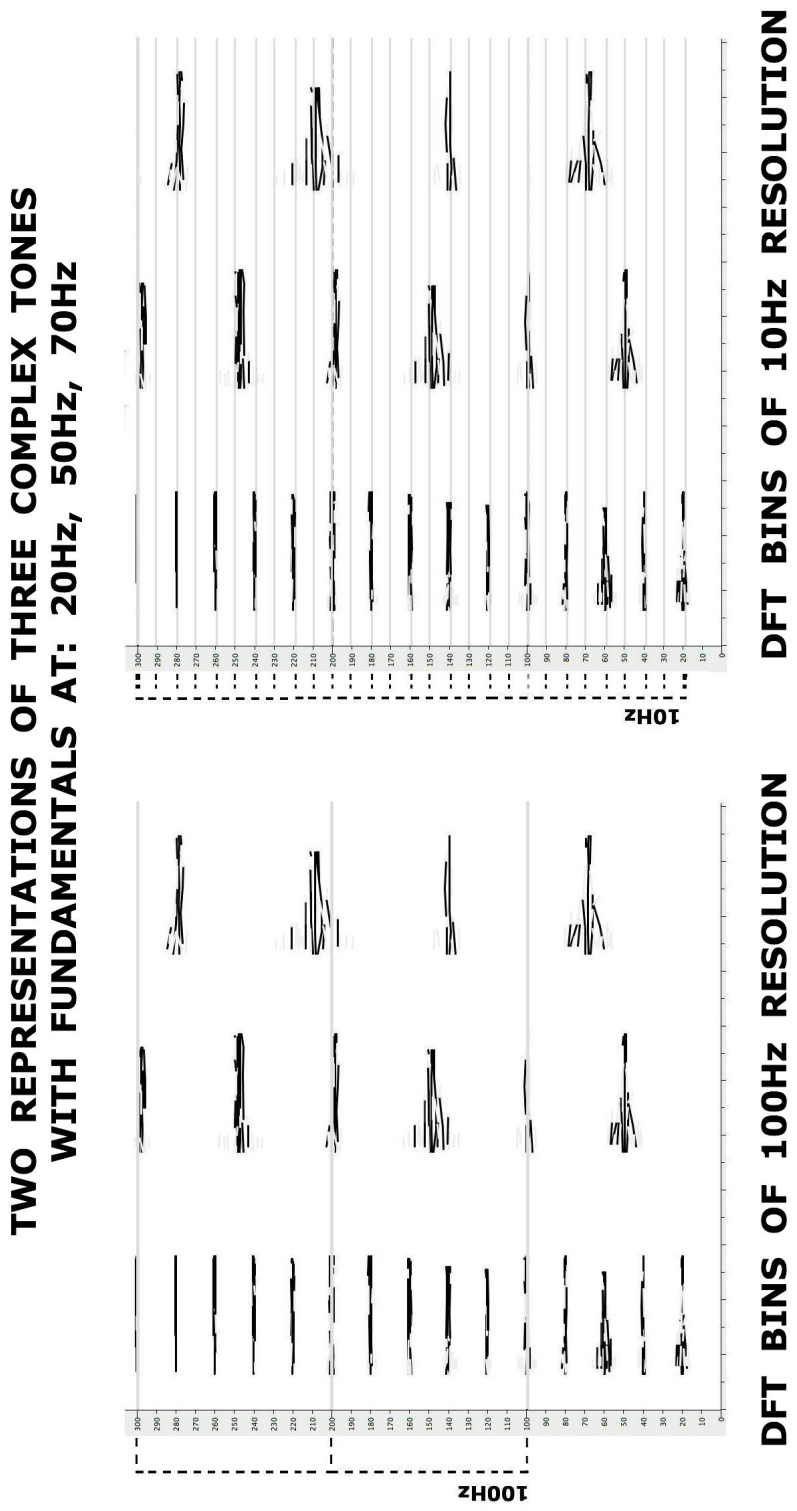

Figure 86 - DFT Bins of Contrasting Resolution

This (exaggerated) example shows the advantage of calculating FFTs from greater numbers of samples, so as to increase frequency resolution. The DFT calculated from a period length corresponding to 100Hz has only three spectral bands (DFT bins) in which to measure frequencies below (approximately) D4 on the piano keyboard. Compare this clearly insufficient resolution with the thirty bins of the period length corresponding to 10Hz.

The vast compositional possibilities inherent in these calculations are also reflected in the wide diversity of techniques for the digital morphing of audio. It will be useful therefore to categorize these many viable techniques according to a simple duality based on how the spectral data is being employed. Interestingly, the two categories that will be employed in the following section to describe digital audio morphing also correspond to one of the oldest theoretical frameworks for the analog synthesis of audio.

3.3 Additive and Subtractive Categories of Audio Synthesis and Morphing

The technical details and compositional relevance of recording, analyzing, and classifying sounds in an electronic music studio will be described at length in Chapter 6. There, Stockhausen's *Four Criteria of Electronic Music* will show how the composer's acoustic research at the GRM was the impetus behind his attempts to synthesize sound electronically. Through analogies to the commonly understood components of speech (vowels and consonants), Stockhausen describes these early experiments with sound synthesis according to the binary categories of ***additive*** and ***subtractive synthesis***:

> "And I started very primitively to synthesize individual sounds by superimposing sine waves [additively] in harmonic spectra, in order to make sounds live vowels, aaah, oooh, eeeh etc., then gradually I found how to use white noise generators and electric filters [subtractively] to produce coloured noise, like consonants: ssss, sssh, fffh, etc."[178]

In theory, both additive and subtractive synthesis may be used interchangeably to generate consonants, vowels, instrumental timbres, or any other type of sound. In practice however, the sonic characteristics of a given target sound might suggest a particular method over its counterpart. Figure 87 illustrates this phenomenon, using the two examples (consonants and vowels) mentioned by Stockhausen above.

[178] Stockhausen, "Four Criteria", 90.

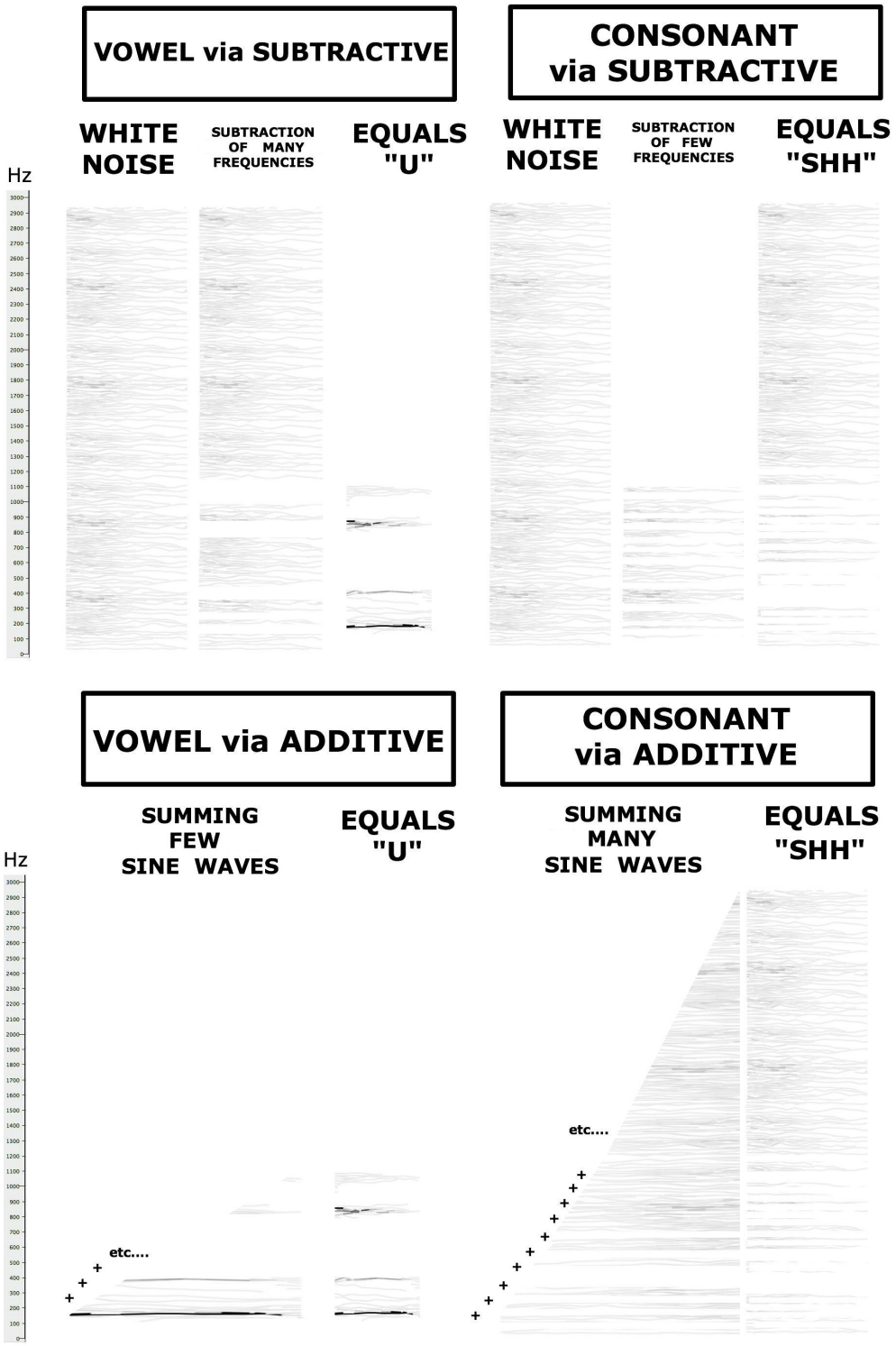

Figure 87 - Additive vs. Subtractive Synthesis (Examples from Speech)

Clearly, the vowel would be better suited to additive synthesis while the opposite would be true of the consonant. In *Elements of Computer Music*, F. Richard Moore describes these two "classical" categories of synthesis, suggesting their inherent suitability to contrasting types of sonic material.

> "The basic notion of additive sound synthesis is that complex musical sounds can be created by adding together multiple sounds components, ***each of which is relatively simple***. Such components are typically not perceived individually, but each component contributes materially to the overall quality of the resulting sound."[179] (emphasis mine)

and:

> "*Subtractive synthesis* is based on the complementary idea of passing a broadband signal through a time-varying filter to produce the desired waveform... --something like taking a sculptor's chisel to a block of marble."[180]

A collection of the lectures delivered in Wesleyan College's Music 109 course on experimental music taught by American composer Alvin Lucier were published in 2012, aptly titled: *Music 109*[181]. Active as a composer during the early years of electronic music, Lucier reflected on creative activity at the Studio Fonologico in Milan where he spent a formative period of study. Lucier describes the hopes of early practitioners in establishing a theoretical framework for electronic music based on an additive/subtractive dichotomy.

> "There was much talk in those days about additive and subtractive synthesis. If you had enough sine-wave oscillators you could eventually produce white noise. Conversely, white noise, which consisted of all frequencies randomly mixed together, could be filtered down to one sine-wave tone. This was a theoretical notion, as far as I could see; I'd never heard it done in real life. But there was a lot of talk about this, as if this dichotomy could give a theoretical basis to this new medium."[182]

Lucier's skepticism regarding the artistic relevance of this dichotomy may be eased somewhat through its present relevance to the manipulation and combination of

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[179] Moore, *Elements*, 207.

[180] Ibid.

[181] Lucier, *Music 109*.

[182] Ibid., 8.

real-world sounds – a pursuit for which Lucier expresses a clear reverence in the bulk of the Studio Fonologico lecture[183]. For in fact, the modern techniques of audio morphing may also be understood to conform loosely to the additive/subtractive dichotomy[184]. The following section will present five techniques for audio morphing organized according to the additive/subtractive dichotomy: two of the former type, and three of the latter.

3.3.1 Additive Approach I – Spectral Peak Interpolation

Additive synthesis that makes use of data obtained through the spectral analysis of an existing sound to ***re-***create a (controllable) copy of said sound is described as ***re-synthesis***. Because of the integral role of spectral analysis, this compound process is referred to as ***analysis/re-synthesis***. The re-synthesis will obviously be an imperfect approximation of the original sonic material, though often indistinguishable within the limits of human perception. Most importantly however, it will be open to manipulation of any kind once the data has been captured and recreated. For instance, if each component frequency is multiplied by two (see Figure 88), the sound will be re-synthesized an octave higher.

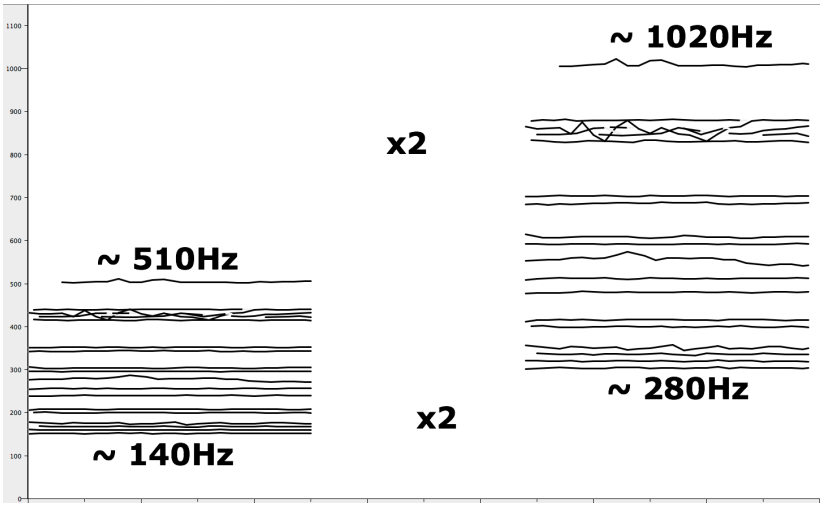

Figure 88 - Octave Transposition Through Re-synthesis

[183] In particular, see his discussions of Schaeffer, Henry, and especially Cage in this chapter of *Music 109*.

[184] This is not to suggest that an additive/subtractive conceptual framework is the ONLY way to group various audio morphing technologies. For instance, Perry Cook and Trevor Wishart both group morphing technologies according to characteristics associated with the means of sound production for the source materials. Cook for instance divides all techniques into one of two categories: "Synthesis models can be loosely broken into two groups: Spectral models, which can be viewed as based on perceptual mechanisms, and physical models, which can be viewed as based on production mechanisms." Cook, "Audio Morph?" 5.

When manipulating re-synthesized spectra, it is important to prioritize the most perceptually relevant partials of an analyzed sound. These components are referred to as ***peaks***, and correspond to DFT bins whose magnitudes are the greatest with respect to their surroundings. If two adjacent bins are equally elevated above their neighbours, it is likely that the actual peak falls somewhere close to the frequency directly between them. As mentioned earlier during discussions of spectral visualization, these peaks will vary in both amplitude and frequency over time, and this inner life of a sound is referred to as its dynamic spectrum. Given the current speed of digital signal processing, the details of a sound's dynamic spectrum may be captured and manipulated in (virtually) real-time prior to re-synthesis.

As in the above figure, this manipulation might take the form of a simple doubling of frequency resulting in a pitch-shift of an octave. However, one could just as easily apply any complex function to the spectral data of a given sound. Furthermore, if analyses are performed on two separate sounds simultaneously, the manipulation of a given re-synthesis could involve the combination of – or transition between – these two streams of data. Combining two sources of spectral data during re-synthesis is called ***cross-synthesis***, in that the re-synthesized sound is a cross between the two original sources. By carefully controlling the degree and rate of cross-synthesis, the morphing of distinct audio sources becomes possible.

In additive cross-synthesis that uses a bank of controllable oscillators, the most simple transition from one set of spectral data (frequency and amplitude pairs for each peak) to another, is direct interpolation (as illustrated in Figure 89 below).

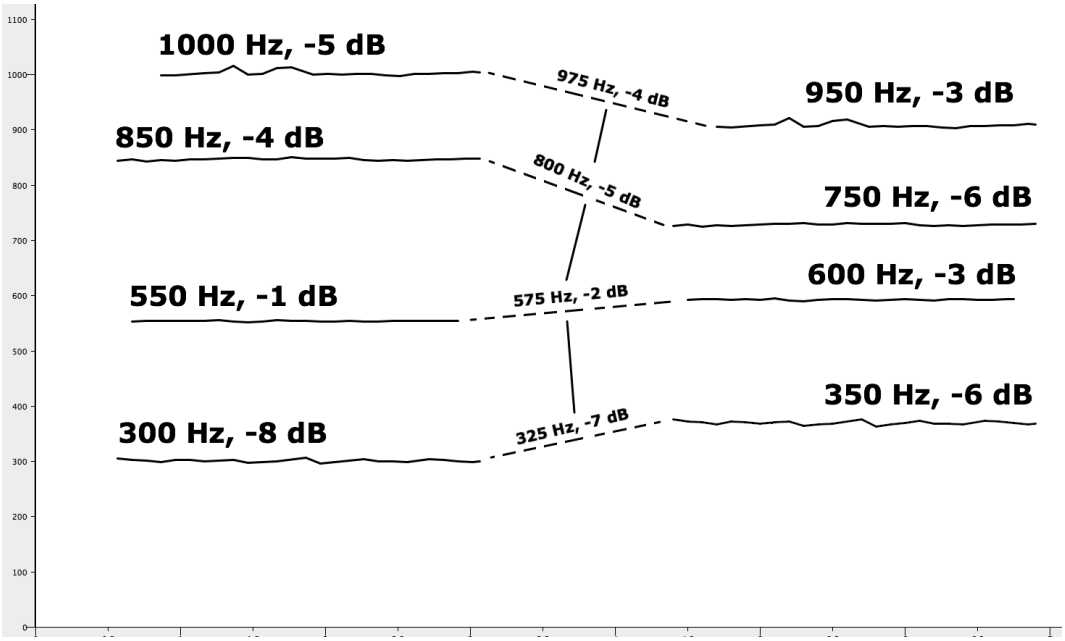

Figure 89 - Interpolation of Four Spectral Peaks

The result is a smooth glissando and volume change for each sinusoidal component of the re-synthesis. The above figure shows the spectral data of two sounds, linked in the middle by a hypothetical (indicated with a dashed line) interpolation. The frequency and amplitude values of each partial are labelled at the points of origin, arrival, and mid-interpolation.

In a recent obituary for English composer Jonathan Harvey (May 3rd 1939–December 4th 2012), fellow English composer Michael Clarke makes specific mention of "the tape piece *Mortuos Plango, Vivos Voco* (1980), [as] a work now widely considered one of the classics of the computer music repertoire."[185] The work explores the timbral characteristics of a great bell and a child's voice, both recorded at Winchester Cathedral (the child in question was in fact Harvey's son)[186]. The following spectral analysis (Figure 90) corresponding to approximately the two minute mark in the recording of

[185] Michael Clarke, "In Memory of Jonathan Harvey (3 May 1939–4 December 2012)," *Computer Music Journal*, Vol. 37, No. 2, (Summer 2013): 5.

[186] See: Jonathan Harvey, "*Mortuos Plango, Vivos Voco*: A Realization at IRCAM," *Computer Music Journal*, Vol. 5, No. 4 (Winter 1981): 22-24. Also, see secondary analyses by Mario Sibilia, and: Patricia Lynn Dirks, "An Analysis of Jonathan Harvey's *Mortuos Plango, Vivos Voco,*" *Contact*, No. 9.2, accessed November 14th, 2014, http://cec.sonus.ca/econtact/9_2/dirks.html.

Mortuos Plango, Vivos Voco[187], shows one of many instances in which Harvey employs an interpolation between spectral peaks to morph the timbre of a sung note into that of a bell.

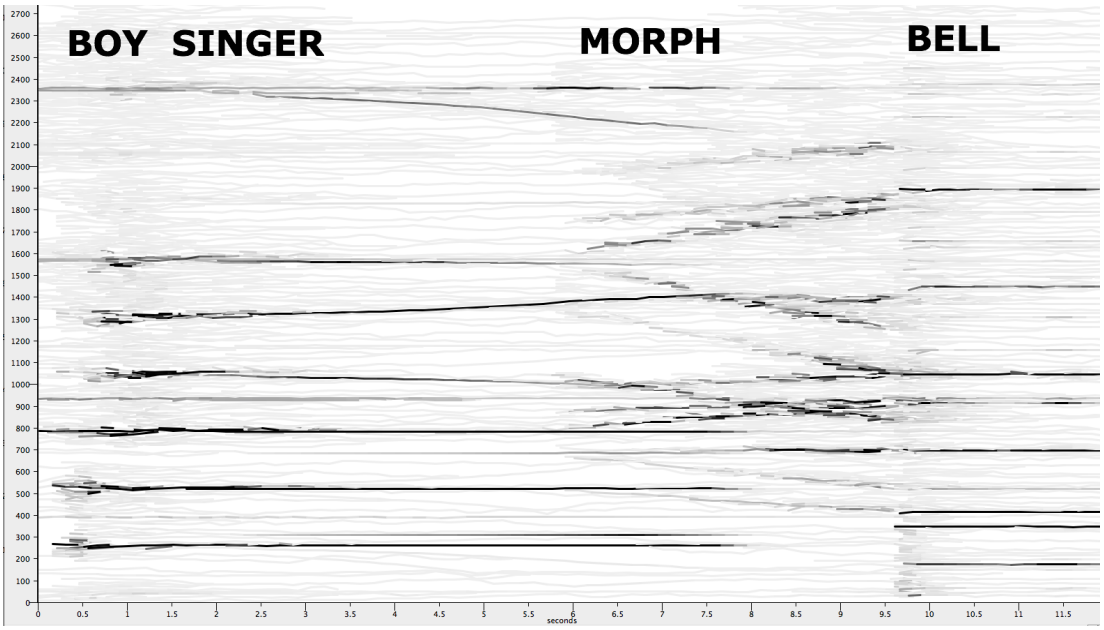

Figure 90 - Harvey: Mortuos Plango, Vivos Voco (circa 2:00)

The entrance of the oscillator bank (labeled "morph" above) is clear both from the increased density of general spectral activity (in grey), and the diagonal black lines which indicate the peak to peak interpolation of the morph.

Because such interpolations require finite departure and arrival values on either end of the morph, the spectral envelope must invariably be sampled or "frozen" at a certain point. Because real world sounds are generally undergoing constant spectral change, perfectly frozen spectra can sometimes sound somewhat sterile or artificial.

[187] Jonathan Harvey, "Mortuos Plango, Vivos Voco," in *Computer Music Currents 5* (Mainz: Wergo, 1990), compact disc.

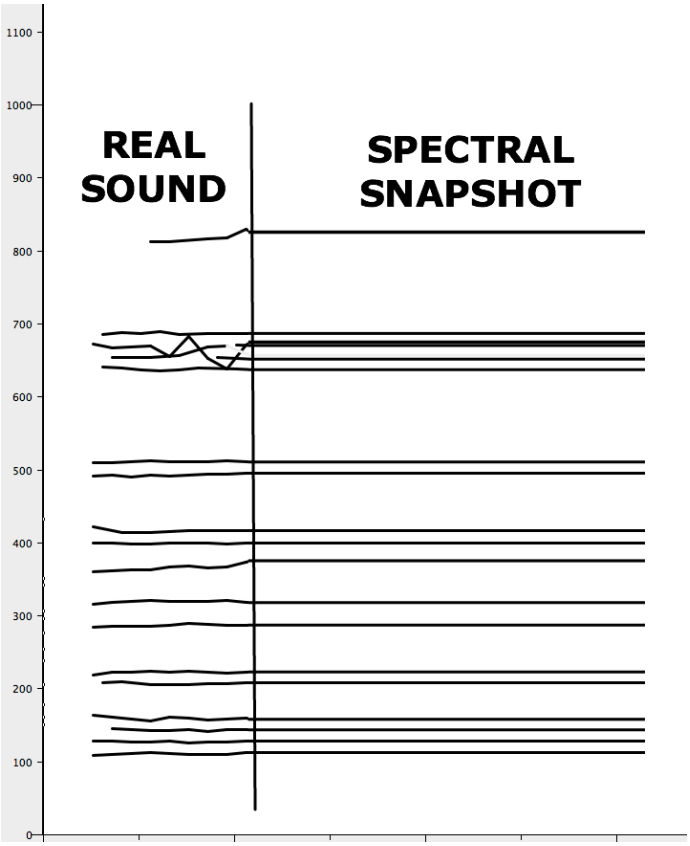

Figure 91 - Spectral Snapshot

Even when depicted graphically as in Figure 91, the unwavering lines of each peak comprising the snapshot reveal its unrealistically synthetic character.

One possible solution to this dilemma is to introduce controlled fluctuations (or ***jitter***) to both the frequency and amplitude values for each peak, simulating a more realistically dynamic spectrum (Figure 92). For added realism, these variations should ideally be modelled on the spectral analyses of real-world sounds and instruments.

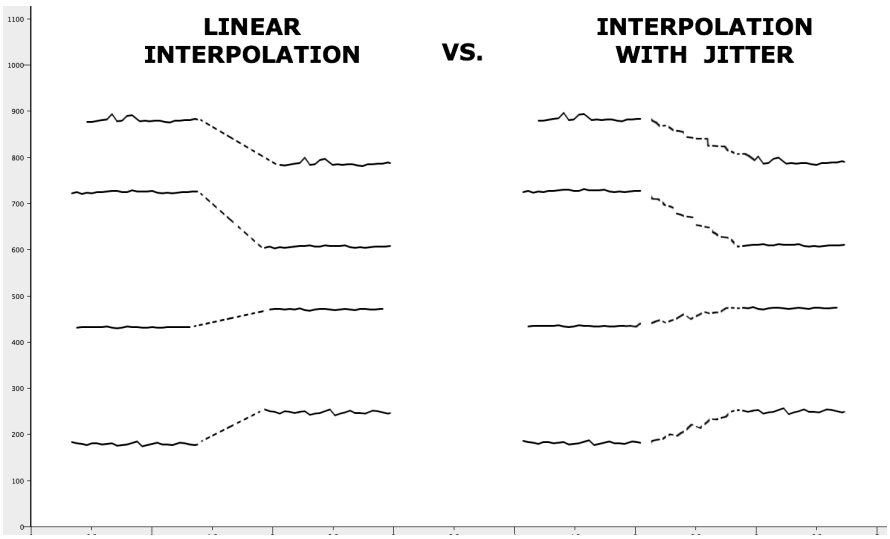

Figure 92 - Introducing Jitter Into Spectral Interpolation

In order to further decrease the ratio of re-synthesized to real (or realistic) audio, American composer and computer scientist Cort Lippe has described[188] a seven-stage morphing process (Figure 93) in which re-synthesis is reserved exclusively for materials that can not be recreated naturally (ie. the interpolation itself).

[188] Lippe presented this method during lectures from the 2009-10 sessions of his graduate computer music seminar at the State University of New York, Buffalo. (heretofore: Cort Lippe, "The FFT," Lecture, computer music seminar at SUNY Buffalo, Buffalo, NY, Winter 2009)

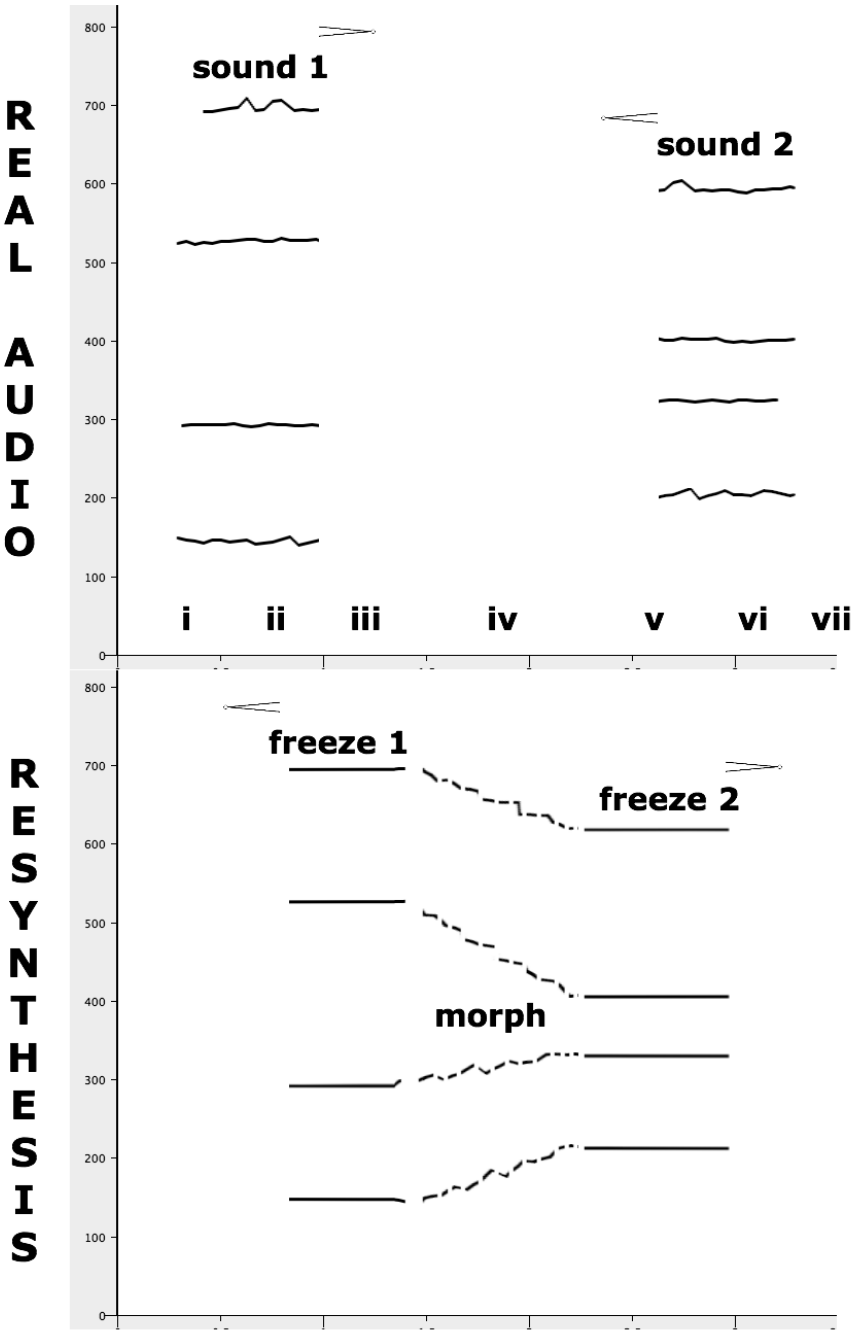

Figure 93 - Seven Stage Morphing (via Lippe)

As in the Harvey example of Figure 90, there is a clear entrance and exit of frozen spectral content (ii and vi) on either extreme of the morphing glissando (iv). The fadeout and return of the actual audio being morphed (at iii and v respectively) should ideally be extended as long as possible to minimize the quantity of unaccompanied synthetic sonorities. For while previously non-existent connective tissue linking two real-world

sounds is the goal of this method, overemphasis on the linkage can create an overall effect of unwanted artificiality.

3.3.2 Additive Approach II – Spectral Peak Interleaving

The connective tissue generated through the above method of spectral peak interpolation can be likened to a band of threads connecting the peaks of sound A to the peaks of sound B. There is however, another type of connective tissue that can be generated using the individual voices of an analysis/re-synthesis. In this scheme the visual analogy for the connective fabric is closer to that of a woven carpet, in that each thread (re-synthesized partial) is cross-faded independently of its counterparts. The resulting texture of the dynamic spectrum at any given moment is a hybrid of both sources, simultaneously containing individual partials from each sound (Figure 94).

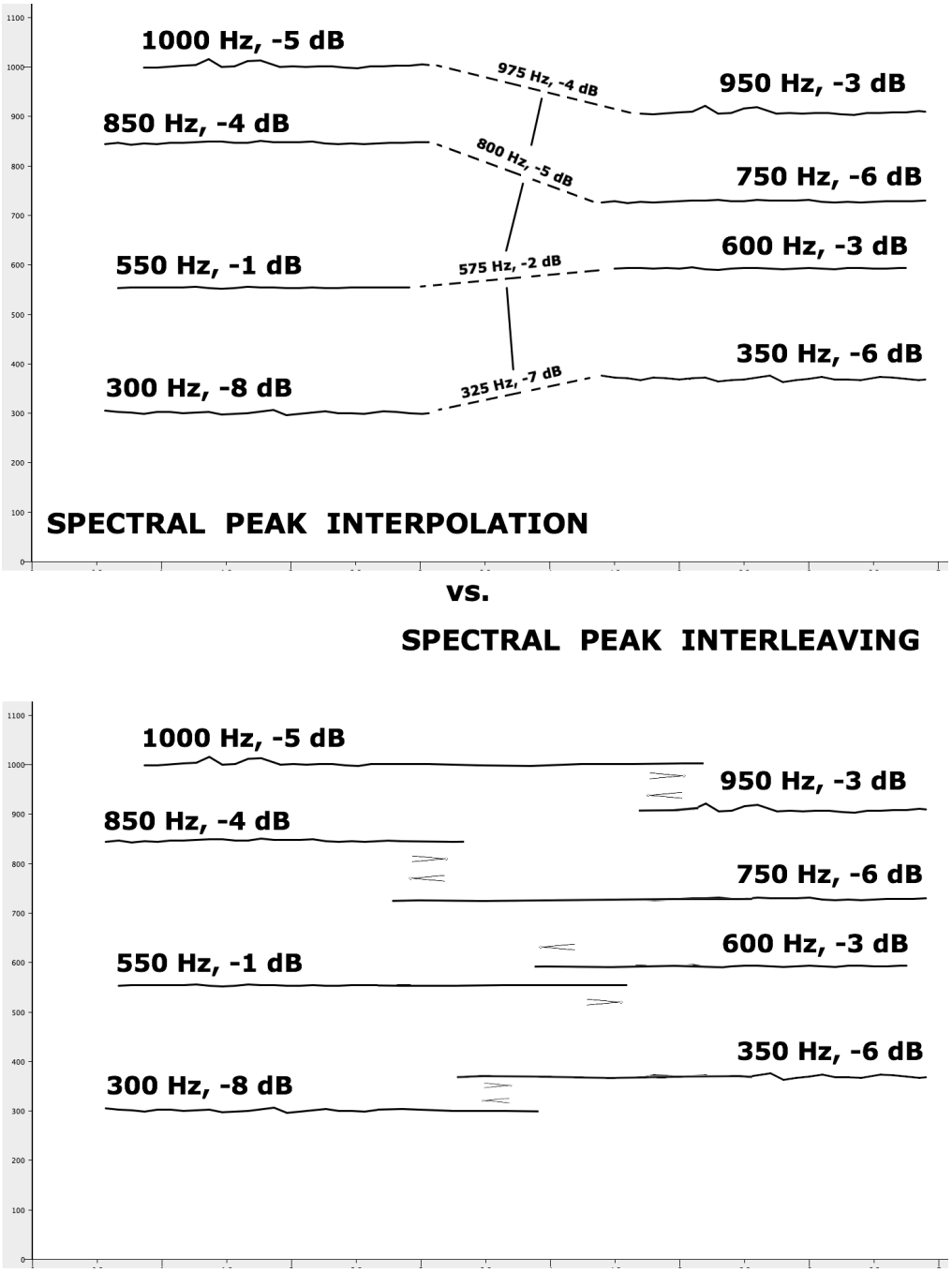

Figure 94 - Interpolation vs. Interleaving

Because the voices in this scheme are not influencing each other's behaviour in any way, there is no morphological connective tissue on a local level (voice one of sound one simply gives way to voice one of sound two, etc.). However, the resulting dynamic

spectrum at any given point in the morph is made up of partials from both sounds, generating a spectrum that could not exist as a result of a simple time-domain cross-fade (see Figure 95).

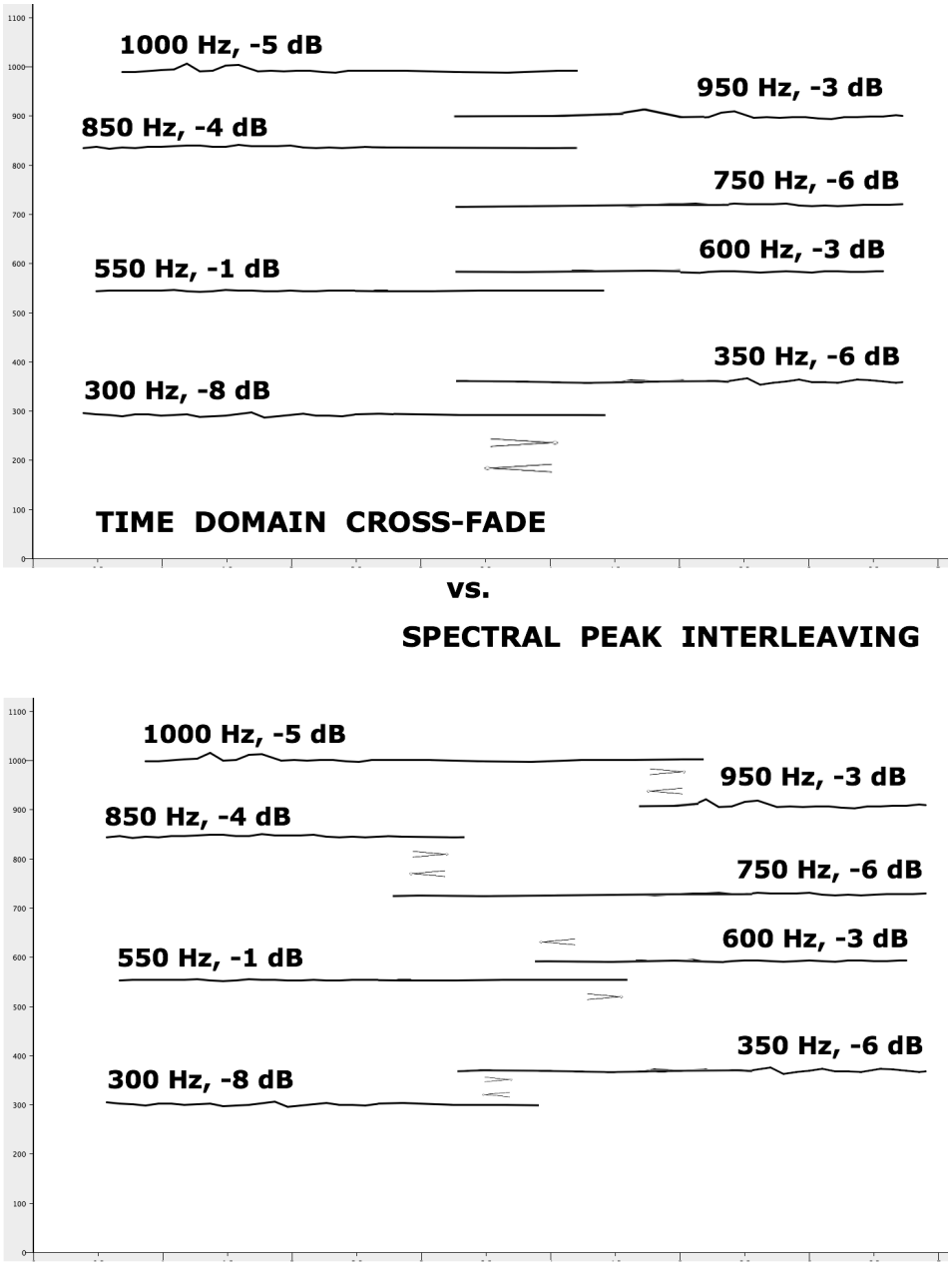

Figure 95 - Interleaving vs. Cross-Fade

The hands-on control of each individual partial in the analysis/re-synthesis of multiple sound sources allows for their morphing through interpolation or interleaving. Both

approaches fall into the additive family of classical synthesis classification in that the dynamic spectra and their morphs are cumulatively built up from simple sinusoidal components. The various subtractive approaches to morphing, with their central role of dynamic filtering will now be considered.

3.3.3 Subtractive Approach I – DFT-Based Cross-Synthesis

Subtractive approaches to morphing involve the filtering of one sound according to spectral characteristics of another. This process is referred to by many names, including: timbre-stamping, convolution, and cross-synthesis. To avoid confusion with loaded mathematical terminology (convolution) and pitch-centricity (timbre-stamping) the following discussions will make exclusive use of the term cross-synthesis.

The connective tissue in a morph employing subtractive cross-synthesis often takes the form of two simple time-domain cross-fades: one from origin sound to cross-synthesized sound, and another from the cross-synthesis to the target sound. These types of morphing are distinct from the morphs associated with additive approaches, in that the degree of hybridization is essentially fixed, and one merely controls a three-part mix of origin, hybrid, and target sounds.

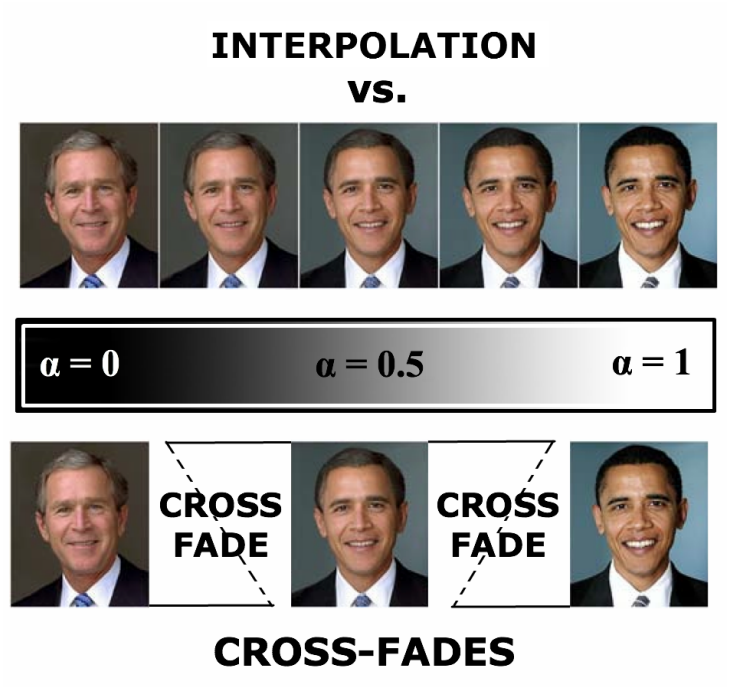

Figure 96 - Cross-Synthesis: Cross-Fade vs. Interpolation

Figure 96 illustrates these two possibilities through Caetano's visual example cited in Chapter 1.

The simplest form of DFT-based cross-synthesis is achieved by maintaining the phases from each DFT bin of a first sound, but using the magnitudes from each corresponding bin of a second signal. The end sonic result is a filtering of the spectrum from the first sound by the spectral envelope of the second. Because of its subtractive nature, the greatest limitation on simple DFT-based cross-synthesis is synchronization in both the time and frequency domains.

For this filtering to be successful, the target sound's spectral envelope requires a spectrum on which to impose itself. In the context of DFT data, this means that some significant (or at least non-zero) magnitude value is required in order to generate audible results. If the desired spectral envelope (supplied by the phases) occurs while the origin sound is silent (providing zero or near-zero magnitude values), the sought-after spectral envelope will pass by unheard (Figure 97).

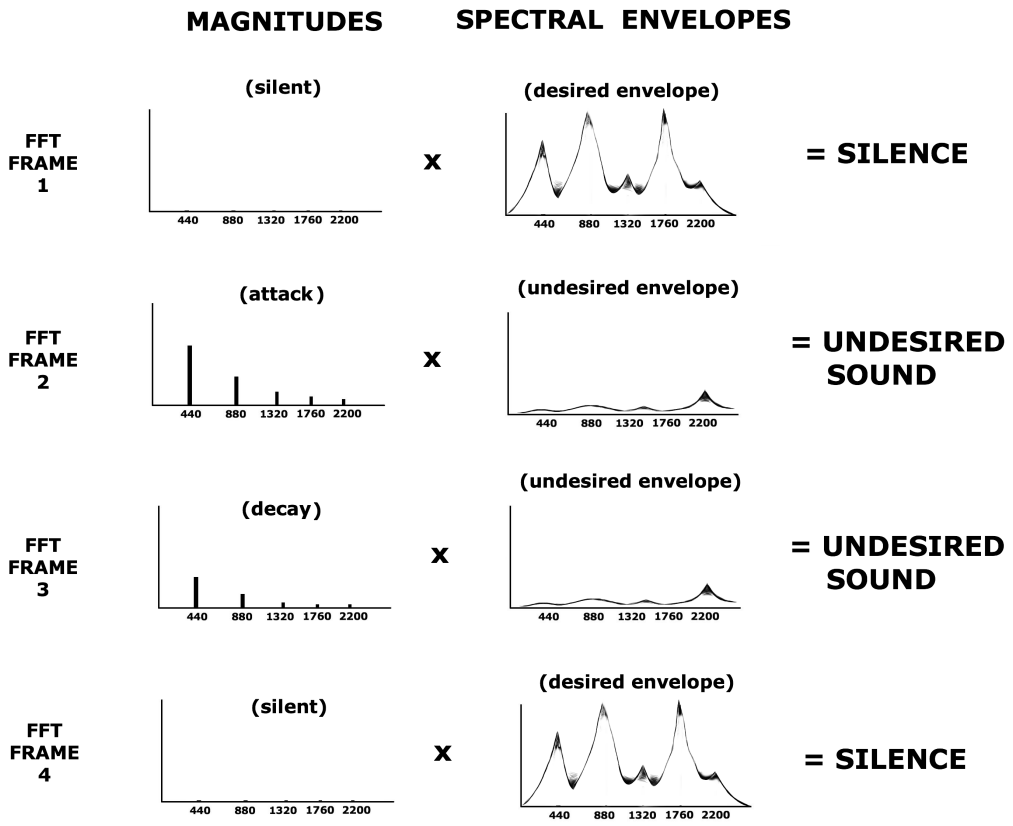

Figure 97 - Lack of Spectral Overlap (Temporal)

Similarly, a lack of overlap in the frequency domain will also result in less than desirable results. Consider Figure 98, in which a spectral envelope peaking around 2200 Hz is applied to an A=440 Hz harmonic tone.

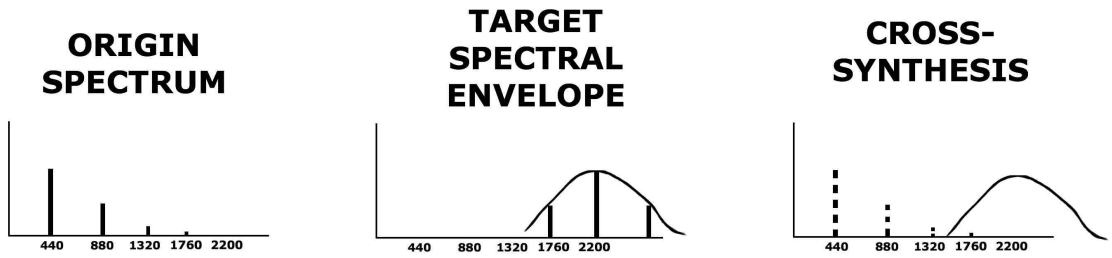

Figure 98 - Lack of Spectral Overlap (Frequency)

While burdened by the necessity of coordination between origin and target sonorities, the cross-synthesis of magnitude and phase information from an DFT analysis is the foundation of a second, more versatile technique.

3.3.4 Subtractive Approach II – IR-Based Cross-Synthesis

A method of cross-synthesis that avoids the synchronization pitfalls of the previously described approach is impulse response (IR) cross-synthesis. This method is used commercially to simulate the acoustic reverberant qualities of specific spaces for audio recorded under less reverberant conditions (generally in a studio)[189]. An ***impulse*** is defined as the presence of all frequencies at full magnitude for an infinitely short amount of time (Figure 99). In practice, a starter's pistol or handclap is often used to approximate this effect.

[189] A popular option is the (self-described) industry standard Altiverb software. See: "Altiverb," Audio Ease Website, accessed November 18th, 2014, http://www.audioease.com/Pages/Altiverb/.

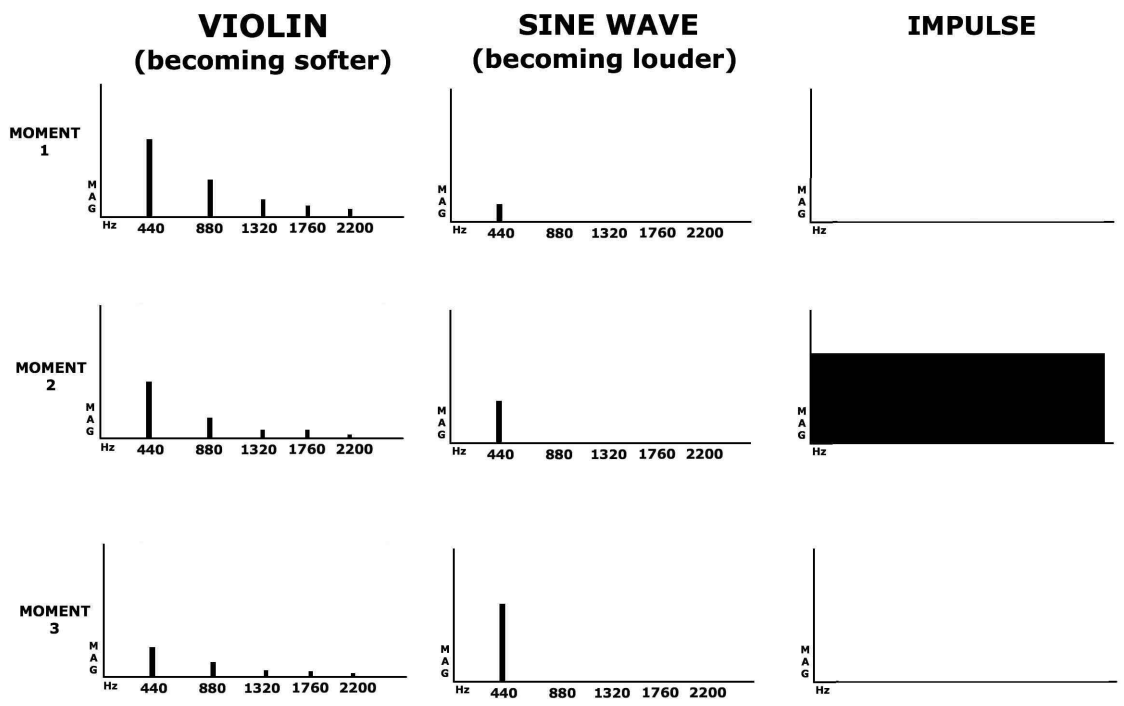

Figure 99 - Frequency Domain Representation of an Impulse

When an impulse occurs within a room, reverberations of the impulse will occur at characteristic resonant frequencies - this is the room's response to the impulse.

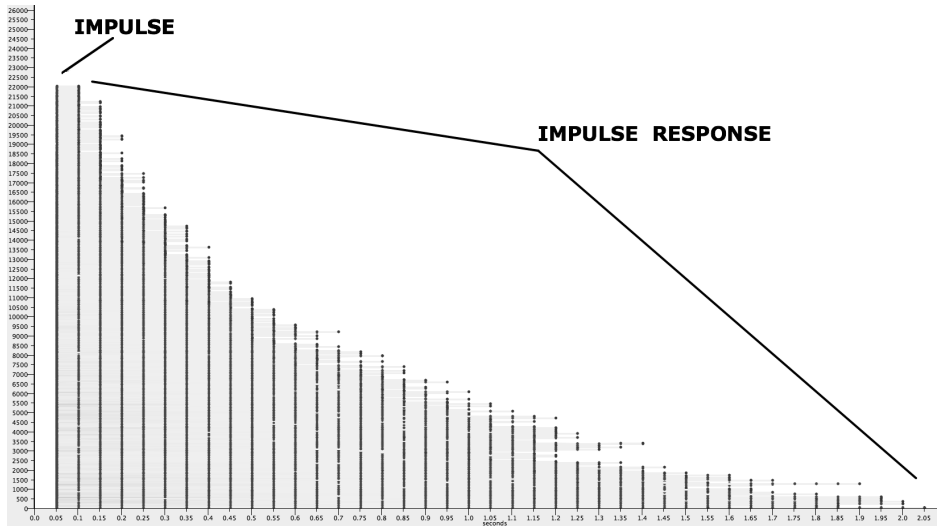

Figure 100 - Two Second Impulse Response of St Paul`s Cathedral

Figure 100 shows a spectrogram of the IR recorded in St. Paul's Cathedral for inclusion in the HISSTools Impulse Response Toolbox[190]. Notice that the higher frequencies die out much more quickly than their lower counterparts.

IR-based cross-synthesis is achieved by multiplying ***every*** DFT frame of the room's IR (from the start of the impulse to the end of the reverberations) by ***every*** frame of an incoming audio signal (Figure 101).

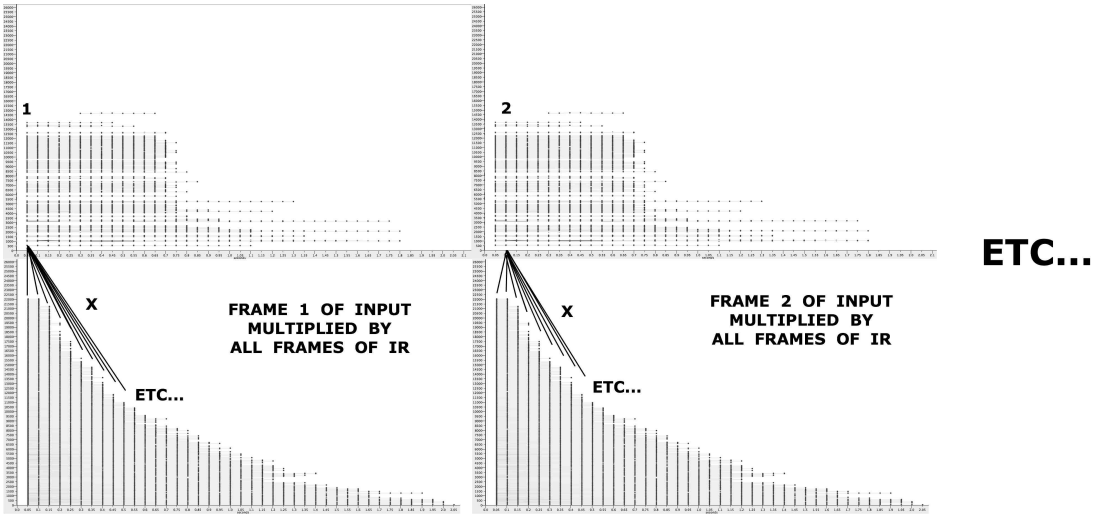

Figure 101 - Frame Multiplication in IR Cross-Synthesis

Because the first frame of the IR is an impulse (with full energy at all frequencies), it is impossible for any frame of the incoming audio signal to be cancelled out due to lack of time or frequency overlap. Furthermore, multiplying each of the incoming audio frames by each of the IR frames also increases the potential for overlap. The term ***convolution reverb*** is used in the labelling of audio plugins that rely on this technique to simulate more spacious recording conditions. Though originally designed for this purpose, the contents of the IR buffer need not actually be the response of an actual space to an actual impulse. Any sound placed into the buffer will be multiplied by every frame of the input audio, resulting in greater potentials for overlap than in simple DFT-based cross-synthesis.

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[190] Alex Harker and Pierre Alexendre Tremblay, "HISSTools Impulse Response Toolbox v1.1" Huddersfield CeReNeM downloads, accessed November 18, 2014, http://www.thehiss.org.

Though this technique results in *more* sound than the previous method of cross-synthesis, it remains a subtractive technique in that the IR is still filtering the input signal. While these two previous techniques relied on DFT data, the final example of subtractive morphing through cross-synthesis involves another variety of signal analysis.

3.3.5 Subtractive Approach III – LPC-Based Cross-Synthesis

Though resting on a different mathematical foundation, cross-synthesis involving Linear Predictive Coding (LPC) also functions by filtering one sound by the spectral characteristics of another.

LPC is a technique of approximating the human vocal apparatus, and treats all incoming signals as the result of a source-filter system[191]. In human vocal production, the source is the buzzing of vocal flaps and the filter is the dynamic body of the vocal tract. LPC analysis is designed to parse out these two constituent elements of vocal production, but can also be used to analyze sounds originating in other ways.

LPC prediction yields an error that corresponds to the source which (like the raw sound of human vocal flaps) is a pitched buzz with a rich spectrum of partials for vowels, or a burst of white noise for consonants. If this error is filtered according to the coefficients yielded by the prediction, then the original signal should be reproduced faithfully (Figure 102).

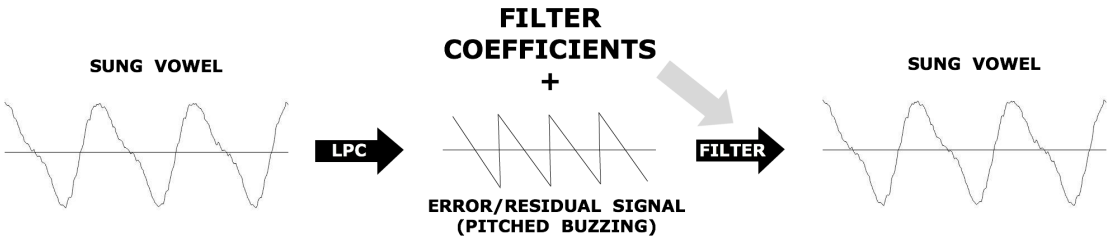

Figure 102 - LPC Analysis and Re-Synthesis

[191] For more on the speech-based origins and applications of LPC technology, see: J.D. Markel and A.H. Gray Jr., *Linear Prediction of Speech* (Berlin: Springer-Verlag, 1982).

As in DFT-based cross-synthesis, one simply conducts two parallel analyses, and maps (crosses) the filter of one sound's source onto the source of a second (or vice versa, as shown in Figure 103 below).

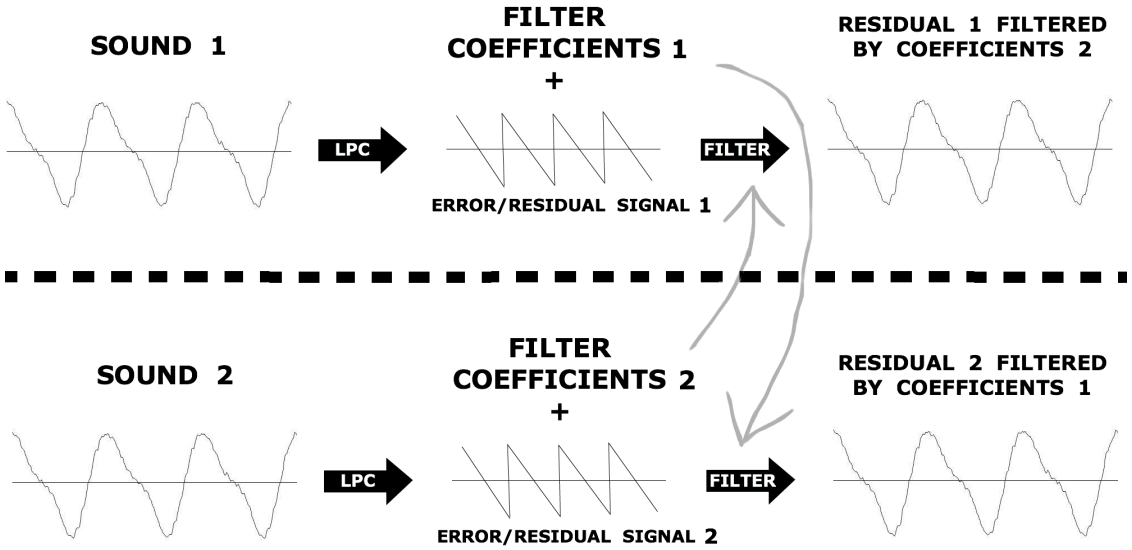

Figure 103 - LPC Based Cross-Synthesis

Also common to both methods of subtractive cross-synthesis is the fact that a quiet or silent source (low magnitude in DFT-based cross-synthesis) will result in a quiet or silent output, as silence filtered by *anything* remains silence. Many such factors influence the success or failure of a given morphing technique when applied to a given audio signal. The most pressing concerns of this sort will now be considered in the context of both subtractive and additive morphing strategies.

3.4 Perceptual Considerations

The importance of analyzing and classifying sonic material will be emphasized during the coming chapters' discussions of post-traditional musical forms and morphologies. This emphasis is explicit in the writings of Russolo, Schaeffer, Stockhausen, and Lachenmann among others. These composers all framed the analytical understanding of one's compositional materials as an aesthetic implication or even necessity of the expanding soundworld. However, the pursuit of such an understanding is a very real *practical* necessity within the realm of audio morphing technology.

As alluded to during the introduction of IR-based cross-synthesis, the type of sound being morphed will dramatically affect the success of any given technique. In terms of temporal overlap during cross-synthesis, the greatest difficulty to overcome is the natural or synthesized decay of a non-sustaining sound. This type of sound corresponds to the *Kadenzklang* family from the Lachenmann table cited in Chapter 6. The chief obstacle involved in the cross-synthesis of this soundtype is the relatively short period during which any significant quantity of sound is present.

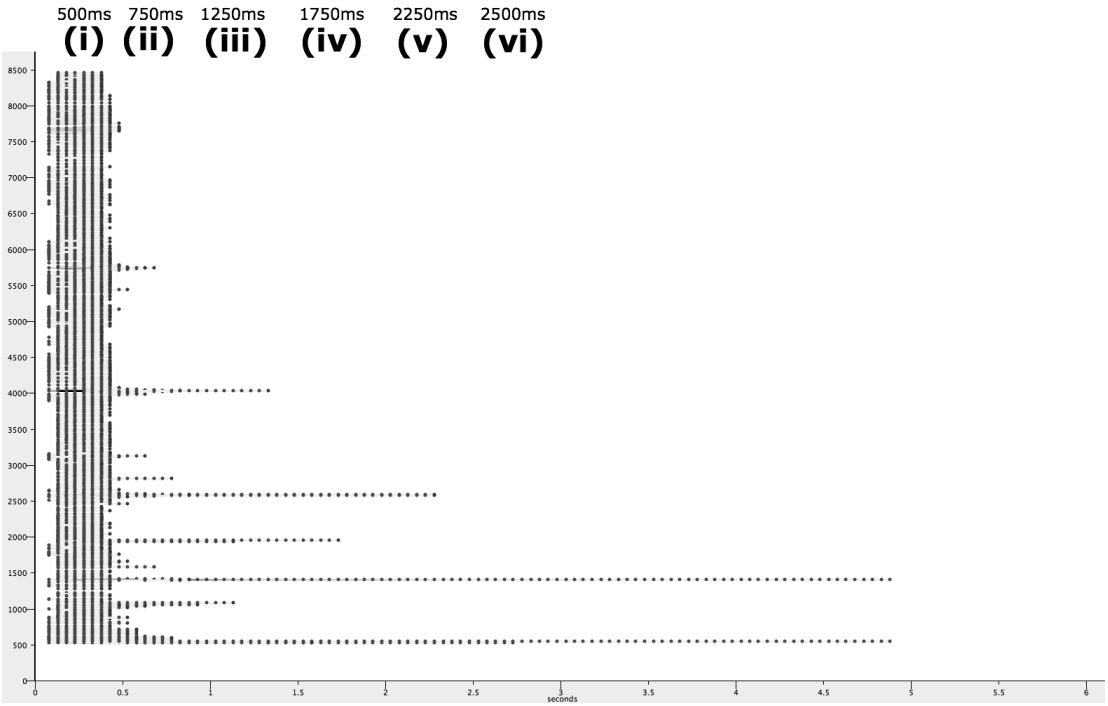

Figure 104 - Spectrogram of Short Bell (Kadenzklang) Sound

Figure 104 shows the rapid drop-off of spectral content in a recording of a single bell strike. The brief burst of broadband noise at point (i) lasts well under half a second, leaving roughly ten thin bands of spectral content at point (ii). Just over a second into the sound at point (iii), these bands have narrowed to single frequencies which also begin disappearing rapidly. The countdown from 6 (iii), 4 (iv), 3 (v), all the way down to 2 (vi) frequencies occurs in just over two seconds. This incredibly short, noisy, attack coupled with similarly short, narrow-band resonances, leaves little useful spectral data to multiply

in a cross-synthesis. Furthermore, when dealing with events so much shorter than a single second, difficulties associated with temporal coordination also appear.

There are two potential solutions for dealing with the cross-synthesis of *Kadenzklang* (decaying) sounds. The first is to make the more attack-oriented sound source the one supplying the articulation (magnitudes) for the morphed sound.

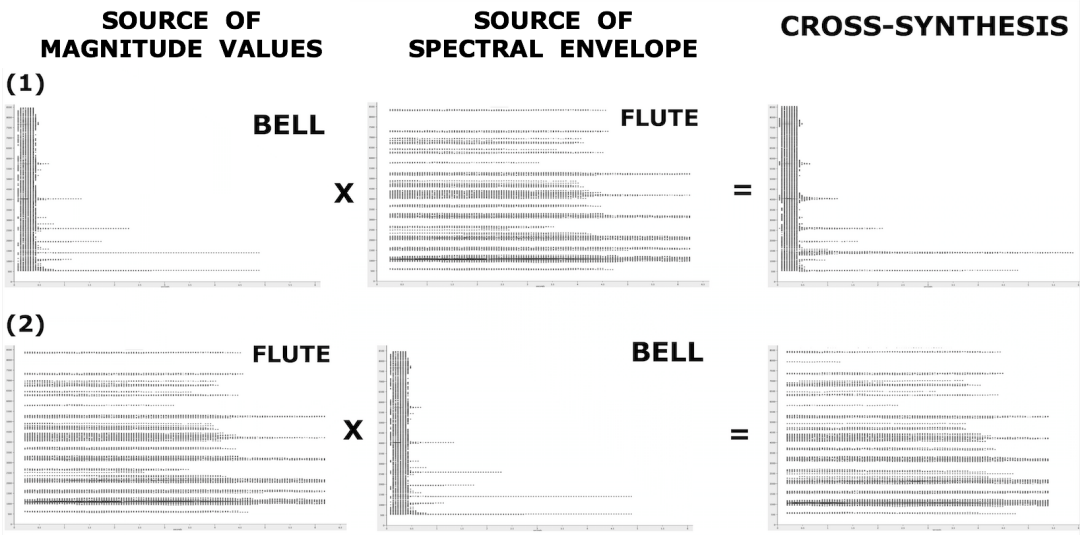

Figure 105 - Two Possible Orders of DFT Based Cross-Synthesis

In Figure 105 above, cross-synthesis (2) is virtually indistinguishable from the recording of the un-altered, sustained, flute sample due to the lack of useful phase data in the bell recording. In the case of cross-synthesis (1) on the other hand, the bands of spectral content that make up the decay are widened significantly, resulting in a much more successful hybrid of both sounds.

The second potential solution is the use of impulse-response cross synthesis, wherein typical attack(s) of the decaying sound are pre-loaded as IRs. In this way, every frame of the rapidly decaying sound will be cross-synthesized with every frame of the input audio. Furthermore, the brief, broad-band attacks of the *Kadenzklang* (bell) samples from the previous two figures behave like actual impulses (see Figure 106), given that they both begin with a quick burst of energy at virtually all frequencies.

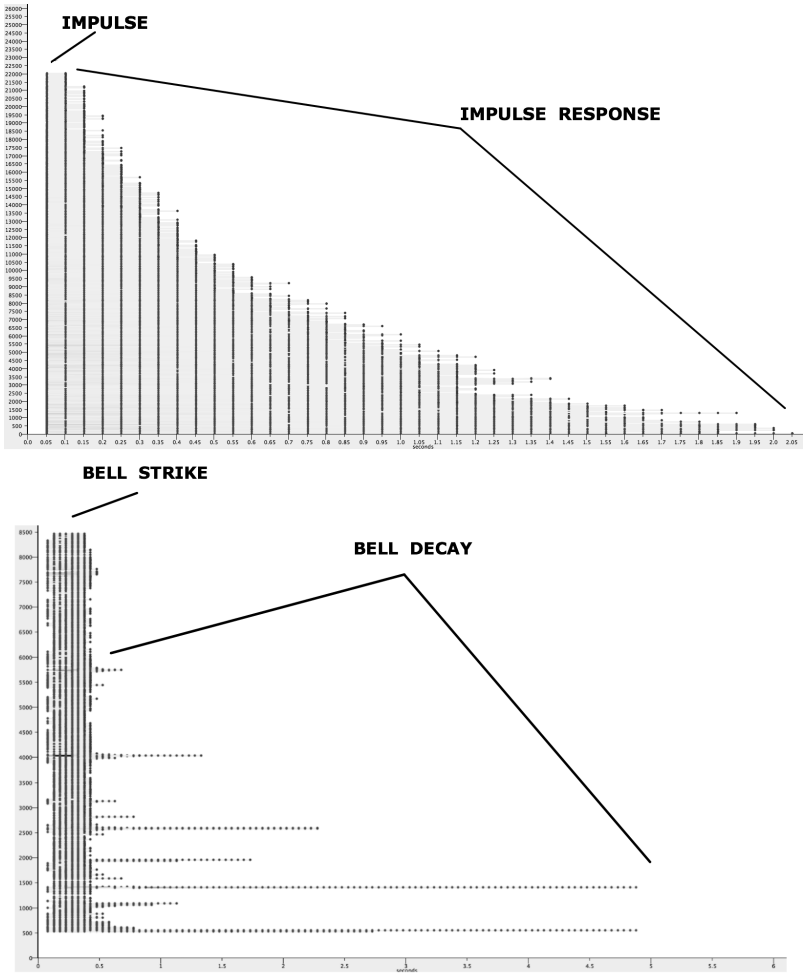

Figure 106 - Comparison of an Impulse Response and a Bell Stroke

A further issue related to spectral overlap results from the characteristic structure of the harmonic and quasi-harmonic sounds that comprise the vast majority of musical sound of the western tradition. The degrees of spectral overlap between two pitched or quasi-pitched spectra are highly dependent on both fundamental frequency and level of harmonicity. The sharp, “comb-like” nature of such sounds leave little room for divergence, even within the context of two purely harmonic sounds.

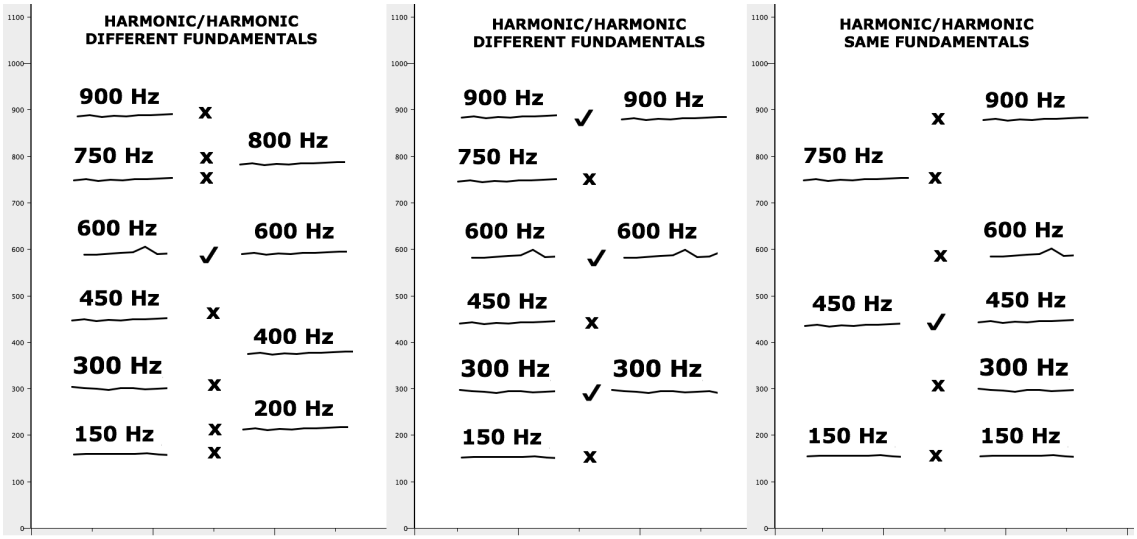

Figure 107 - Spectral Overlap: Harmonic on Harmonic Spectra

Note from the three examples of Figure 107 that having the same fundamental for two equally harmonic sounds is no guarantee of spectral overlap.

Similarly, different combinations of harmonic and inharmonic spectra can also display completely variable levels of spectral overlap.

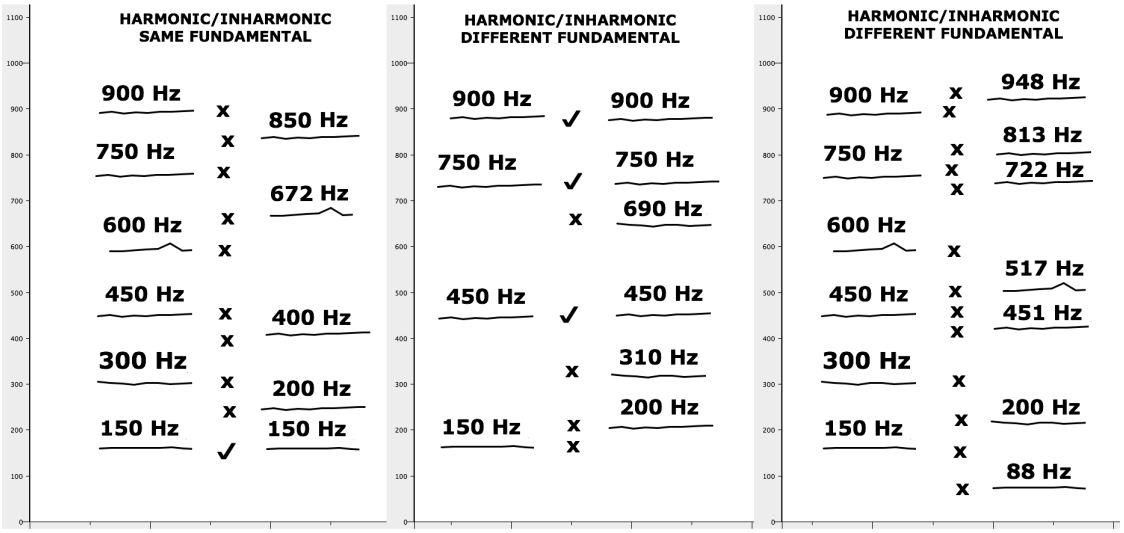

Figure 108 - Spectral Overlap: Harmonic on Inharmonic Spectraa

Figure 108 includes a case in which the combination of harmonic and inharmonic spectra over two different fundamentals results in zero overlap. However, it is worth noting that

the first two examples of the previous figure disprove a correlation between overlap and common fundamental when dealing with at least one inharmonic spectrum.

Cases involving two inharmonic spectra further emphasize this fact, given the widely varying quantities of potential overlap.

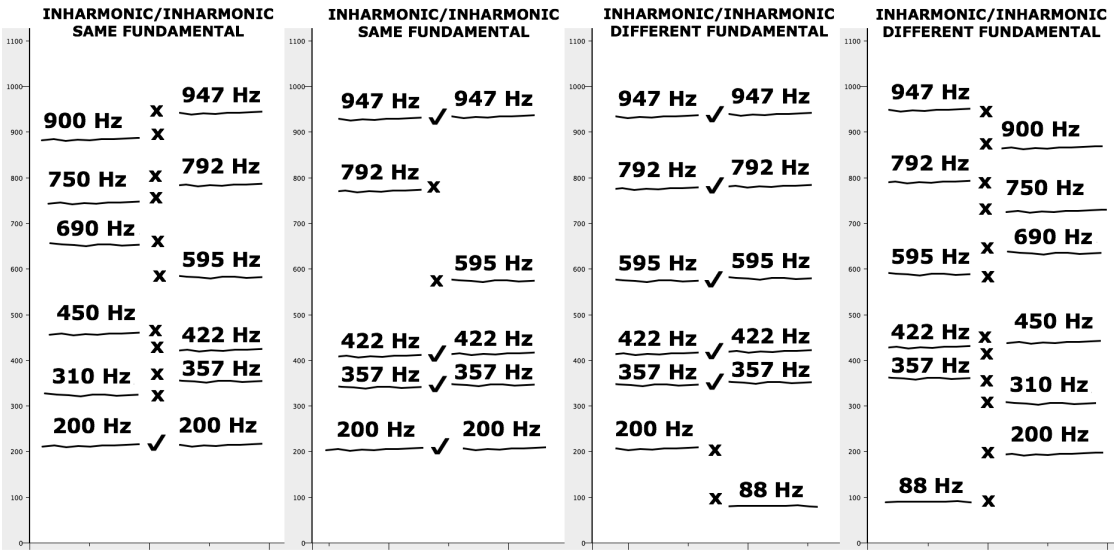

Figure 109 - Spectral Overlap: Inharmonic on Inharmonic Spectra

As the four hypothetical examples of Figure 109 indicate, it is possible for the juxtaposition of two inharmonic spectra built over different fundamentals to exhibit high levels of spectral overlap. In fact, they are among the highest in the context of all three previous figures.

Given its origin as a technique of speech synthesis, it is not surprising that LPC is particularly well equipped to deal with harmonic or quasi-harmonic tones with varying degrees of harmonicity. The separation of an assumed source and filter under the LPC model (Figure 110), largely frees this sort of cross-synthesis from the concerns of spectral overlap described above.

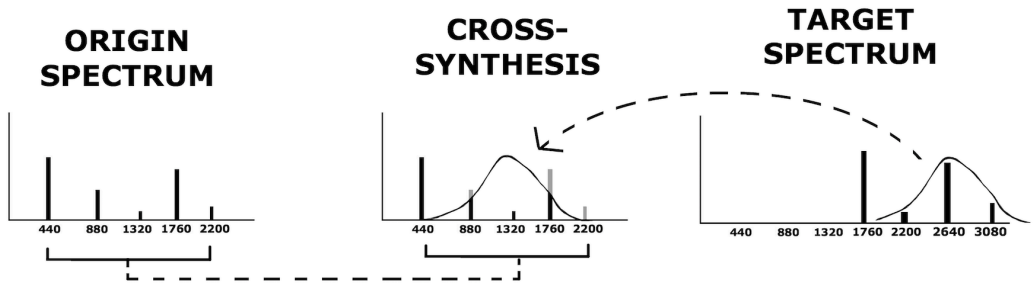

Figure 110 - Source-Filter Separation in LPC Cross-Synthesis

The assumed presence of a source and filter help LPC-based methods of cross-synthesis to cope with a wide variety of pitched and quasi-pitched materials. However, this same assumption makes it less suitable for the analysis and cross-synthesis of more complex waveforms.

In a practical sense, additive techniques of audio morphing that involve the manipulation of spectral peaks through analysis and re-synthesis are even less dependent on spectral context. No overlap at all is required in order to interpolate between the peaks of any two given spectra; whether they be short, long, harmonic, similarly pitched, or even pitched at all. Any pair of frequency and amplitude values corresponding to the peak of one sound can be interpolated to any other pair from the peak of any other sound. Consider the extreme case (Figure 111) of the following interpolation between white noise and a delicate flute tone.

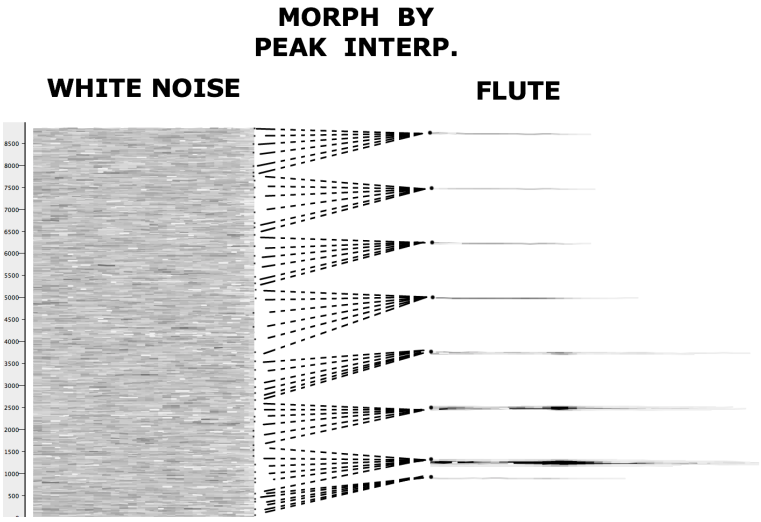

Figure 111 - Interpolation of Dramatically Contrasting Spectra

Even in exaggerated cases such as white noise, with its infinitely dense field of frequency components, a sufficient number of peaks may be selected for interpolation to the (likely much more sparse) spectral content of the subsequent sound.

While no *technical* obstacles stand in the way of such dramatic additive morphs, certain perceptual and musical difficulties arise. In general, it is difficult to convincingly interpolate between two sounds the more they vary in character. Results become more satisfying as the distance between peaks decreases. The interpolation of two harmonic spectra built over the same fundamental is particularly effective (Figure 113), as the morph simply becomes the re-weighting of harmonic content with no pitch glissando at all.

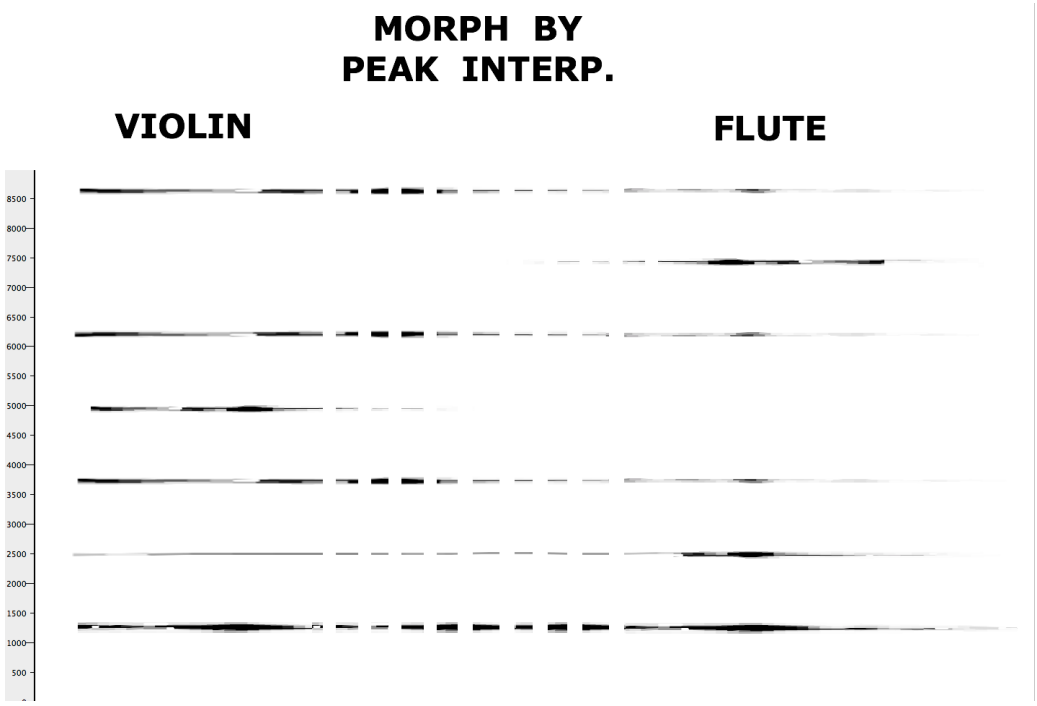

Figure 112 - Interpolation of Similar Spectra

The presence of a common fundamental for the two sustained, pitched, and harmonic sounds acts as a perceptual frame of reference during such morphs.

This perceptual foundation is analogous to persistence of vision in video morphs. Specifically, the reliance on the visual frame of a human face (and specifically the consistent placement of the subjects' eyes) has been described as the equivalent of using

two clearly pitched sounds on a common fundamental[192]. The morphing of such a sound to one that is much more spectrally complex on the other hand, has been described by Cort Lippe as more akin to a video morph between "a face and mack truck"[193].

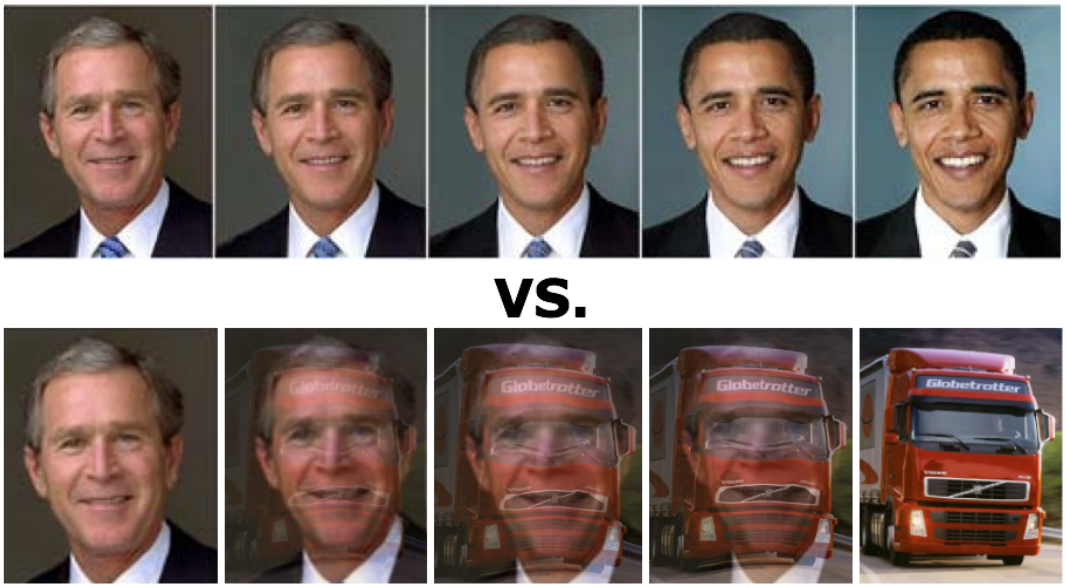

Figure 114 - Illustration of Lippe`s Visual Analogy

Comparing the disparate levels of continuity from the visual example of Figure 114, and the aural examples of the previous two figures confirms this assessment.

Given the existence of such a vast collection of morphing techniques and perceptual considerations, the value of a hybrid and/or context dependent approach is difficult to overstate. In Chapter 1, the impossibility of finding a single, unambiguous definition for the audio morph was described on a semantic level. The contents of the present chapter further emphasize this difficulty on a technical level.

Having thus defined the technical terminology and current landscape of audio morphing software, the key figures and writings may now be addressed in a loosely chronological order.

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[192] Cort Lippe drew the following analogy during a lecture from the 2009-10 session of his graduate computer music seminar at the State University of New York, Buffalo (Lippe, "The FFT").

[193] Lippe, "The FFT".

3.5 An Overview of the Literature

Given that the following researchers and composers have continued to explore issues related to audio morphing over the course of long (and in many cases ongoing) careers, a strictly linear chronology is not possible. The admirable tendency of practitioners in this field to consistently cite the existing literature and data however, suggests one attempt to understand these developments along some sort of loose historical trajectory. It is important to note however, that individual researchers were often tackling these issues concurrently, and that the diversity of the subject matter is also reflected through highly individualized approaches. It is possible however to establish a fairly definitive foundation for audio morphing research in the work of two early and frequently cited figures: John M. Grey and (the recently deceased) David L. Wessel.

3.5.1 The Literature of Morphing Software I – Early Timbral Research

Klangfarbenmelodie will be addressed in Chapter 5, whereby a transformation of timbral materials analogous to audio morphing can be achieved in purely acoustic media. The types of morphing described in the present chapter however, all rely on tools of digital audio manipulation. A bridge between these two eras of timbral composition can found in the psychoacoustic studies of timbre perception initiated by figures such as American researchers John M. Grey and David L. Wessel.

Though Grey was a member of the music department at the time of his 1975 Stanford University report *STAN-M-2: An Exploration of Musical Timbre*[194], the document is a work of pure psychoacoustic research. Describing results for a total of 8 experiments, the report deals with how timbre is perceived by human test subjects, and how those findings can be graphed onto a multi-dimensional ***timbre-space***.

The notion of a timbre-space involves plotting various simplified instrumental tones (synthesized according to Grey's empirically verified perceptual criteria) on a graph. Because many factors contribute to the perception of timbre, such a space can rise into higher numbers of dimensions than can be visualized. Grey however, limits himself to three dimensions, which he describes as follows.

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[194] John M. Grey, *An Exploration of Musical Timbre*. Stanford University Report: STAN-M-2, 1975.

> "One dimension [is] related to the *spectral energy distribution*, while the other two [are] related to the temporal pattern of the attack and decay of the tones, namely, the presence of *low-amplitude, high-frequency energy* in the initial attack segment and the presence of *synchronicity* in the attacks and decays of the higher harmonics"[195]

According to these three dimensions, Grey plots the locations of his sixteen synthesized instrument tones[196]. The wall and floor of the three-dimensional space (Figure 115) show the two-dimensional "shadows" cast by each instrument.

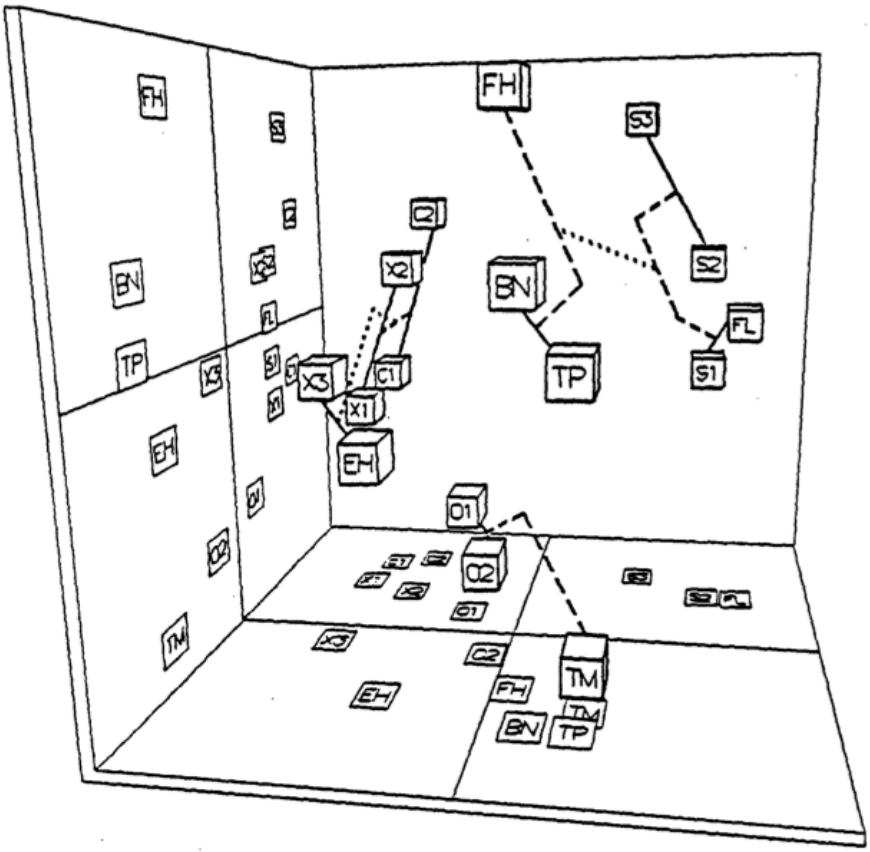

Figure 115 - Grey: Timbre Space

While earlier psychoacoustic research into timbre exists, Grey's relevance to the study of audio morphing software lies in the design of the final four experiments of *STAN-M-2*. With these experiments, Grey probes the areas of the timbre space that lie

[195] Grey, *Musical Timbre*, 67.

[196] Ibid., 62.

between instruments . His primary concern is determining whether the perception of timbre is categorical or continuous. He describes this distinction as follows.

> "If perception were *continuous* in the timbre space, then a set of tones generated by a regular acoustical interpolation between two familiar instrumental notes in the space would be heard as a gradually changing transition in timbre between the two extremes. If timbre perception were *categorical*, however, then the acoustically even interpolation would be perceived discontinuously, suddenly jumping from the first tone to the second tone, the tones in between all taking the identities of one of the two extreme tones, with little or no ambiguity even in the center of the transition."[197] [italics Grey's, bolded emphasis mine]

The experimental use of multiple, individual, tones (rather than a single sustained/evolving timbre) are a consequence of the psychoacoustic importance ascribed to attack and decay in Grey's research. In order to perceive changes in attack and decay, they must be heard repeatedly during the interpolation process. Grey utilizes an eight step interpolation, as seen graphically below (Figure 116) in a synthesized string to french horn transition[198].

[197] Ibid., 75.

[198] Ibid., 78.

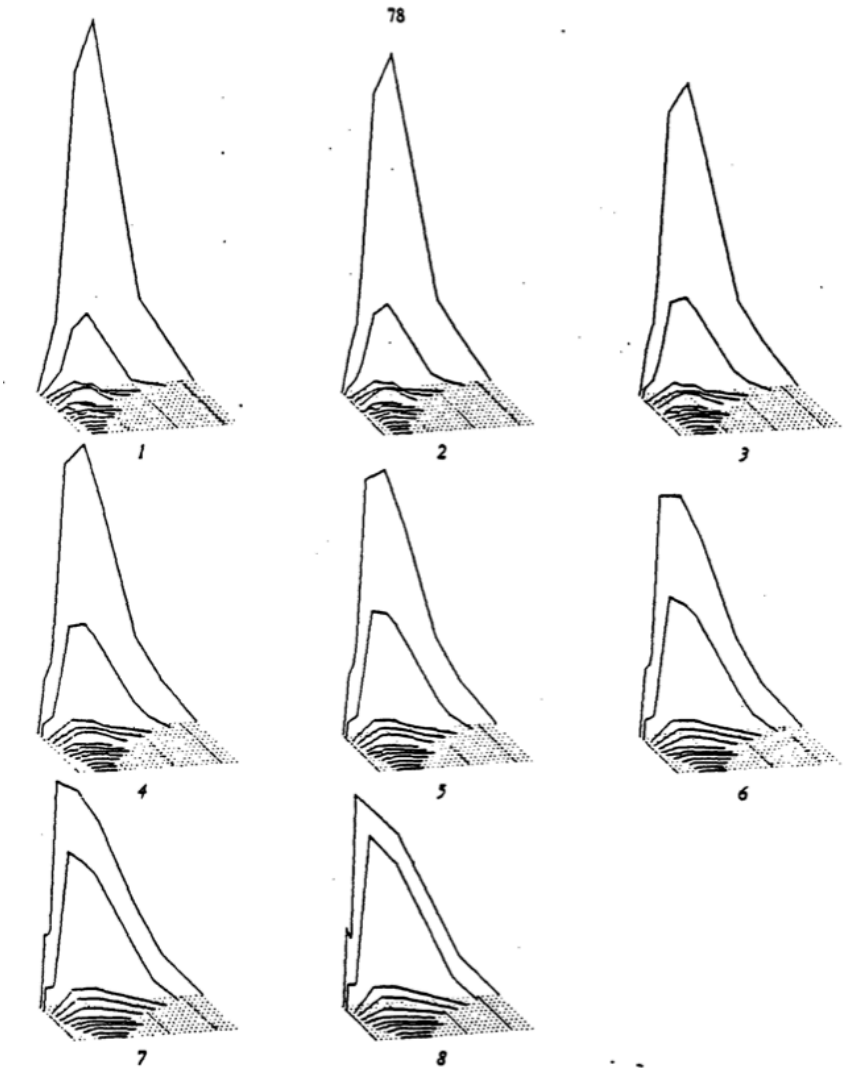

Figure 116 - Grey: Synthesized Morph

Through these experiments, Grey concludes that timbre and instrument identity *are* in fact perceived continuously. Summarizing his findings, he states:

> "The lack of sharp categorical boundaries and the ***sensitivity to context*** of the identification functions would suggest that, strictly defined, these transitions are not perceived categorically."[199] [emphasis mine]

Thus, not only has Grey utilized 1975 analysis and re-synthesis software to create early audio morphing effects, but he has also provided empirical proof of the perceptual continuum on which all morphing takes place. Furthermore, the fact that these

[199] Ibid., 82.

interpolation experiments require a timbre-space of many dimensions in order to be realized, is further evidence to support a fluid definition of the audio morph. Emphasizing this quality of timbral multi-dimensionality and the fact that any given transition is only one of many possible interpolations Grey states:

> "In that an interpolation is generated through multidimensional physical space in the case of timbre, there exist many paths between two given points, and the selection of some particular algorithm is only the selection of one particular path… ***There are no naturally occurring interpolations between discrete musical instruments***, and we have little experience with the concept of transitions in this domain."[200] [emphasis mine]

Despite the vast creative possibility of these findings, Grey's report is not concerned with compositional outcomes. Four years later however, American researcher and composer David L. Wessel would continue Grey's research at IRCAM (utilizing Grey's synthesis data) to suggest a role for timbre space as a compositional resource. In his 1979 article: "Timbre Space as a Musical Control Structure"[201], Wessel draws an analogy between pitch structures and his proposed timbral structures.

> "Composers frequently make transpositions of pitch patterns. It seemed natural to ask if *transpositions of timbral sequences* work as well."[202]

In order to pursue the compositional analogy of transposition, Wessel designs a psychoacoustic test to determine whether or not the notions of proportion and pattern are transferable from pitch space to timbre space. Presenting listeners with timbres A, B, and C, Wessel poses a question along the following lines: if timbre A is to timbre B as timbre C is to timbre D, which of the following four options is the most ideal timbre D[203]? The four possibilities for timbre D vary in closeness to the actual location of the ideal point D in timbre space, represented visually in Figure 117.

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[200] Ibid., 76.

[201] David Wessel, "Timbre Space as a Musical Control Structure" [1979], *Computer Music Journal,* Vol. 3, No. 2 (June 2007): 45-52.

[202] Wessel, "Timbre Space", 50.

[203] Ibid.

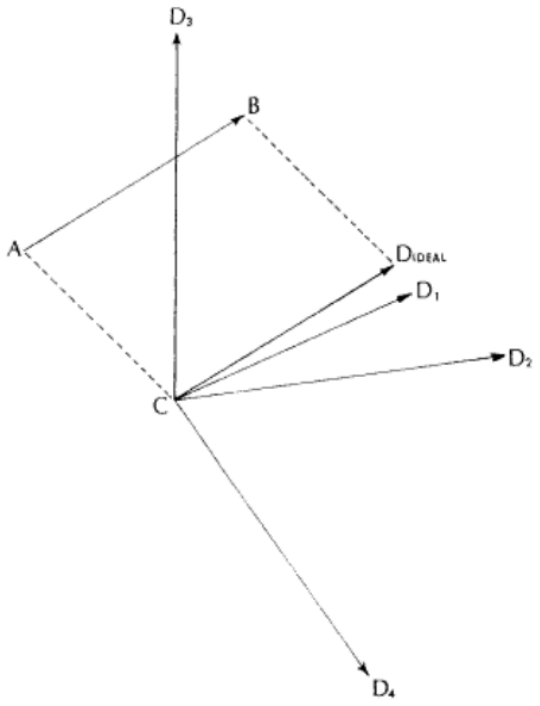


Figure 117 - Wessel: Design of 1979 Experiment

The results of Wessel's experiment confirm that the concept of timbral transposition is in fact perceptually valid. Human test subjects consistently chose the hypothetical point D that was closest to the ideal point of D.

Such a proof is empirical evidence that a classification of timbre (as plotted in a multi-dimensional timbre space) may be used as the terrain within which musically meaningful structures can be built. To this end, Wessel describes his compositional experiments and plans for electroacoustic performance utilizing control over the dimensions of timbre space. Despite the fact that no musical excerpts are provided, the development and use of timbre space software has been undertaken for both electronic performance and pre-compositional planning in the music of Wessel and other composers.

In particular, American/Canadian composer John Celona[204] has developed a suite of software called TimbreSpace, based on the research of Grey and Wessel. The real-

[204] "[Celona] has been active in the development of integrated media software used in electroacoustic composition and performance, and has created a realtime music composition, orchestration, analysis and performance software for the Macintosh platform, called TimbreSpace." (Gary J. Hayes, "John Celona,"

time sound synthesis capabilities of this software have been highlighted recently through Celona's live performances as a member of the Canadian electroacoustic trio: The Krells[205]. However, the suite has also been employed extensively as a compositional and pre-compositional tool for crafting works that employ traditional instrumentation. Celona identifies *Basilica Nuova: per sax tenore e sei strumenti*[206] as the best such example of acoustic music created with the assistance of TimbreSpace[207].

Digital sketches from the composition of *Basilica Nuova* are included in the 1996-7 TimbreSpace documentation[208], which features screen captures showing how three dimensional plots similar to those employed by Grey and Wessel can be used to organize combinations of up to 37 unique orchestral instruments. For the purposes of *Basilica Nuova*, only the six instruments of the Ex Novo Ensemble di Venezia are plotted, as in Figure 118[209].

The Canadian Encyclopedia, accessed January 28th 2015, http://www.thecanadianencyclopedia.ca/en/article/john-celona-emc/.

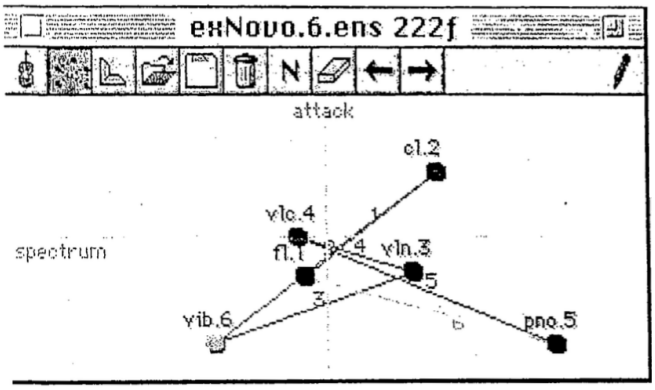
[205] The other two members of The Krells are: "Kirk McNally (Max/MSP audio processing and spatialization) and Daniel Godlovitch (manning the Buchla synth)." from "The Krells", The Krells' personal website, accessed January 28, 2015, http://www.thekrells.com.

[206] John Celona, *Ouverture* (Venice: Ex Novo Ensemble di Venezia, 1998), compact disc.

[207] Email to the author, dated January 29th, 2015 (heretofore: John Celona, "Email correspondence with author", January 2015.)

[208] John Celona and John Wright, *Users Guide for TimbreSpace v2.0.1* (Self Published, 1996-7).

[209] Celona, *Users Guide*.



Instrumentation for the Ex Novo Ensemble
di Venezia (Claudio Ambrosini, director):
1 flute
2 clarinet in Bb
3 violin
4 violoncello
5 piano
6 vibraphone

Imaged according to spectrum and attack

Figure 118 - Celona: Timbre Space for Ex Novo Ensemble

The software's ability to scale and rotate these diagrams enabled Celona to map out "ensemble relationships represented by different line connections"[210], such as those found in Figure 119.

[210] Celona, *Users Guide*.

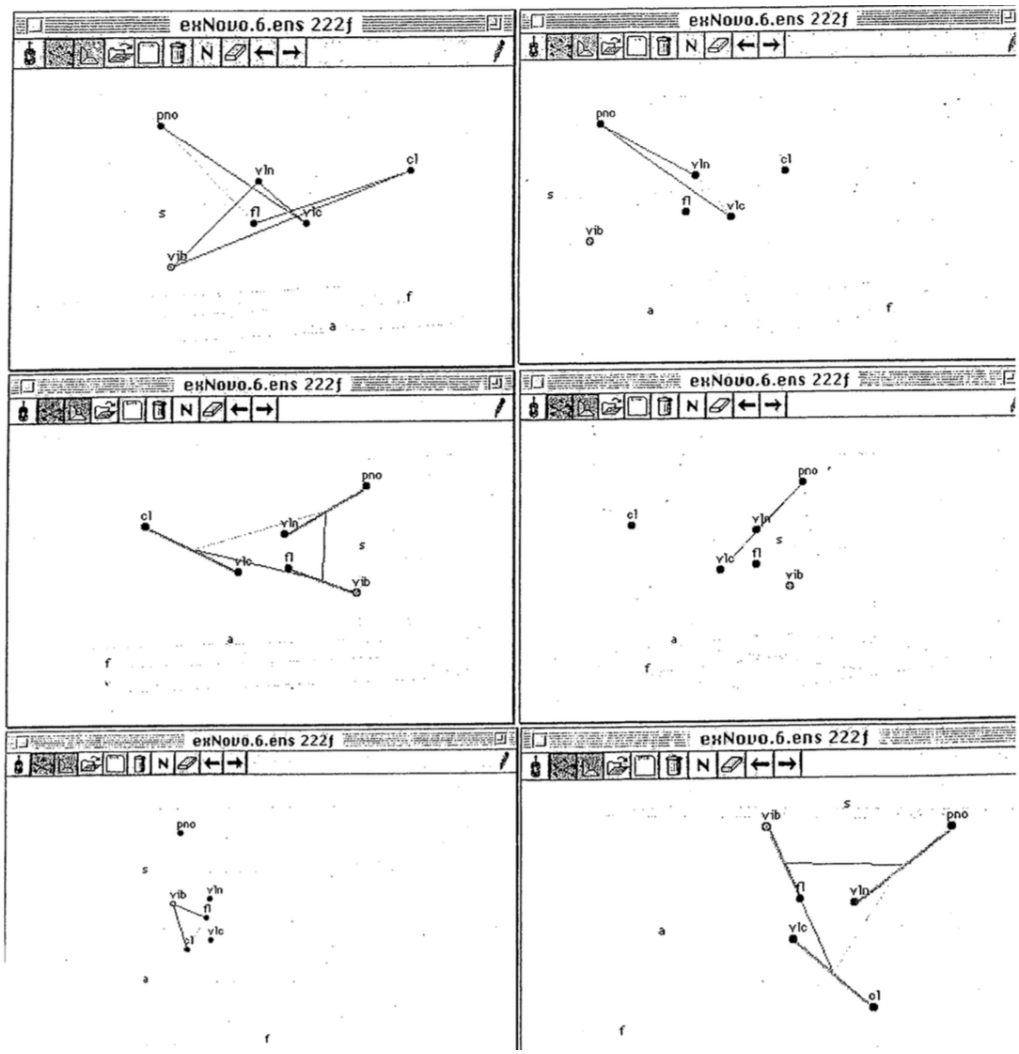


Figure 119 - Celona: Networks of Timbral Relationship

These relationships map out the orchestration of the work (Figure 120), presented in a subsequent diagram as a time-coded summary (located below the playbar) and colour-coded realization (plotted on the four staves containing pitch material derived from "an amplitude modulation waveform created in the Modulation Generator Window"[211]).

[211] Celona, *Users Guide*.

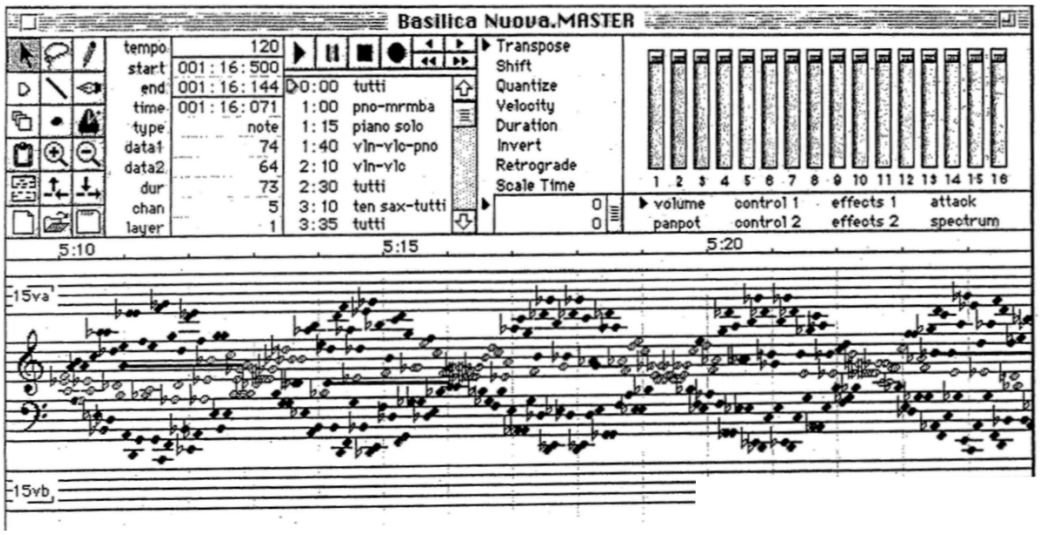


Figure 120 - Celona: Basilica Nuova (Digital Sketch)

Finally, this midi data can be output to conventional notation software such as Finale (as in Figure 121 below).

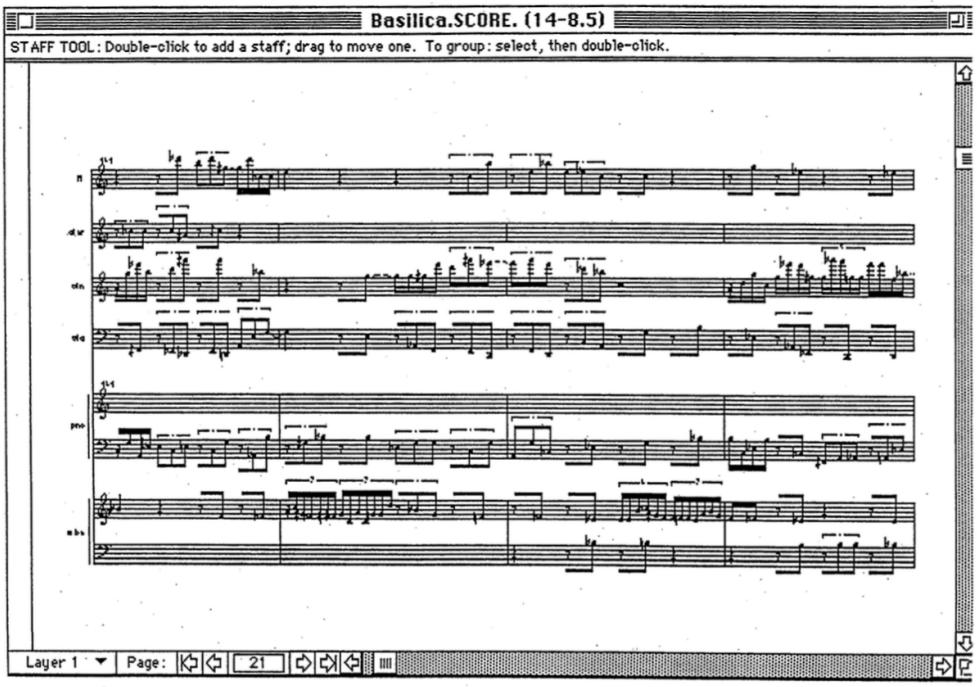


Figure 121 - Celona: Basilica Nuova (Score)

Note the contour of the above waveform visible in the outlines of both the pitch material, and deployment of the various instruments.

Basilica Nuova is a particularly clear manifestation of the musical possibilities inherent in the (seemingly) pure technical work of early timbral researchers. Another important figure to consistently emphasize this compositional context for acoustic research is Trevor Wishart.

3.5.2 The Literature of Morphing Software II – The Compositional Context

Contributions to the literature of musical morphing and morphology from English composer, writer, and software developer Trevor Wishart were discussed in Chapter 1. Wishart's philosophical basis for a pursuit of audio morphing technology was also discussed in terms of its influence on my compositional activity during the previous chapter. Distinct from these topics, Wishart has also written on the purely technical aspects of audio morphing, especially in the 1994 book *Audible Design*[212].

Despite this technical rigour, or perhaps as a result of his primary role as a composer, Wishart emphasizes the phenomenological aspects of audio morphing even in technical discussions. This emphasis on perception leads Wishart to describe the process of morphing (referred to as "interpolation" in *Audible Design*) according to a linear perceptual scale reminiscent of the Caetano morphing index, or Grey's continuous interpolations. More in keeping with Caetano than Grey however, Wishart's linear interpolation index also corresponds to techniques that are themselves likely to be non-linear.

> "Achieving a successful interpolation is about creating convincing, small *perceptual* changes in the resulting sounds – not about the internal mathematical logic that produces them. To achieve an approximately linear sense of interpolation along a set of sounds may require a highly non-linear sequence of processing parameter values."[213]

The entire 12th chapter of *Audible Design* ("Interpolation") is dedicated to techniques of audio morphing. Wishart defines interpolation as a transition between two

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[212] Wishart, *Audible Design.*

[213] Ibid., 102.

sounds distinct from a simple time-domain cross-fade, in that both signals are acting upon each other. Again, the role of perception is highlighted.

> "We wish to achieve some sense of perceptual *fusion* between the two original percepts – a mere superimposition of one over the other is not acceptable as an interpolation... [what is important is] feeling that we have moved away from one type of sound and arrived at a different type."[214]

Simple time domain mixing or blending is ineffective because:

> "...our brain manages to unscramble the many sound impinging on our ears at any time and to sort them into separate sources. We hear mix, not fusion. This is due partly to the ear's sensitivity to onset synchronicity (or the lack of it) and partly to the parallelism of micro-fluctuations of the components in any one source, at the same time being different from that in other sources."[215]

As described in the excerpts from *On Sonic Art* cited in Chapter 1, Wishart regards the study of all composition as some form of morphology. A distinction between this sort of general musical morphology and audio morphing as described in *Audible Design* however, is framed not only by the above descriptions of perceptual effect, but also in terms of raw material.

> "All compositional processes might be described as so many sophisticated variants of interpolation. However, in this chapter we will deal largely with compositional processes which interpolate between two (or more) *pre-existing* sounds."[216]

Wishart goes on to say that the additional technical foundations of interpolation are "modifications to onset characteristics, [and] the rate of spectral change"[217], the exact quantities by which Grey and Wessel set out to define their timbre spaces.

Having thus established the scope of interpolation, Wishart categorizes all of his techniques of interpolation as either static or dynamic. Much like the synthesized examples of instrumental morphing prepared for psychoacoustic experimentation by Grey (see the final Grey figure above), static interpolation involves the synthesis of

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[214] Ibid., 96.

[215] Ibid., 98.

[216] Ibid., 96.

[217] Ibid., 97.

intermediate "steps" that span a continuum between two sounds, but are not themselves in a state of continuous change. The composer in this case will:

> "...create a whole set of sounds, whose properties are intermediate between those of the source and those of the goal. We will describe this mediation by progressive steps as *static interpolation*."[218]

Dynamic interpolation on the other hand, is described by Wishart as follows.

> "Alternatively, provided our sound is sufficiently long, we may gradually apply a compositional process changing the value of various parameters through time... In these cases we have a process of *dynamic interpolation* taking place through the application of a continuously time-varying process."[219]

Having established the context and content of interpolation, Wishart goes on to describe three techniques of audio morphing. The first is akin to the linear predictive coding (LPC) based cross-synthesis illustrated previously. Wishart ascribes the success of this type of cross-synthesis to the fact that partials and formants are not perceived in a unified fashion.

> "The distribution of partials in a spectrum (spectral form) and the spectral contour (formants) are separable phenomena and impinge differently on our perception... we can impose the formant variation of the first [sound] on the spectral form of the second to create a dual percept."[220]

Wishart then provides an illustration to clarify the procedure[221], reproduced below as Figure 122.

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[218] Ibid., 96.

[219] Ibid.

[220] Ibid., 100.

[221] Ibid.

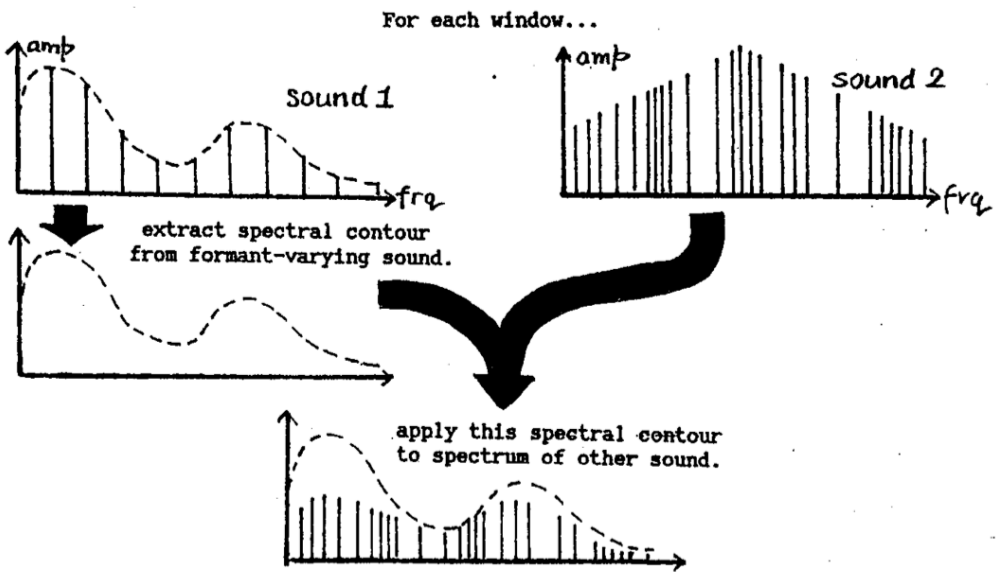

Figure 122 - Wishart: Formant Based Cross-Synthesis

The second technique of interpolation – spectral masking – is reminiscent of the technique described as the interleaving of spectral peaks in the present study. Here, Wishart's sentiment is in agreement with the author's that such a technique is not (in the strictest sense) a true interpolation, in that it is essentially additive.

> "Another way in which we can achieve interaction between the spectra of two or more sounds is via *spectral masking*. Here we construct a goal sound from the spectra of two (or more) source sounds by selecting the loudest partial on a frequency-band by frequency-band basis for each time window... This technique should, in general, be regarded as a form of spectrally interactive *mixing*, rather than interpolation in the true sense."[222]

Finally, the technique of spectral peak interpolation defined earlier in this chapter was also described as spectral interpolation by Wishart in his 1994 text. Both Wishart and the present study agree on the role of frequency and amplitude "wobble" or "jitter" (respectively) for each component of the interpolated spectrum. Wishart describes how interpolating between the *difference* in source and destination pairs of amplitude/frequency data rather than the values themselves can allow for each sound's distinct fluctuations to be preserved.

[222] Ibid., 101.

> "The most satisfactory form of dynamic interpolation is achieved by interpolating progressively between the time-changing spectra of two sources. (s*pectral interpolation*)... It is important to understand that we are interpolating over the *difference* between the values in successive windows. We are moving gradually away from the *current* value in sound 1 towards the *current* value in sound 2... a linear translation between two static spectral states, would produce merely a spectral glide perceptually disconnected from both source sounds. Our process, in contrast, is moving from the 'wobbling' of one spectrum into the 'wobbling' of the other."[223]

A final instance in which the present study has echoed Wishart's 1994 book, can be found in the role ascribed to compatibility of source and destination sounds. Wishart describes this as an issue of perceptual similarity.

> "It is also important for the two sources to be perceptually similar (e.g. same pitch, similarly noisy), if the seamless transition is to be achieved without intervening artefacts which either suggest a third and unrelated physicality/causality in the sound, or even reveal the mechanics of the process of composition itself."[224]

With three books, many shorter publications, and decades worth of musical compositions; Wishart is by far the most prolific author/composer dealing explicitly with the subject of musical morphology: both in general and specialized technological contexts. Though plans exist to port his audio software to the current industry-standard *Max/MSP* environment, it is presently available as an open-source download[225].

3.5.3 The Literature of Morphing Software III – Surveying the Landscape

Much as Wishart drew his main inspiration from vocal production, former Princeton University computer scientist Perry R. Cook also establish a link between these phenomena and audio morphing software. Like Wishart, Cook regards the flexibility of the human vocal apparatus as a natural model for audio morphing, in contrast to the more physically and sonically rigid instruments of the western tradition. However, in the 1998

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[223] Ibid.

[224] Ibid., 102.

[225] "*Sound Loom* Download," Desktop Composers Project, accessed November 21st, 2014, http://www.composersdesktop.com.

DAFX paper cited in Chapter 1, he also identifies a second more practical link between vocal production and audio morphing developments.

> "In modern times, computer music composers have time and again been attracted to vocal sounds and processing. Part of this is due to the legacy of computer music tools, with many of them arising from the great speech labs of the world."[226]

As discussed in Chapter 1, Cook's oft-cited 1998 paper is essentially a survey of potential techniques for the morphing of audio. The seven techniques that constitute this survey are summarized in Table 9.

Spectral Subband Vocoders
Linear Prediction
Frequency Modulation
Formant Wave Functions - FOF
Formant Filter Models
Sinusoidal Models
Acoustic Tube Physical Models

Table 9: Cook's Seven Morphing Techniques

While Wishart divided his techniques into classes of static and dynamic morphing, Cook discusses his selection of techniques in terms of a spectral vs. physical dichotomy. In essence, these two categories correspond to how audio morphs are either created or heard.

> "Synthesis models can be loosely broken into two groups: Spectral models, which can be viewed as based on perceptual mechanisms, and physical models, which can be viewed as based on production mechanisms."[227]

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[226] Cook, "Audio Morph?", 1.

[227] Ibid., 5.

Of the techniques discussed previously in this chapter, both LPC and DFT -based cross-synthesis could fall into Cook's category of physical models. While the physical nature of LPC cross-synthesis is implicit in the required source/filter separation, DFT based cross-synthesis also falls into the physical category only because Cook exclusively employs it for the modelling of filters approximating vocal formants. In a more abstract sense, it might more accurately be described as a spectral model.

Aside from LPC and DFT -based techniques, the only other method described by Cook that can not fit neatly into the category of spectral modelling is the use of Acoustic Tube/Physical Models.

Similar to the LPC separation of source and filter, physical models attempt to approximate the action of the human vocal apparatus. Again, vocal formants are simulated through the application of filters designed to mimic the vocal tract. Cook points out that the efficiency of this method arises from the fact that only one dimension (longitude) of the system need be modelled.

> "The one dimensional approximation is justified by noting that the length of the vocal tract is significantly larger than any width dimension, and thus the longitudinal modes dominate the resonance structure up to about 4000 Hz. Modal standing waves in an acoustic tube correspond to the formants."[228]

As apparent in the following diagram from Cook's paper (Figure 123), the approximation of the vocal tube occurs as connected cylinders of varying diameter (rings).

[228] Ibid., 4-5.

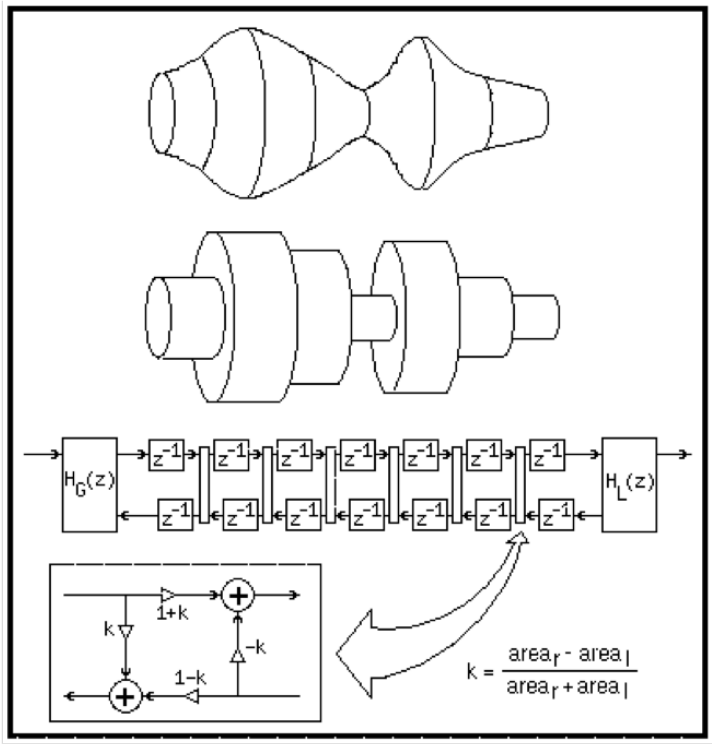

Figure 123 - Cook: Acoustic Tube Model Diagram

As in actual vocal production, portions of the filtered signal emanating from each segment of the tube travel both forwards and backwards due to partial reflection. This phenomenon is responsible for the non-linearity of formant resonance and is illustrated by the schematic at the bottom of the figure[229].

Within Cook's category of spectral synthesis models, two have been dealt with previously in this chapter. Cook's Sinusoidal Models correspond to the technique of spectral peak interpolation (or simply spectral interpolation in the writings of Wishart). Furthermore, the technique of Formant Wave Function (abbreviated FOF from the French original) corresponds to the use of IR based cross-synthesis described earlier in the chapter. The main difference however, is that Cook's FOF technique is a time-domain implementation, as illustrated by Figure 124 below[230].

[229] Ibid., 5.

[230] Ibid., 4.

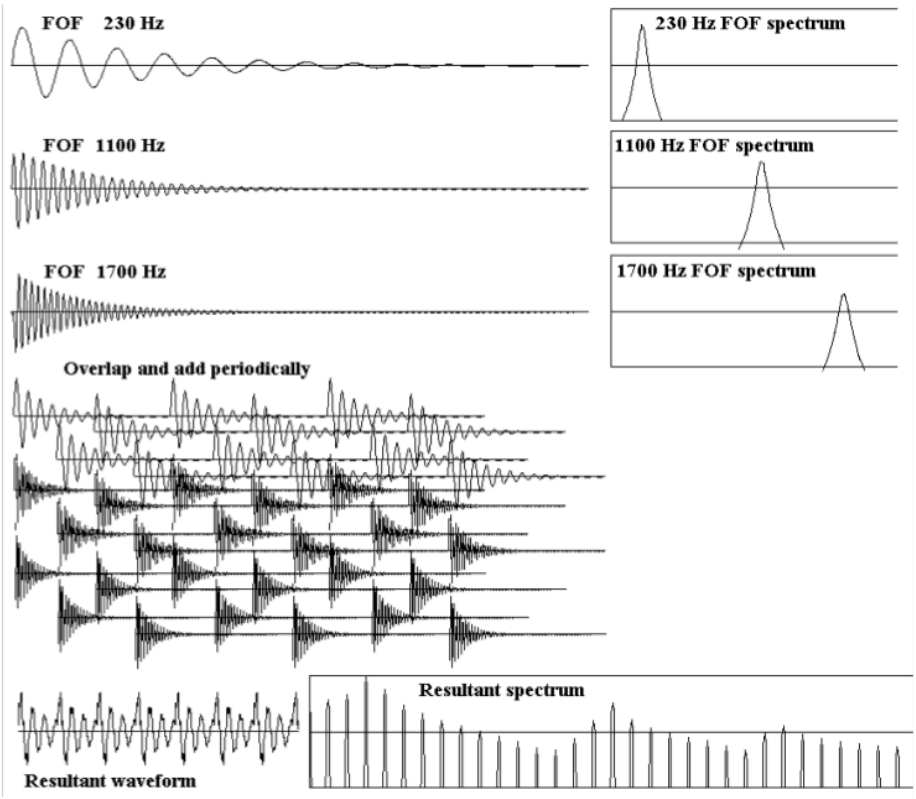

Figure 124 - Cook: FOF Diagram

Finally, the Spectral Subband Vocoder is an older hardware application designed specifically to analyze and synthesize the human voice. Unlike the more clearly physical models described above however, spectral data is assessed in uniform frequency bands rather than variable formant regions. This shared characteristic (the use of frequency bands/bins) is why the phase vocoder derives its name from the older technology, despite its use of DFT analysis rather than source/filter separation. Cook clarifies the distinction.

> "Unlike the channel vocoder, the phase vocoder does not perform an explicit source/filter decomposition, and there is no parametric model of the source. The phase vocoder does not strictly assume that the signal is speech, and thus can generalize to other sounds. For this reason, the phase vocoder has found extensive use in computer music composition."[231]

Though included by Cook as a spectral technique for the synthesis of vocal sounds, Frequency Modulation (FM) has no direct application to the realm of audio

[231] Ibid., 2.

morphing. Cook identifies the impossibility of continuous vowel/pitch change, parametric analysis of a source, and cross-synthesis as the primary limitations of FM in a morphing context.

> "In order to generate a harmonic voice spectrum using FM synthesis, the carrier frequencies must be integer multiples of the fundamental modulator frequency. For this reason, it is impossible to generate vocal sounds which smoothly vary arbitrarily from vowel to vowel, or from pitch to pitch on a single vowel. **Also, there is no closed-form analysis technique for identifying FM parameters to yield an identity resynthesis of an arbitrary sound.**" (emphasis mine) [232]

Cook's inclusion of FM synthesis in an article on audio morphing clearly establishes his secondary (and explicit) aim in of exploring the synthesis and manipulation of vocal sounds[233]. In contrast to this specialized application, other computer scientists such as Naotoshi Osaka have explored morphing algorithms in their most general sense.

3.5.4 The Literature of Morphing Software IV – Refining Algorithms

Japanese composer and computer scientist Naotoshi Osaka has contributed a great deal to the field of timbral morphing and composition[234]. While Osaka has published papers on the algorithmic classification of timbre for the development of notation and reverse-lookup databases[235], it is his companion papers on sinusoidal models of audio morphing that are of primary interest to the present study.

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[232] Ibid., 3.

[233] It is also a testament to the wide adoption of the technique in music making, in the realms of both instrument design (such as the technology behind the popular Yamaha DX7 synthesizer), and musical composition (such as John Chowning's 1977 composition *Stria*). For more on the former, see: John Chowning, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation," *Journal of the Audio Engineering Society*, Vol. 21, No. 7 (1973): 526-534; and for more on the latter, see the special issue of *Computer Music Journal* dedicated to the work's thirtieth anniversary: Douglas Keislar, ed. "The Reconstruction of "Stria"," *Computer Music Journal,* Vol. 31, No. 3 (2007): 23-81.

[234] In particular, his influence on Marcelo Caetano's work has been substantial.

[235] Naotoshi Osaka, "Toward Construction of a Timbre Theory for Music Composition," *Proceedings of the ICMC* (2004): 1-4; deals with the development of a timbral notation arising from computer analysis, while Naotoshi Osaka, "An Electronic Timbre Dictionary and 3D Timbre Display," *Proceedings of the ICMC* (2008): 9-12; describes Osaka's creation of a sound database catalogued according to timbre classification rather than verbal description.

The first of these papers, "Timbre Interpolation of Sounds Using a Sinusoidal Model"[236], appeared in 1995. Because the focus of Osaka's research is much tighter than that of the previous figures (he uses only a single morphing technique – that of spectral peak interpolation) the technical depth of his work is much greater. In addition to the detailed interpolation algorithms included in Osaka's morphing papers, he also goes into greater detail in defining the sinusoidal components of a given sound.

> "Partials are classified into four categories.
>
> 1. harmonics (quasi harmonics)
> 2. auxiliary harmonics
> 3. inharmonics
> 4. residual
>
> Harmonics (hereafter including quasi harmonics) generally have large magnitude and duration... Auxiliary harmonics are defined as partials with middle level and duration time, the frequency of which is either as an integer or a half multiple of fundamental frequency. These are observed in the beginning and the end of the sound.... Inharmonics contribute a lot to timbre. The rest of the partials are defined as residuals. The number of residual partials are much greater than the other three classes. The residuals are noise, and level and duration of each partial are relatively smaller than the other three classes thus its not meaningful to study each sinusoid perceptually."[237]

By classifying the components of a sinusoidal model according to these factors, Osaka introduces the concept of perceptual relevance, which has had a noted influence on the work of Marcelo Caetano.

Following analyses according to the above guidelines, "partials among the same class are interpolated"[238], ensuring that the transition will be as perceptually logical as possible. Such an approach also simplifies sinusoidal morphing, in that the components of a sound analyzed as residual "noise", are treated as they are perceived: a stochastic mass of indeterminate makeup. This assessment greatly reduces the necessary level of control and manipulation.

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[236] Naotoshi Osaka, "Timbre Interpolation of Sounds Using a Sinusoidal Model," *Proceedings of the ICMC* (1995): 408-411.

[237] Osaka, "Timbre Interpolation", 409.

[238] Ibid.

Osaka extended the reach of his perceptual hierarchy while refining his 1995 algorithm in a 2005 *ICMC* presentation[239]. Here the algorithm takes on dimensions of control analogous to part-writing rules in traditional music. In Osaka's words

> "The algorithm is modified... so that it finds appropriate correspondence for various patterns of peak displacements among two successive frames."[240]

The visual origin of audio morphing technologies is once again foregrounded as Osaka describes the necessity of a sophisticated algorithm for this task in the aural realm.

> "In image morphing, the first step is to find the corresponding points between the two images. In commercial software, this correspondence is done manually. Similarly in sound morphing, there are many cases when correspondence of represented parameters for two sounds should be found and interpolated. Since so many numbers of parameters are needed in a sinusoidal model, it is not practical to find correspondence manually. Therefore, [an] algorithm to find the correspondence is indispensable."[241]

Though the mathematics utilized by Osaka are beyond the scope of the present study, the visual representations supplied in the paper (Figure 125) clearly illustrate the algorithm's implementation.

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[239] Naotoshi Osaka "Concatenation and Stretch/Squeeze of Musical Instrumental Sound Using Sound Morphing," *Proceedings of the ICMC* (2005): 1-4.

[240] Osaka, "Concatenation", 1.

[241] Ibid.

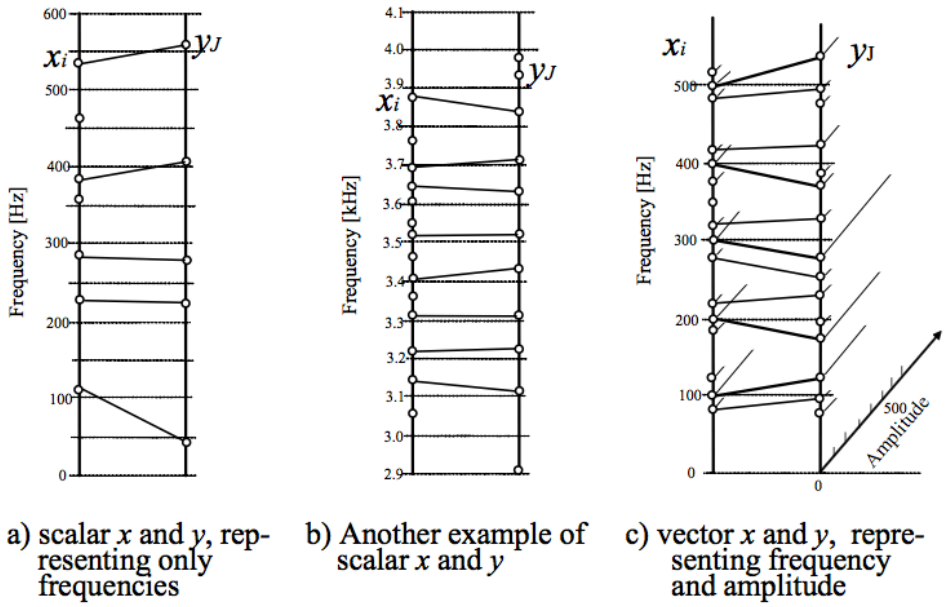

Figure 125 - Osaka: Interpolation Diagram

The matching of amplitude (plotted on the z-axis) is shown in the diagram the furthest to the right.[242] Time is shown along the x-axis, analysis frames are indicated by vertical lines, and frequency values are indicated by empty circles along the y-axis' analysis frames.

With the narrowing of scope in Osaka's sinusoidal morphing research, came an increased degree of the precision in the analysis and implementation of timbral interpolation. Far from being a purely technical exercise however, Osaka has repeatedly emphasized the role of perceptually relevant features. The influence of Osaka's work can be seen in what is by far the most extensive technical document on the subject of audio morphing technologies to date.

3.5.5 The Literature of Morphing Software V – Perceptual Features

Brazilian computer scientist Marcelo Caetano completed his PhD dissertation at IRCAM in 2011. Extending Osaka's method and rigour to encompass the entire field of audio morphing technologies discussed in this chapter (in much greater detail), Caetano's dissertation cited earlier: *Morphing Isolated Quasi-Harmonic Acoustic Musical*

[242] Ibid., 4.

Instrument Sounds Guided by Perceptually Motivated Features is the definitive technical resource on the subject.

While technical in scope and presented in mostly mathematical language, Caetano is quick to point out that the dissertation is rooted in perception. This focus is made clear by the title, the inclusion of several psychoacoustic tests administered by Caetano, and the opening preface.

> "This work is about sounds, not sound waves or waveforms. Sound waves are the pattern of pressure waves that travels in a compressible physical medium, and, as such, sound waves are the subject of acoustics, a brach of physics that studies mechanical waves and phenomena associated with them. When the sound wave reaches our ears, we hear sounds. Sounds are cognitive representations of sound waves resulting from the subjective experience of sound perception."[243]

Though he also goes on to describe his work as a study in signal processing, Caetano is always clear on the point that the information contained within his signals must maintain perceptual relevance.

Despite the compositional interest generated by his work, Caetano is not primarily a composer. His identity as a computer scientist allowed him to engage in a task as problematic as (the present chapter has revealed) audio morphing (to be), from a purely technical perspective. Caetano notes that "even though everybody seems to be very excited about sound morphing for its creative potential, not many people have actually worked on it."[244]

As seen above, this fundamental difference between composer-researchers and pure scientists is manifest through an increased use of formulas, with a decreased selection of musical examples. However, there is also a subtle difference in the *quality* of sonic materials being considered by each group. A modern composer such as Trevor Wishart for example makes frequent musical and pedagogical use of sound sources as disparate as rushing water, slamming doors, buzzing insects, and screaming humans. Caetano on the other hand, is interested in the instruments of the western tradition, with new materials not extending beyond the scope of hybridization.

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[243] Caetano, *Morphing*, 11.

[244] Ibid.

> "The aim of morphing between different musical instrument sounds across perceptually salient timbre dimensions is to obtain sounds that would correspond to hybrid instruments. That is, sounds that seem to come from an instrument that contains characteristics that are intermediate to the original sounds'."[245]

Such is not to say that Caetano's techniques (and especially research contributions) are of limited utility in the more extended musical context of contemporary composition. In fact, quite the opposite is true. The persistence of early speech technologies in the present landscape of audio morphing is a clear demonstration that even seemingly remote technologies may be of great compositional utility.

3.6 Conclusions

Just as the expanded pitch spaces of late Romanticism opened the way to timbral composition for acoustic instruments (to be discussed in Chapter 5), so too has an increased focus on instrumental timbre paved the way for new technologies of sound manipulation. Beginning with the analysis and charting of timbre spaces, the technical means and compositional motivations behind their exploration became increasingly refined. Recent publications from researchers such as Osaka and Caetano have solidified the mathematical foundations of virtually all present techniques for audio morphing.

Far from a linear trajectory however, this development of timbral technology is capable of looping back upon itself, inspiring creative and/or purely acoustic works of a technologically derived nature. The influence of technology on compositional procedures will be discussed in Chapter 6 via examinations of 20th century works from Stockhausen and Grisey (among others).

Having thoroughly addressed various technical and semantic aspects of audio morphing, let us now consider how my personal understanding of musical transformation in purely acoustic music served to inform the composition of *for chelsea smith.*

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[245] Ibid., 65.

4 Pitch Transformation and Morphing Principles

4.1 Introduction

As defined in the Chapter 1, an audio or musical morph occurs when an aural continuum of intermediate material links two distinct sonic entities. This new material is generated through the careful distortion of both entities to resemble each other, so that a seemingly continuous transformation can occur. While the electroacoustic media necessary for the literal execution of this effect were described in the previous chapter, Chapter 2 investigated many purely acoustic adaptations of morphing ***principles*** in my own compositional work. Similarly, in the three following chapters, music of the past will be examined in terms of such transformative principles. Analyses of acoustic transformations in the realms of pitch, trimbre, and form (respectively), have shaped my understanding of musical morphology, and have thereby influenced my compositional activity.

The present chapter deals with how transformational phenomena might be considered within the realm of pitch. Table 10 shows how several examples from composers of the western tradition will be explored according to four main historical periods and styles:

HISTORICAL PERIOD(S)	ORGANIZATION OF PITCH	TRANSFORMATIONAL CHARACTERISTICS	COMPOSERS STUDIED
Pre-Baroque	Modality	Suspension/Resolution of Local Dissonances	Richafort
Baroque/Classical	Tonality	Common Practice Harmonic Modulation	Mozart
Romantic	Extended Tonality	Extreme Chromaticism and Mode Mixture	Wagner, Mahler
Modern	Post-Tonality	Highly Individualized Contextualizations	Berg, Boulez, Xenakis, Tenney

Table 10: Overview of Chapter 4

4.2 Transformations of Pitch in the Common Practice Period

All of the periods listed above employ distinct stylistic rules to govern the treatment of pitch[246]. However, the identities of the first three are united through their common reliance on a dialectic of consonance and dissonance. During these three earlier periods, a constantly evolving yet relatively stable modal/tonal practice underpinned how consonance and dissonance interacted[247]. As indicated by the above table, the embellishment of structural sonorities (consonances) through the temporary appearance of secondary sonic entities (dissonances) can occur in many different ways, and at various structural levels[248]. The following analyses of such temporary disruptions to the overall, consonant pitch structures of modal/tonal music of the past serve to historically contextualize the pitch transformations in my own music. From such a perspective, our definition of musical morphing as the continuous distortion of one sonority into another might be reflected through any appearance of a dissonance that: 1) links two ***different*** consonances (ie. resolves to a different consonant sonority than it departed from), and 2) contains traces of both bordering consonances simultaneously.

Given that the identities of modal, tonal, or extended-tonal syntaxes are inseparably linked to their rules governing consonance and dissonance, various examples of pitch transformation can be found in music from the pre-baroque, baroque, classical, and romantic periods. A few examples representing each of these periods will begin the present chapter. The stylistic/historic trajectory of this investigation will culminate in a disproportionately large treatment of the post-tonal repertoire[249].

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[246] This statement is meant in its broadest possible sense (ie. without recourse to individual, historical, geographical, or cultural context). In a nutshell: I contend that it is possible to distinguish between works of the four representative periods based solely on how pitch is treated.

[247] In his 1965/6 dissertation [Carl Dahlhaus, *Untersuchungen über die Entstehung der harmonischen Tonalität* (1965/6) trans. Robert O. Gjerdingen (Princeton: Princeton University Press, 1990)], Carl Dahlhaus defined common practice tonality with recourse to the earliest known definitions of the term: "In 1844, F.J. Fétis defined "tonality," a term borrowed from Castil-Blaze, as the "set of requisite relationships, simultaneous or successive, among the tones of the scale"" [Dahlhaus, *Tonality*, 3], before going on to note its roots in earlier modal practices "the evolution toward harmonic tonality can best be observed in changes in the function and disposition of cadences" [Dhalhaus, *Tonality*, 4].

[248] See column three of the previous table.

[249] Such an emphasis on the more recent past reflects both the diversity of contemporary compositional practice, and also the composition-centric focus the present study. Earlier periods – employing slightly more universal common practices – will be viewed through the lens of a select few representative figures.

4.2.1 Common Practice Pitch Transformation I – Pre-Baroque Modality

Little biographical information has survived about the Franco-Flemish Renaissance composer Jean Richafort, though his approximate birth and death dates have been narrowed down to c1480 and c1550 respectively[250]. Evidence of his existence in surviving documents generally focuses on his reputation as a composer. In particular, the *Grove Music Online* entry on Richafort mentions "...early editions of Lodovico Guicciardini's *Descrittione di tutti i Paesi Bassi* (1567) [which] placed Richafort in a list of the most distinguished deceased Netherlandish musicians of the preceding generation."[251] This reputation is substantiated by the influence that his work exerted on later generations, such as the motet "...*Quem dicunt homines*, a model of formal clarity, which served as model for parody masses by Divitis, Mouton, Lupus or Pierkin de Raedt, Pseudo-Josquin, Charles d'Argentille, Morales, Vincenzo Ruffo and Palestrina.[252]" There is evidence to suggest that Richafort was a student of Josquin des Prez, whose death in 1521 was commemorated by Richafort in a *Requiem Mass*[253].

Scored for six voices, the *Requiem* clearly demonstrates the transformation of pitch according to the criteria outlined above: the linking of two distinct consonances by a dissonance composed of elements from both of the bordering sonorities. In a polyphonic modal idiom, the most obvious such transformation can be heard during the appearance of suspension-resolution patterns. By momentarily holding over one or more consonant elements of a first harmonic sonority into the next consonant sonority, there is a middle step during which distorted (now dissonant) aspects of both outer sonorities are present simultaneously. Consider for instance the top voice of the *Requiem*'s Kyrie at measures 24-25[254], as reproduced in Figure 126 below.

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[250] Howard Mayer Brown and John T. Brobeck. "Richafort, Jean," *Grove Music Online. Oxford Music Online*, Oxford University Press, accessed September 19, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/23376.

[251] Brown, "Richafort".

[252] Ibid.

[253] Jean Richafort, "Requiem: zu 6 Stimmen," in *Chorwerk Vol 124*, edited by Albert Seay, 1-36, (Wolfenbüttel: Möseler Verlag, 1976).

[254] Also of interest are the extended melismatic dissonances over consonant pre-cadential pedals that end all sections of the mass.

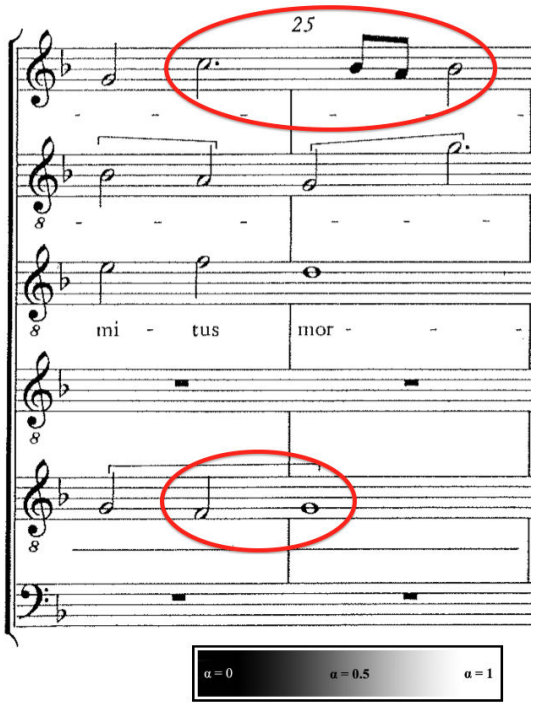

Figure 126 - Richafort: Requiem, Kyrie (Vocal Score, mm. 24-5)

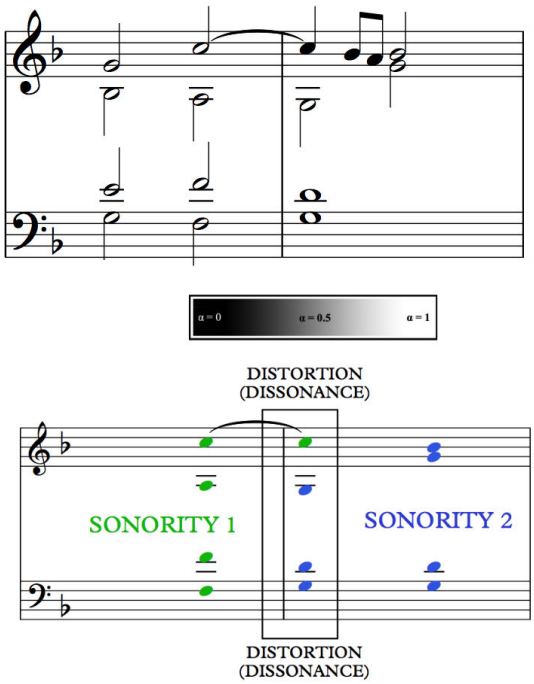

Figure 127 - Richafort: Requiem, Kyrie (Two Reductions, mm. 24-5)

In this example the melodic contour of the top voice causes a C5 to be held over from m. 24's F-major sonority into the first beat of m. 25's g-minor sonority. This first beat constitutes a transitional moment during which elements from both adjacent consonances are distorted towards each other through fleeting, dissonant, connective tissue (see the colour-coded reduction of Figure 127). It is worth noting that while this is a harmonic effect, it is the result of the melodic voice leading that defines the style[255].

4.2.2 Common Practice Pitch Transformation II – Classical Tonality

As the importance ascribed to a composition's harmonic structure began to assume a level of importance on par with that of its contrapuntal construction, the modality of pre-baroque western art music gave rise to the common practice tonality of the baroque and classical periods[256]. Aided by the adoption of new tuning systems in which the differences between modes was minimized, single works now began to navigate various key centres more and less closely related to the initial mode rather than remaining within that outlined by a work's initial material.

Often in works of this period[257], the tonicization of new keys was smoothed over by the employment of a *pivot chord*: a sonority that belonged to both the keys of departure and arrival, often retaining its structural function (generally that of a pre-dominant harmony) in both keys. Consider how the following example of a common practice tonal modulation from W.A. Mozart's *String Quartet No. 19 in C Major*, K.465, the so-called "Dissonace Quartet"[258] (see Figure 128) fits the definition of a morph-like

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[255] Dahlhaus describes the reduced role of verticalities in defining modal orientation and practice "By comparison, in music from the 14th through the 16th century... the method of linking vertical combinations of tones did not primarily serve the presentation of the mode." [Dahlhaus, *Tonality*, 4.]

[256] Carl Dahlhaus identifies a historical development from modality's ***succession*** of pure intervals to tonality's ***progression*** of chords (see the introductory sections of: Dahlhaus, *Tonality*)

[257] In addition to the Mozart excerpt of Figure 19, consider the following examples from Bach, Haydn, and Beethoven (respectively): the first D Major triad in the Chorale from Bach's *Ach Gott, vom Himmel sieh darein*: J.S. Bach, *Ach Gott, vom Himmel sieh darein* [BWV 2]. (Leipzig: Breitkopf & Härtel, 1851); the f minor(/Major) chord in measure 20 of the finale to Haydn's *Keyboard Sonata No. 33*: Joseph Haydn, *Sonaten für Klavier zu zwei Händen* [Hob.XVI:20] (Leipzig: C.F. Peters, 1937.); and the e minor triad in measure 7 of the third movement from Beethoven's *Piano Sonata No. 25, Op. 79*: Ludwig van Beethoven, *Sonaten für das Pianoforte*, ed. Heinrich Schenker, (Vienna: Universal Edition, 1918-21.)

[258] Wolfgang Mozart, *Streichquartett in C, K.465* (Kassel: Bärenreiter, 1990), mm. 43-49.

pitch transformation. By means of a pivot chord, an aural continuum linking two distinct sonic entities is established through the careful distortion of the first into the second.

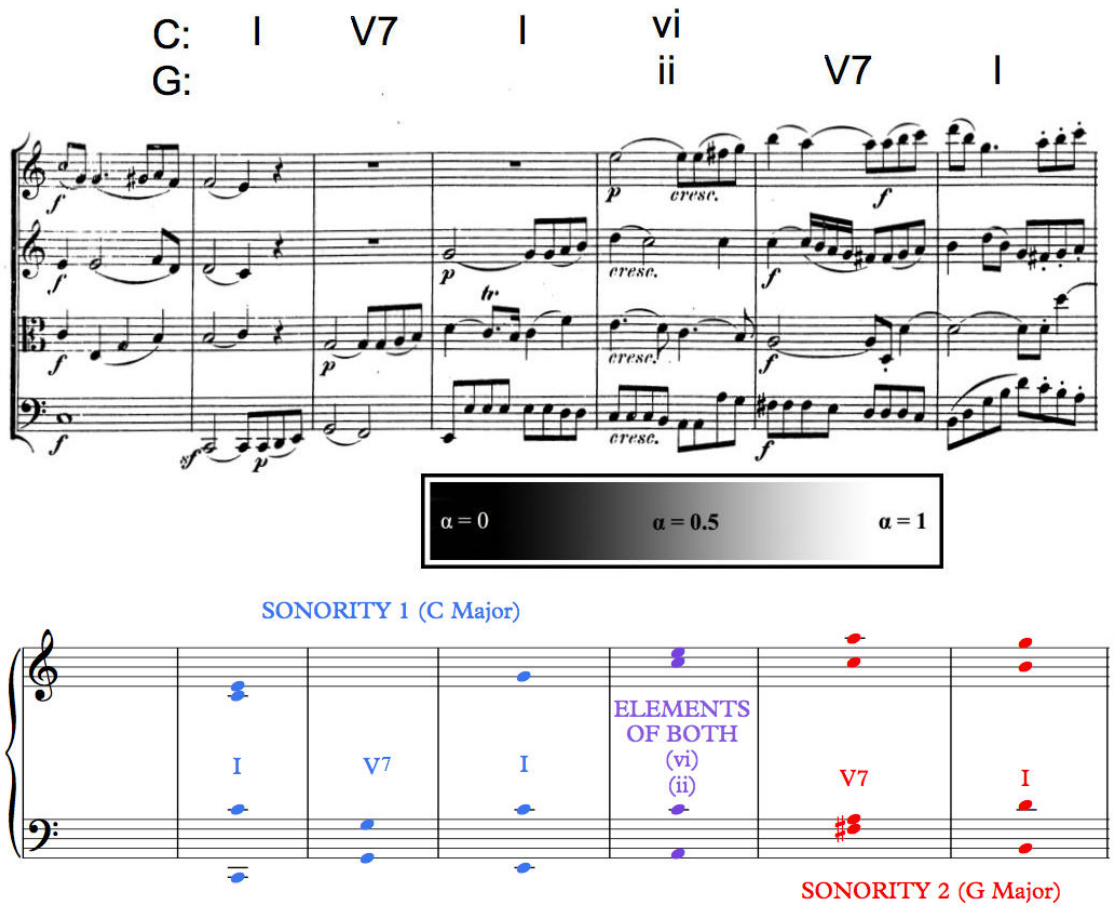

Figure 128 - Mozart: Quartet K. 465, i (mm.43-9)

Though this shared sonority and function will smoothly bridge the two adjacent tonalities, the syntax of both partial phrases is distorted in the middle, so that the first never reaches tonal conclusion, and the second did not possess a tonal beginning (in that it had not yet been established as the tonic in measure 45).

While the functional harmony of Classical tonal syntax (as found in the above passage) still informed pitch treatment in the late Romantic period, its extension in the music of composers such as Richard Wagner and Gustav Mahler yielded further examples of morph-like pitch transformation more characteristic of the latter period.

4.2.3 Common Practice Pitch Transformation III – Extended Tonality

Writing in 1974, Carl Dahlhaus describes the difference between Classical and Romantic tonal practice, citing the latter period's: temporal, gravitational, structural, and textural extensions of the medium.

> "The fragmentation of classical tonality, with its ability to delineate form across wide spans, into brief tonal particles which follow each other in line, connected like links in a chain rather than assembled round a common centre, by no means represents aesthetic weakness, the relinquishment of harmonic function; it is rather the precise correlative of a sense of form which is concerned less with the clearly perceptible grouping of separate parts than with the weaving of an ever denser network of motivic relationships."[259]

This conception of harmony as being more "chain-like" and less "assembled round a common centre" calls to mind the notion of sonic continua described at the beginning of Chapter 1's introduction to audio morphing . The emphasis in both cases is on the "connective tissue" between points of departure and arrival, echoing my own compositional concerns as described in Chapter 2.

This increased importance ascribed to pitch materials associated with transformation altered harmonic practice in a fundamental way: primarily by weakening tonal gravity and increasing the quantity of chromatic elaborations. As described previously, the development of common practice tonality was characterized by a harmonic language based less on a succession of intervals and more on the progression of chords. Dahlhaus describes a comparable paradigm shift occurring towards the end of common practice tonality wherein the tissues and linkages of Wagner's connective, chain-like harmonic practice assume primary importance.

> "In Wagnerian harmony, with its reliance on chromatic alteration and its consequent tendency towards "wandering" or "floating" tonality (that is, a linear succession of fragmentary allusions to keys), the accent falls on harmonic details—on single chords or unusual progressions—and there is such a degree of differentiation in the compositional technique (the interrelationship of harmony and instrumentation) that it is no

[259] Carl Dahlhaus, *Between Romanticism and Modernism* [1974], trans. Mary Whittall (Berkeley: University of California Press, 1980): 69.

> exaggeration to speak of an individualization of harmony, which is hardly less important than that of thematic and motivic material."[260]

The second half of this statement by Dahlhaus – wherein orchestration and harmony are linked as essential, interdependent, and highly individualized compositional resources – has implications for the development of timbre as a primary parameter in the 19th and 20th centuries. This discussion will be the focus of the following chapter, where the 20th century writings and music of Arnold Schoenberg will be presented. This merger of tone and tone colour under Schoenberg (as influenced by Wagner) will be shown to pave the way for a new kind of compositional practice wherein timbre becomes a primary, foregrounded parameter. However, before pursuing the evolution of post-Wagnerian timbral composition, it is instructive to first examine the harmonic progression from *Tristan und Isolde* alluded to in the first half of the Dahlhaus statement quoted above, and reproduced in Figure 129 below.

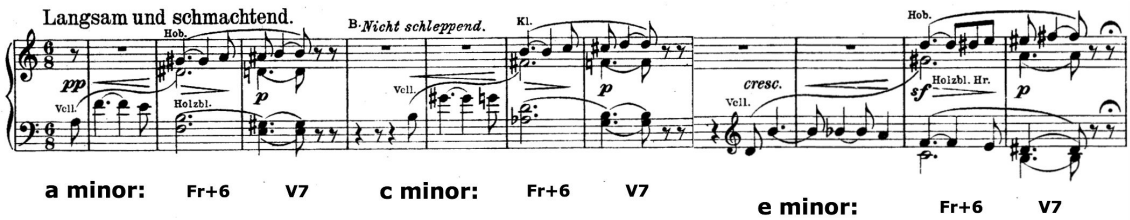

Figure 129 - Wagner: Tristan und Isolde (Reduction, mm.1-11)

With each statement of the opening gesture (mm. 1-4, 5-8, and 9-12) the functional chords (Augmented 6th and Dominant 7th chords – with embellishments) imply a chain of tonal centres related by third (Am, Cm, and Em), resulting in what Dahlhaus described above as "a linear succession of fragmentary allusions to keys."[261]

This passage is significant not only because of the enriched tonal relationships – movement by thirds rather than fifths as seen in the earlier Mozart example – but also due to the fact that tonal closure is avoided. Measure 9 fails to provide the expected C minor resolution just as measure 5 fails to provide the expected A minor resolution

[260] Dahlhaus, *Romanticism and Modernism*, 73.

[261] Ibid.

(incidentally, the eventual rounding out of the section in A minor involves a deceptive cadence rather than an authentic one)[262].

This lack of tonal closure represents a foregrounding of the "connective tissue" associated with pitch transformation. Though A minor eventually returns, the functional departure and arrival points of the opening section are undermined by the expanded (temporal and tonal) scope of the intervening material. On an even finer level of detail, the many accented dissonances also serve to obscure the identities of even the most strongly functional sonorities (Aug. 6th and Dom. 7th chords). All of these factors contribute to what Dahlhaus describes as quintessentially: "Wagnerian harmony, with its reliance on chromatic alteration and its consequent tendency towards "wandering" or "floating" tonality (that is, a linear succession of fragmentary allusions to keys)"[263].

Both Dahlhaus' description of Wagner's harmonic method and the transformation of pitch material are based on notions of linkage and sequential connectivity. According to Dahlhaus this characteristic is the essence of Wagnerian harmonic innovation, when considered in light of the previous (hierarchical) tonal practice.

> "They [tonal centres] should rather be seen as joined together like the links in a chain, without there necessarily being any other connection between the first and third links than the second. In the light of this theory, the characteristic function of Wagner's use of harmony is to establish not hierarchies but an order of succession."[264]

This notion of harmony as a linear succession contributes to what Dahlhaus describes as Wagner's "reliance on chromatic alteration"[265], as does the heavily chromatic voice-leading apparent in Figure 129. Himself an admirer and conductor of Wagner's music[266], Gustav Mahler also contributed to the extension of Late Romantic tonal practice through

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[262] Given the vast wealth and specialization of literature on this topic, further reading should begin with general sources and their bibliographies. For instance, the Norton critical score [Richard Wagner, *Prelude and, Transfiguration from Tristan and Isolde; authoritative scores, historical background, sketches and drafts, views and comments, analytical essays*, ed. Robert Bailey (New York: Norton, 1985)] offers a great deal of context and avenues for further reading, as does the annotated bibliography found in: Michael Saffel, *Richard Wagner; A Guide to Research*, (New York: Routledge, 2002).

[263] Dahlhaus, *Romanticism and Modernism*, 73.

[264] Ibid., 66.

[265] Ibid., 73.

[266] For more on Mahler's contact with Wagner's music as a conductor, see: Andrew D. Keener, "Gustav Mahler as Conductor," *Music & Letters*, Vol. 56, No. 3/4 (July-October 1975): 341-55.

chromatic alteration. However, if Wagner's harmonic innovations can be described in terms of succession, Mahler might best be described in terms of simultaneity.

An aspect of Mahler's tonal language manifest in his *Symphony No. 9*[267] is the use of mode mixture which – as the name implies – is the simultaneous use of a secondary mode or modes within the context of an established key[268]. This technique involves the expansion or distortion of – for instance – a major key to include the pitch classes of its parallel minor. Such is the case in the following excerpt (Figure 130) from the opening of the *Symphony No. 9*.

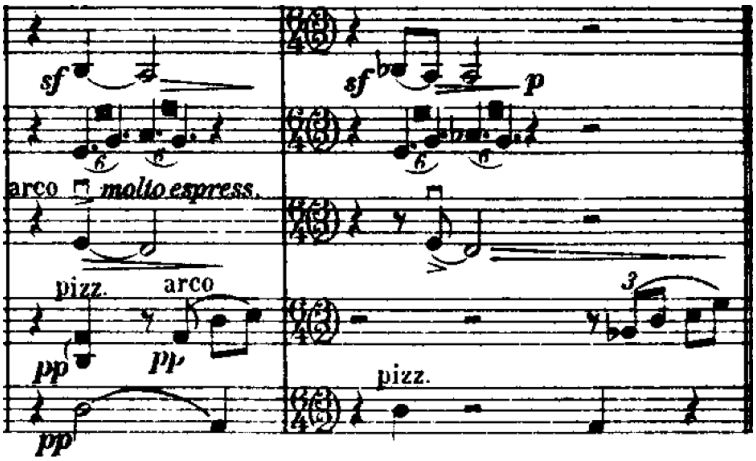

Figure 130 - Mahler: Ninth Symphony, i (Strings, mm. 25-6)

In Figure 130 the sixth scale degree of D Major (B-natural) presented in measure 25 is immediately replaced in both its melodic and harmonic appearances in measure 26 by the sixth scale degree of D minor (B-flat). Furthermore, this replacement of the natural sixth degree with its flattened counterpart from the minor mode occurs simultaneously with the continued use of the major third from the former mode (highlighted in Figure 131 below).

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[267] Gustav Mahler, *Symphony No. 9*. Wien: Universal, 1969.

[268] For more on mode mixture in the nineteenth century, see: Gregory Proctor, *Technical Bases of Nineteenth-Century Chromatic Tonality: a Study in Chromaticism* (Ph.D. dissertation, Princeton University, 1977). Also see: Harald Krebs and William Kinderman eds., *The Second Practice of Nineteenth-Century Tonality* (Lincoln: University of Nebraska Press, 1996).

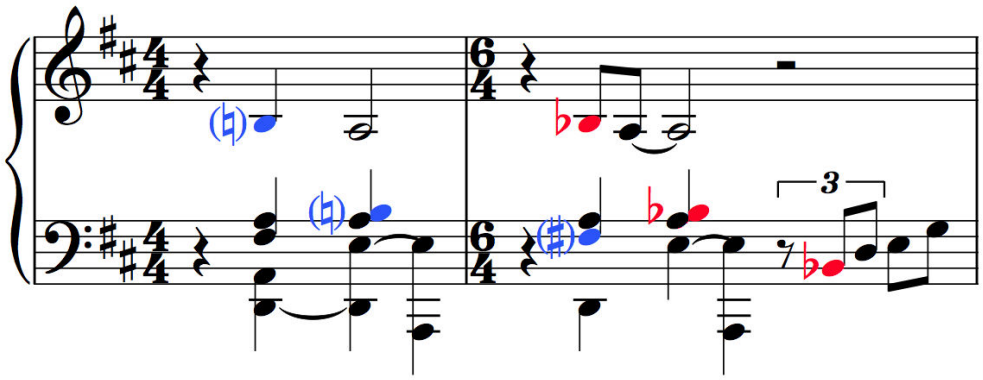

Figure 131 - Mahler: Ninth Symphony, i (Reduction of Strings, mm. 25-6)

The concept of a hybrid tonal centre produced through mode mixture over a common tonic (as with Mahler's simultaneous use of parallel keys) can be regarded as the transformational connective tissue joining two distinct entities (in this case two separate keys). Figure 132 illustrates this continuum.

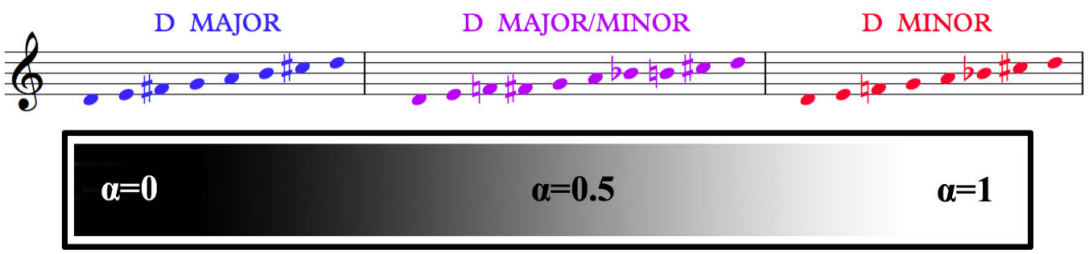

Figure 132 - D Major, D Major/minor, D minor

Furthermore, if one substitutes the terms: fundamental for tonic; partial for scale degree; and spectrum for mode, a clear analogy between mode mixture and timbral morphology (to be discussed at length in the following chapter) emerges[269]. It is interesting to note that a composer deeply affected by Mahler (Arnold Schoenberg, writing in 1911) was dealing with harmony as a direct consequence of spectral

[269] For more on the connection between timbre and pitch in Mahler, see: Louis de la Grange, *Mahler* (Oxford: Oxford University Press, 1995-2008); and Theodor W. Adorno, *Mahler* [1960] (Chicago: University of Chicago Press, 1996).

phenomena at the same time in the same city[270]. In the chapter of his *Harmonielehre*[271] dealing with consonance and dissonance, Schoenberg describes the role of the harmonic (or overtone) series.

> "In the overtone series, which is one of the most remarkable properties of the tone, there appear after some stronger-sounding overtones a number of weaker-sounding ones. Without a doubt the former are more familiar to the ear, while the latter, hardly perceptible, are rather strange. In other words: the overtones closer to the fundamental seem to contribute more or more perceptibly to the total phenomenon of the tone – tone accepted as euphonious, suitable for art – while the more distant seem to contribute less or less perceptibly. But it is quite certain that they all do contribute more or less, that of the acoustical emanations of the tone nothing is lost."[272]

The consequence for Schoenberg at the time, was a harmonic practice that embraces either: pitch classes from further up the harmonic series (such as the notes of the minor mode); or more dense and varied collections of pitch classes in general (such as the use of hybrid keys). The connection is made explicit in the continuation of the above cited passage, where Schoenberg begins to merge the notions of harmonic series and harmonic language.

> "Hence, the distinction between them [higher and lower harmonics] is only a matter of degree, not of kind. They are no more opposites than two and ten are opposites, as the frequency numbers indeed show; and the expressions 'consonance' and 'dissonance', which signify an antithesis, are false. It all simply depends on the growing ability of the analyzing ear to familiarize itself with the remote overtones, thereby expanding the conception of what is euphonious, suitable for art, so that it embraces the whole natural phenomenon. What today is remote can tomorrow be close at hand; it is all a matter of whether one can get closer. And the evolution of music has followed this course: it has drawn into the stock of artistic resources more and more of the harmonic possibilities inherent in the tone."[273]

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[270] Both Schoenberg's *Farben* (to be discussed in the following chapter) and Mahler's *Ninth Symphony* were written in Vienna in 1909, while the *Harmonielehre* was first published in 1911.

[271] Arnold Schoenberg, *Theory of Harmony* (*Harmonielehre)* [1911], translated by Roy E. Carter (London: Faber and Faber, 1978).

[272] Schoenberg, *Harmonielehre,* 20.

[273] Ibid., 20-21.

The timbral consequences of Schoenberg's statement are significant, and will be revisited in the following chapter. However his closing remarks on the evolution of tonal practice in western art music do a great deal to illuminate his historical relationship to Mahler. Schoenberg famously went on to draw "into the stock of artistic resources" the complete chromatic collection with the birth of dodecaphony. Mode mixture in the music of Mahler however, constitutes an intermediate step in this evolution through the use of "more and more of the harmonic possibilities inherent in the tone."

This extension of tonality through the simultaneous presentation of multiple pitch collections can be illustrated at another level of organization in the *Ninth Symphony*. In his 1984 book *Tonal Coherence in Mahler's Ninth Symphony*, Christopher Orlo Lewis lays out the tonal framework of the first movement[274], reproduced below as Figure 133.

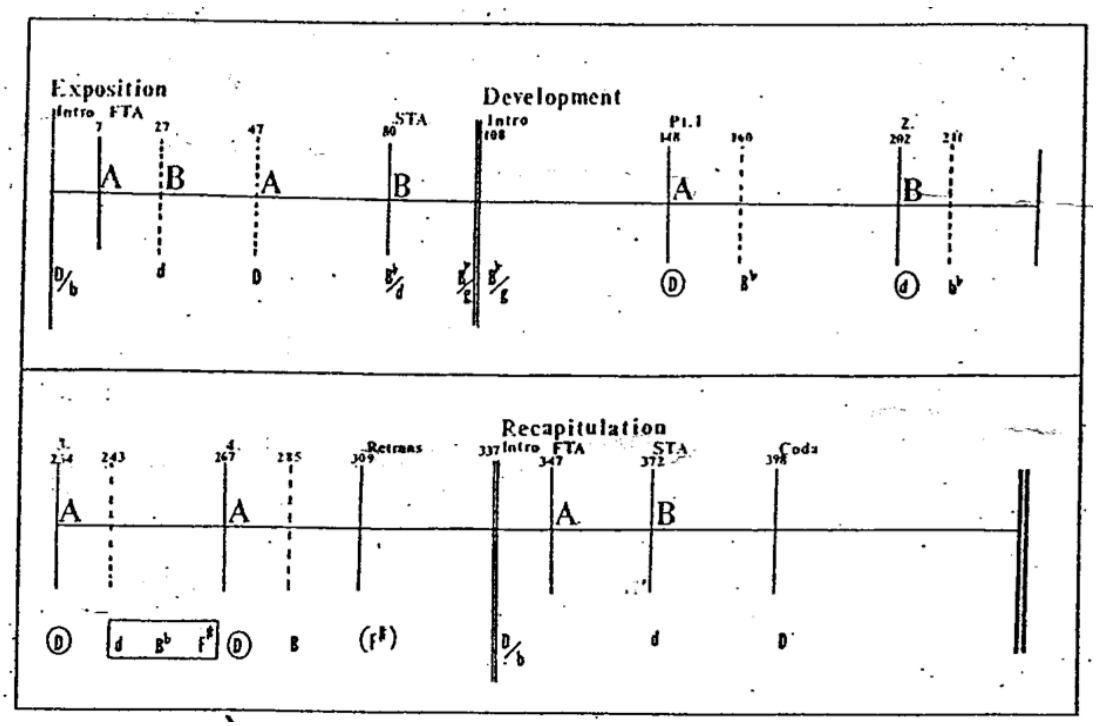

Figure 133 - Christopher Orlo Lewis: Tonal Plan for Mahler's Ninth Symphony, i

Lewis' tonal plan reveals no less than four ambiguous key centres – that is – sections in which elements from more than one tonality are present simultaneously (as in mode

[274] Christopher Orlo Lewis, *Tonal Coherence in Mahler's Ninth Symphony* (Ann Arbor, UMI Research Press, 1984): 13.

mixture). For instance, the first two appearance of the second theme ("B"), are in d-minor and Bb-Major/d-minor, respectively (compare Figure 134 and Figure 135 below).

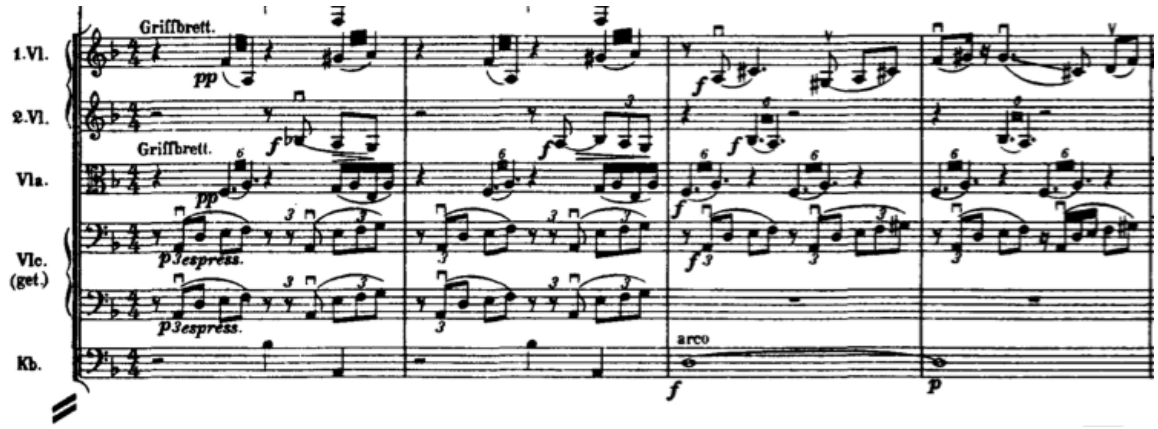

Figure 134 - Mahler: Ninth Symphony, i (Strings, mm. 27-30)

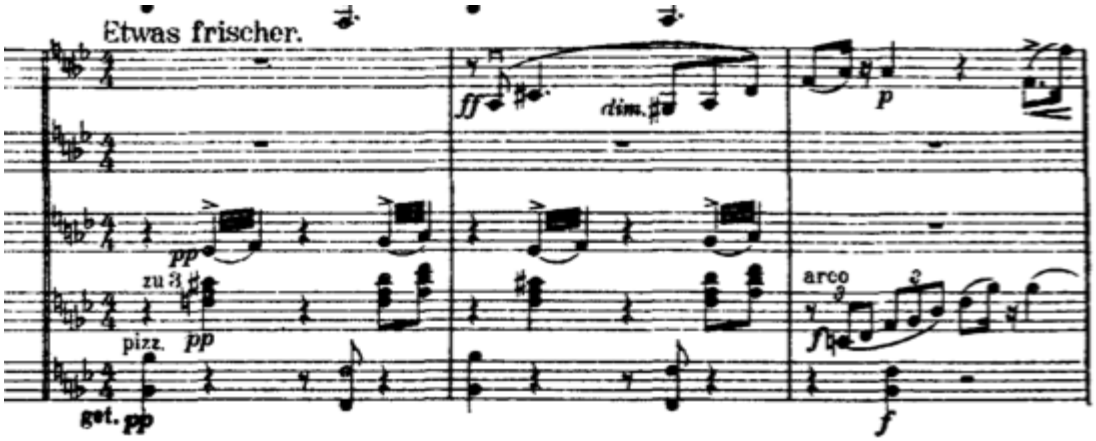

Figure 135 - Mahler: Ninth Symphony, i (Strings, mm. 80-2)

More than a simple modulation to Bb Major, Figure 136 shows that the second appearance of this theme is presented in the contexts of ***both*** Bb Major and d minor simultaneously.

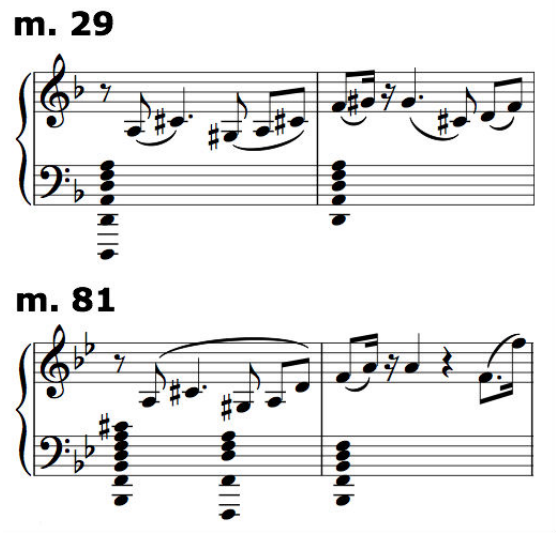

Figure 136 - Mahler: Ninth Symphony, i, Second Theme (Reduction)

While the key signature at measure 81 is that of B-flat Major, and the lowest notes of the harmonization unambiguously reinforce this key, the upper voices betray traces of d minor. The continued presence of the leading tone, (essentially) unaltered melodic contour, and mid-register harmonizations indicating d-minor result in the hybrid B-flat Major/d minor identified by Lewis above.

As with the D Major/minor mode mixture of the opening, the result is an extended pallet of pitch resources. This hybrid collection contains elements of both sonorities, resulting in a swath of connective material in which each sonority is distorted towards the shape of the other.

As noted by Dahlhaus, the treatment of harmony by Late Romantic composers began to take on a level of individualization previously reserved for thematic creation in earlier eras. A comparison of Wagner's sequential approach with Mahler's use of tonal simultaneity and hybridization substantiates this assessment, while reaffirming the slippery identity of pitch transformation as it relates to extended tonality. Having examined two contrasting, transitional figures from the very end of the common practice period, it is logical to now turn to the pitch transformations of a figure from the earliest stages of the post-traditional[275] period.

[275]The term "post-traditional" will henceforth be used throughout the present study in the same sense as employed by the editors of *Music and Aesthetics in the 21st Century, Vol. 2 – Musical Morphology* (cited

4.3 The Transformation of Pitch Following the Common Practice Period

In order to understand the highly individualized transformation of pitch materials that rose to prominence after the common practice period, transitional works on the latter end of the divide are also instructive. The extended tonality of Wagner and Mahler was not abruptly ruptured or abandoned, but rather expanded to a point of complete dissolution[276]. Furthermore, the newly expanded behaviours of consonance and dissonance did not negate their identities, but simply altered their relationship to the determination of form. Writing in 1974 Carl Dahlhaus describes what exactly is meant by the emancipation of consonance and dissonance that resulted during the harmonic practice of this period, with specific recourse to form.

> "The "emancipation" does not mean that there is no longer any difference to be discerned between consonance and dissonance... only that the difference is no longer an integral part of the musical structure: it exists, but it is no longer an element in the construction of the form."[277]

4.3.1 Post-Common Practice Pitch Transformation I – Dissolution of Tonality

Analyzing a harmonic accompaniment from his pupil Alban Berg's second opus[278], Schoenberg identifies a new way of working with tones, in which "the chord-building capacity of dissonances does not depend on possibilities of or tendencies toward resolution."[279] The passage in question is from Berg's Opus 2, Number 4[280], where two complex sonorities follow each other directly (see Figure 137 below).

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earlier) to indicate "new music since 1945" which stands in opposition to "common-practice music [with its] concepts such as theme or motive, phenomena such as line or melody, and systems of syntax and rhythm [that] are generally taken to be self-explanatory" (Mahnkopf et al., *Musical Morphology*, 7). The relevant passage is cited in full in "Musical Morphology V – Claus-Steffen Mahnkopf" from Chapter 1 of the present study.

[276]For more on the dissolution of tonality, see: Rudolph Reti, *Tonality, Atonality, Pantonality; a Study of Some Trends in Twentieth Century Music* (London: Rockliff, 1958).

[277]Dahlhaus, *Romanticism and Modernism*, 61.

[278]For more on Berg's Opus 2, see: Robert Gauldin, "Reference and Association in the *Vier Lieder, Op. 2*, of Alban Berg," *Music Theory Spectrum*, Vol. 21, No. 1 (Spring, 1999): 32-42; and Gary Richard Tucker, *Tonality and Atonality in Alban Berg's Four Songs, Op. 2* (Lewiston: Edwin Mellen Press, 2001).

[279] Schoenberg, *Harmonielehre*, 419.

[280] Alban Berg, *Vier Lieder für eine Singstimme mit Klavier, Opus 2* [1910] (Wien: Universal, 1956).

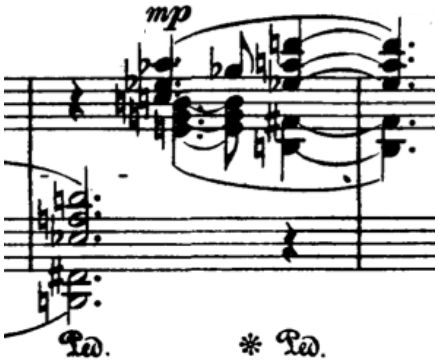

Figure 137 - Berg: Op. 2, No. 4 (Piano, mm.22-3)

The lack of traditional resolution can be interpreted as an extension of Wagner's floating tonality - in fact - Schoenberg cites many examples from Wagner leading up to his discussion of Berg[281]. He also goes on to draw parallels between absent resolution in earlier and later eras, justifying the innovations of the latter by the precedents of the former: "that [resolution] does not come can do no more damage here than when the resolution is omitted in simple harmonies"[282]

However, one might also draw a parallel to the use of mode mixture in Mahler's *Ninth Symphony*, where the available complement of pitch-classes has risen from the seven of D Major, to the ten of D Major/Minor. Schoenberg sees the increased use of transformational materials (up to the point of all twelve chromatic tones) as a foundation for the new of harmonic practice of the Berg example cited above:

> "It seems that the progression of such chords can be justified by the chromatic scale. The chord progression seems to be regulated by the tendency to include in the second chord tones that were missing in the first, generally those a half step higher or lower. Nevertheless, the voices seldom move by half step."[283]

While this is true of the harmonies in measure 22, the remainder of the songs' accompaniments contain a great deal of movement by half-step. In fact, the first chord of measure 22 is itself approached by a chain of half-step motion (Figure 138).

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[281] Beginning with "Chapter XIV – At The Frontiers of Tonality" of the *Harmonielehre*, there are over a dozen specific mentions of Wagner with six references to specific works/passages.

[282] Schoenberg, *Harmonielehre*, 418.

[283] Ibid., 420.

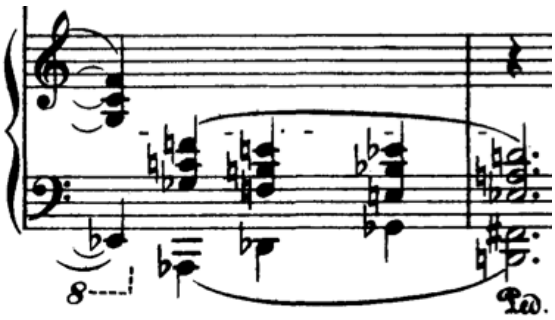

Figure 138 - Berg: Op. 2, No. 4 (Piano, mm.21-2)

This progression introduces another aspect of Berg's harmonic practice addressed by Schoenberg. While one might expect the idiomatic piano texture of right-hand octaves in this passage, the outer intervals are instead major 7ths. Schoenberg goes on to offer a possible explanation.

> "Then, I have noticed that tone doublings, octaves, seldom appear. The explanation for that is, perhaps, that the tone doubled would acquire a predominance over the others and would thereby turn into a kind of root, which it should scarcely be."[284]

The far-reaching consequences of negating root and resolution (resulting in the freedom to move unrestricted amongst the complete contents of chromatic pitch space) affected the treatment of pitch in western art music in general, and the transformation of pitch specifically. While composers now needed to invent (or at the very least, choose) their own harmonic practice with each new work, transformational possibilities in the realm of pitch were virtually unbound by previous tonal restrictions. Attempts to cope with and systematize this newly opened field resulted most famously in the twelve-tone method of the second Viennese school[285].

The techniques of twelve-tone composition have little direct relevance to pitch transformations that evoke the principles of audio morphing described in previous chapters: with one exception. Using a twelve-tone series as the structural framework for a given composition's pitch content has traditionally involved the use of row

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[284] Ibid.

[285] For more see: Paul Griffiths, George Perle, and Oliver Neighbour, *The New Grove Second Viennese School* (New York: Norton, 1997); and Carl Dahlhaus, "Schoenberg's Late Works," in *Schoenberg and the New Music*. Translated by Derrick Puffett, 156-168 (Cambridge: Cambridge University Press, 1989).

transformations as the fundamental means of achieving surface variety[286]. The three basic row transformations (inversion, retrograde, and retrograde-inversion) can be depicted both notationally and visually as follows in Figure 139.

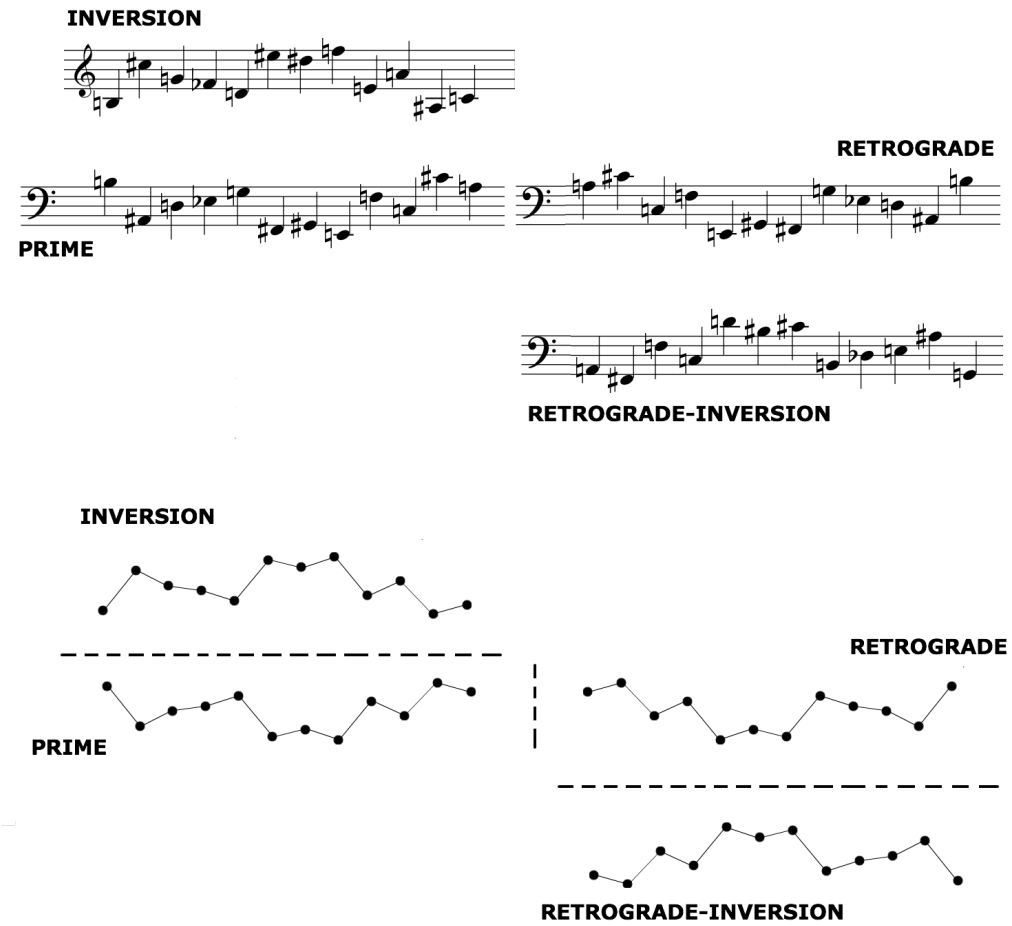

Figure 139 - Row Forms (Notation vs. Graphics)

When expressed visually, one can obtain the row transformations by mirroring the prime form vertically (inversion), horizontally (retrograde), or both (retrograde-inversion). The dotted lines in Figure 139 indicate the positions of these hypothetical mirrors.

In this way, new materials can be obtained through the distortion of the original material in two dimensions, while maintaining its internal proportions. Admittedly, this

[286] These relationships and their appearance in music of the second viennese are described in: Joseph N. Strauss, *Introduction to Post-Tonal Theory* (Upper Saddle River: Prentice-Hall, 1990): 150. This same volume may be consulted for details of twelve-tone composition unfamiliar to the reader.

is a fairly tenuous connection to the transformation of pitch material as it has been described previously. However, the idiomatic twelve-tone practice of Schoenberg's other famous pupil – Anton Webern (1883, Vienna – 1945, Mittersill) – does foreshadow some important later developments (to be discussed in the subsequent section).

The twelve notes found in the above figure are those of the row from Webern's *Konzert* of 1934[287], as labeled on the first page of the score reproduced as Figure 140.

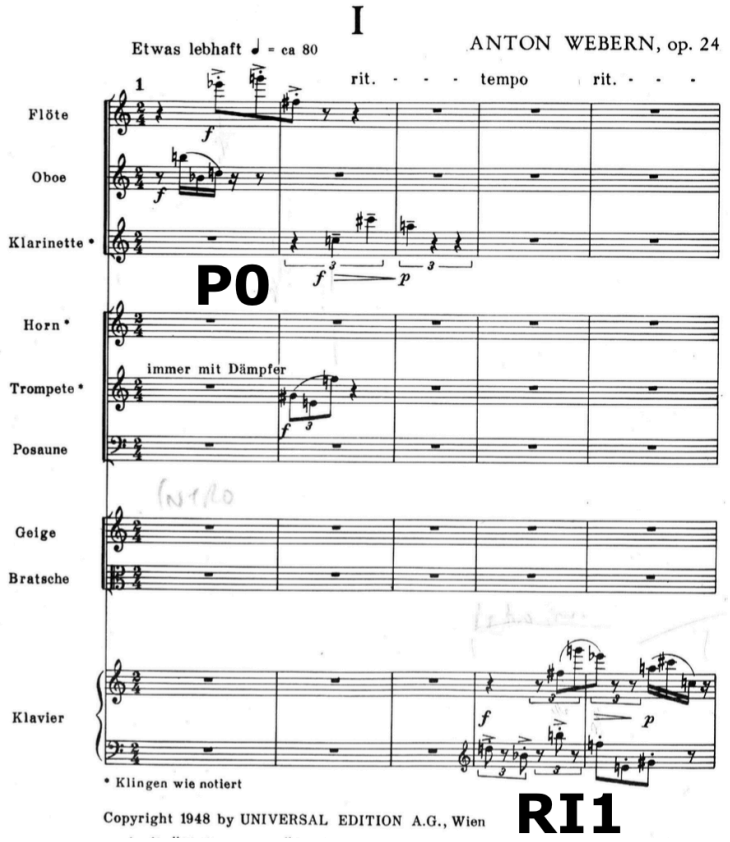

Figure 140 - Webern: Konzert, Op. 24 (mm. 1-5)

The label P0 corresponds to the row in prime form, with RI1 indicating a presentation of the row in retrograde-inversion at the transpositional level of one semi-tone. The three note sub-groupings in both presentations hint at this row's particular significance: it is divisible into smaller units corresponding to the prime form and three transformations of

[287] Anton Webern, *Konzert für Flöte, Oboe, Klarinette, Horn, Trompete, Posaune, Geige, Bratsche und Klavier, Op. 24* [1934] (Wien: Universal, 1948).

the first three notes (Figure 141).

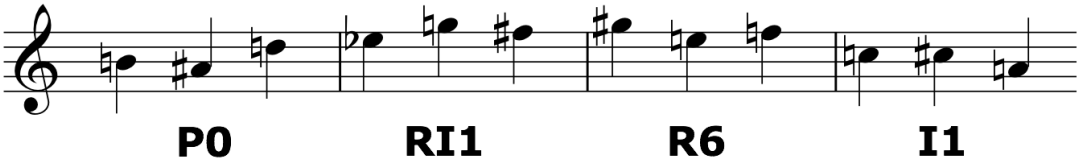

Figure 141 - Webern - Konzert, Op. 24 (Row Sub-Structure)

While a great deal has been written on the *Konzert* and its row[288], it is the emphasis on intervalic shapes as structural entities that is of the greatest relevance to the transformation of pitch materials in post-tonal music. The techniques of pitch transformation found in the music of French composer Pierre Boulez rely on this understanding of intervallic primacy, perhaps unsurprisingly given the influence of Webern on the younger composer[289].

4.3.2 Post-Common Practice Pitch Transformation II – Intervallic Shapes

As we have seen, the democratization of the chromatic field in the early atonality and serialism of the second Viennese resulted in the negation of tonally imposed structures for pitch material. In the common practice period, the acceptable behaviours of individual pitches and intervals were strictly governed by the tonal context in which they appeared, and that they in turn helped to reinforce. The dissolution of tonality in the late nineteenth century elevated the importance of intervals in their own right, culminating in the establishment of the interval as the main constructive element for post-tonal music (as seen above in the *Konzert*)[290]. With even the most tonally remote regions relinquishing their control of motivic material (ie. intervals) new systems for the

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[288] See in particular: Kathryn Bailey, "Symmetry as Nemesis: Webern and the First Movement of the *Concerto, Opus 24*" *Journal of Music Theory*, Vol. 40, No. 2 (Autumn 1996): 245-310; and David Cohen, "Anton Webern and the Magic Square," *Perspectives of New Music*, Vol. 13, No. 1 (Autumn-Winter 1974): 213-15.

[289] See the essays on Webern in: Boulez, *Notes.*

[290] It is important to note however, that Dahlhaus also identified Wagner's propensity for real sequence (the preservation of the exact intervals that make up thematic material, even during transpositions in which these intervals step outside the available resources of the given tonal context), as a contributing force behind tonality's dissolution: "The only suitable means of continuing the motive is sequential repetition, which leads it into tonally remote regions." Dahlhaus, *Romanticism and Modernism*, 45.

sculpting and transformation of pitch collections (or pitch-class sets) began to develop, with the importance of the music's intervalic content assuming primary importance[291].

The next logical step in this trend is the technique of pitch-class set multiplication pioneered by French composer Pierre Boulez, particularly in his 1953-5 composition: *Le Marteau sans maître*[292]. Citing and expanding Boulez's 1971 description of the technique[293], American composer, theorist, and clarinettist Stephen Heinemann's 1998 article: "Pitch-Class Set Multiplication in Theory and Practice"[294] describes a process that: "can be understood informally as the construction of one set upon each element of another."[295]

This description echoes the language of cross-synthesis, a fundamental technique of digital audio morphing described fully in Chapter 3 (in a nutshell, the superimposition of one sound's spectral shape onto that of another). Leaving aside technical language, a few simple examples of pitch-class set multiplication will demonstrate how this technique is related to the transformation of pitch shapes, and how this relationship highlights the previously established importance of visual analogies in describing the morphing and morphology of music.

As the name implies, pitch-class set multiplication can be expressed entirely numerically. The first part of the term: pitch-class is – simply put – the idea that any given pitch is equivalent to all other pitches with the same name in any register (ie. octave equivalency). The term "set" refers to any grouping of pitch-classes, labeled according to their intervalic relationships, as measured in semi-tones. For example, a unison spans the distance of zero semi-tones and is labeled 0, a minor second spans a distance of one semi-tone and is labeled 1, and so on (see Figure 142 below).

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[291] While a brief introduction to set theory will follow, it will be presented in only enough detail to facilitate the discussion of pitch class set multiplication. For a complete understanding of pitch class theory, see both: Allen Forte, *The Structure of Atonal Music* (New Haven, Yale University Press, 1973); and the previously cited: Straus, *Post-Tonal Theory*.

[292] Pierre Boulez, *Le marteau sans maître* [1953-4] (London: Universal, 1957).

[293] Pierre Boulez, *Boulez on Music Today* (London: Faber and Faber, 1975).

[294] Heinemann, Stephen. "Pitch-Class Set Multiplication in Theory and Practice" in *Music Theory Spectrum*, Vol. 20, No. 1 (Spring, 1998): 72-96.

[295] Heinemann, "Theory and Practice", 73.

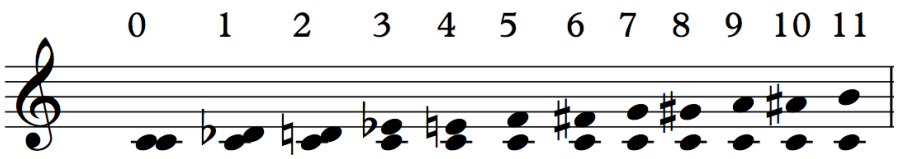


Figure 142 - Measuring Sets of Two Pitches in Semitones

When labelling a set, the entire list of intervals is given beginning with – and in reference to – the lowest pitch-class (itself indicated by a 0). Figure 143 provides four examples.

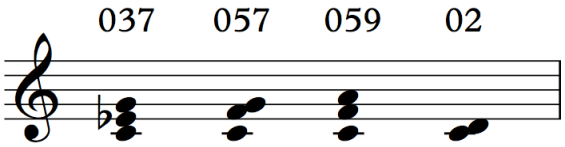


Figure 143 - Labeling Pitch Class Sets According to Interval Content

Finally, a pitch-class set is said to be in normal form when it is arranged in the most compact fashion possible (Figure 144).

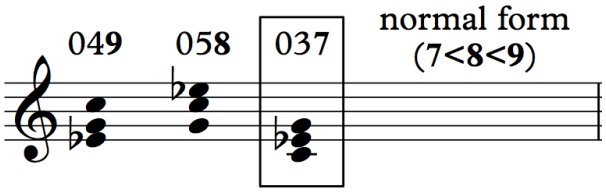
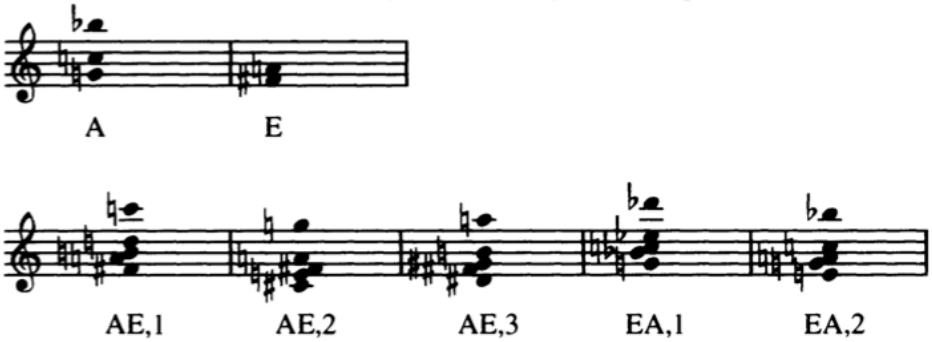


Figure 144 - Three Possible Arrangements of Same Set (Normal Form Highlighted)

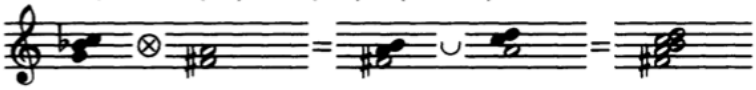
To perform pitch-class set multiplication, every note from each form of set 1 is "transposed" onto every note of set 2 in normal form, and vice versa. In Figure 145 from Boulez (as cited by Heinemann[296]), this process is shown in both musical and mathematical notation (note: Boulez uses the letters t and e to indicate intervals 10 and 11, respectively).

[296] Ibid., 76.

a. From *Boulez on Music Today:* Trichord, dyad → five products

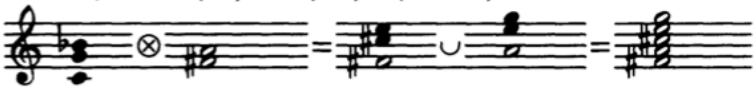


b. AE,1 = < 7{t0} > ⊗ {69} = {69e02}



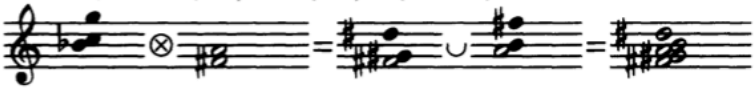
5	e	2
3	9	0
0	6	9
⊗	6	9

c. AE,2 = < 0{7t} > ⊗ {69} = {14679}



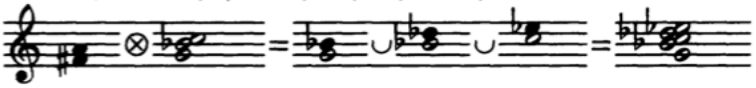
t	4	7
7	1	4
0	6	9
⊗	6	9

d. AE,3 = < t{07} > ⊗ {69} = {3689e}



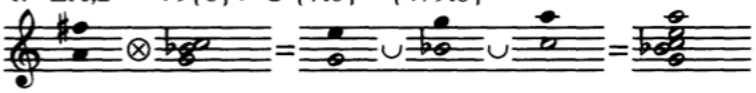
9	3	6
2	8	e
0	6	9
⊗	6	9

e. EA,1 = < 6{9} > ⊗ {7t0} = {7t013}



3	t	1	3
0	7	t	0
⊗	7	t	0

f. EA,2 = < 9{6} > ⊗ {7t0} = {479t0}



9	4	7	9
0	7	t	0
⊗	7	t	0

Figure 145 - Boulez (via Heinemann): Pitch Class Set Multiplication

The technique of pitch-class set multiplication relates to principles of musical and audio morphing for two main reasons. First, it is a purely acoustic application of the principles of cross-synthesis (as described in Chapter 3), as the mapping of one sonority's characteristics onto a second is the basis of the technique. Secondly, in both cases a continuum of intermediate material not present in either sound (or collection of pitches) is obtained through the distortion of each sonority (or collection of pitches) to resemble its counterpart. The results of the Boulez example cited above might even be mapped onto the Caetano morphing continuum as in Figure 146 below.

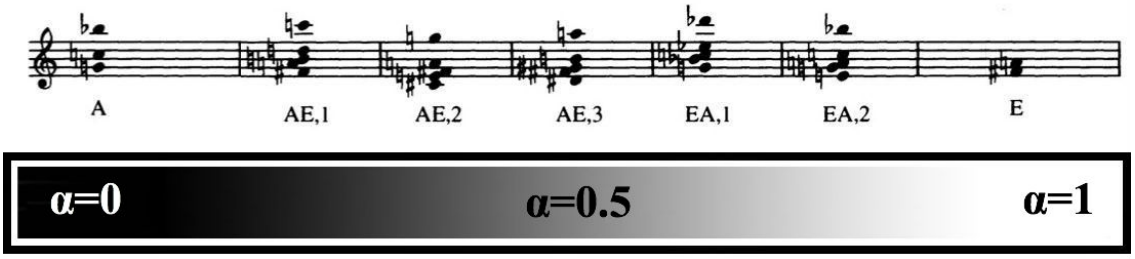


Figure 146 - Continuum Generated Through Pitch Class Set Multiplication

The emancipation of pitch from the organizational framework of tonality allowed for its manipulation based purely on interval content – or shape. Boulez's pitch-class set multiplication (and to a lesser extent, the earlier dodecaphonic procedures described in the previous discussion of the *Konzert*) facilitated the mapping of one shape onto another. As illustrated above, this purely intervallic evocation of the principles behind cross-synthesis resulted in a continuum linking two distinct interval shapes via gradual distortion to eventually resemble each other. While the multiplicative music of Boulez spins out from this continuum of cross-synthesized interval shapes[297], there is still a discontinuous aspect to these transformations in that they utilize discrete pitch steps. The frequent structural use of glissandi in the music of Greek composer Iannis Xenakis on the other hand, bridges these steps with the connective tissue of continuous pitch change.

[297] Stephen Heinemann, *Pitch-class set multiplication in Boulez's Le marteau sans maître* (D.Mus. Thesis, University of Washington, 1993).

4.3.3 Post-Common Practice Pitch Transformation III – Smooth Pitch Space

New avenues in pitch transformation became available in art music of the mid-twentieth century through innovative frameworks for interval structuring, which transcended the rules and hierarchies of interval treatment found in common practice period tonality. Though composers could now move freely amongst the twelve-tones of the chromatic collection, the division of western pitch-space into equal, discrete, semi-tone steps still imposed a strict grid (described as a lattice by Trevor Wishart in Chapter 2). The effect of such a grid or lattice on *visual* shapes is quite clear, as in Figure 147.

Figure 147 - Large, Discrete Steps Represented Visually

If the steps of a lattice are rendered small enough, and begin to approach the limits of human perception, movement between adjacent steps can be perceived as continuous. This is the basis of sampling in all media, be it the frame rate of a motion picture, the sampling rate of a digital audio file, or the resolution of a digital graphic image. The smoother of the two ovals from Figure 147 for instance, still employs discrete steps rather than a truly continuous curve – they are simply small enough that a continuous shape is perceived in contrast to the large steps used in the oval to the right. In the case of pitch-space steps of roughly 10 cents (a tenth of a semi-tone) are required to create the impression of continuity, as they approach the just noticeable difference for pitch in human perception.

The work of Greek composer Iannis Xenakis however, is notable for its use of ***literally*** continuous pitch-space. This revolutionary treatment of pitch is present in the key works of his early period: 1953-4's *Metastasis* and 1956's *Pithoprakta*, where masses of string instruments perform simultaneous glissandi to outline textural shapes and planes of pitch[298].

[298] Speaking with Mario Bois in 1967, Xenakis compared his methods to serialism, with explicit reference to continuous transformation of pitch: "With the serial system one cannot, for example, encompass systems

In the later violin solo: *Mikka "S"* (1976), two distinct melodic lines (played by a single soloist) are also treated in a completely continuous fashion. The treatment of pitch-space as a continuum (rather than a series of steps) is so foreign to western notation, that Xenakis is required to preface the score with written instructions indicating the transient nature of the boundary pitches he uses to outline his continuous motion.

> "The glissandi are to be played in such a way that, to the ear, the pitch change will be absolutely uniform... the notes from which stems the glissando line should not be held; the corresponding glissando starts at once."[299]

The following figure shows a comparison of measures 4-7 in the score, and a spectral analysis (in which the fundamentals have been isolated) of the same passage from the 1991 recording by Irvine Arditti[300]. The gentle curves of the music as performed stand in stark contrast to the discrete pitch steps of western notation in the score (see Figure 148).

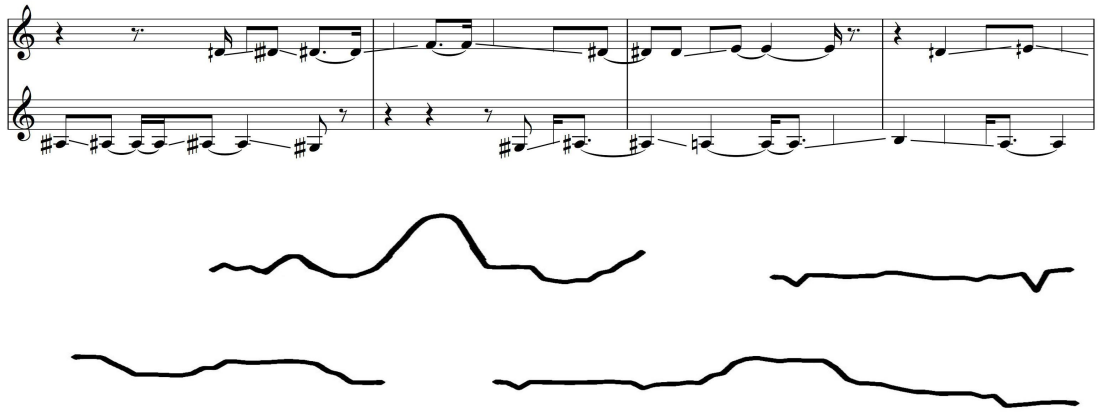


Figure 148 - Xenakis: Mikka "S" (Score and Spectral Analysis, mm. 4-7)

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with glissandi, or continuous evolutions." Mario Bois, *Iannis Xenakis – The man, his* music (London: Boosey and Hawkes, 1967). This focus on "continuous evolution" in the context of compositional systems related to the structuring of pitch, is what distinguishes the work of Xenakis from earlier extensive usage of glissandi in the music of composers such as Stravinsky, Bartók, and Varèse. Even a work containing as many glissandi as Bartók's *Music for Strings, Percussion, and Celesta* for instance, still employs a global structure based on discrete pitch relationships (in this case, a cycle of fifths).

[299] Iannis Xenakis. *Mikka "S"* (Paris: Editions Salabert, 1976).

[300] Iannis Xenakis and the Arditti Quartet, "Mikka "S"," in *Iannis Xenakis 1* (Montaigne: Auvidis, 1994), compact disc.

The treatment of pitch space as a true continuum under Xenakis, marks an important turning point in the history of western pitch morphology. The emancipation from tonality and the establishment of pitch structures based on the meaningful distortion of intervalic shapes were illustrated above through the music of the second Viennese and Boulez, respectively. Despite these developments, new pitch morphologies were still encased within the lattice of equal temperament. The reframing of pitch-space as a continuum rather than a grid, removes the final remaining obstacle to free movement of pitch in the western tradition. In the work of composers such as American/Canadian composer James Tenney, pitch begins to receive organization according to its defining empirical characteristic: frequency[301].

4.3.4 Post-Common Practice Pitch Transformation IV – Frequency as Pitch

The abandonment or weakening of pitch grids (be they tonal, chromatic, serial, or microtonal), suggests a new paradigm of pitch transformation, based on continuous rather than discrete change. Given that recent pitch resources have come to encompass the unrestricted range of humanly audible frequencies, it is not surprising to see frequency itself supersede pitch-class as the framework by which periodic sounds are understood.

Spectral music is one very clear example of this historical trajectory. Given its close relationship to issues of timbre, the music of the French Spectral tradition (Grisey, Murail, etc.) will be taken up in the following chapter. The music of American/Canadian composer James Tenney however, provides an explicit illustration of music in which frequency relationships (regardless of previously established pitch grids) are the primary structural features.

Written in 1971 for solo violin, *Koan* was fleshed out for string quartet by Tenney in 1984. The 1984 version of the score (Figure 149) features four methods of notating pitch: 1) traditional notation, 2) microtonal deviations indicated in cents, 3) the frequency ratio of all pitches in a measure, and 4) the frequency ratio and number of cents separating a given instrument's pitch from the current open string of the first violin.

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[301] As will be discussed in subsequent chapters, electro-acoustic media such as synthesizers and variable speed tape recorders also enabled such freedom and precision in the control of pitch (measured as frequency). The focus of the present chapter however remains purely acoustic media.

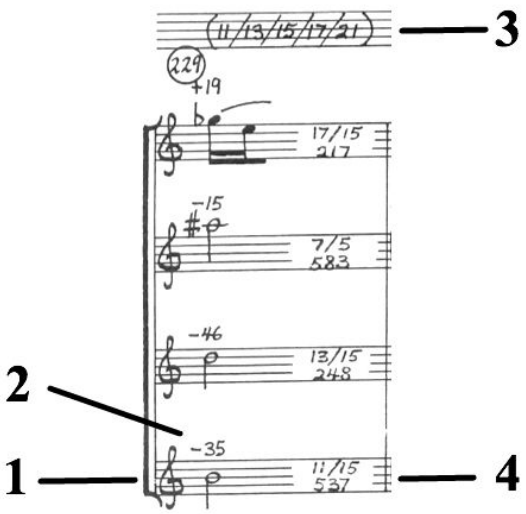

Figure 149 - Tenney: Koan (Frequency Notation, m. 229)

The frequency ratios stated explicitly in each measure are clear cues for the understanding of pitch-space as a field of frequency in the work. The compositional importance of this understanding is also reflected in the design of the original violin version and the harmonic additions of the 1984 quartet. Summarizing the original version, Tenney states:

> "In 1971 I wrote a piece called "KOAN for Solo Violin," which was concerned with the perceptual effects of an absolutely linear and predictable formal process - involving a bowed tremolo progressing through a series of microtonal intervals on progressively higher pairs of strings… the intervals played by the first violin are determined by the simplest frequency ratios within "tolerance" of successive steps of one-sixth of a tempered semi-tone."[302]

The derivation of the 1984 harmonies are also explicitly frequency-based. The following score excerpts (Figure 150) and annotations illustrate Tenney's explanation of the new supporting material, wherein he indicates the lower and higher pitches of violin one as f1 and f2, respectively[303].

[302] James Tenney, *Koan for String Quartet* (Hollywood: Alpheus, 1984).

[303] This figure originally appeared as the author's second handout during a 2011 presentation on *Koan*.

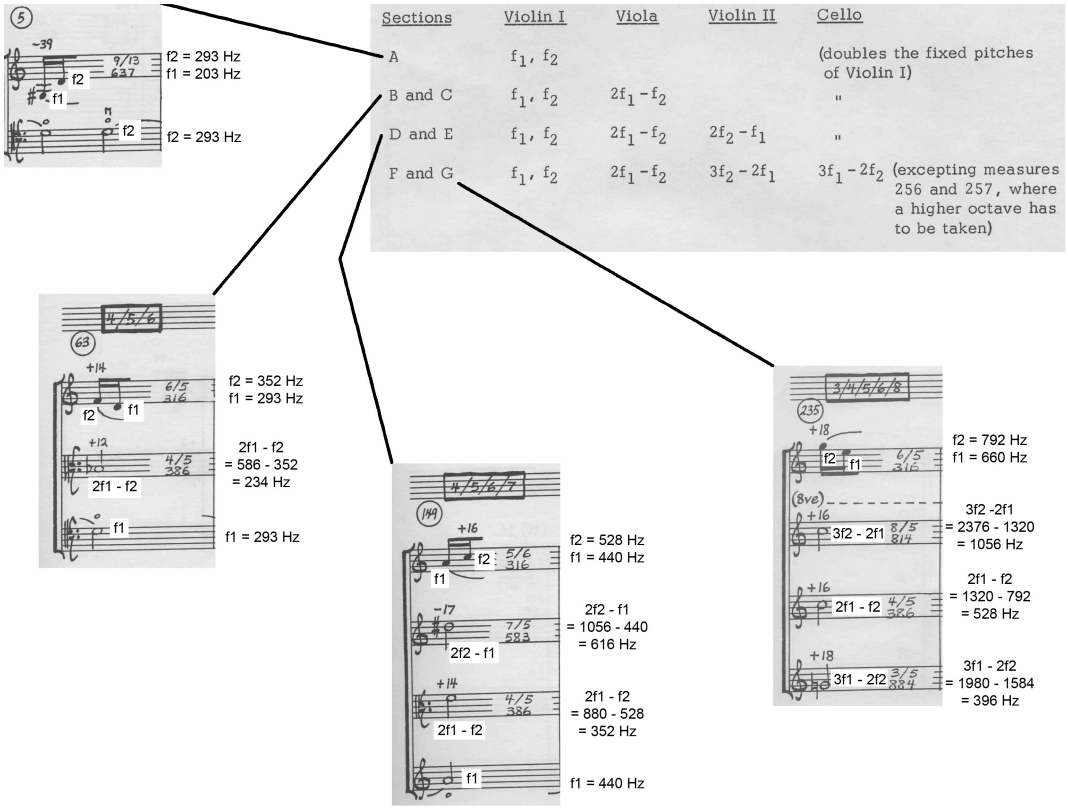

Figure 150 - Tenney: Koan (Annotated Table of Frequency Relationships)

These exact frequency calculations are carried out over the course of the entire quartet without exception. In such a way, Tenney builds an entire work out of a handful of simple pitch operations, inseparable from the understanding of pitch as frequency. While the understanding of pitch as frequency has major implications for morph-like pitch transformation (any shape can now transform into any other shape continuously), the work as a whole could itself be regarded as a single, long, pitch transformation as shown in Figure 151.

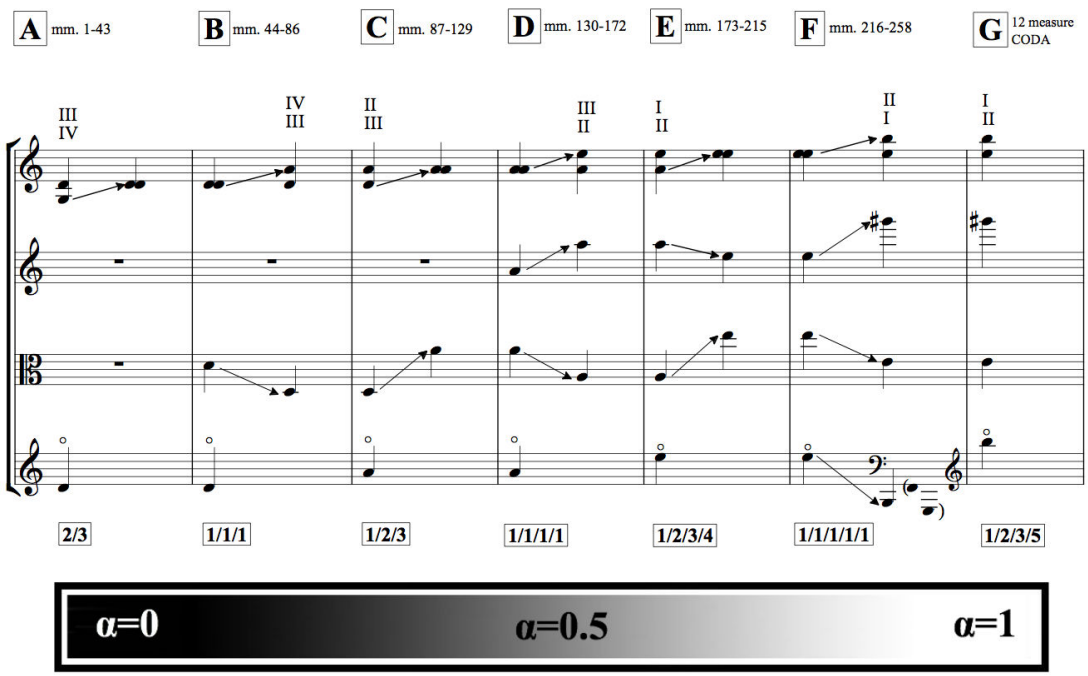

Figure 151 - Tenney: Koan, Form as One Continuous Pitch Transformation

Beginning with the G3-D4 dyad of measure one, all pitch content moves continuously towards the final sonority of E4-E5-B5-G#6 of the coda. Though non-linear (instruments other than the first violin change direction), all movement is either continuous or reached by step to a pitch that has been reached continuously by another instrument.

4.4 Conclusions

Throughout the previous survey of pitch transformation in the western tradition, external systems of control based on consonance and dissonance have repeatedly been shown to expand to the point of dissolution. This trajectory could be traced from the handful of stylistically acceptable sonorities of pre-baroque counterpoint, to the remote modulatory possibilities of extended tonality. Furthermore, the development progressed from the chromaticism of late romantic harmony to the unrestricted movement among all twelve pitch-classes of early atonality. Finally, one can observe the free perpetuation of intervalic shapes in Boulez's pitch-class set multiplication give way to the free and

continuous movement through the entire audible spectrum as practiced by Tenney and Xenakis.

Throughout all of this expansion and dissolution of pitch regulation, the principles underlying sonic morphing have been reflected through transformative phenomena such as: the suspension and resolution of accented dissonances, the connective tissue of pivot chords, the hybridization of mode mixture, the amorphous and floating quality of late-romantic harmonic resources, the free movement of post-tonal chromaticism, the acoustic cross-synthesis of pitch-class set multiplication, and finally the networks of continuous interconnection and movement through pitch space as a continuum of frequency. All of these methods for the transformation of pitch – with their various echos of the principles underlying audio morphing – have influenced how I treat pitch in my compositional activity (as described in Chapter 2).

Perhaps even more importantly however, from Mahler and Schoenberg onwards, the relationship between pitch and timbre was shown to expand substantially. This tendency culminated with the elevation of frequency and spectra to structural determinants of pitch transformation in the music of the more recent past. In the following chapter, the purely acoustic manipulation of timbre (with its reliance on spectral characteristics) will be explored as another consequence of this trajectory.

5 Transformation of Timbre in Instrumental Works of the 19th and 20th Centuries

5.1 Introduction

The previous chapter drew attention to many examples of musical transformation from the western tradition that were realized entirely with conventional (acoustic) instrumentation, and through the relationship between consonance and dissonance. A general trend was observed in which an increased structural emphasis was ascribed to the previously impermanent and unstable dissonant sonorities of various eras. Compare for instance: the fleeting suspension-resolution ornamentation of polyphonic modality; the modulatory possibilities of common practice tonality; and eventually the long-term inhabitation of distant, unstable, and ambiguous key centres in late-romantic extended tonality. As illustrated through representative works of the early/mid-twentieth century, this process culminated with the emancipation of consonance and dissonance from inherited hierarchies, and the consequent establishment of new and highly individualized schemes of pitch organization based on the concept of pitch as frequency.

The late Romantic period marks the tipping point in this evolution away from inherited systems of pitch organization towards a diversification of hierarchies. The characteristics of tonal practice that call to mind the principles of morphing such as: mode mixture, highly chromatic ornamentation and voice-leading, remote modulatory possibilities, and prolonged chains of dissonant embellishing harmonies, begin to assume enough importance so as to weaken the very tonal context that gave them initial meaning[304]. It is no coincidence that during this same period (the end of the 19th century), another purely acoustic transformational effect – that of acoustic timbral manipulation – was also rising to prominence[305]. The following chapter will treat the

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[304] For more on this gradual transition, see (the previously cited): Dahlhaus, *Romanticism and Modernism*.

[305] American theorist Paul Matthews opens a discussion of late Romantic orchestration from his 2006 collection: *Orchestration: An Anthology of Writings* with the following citation of Rimsky-Korsakov's preface to an 1891 draft of his *Principles of Orchestration*: "Our epoch, the post-Wagnerian age, is the age of brilliance and imaginative quality in orchestral tone coloring. Berlioz, Glinka, Liszt, Wagner, modern French composers - Delibes, Bizet and others; those of the new Russian school - Borodin, Balakirev, Glazounov and Tschaikovsky - have brought this side of musical art to its zenith; they have eclipsed, as colorists, their predecessors." Paul Matthews, *Orchestration: An Anthology of Writings* (New York: Routledge, 2006): 117.

history of timbral manipulation in significant detail, as the influence of transformations related to tone colour have been even more influential on my compositional method than those associated with pitch.

Though the term *Klangfarbenmelodie* is generally understood in a horizontal/melodic context (likely owing to the presence of the word *melodie*), Arnold Schoenberg – the originator of the term – had a much more vertical/harmonic concept in mind[306]. Examples from both categories will follow; but in short, the melodic class of *Klangfarbenmelodie* is embodied by a horizontal sequence of individual tone colours analogous to – and generally occupying – individual pitches in a melody. The harmonic class of *Klangfarbenmelodie* on the other hand is embodied by complex vertical sonorities – generally containing large numbers of individual pitches and instruments – that are subtly blended into other similarly complex vertical sonorities. This dual importance of both horizontal (melodic) and vertical (harmonic) phenomena associated with the term *Klangfarbenmelodie* will require a two-pronged investigation.

Furthermore, the merger of harmony and timbre as expressed in Schoenberg's music and writings has an obvious connection to the spectral and timbre-based music of later eras, such as that of the French spectral school. As such, the purely acoustic manipulation of timbre will be explored in three distinct categories, summarized in Table 11.

SECTION	**FIGURES CONSIDERED**
I - Melodic Klangfarbenmelodie	Schoenberg, Wagner, Mahler
II - Harmonic Klangfarbenmelodie	Schoenberg, Berg
III - Timbre as Primary Compositional Material	Stockhasuen, Messiaen, Grisey

Table 11: Overview of Chapter 5

[306] This understanding of *Klangfarbenmelodie* is described in the present chapter under the heading "harmonic *Klangfarbenmelodie*", and relies heavily on the following 2002 article, to be described during said section: Alfred Cramer, "*Klangfarbenmelodie*: A Principle of Early Atonal Harmony," *Music Theory Spectrum*, Vol. 24, No. 1 (Spring 2002): 1-34.

5.2 Melodic Klangfarbenmelodie

In 1911 when his own harmonic language was moving beyond the confines of tonal hierarchies, Arnold Schoenberg wrote that "our attention to tone colors is becoming more and more active, is moving closer and closer to the possibility of describing and organizing them."[307] The source of this statement is the passage immediately preceding the first appearance of the term *Klangfarbenmelodie*: the earliest and most well-known descriptor of timbral manipulation [308]. Perhaps even more important than what follows the above statement however, is the context in which it appeared: the end of Schoenberg's pedagogical *Theory of Harmony*[309]. The connection between pitch and timbre then, is explicit and important. For Schoenberg timbre is not merely the colouristic quality of a tone, but rather the fundamental perceptual category of which pitch is merely a subset:

> "The distinction between tone color and pitch, as it is usually expressed, I cannot accept without reservations. I think the tone becomes perceptible by virtue of tone color, of which one dimension is pitch. Tone color is, thus, the main topic, pitch a subdivision. Pitch is nothing else but tone color measured in one direction."[310]

Here Schoenberg is describing the spectral aspect of pitch perception. The concept of pitch perception as dependent on spectral makeup was suggested as early as 1841[311], and

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[307] Schoenberg, *Harmonielehre*, 421.

[308] The earlier (Romantic) importance of timbre in the music of Hector Berlioz is also noteworthy. Although explicit language regarding the morphology of timbre was not the primary content of Berlioz's influential treatise on orchestration (Hector Berlioz, *Treatise on Instrumentation* [1843-4]. trans. Theodore Front. New York: Kalmus, 1948.), Princeton doctoral graduate Su Lian Tan describes the structural role of timbre in Berlioz's *Symphonie Fantastique* in: Su Lian Tan, *Hector Berlioz's Symphonie Fantastique, op. 14: An exploration of musical timbre* (Doctoral Dissertation: Princeton University, 1997).

[309] Schoenberg, *Harmonielehre*.

[310] Ibid., 421.

[311] Gareth Loy, the American author of a two volume acoustics textbook: *Musimathics*, describes the missing fundamental problem in the section on pitch perception: "The place theory of Ohm hit a major stumbling block with an experiment performed by August Seebeck (1841). Suppose I play two tones for you: one is a pure sinusoid, the other is pitched but complex (having many harmonics). You can adjust the pitch of the pure tone with a knob. Your job is to adjust the pitch of the pure tone to match the pitch of the complex tone. It is virtually certain that you will adjust the frequency of the pure tone to the fundamental frequency of the complex tone *even if there is no measurable energy at the fundamental frequency* (see section 2.8.1). Suppose the partials of the complex tone are 300, 400, and 500 Hz. You will most likely distinctly hear a "fundamental" at 100 Hz, the greatest common factor of the overtones. You will *not* hear an inharmonic tone with fundamental at 300 Hz. So convinced are our ears of the ubiquitous phenomenon of a fundamental with harmonics at integer multiples that even if there is no fundamental, our hearing is hardwired to invent one." Gareth Loy, *Musimathics – The Mathematical Foundations of Music Vol. 1*, (Cambridge: MIT Press, 2006): 157.

can be easily verified today through the aptly-named "missing fundamental" demonstration. To conduct this experiment, the fundamental of a synthetic pitch is omitted during synthesis, or the fundamental of a natural tone is suppressed during playback. In such cases, the harmonic relationship of the partials present imply the pitch identity of the missing fundamental. This phenomenon is particularly relevant in the modern consumer audio landscape, with the widespread use of laptop, earphone, or cell phone speakers[312].

Possessed of this prescient though intuitive relationship between tone and tone colour, Schoenberg turned his attention to the compositional treatment of timbre and *Klangfarbenmelodie*:

> "Now, if it is possible to create patterns out of tone colors that are differentiated according to pitch, patterns we call 'melodies', progressions, whose coherence (*Zusammenhang*) evokes an effect analogous to thought processes, then it must also be possible to make such progressions out of the tone colors of the other dimension, out of that which we call simply 'tone color', progressions whose relations with one another work with a kind of logic entirely equivalent to that logic which satisfies us in the melody of pitches.[313]

It is clear from the above statement that Schoenberg is not speaking of a literal melodic presentation of tone colours[314]. Rather than some strict linear sequence of individual timbres mimicking the sequential procession of individual pitches in a melody, Schoenberg is calling for an organizational rigour "***equivalent*** to that logic which satisfies us in the melody of pitches" (emphasis mine)[315]. This more nuanced understanding of what is meant by *melodie* in the context of *Klangfarbenmelodie* is obscured somewhat by the term itself. However, it is also important to note examples of literally melodic proto-*Klangfarbenmelodie* timbral manipulation in works by composers as influential as Berlioz[316], Debussy[317], Wagner, and Mahler. The two latter composers

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[312] "The phenomenon of the missing fundamental is what enables us to hear satisfying music come from the tiny speaker of a transistor radio: our hearing invents the fundamentals that the speaker can't reproduce." Loy, *Musimathics Vol. 1*, 158.

[313] Schoenberg, *Harmonielehre*, 421.

[314] This distinction is a primary focus of the 2002 Alfred Cramer article cited above.

[315] Schoenberg, *Harmonielehre*, 421.

[316] See the *Symphony Fantastique*, and its timbral analysis by Su Lian Tan cited above.

are of particular interest, given their vast, mutual influence on Schoenberg[318]. As such, several examples of highly melodic proto-*Klangfarbenmelodie* timbral manipulation will be explored in excerpts from their works.

5.2.1 Melodic Klangfarbenmelodie I – Wagner

One of the first incidents of melodic proto-*Klangfarbenmelodie* can be found in Act II Scene 3 of Richard Wagner's 1856 opera *Die Walküre* (Figure 152)[319].

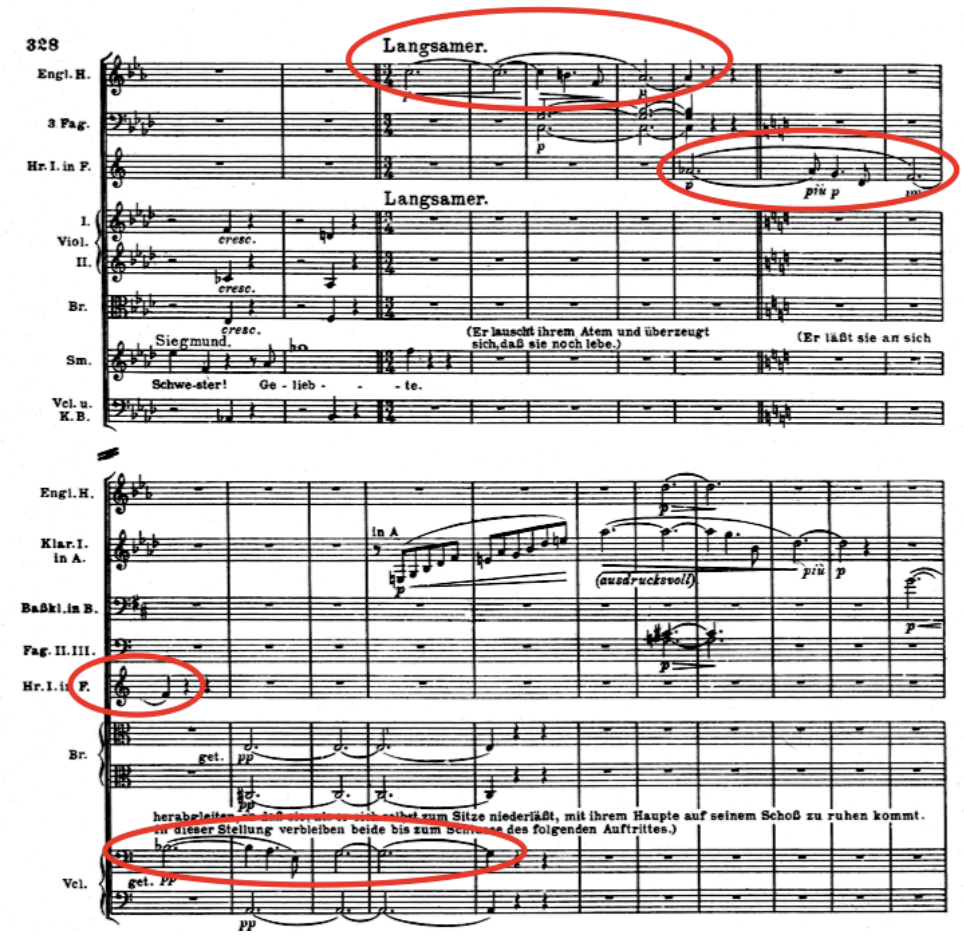

Figure 152 - Wagner: Die Walkure (Score, Act II, Scene 3)

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[317] See the *Sonata for Flute, Viola, and Harp*, and its analysis in: Deanne Elaine Walker, *An analysis of Debussy's "Sonata for Flute, Viola, and Harp"* (Masters Thesis: Rice University, 1988).

[318] Mahler's influence on Schoenberg has been noted above. For more on Wagner and Schoenberg, see: Julie Brown, "Schoenberg's early Wagnerisms," *Cambridge Opera Journal*, Vol. 6 (1994): 51-80.

[319] Richard Wagner, *Die Walküre* (New York: Dover, 1978).

This excerpt demonstrates the "melodic" type of *Klangfarbenmelodie*, in which the gradual addition of a second instrumental colour to the gradual disappearance of a first instrument(s) produces a purely acoustic "cross-fade" on a single note of a melodic line. Calling to mind our definition of sonic morphing, the resulting effect is a transitory moment during which the initial tone colour seemingly transforms into the second, resulting in a brief band of connective material that is neither colour one nor colour two. In the above excerpt, the overall effect is that of a melody played on a "hyper-instrument" that is first heard as an english horn, whose timbre is then combined with and taken over by that of a french horn, before being combined with and taken over by that of a cello (see the reduction of Figure 153 below).

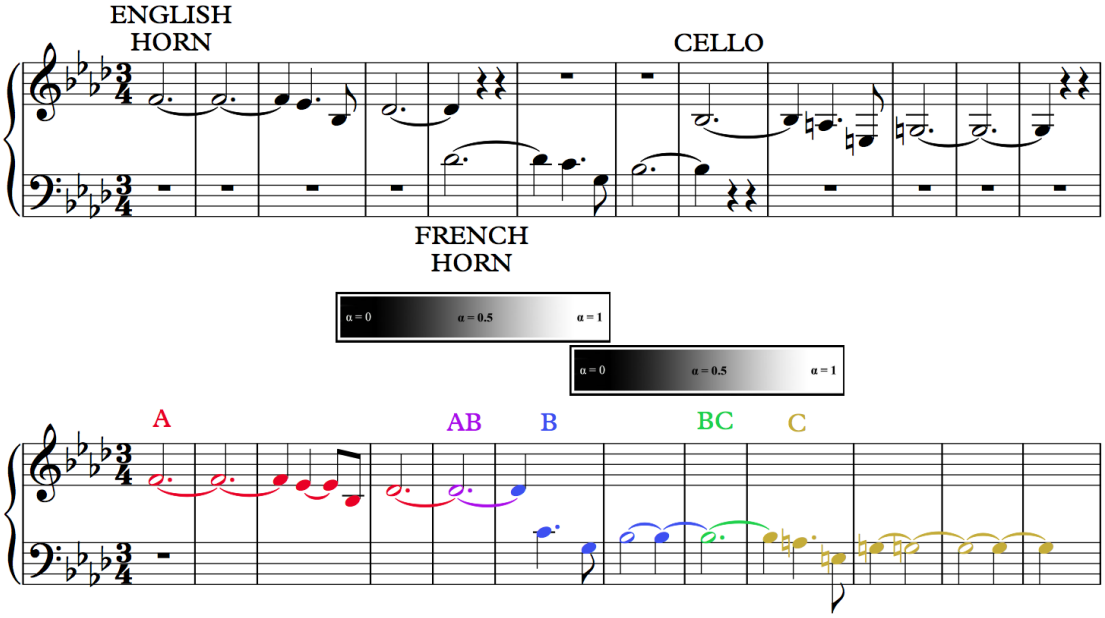

Figure 153 - Wagner: Die Walkure (Reduction, Act II, Scene 3)

5.2.2 Melodic Klangfarbenmelodie II – Mahler

Perhaps the most significant and abundant source of proto-Schoenbergian *Klangfarbenmelodie* of the melodic type (a continuously eliding sequence of instrumental colours presenting a linear sequence of pitches), is the music of Gustav Mahler. *Das Abschied*, the sixth movement of Mahler's 1908-9 orchestral song cycle *Das Lied von der Erde* contains a particularly large and diverse collection of examples. The following four examples from the movement will illustrate the manipulation of instrumental timbre

through the use of *Klangfarbenmelodie* of the melodic type in various instrumental contexts.

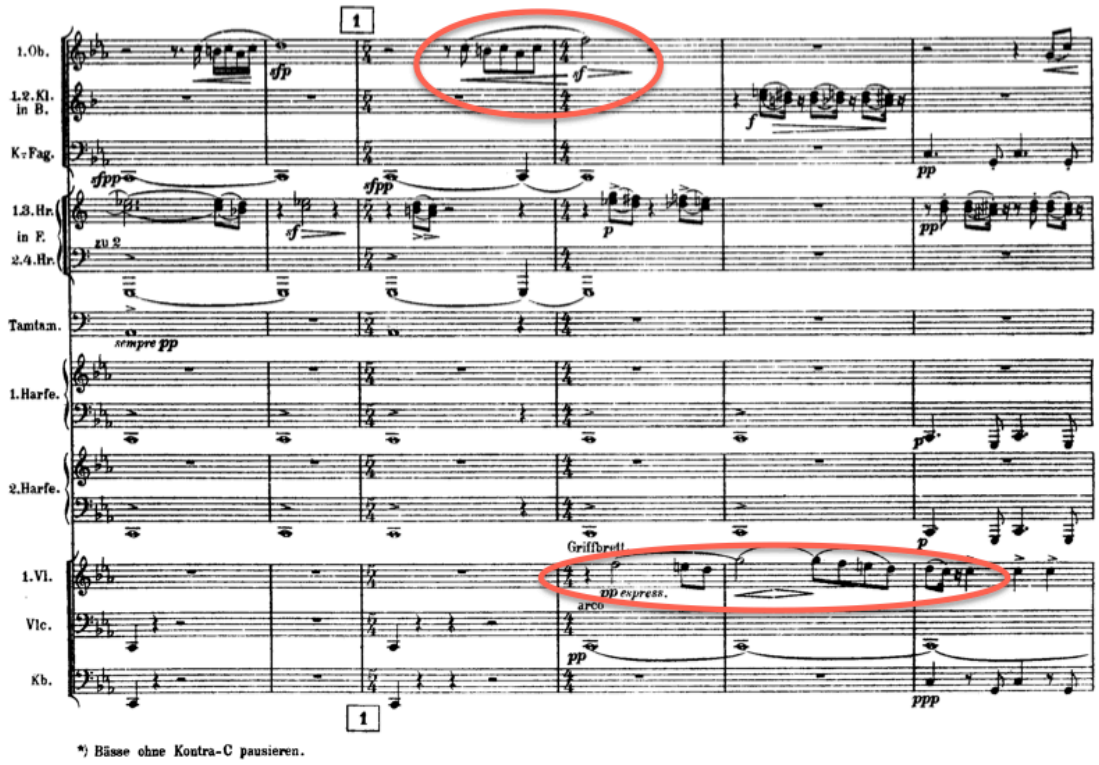

Figure 154 - Mahler: Das Lied von der Erde, vi (Score, mm. 7-12)

In Figure 154[320] from the opening of the movement, a single melodic line is passed from the oboe to the first violins. As in most cases of purely acoustic timbral morphing, the initial instrument simply fades out with the entry of the second instrument (in this case the first violins' F5 at measure 10), resulting in a seamless transition from one instrumental colour to another (Figure 155).

[320] Gustav Mahler, *Das Lied von der Erde* (Wien: Universal Edition, 1962), mm. 7-12.

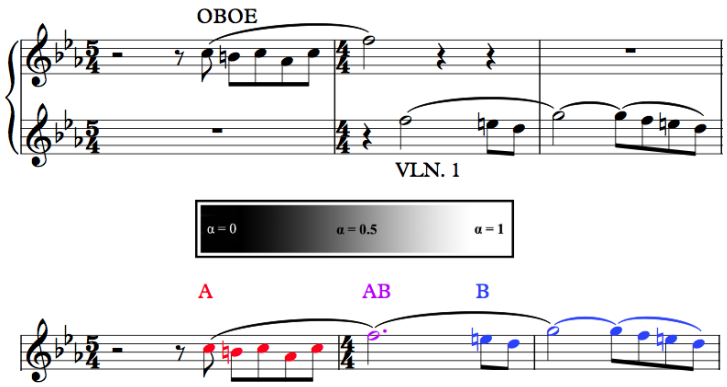

Figure 155 - Mahler: Das Lied von der Erde, vi (Reduction, mm. 9-11)

A slightly more complex example can be found at measures 130-6, shortly after rehearsal 17 in the score (Figure 156)[321].

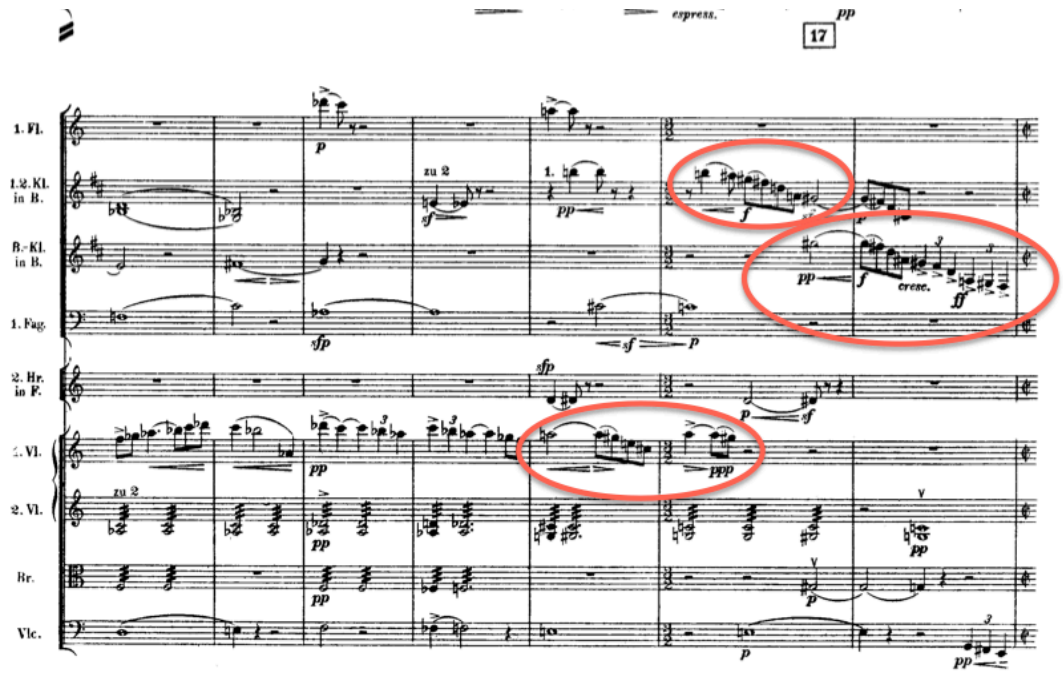

Figure 156 - Mahler: Das Lied von der Erde, vi (Score, mm. 130-6)

[321] Mahler, *Das Lied*, mm. 130-136.

Much like the Wagner example cited earlier, this is a two-stage melodic transformation of timbral colour. The melody is passed from the first violins to the clarinet, followed by the bass clarinet. The second stage of the melody's timbral transformation is particularly subtle, given the close relationship between a clarinet and its low register counterpart: the bass clarinet. Though another instrument clearly takes over the line in measure 136, this second transition could also be interpreted as the emergence of a "hyper-instrument": some sort of imaginary clarinet with an unusually wide range (see Figure 157).

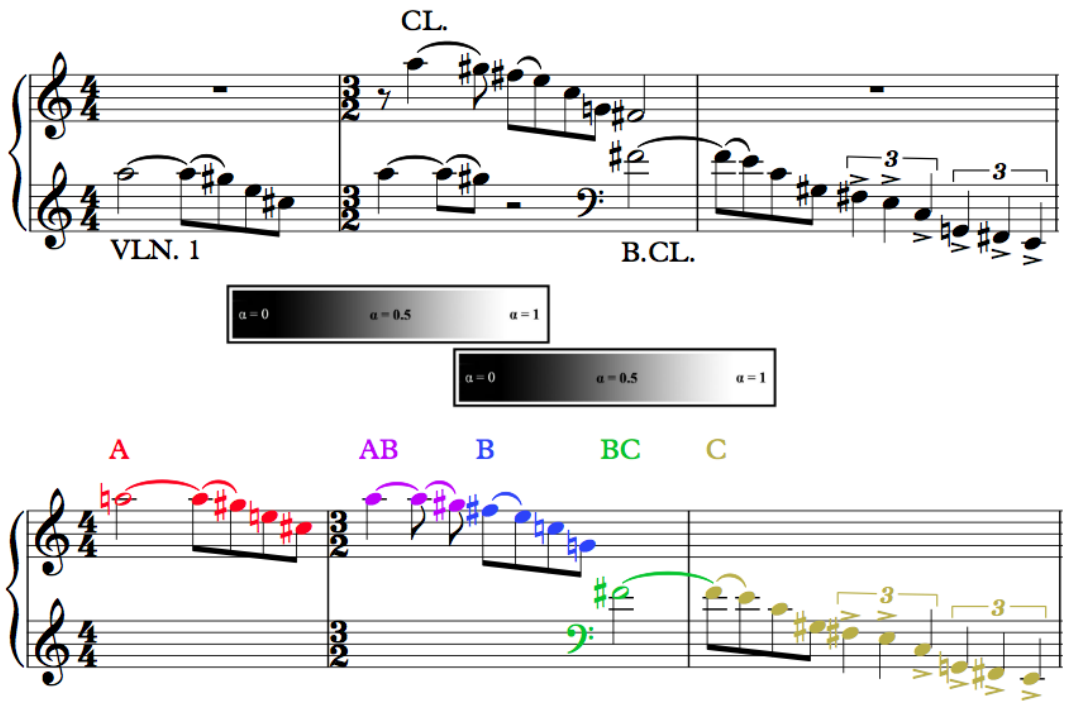

Figure 157 - Mahler: Das Lied von der Erde, vi (Reduction, mm. 134-6)

While the cross-faded dynamics that one can expect of acoustic timbral manipulation are again present, the effect is also strengthened through Mahler's use of pitch. The half-step motion between A5 and G#5 that begins measure 135 is shared by both the outgoing violins, and the incoming clarinet. By eliding the instrumental colours over two notes rather than only one, the transformation between these two instruments is enriched by an extra level of continuity.

An even more compressed form of melodic elision occurs during a back and forth exchange of the line shared by the solo cello and english horn at measures 314-5, shown in Figure 158 below[322].

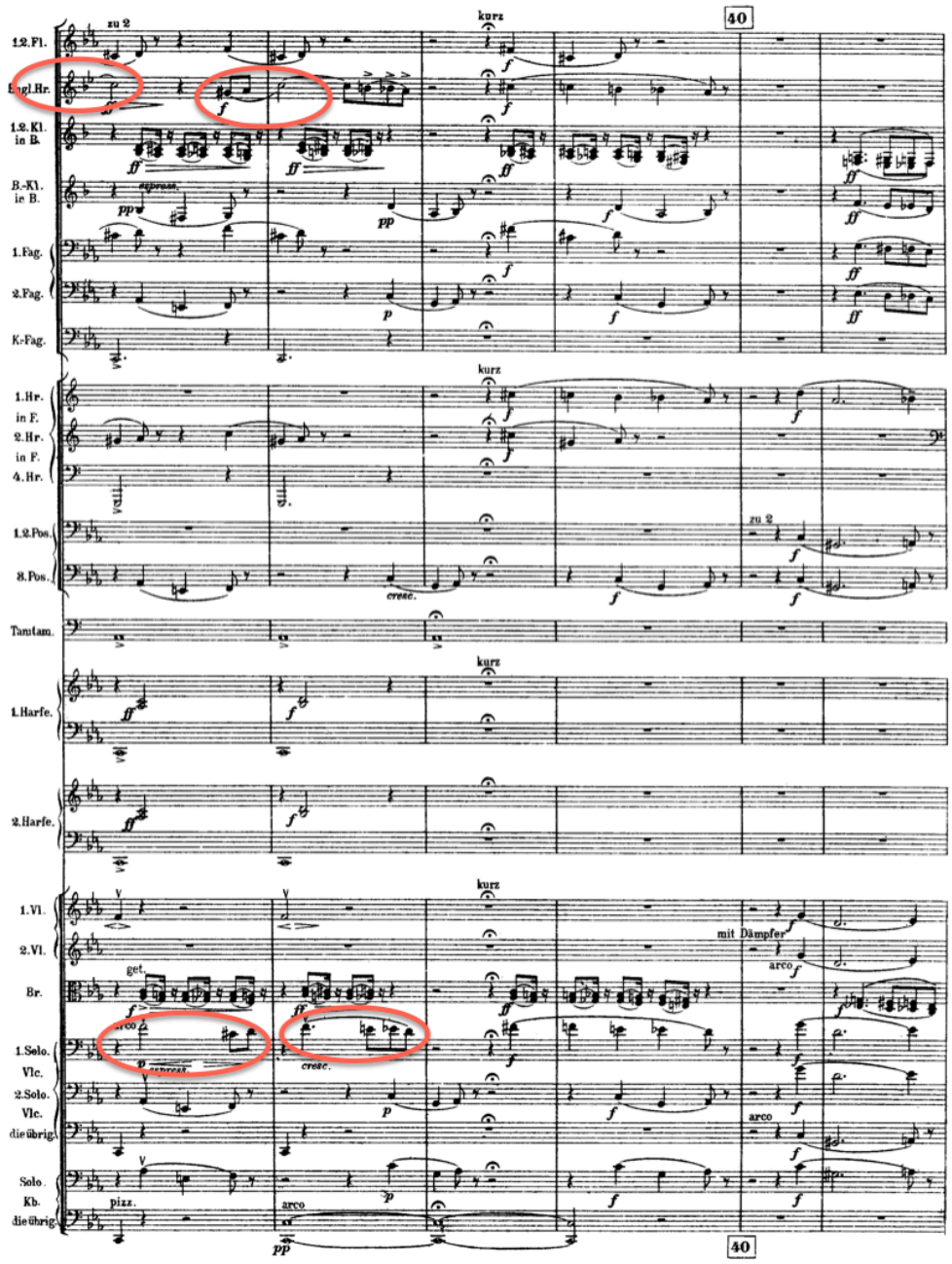

Figure 158 - Mahler: Das Lied von der Erde, vi (Score, mm. 314-9)

[322] Mahler, *Das Lied*, mm. 314-319.

Again carefully sculpted dynamics allow for the perception of a smooth transition between quite diverse instrumental forces. In this example however – even more so than the previous one – the overlap of melodic material is essential for the blending of the high double reed and solo cello lines. The consequently thick texture leaves room for only a single quarter note rest in each instrument, though the overlapping crescendi and decrescendi maintain a constant shift of perspective between the two lines (see the reduction of Figure 159).

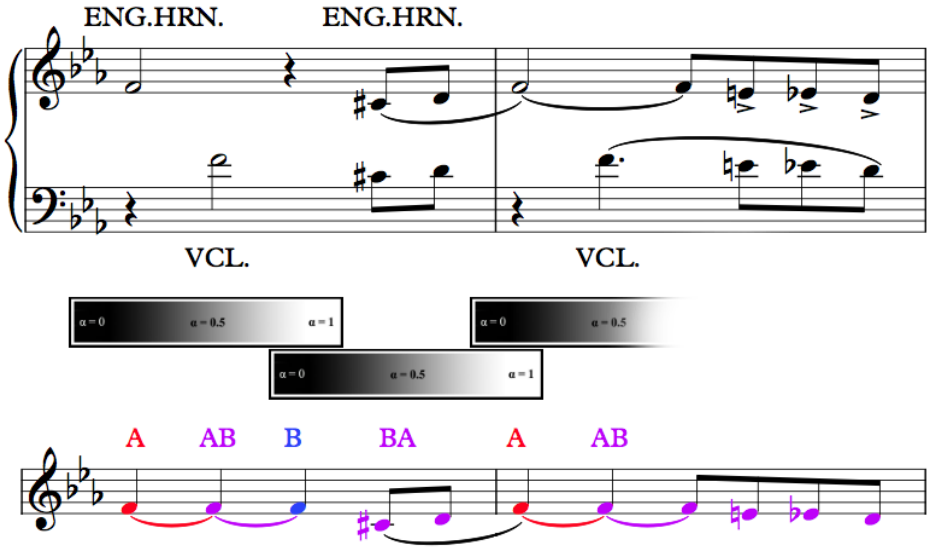

Figure 159 - Mahler: Das Lied von der Erde, vi (Reduction, mm. 314-5)

An even further extension of this principle occurs at measures 348-52 (see Figure 160 and Figure 161)[323]. While previous examples have shown only a handful of shared pitches overlapping during the transfer of a single melodic line, this excerpt involves the transfer of an active, repeating eighth note figure doubled at the interval of a sixth: first by the flutes and oboe, next by the first and second violins.

[323] Mahler, *Das Lied*, mm. 324-337.

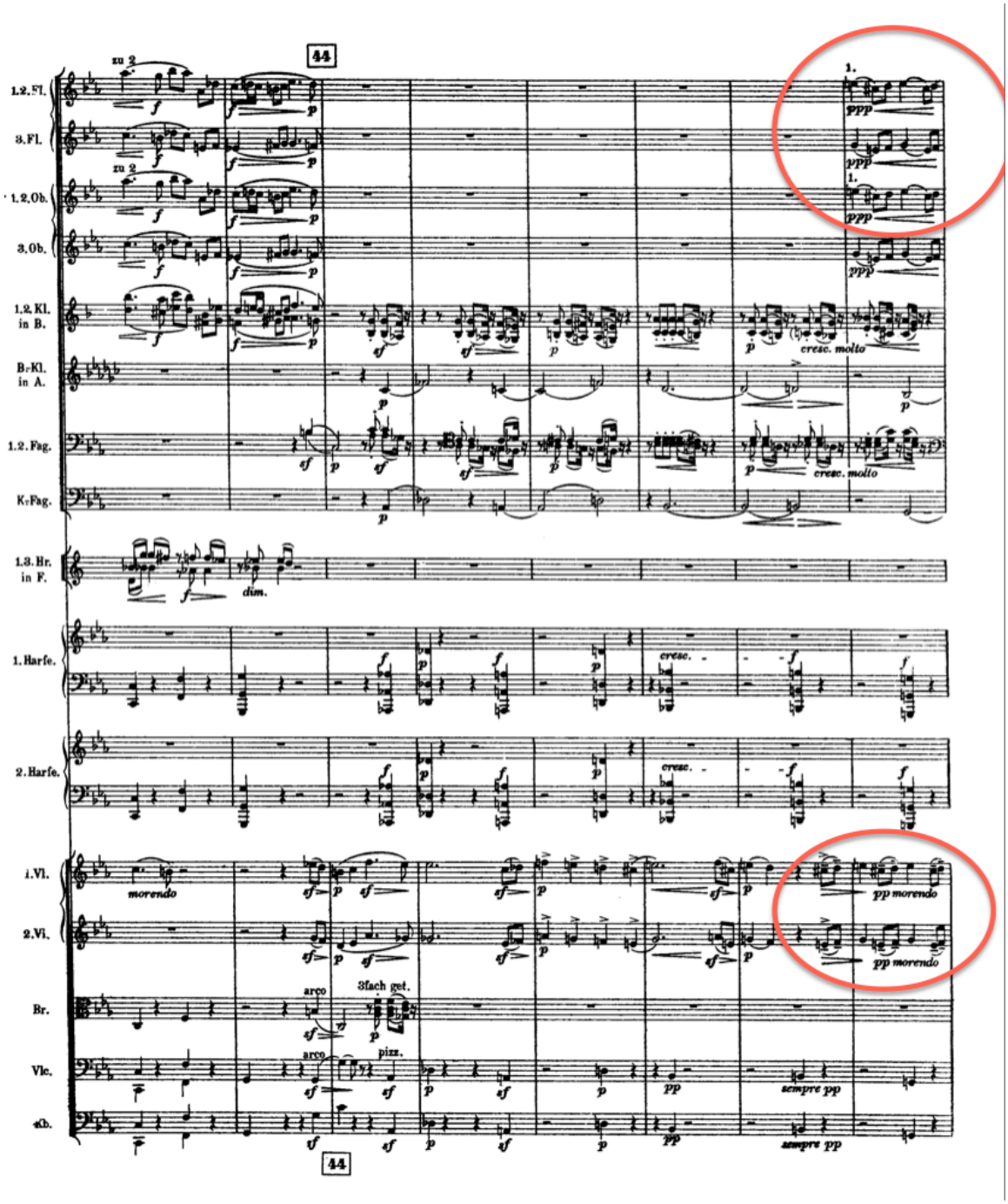

Figure 160 - Mahler: Das Lied von der Erde, vi (Score, mm. 324-9)

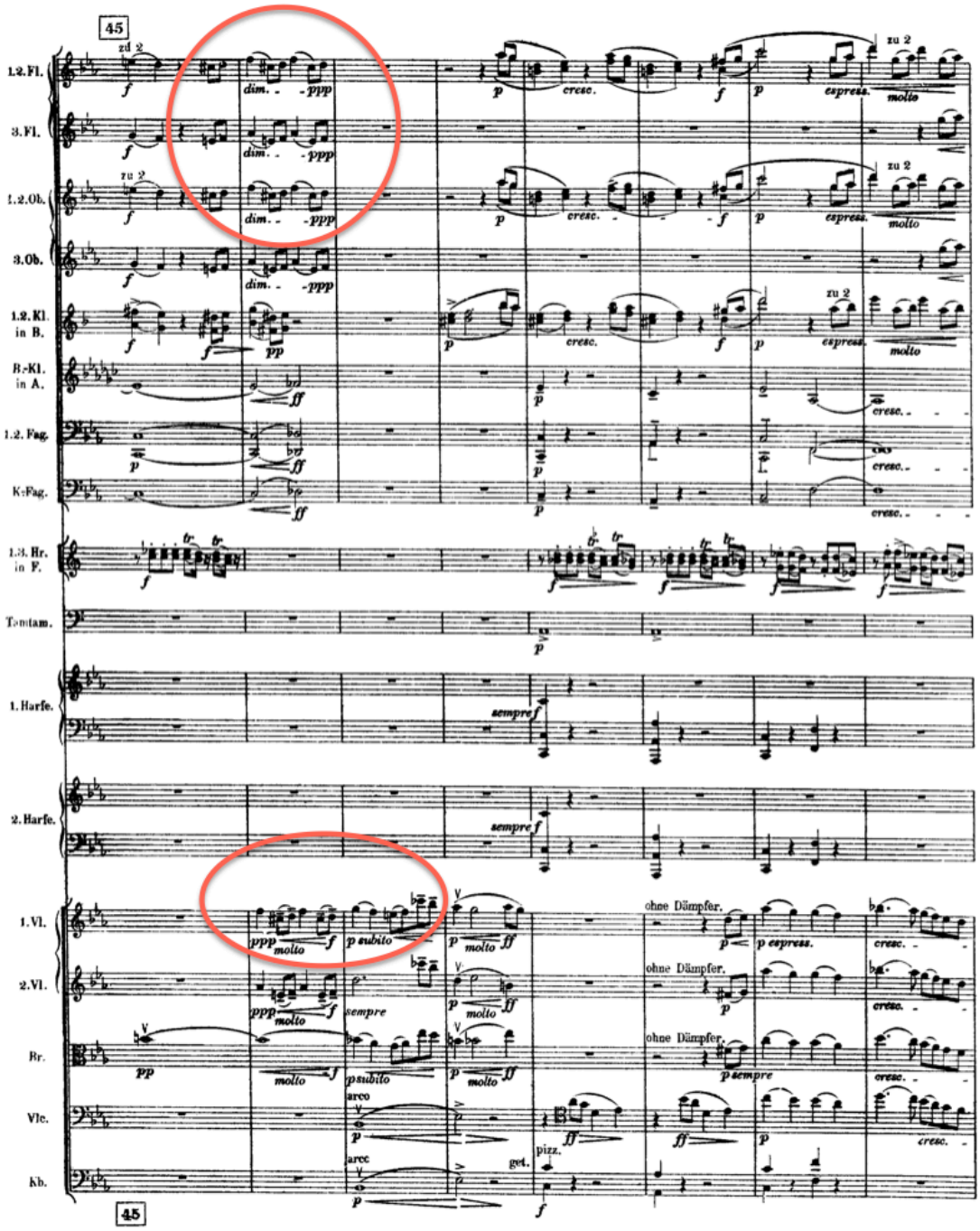

Figure 161 - Mahler: Das Lied von der Erde, vi (Score, mm. 330-7)

Again the careful use of dynamics – both compositionally and in performance – are essential to the success of this passage. Despite the relatively dense texture visible even in the following reduction, the excerpt remains an example of the melodic type (ie.

occurring over the course of a single melody). The presence of the second voice is purely homophonic, resulting in a single line's passage through a sequence of instruments (illustrated in Figure 162).

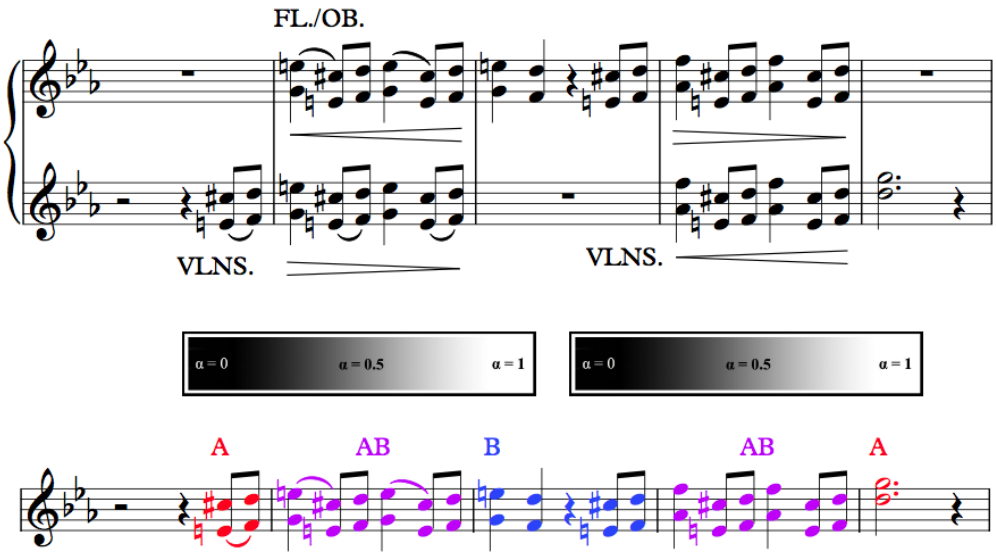

Figure 162 - Mahler: Das Lied von der Erde, vi (Reduction, mm. 348-52)

Not surprisingly, an increase in textural density in *Klangfarbenmelodie* of the melodic type begins to encroach upon the territory of *Klangfarbenmelodie* in a more harmonic sense. The following section will deal with the phenomenon of timbral manipulation in a harmonic sense, as found in various instrumental works. Schoenberg's own writings and music (as well as the music of his pupil Berg) will demonstrate the relationship between extended harmonic practice and the origins of the term.

5.3 Harmonic Klangfarbenmelodie

Though the above "melodic" instances of *Klangfarbenmelodie* seem to correspond most closely to the phenomenon implied by the term, American author and theorist Alfred Cramer attempted to debunk such an understanding in his 2002 article: "*Klangfarbenmelodie*: A Principle of Early Atonal Harmony"[324]. Cramer cites the

[324] Cramer, "*Klangfarbenmelodie*".

context in which the term first (and repeatedly) appears as evidence of its close ties to Schoenberg's harmonic practice:

> "Schoenberg's discussion of *Klangfarbenmelodie,* then, is no speculation about timbral composition appended tangentially to the end of a book about harmony; it continues a thread woven throughout the *Harmonielehre.* As a discussion of harmony, it is only the last and furthest-reaching of several aesthetic and philosophical sidetracks explored during the making of the final chapter's general point that chords of six or more tones are too new for their laws to have been discerned."[325]

It is true that the first discussions of harmony constructed according to timbral logic appear quite early in the *Harmonielehre*. To revisit the following passage (cited earlier) from the second chapter (on consonance and dissonance) in which the constituent notes of a harmony are described in terms of their relationship to the partials of the harmonic series:

> "The more immediate overtones contribute *more*, the more remote contribute *less*. Hence, the distinction between them is only a matter of degree, not of kind. They are no more opposites than two and ten are opposites, as the frequency numbers indeed show; and the expressions 'consonance' and 'dissonance', which signify an antithesis, are false. It all simply depends on the growing ability of the analyzing ear to familiarize itself with the remote overtones, thereby expanding the conception of what is euphonious, suitable for art, so that it embraces the whole natural phenomenon.
>
> What today is remote can tomorrow be close at hand; it is all a matter of whether one can get closer. And the evolution of music has followed this course: it has drawn into the stock of artistic resources more and more of the harmonic possibilities inherent in the tone."[326]

Thus *Klangfarbenmelodie* is not only an outgrowth of Schoenberg's conception of tone (as cited earlier), but also his notion of harmony. Much more so in fact, does true Schoenbgergian *Klangfarbenmelodie* relate to harmony than it does to either orchestration or melody. Alfred Cramer summarizes this relationship as follows:

> "Schoenberg himself insisted that *Klangfarbenmelodie* did not entail varying instrumentation and implied that it involved harmonic

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[325] Ibid., 10.

[326] Schoenberg, *Harmonielehre,* 20-21.

> progression. His retrospective 1951 essay "Anton Webern: *Klangfarbenmelodie*" makes no mention of instrumentation, but rather associates *Klangfarbenmelodie* with harmony. He also makes no suggestion that "*melodie*" referred to a succession of individual tones of varying timbre. Instead, he writes, it denotes a structured quality: "These I called melodies, because, like melodies, they would need to be given form... ***I meant something different by Klänge, and especially, though, by Melodie...*** They are never merely individual tones of different instruments at different times, but rather combinations of moving voices. However, these are still not melodies, but isolated occurrences within a form to which they are subordinate. They would become melodies if one found the point of view to arrange them so that they would form a constructive unity of absolute autonomy." [emphasis mine]"[327]

5.3.1 Harmonic Klangfarbenmelodie I – Schoenberg

Likely owing to its subtitle (*Farben*[328]), the third piece from Schoenberg's *Five Pieces for Orchestra* Op. 16 (1909) is closely tied to the origins of *Klangfarbenmelodie*. In addition to the subtitle, American musicologist and theorist Charles Burkhart wrote in the 1973 article "Schoenberg's Farben" that the misinterpretation of a performance note was also a potential factor behind the mistaken and popular belief that *Farben* contains only a single chord, continually re-stated in various orchestrations:

> "Perhaps Schoenberg's footnote, directing that entering instruments become noticeable solely by means of their color, was wrongly taken to imply that changes of pitch did not occur."[329]

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[327] Cramer, "*Klangfarbenmelodie*", 4.

[328] For a history of the subtitling in Schoenberg's Opus 16, see Charles Burkhart. "Schoenberg's Farben," *Perspectives of New Music*, Vol. 12, No. 1-2 (1973-4): 141-172.

[329] Burkhart, "Farben", 141.

Despite these past misconceptions, Burkhart points out that "today it is no longer necessary to refute the long-lived myth"[330], and dedicates his analysis to the relationship between tone and tone colour in *Farben*. This relationship is of course, characteristic of Schoenberg's 1951 description of *Klangfarbenmelodie* cited by Cramer above. In particular, the statement that *Klangfarbenmelodie* is "never merely individual tones of different instruments at different times, but rather combinations of moving voices"[331] rings particularly true when one considers the opening texture. Certainly, a successful interpretation that honours Schoenberg's above cited performance note will emphasize the textural exchange of timbres. However, the underlying structure is clearly an eight-voice canon (see Figure 163 below)[332] on a three-note motive consisting of a rising minor second, followed by a falling major second[333].

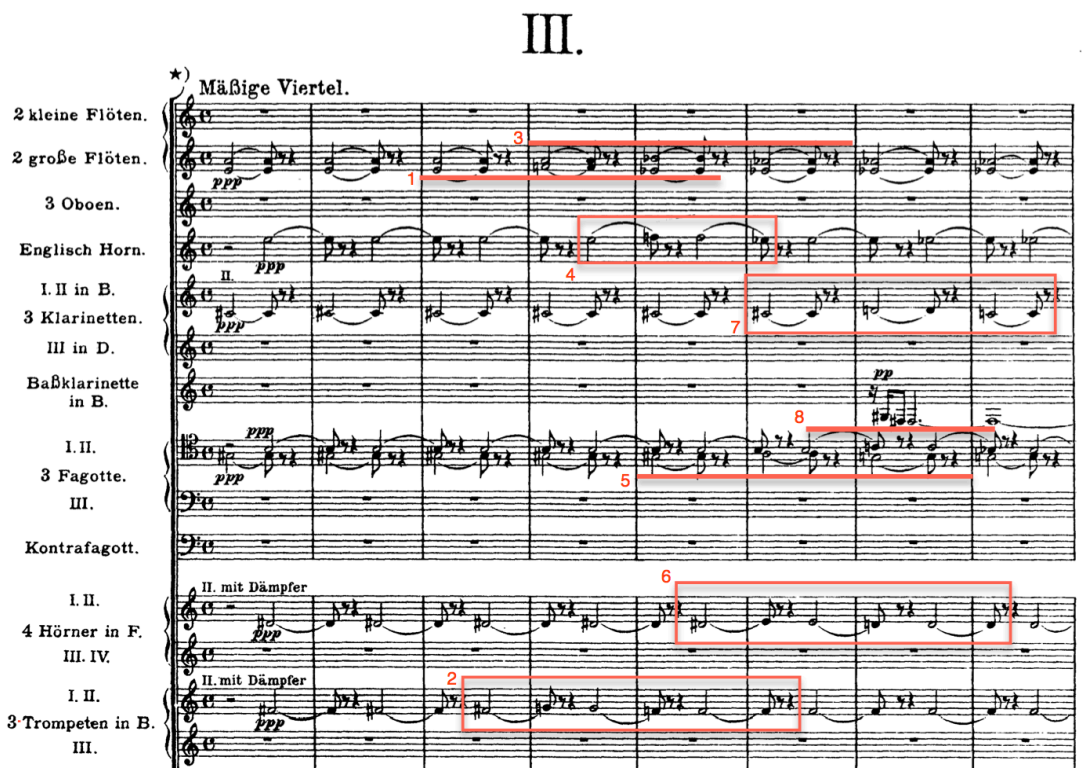

Figure 163 - Schoenberg: Farben (Canonic Entrances, mm. 1-8)

[330] Burkhart, "Farben", 141.

[331] Cramer, *Klangfarbenmelodie*, 4.

[332] Arnold Schoenberg, *Fünf Orchesterstücke: Op. 16* (New York: Peters, 1952), mm. 1-8.

[333] Burkhart, "Farben", 146.

The limited and condensed melodic content of this canon allows for the textural, orchestrational, and harmonic aspects to move to the perceptual foreground. The shifting of attention away from melodic contour in favour of these other facets corresponds closely with Schoenberg's generally harmonic conception of *Klangfarbenmelodie:* "these are still not melodies, but isolated occurrences within a form to which they are subordinate."[334]

Burkhart describes the work's pitch materials and the "form to which they are subordinate", in relation to this opening gesture:

> "The pitch organization of Farben reveals two general layers: a stream of five-voice chords (continually subjected to changes in instrumentation) and a group of very short ejaculatory motives… ***the chords are the essence of the pitch content of the work...*** The primary pitch referent of Farben is the first chord... Not only is this chord regained at m. 30 and at the end, but other transpositions of it occur in identical spacing in the course of the composition. [emphasis mine]"[335]

The first such transposition of the intial chord ("C-0" in Burkhart's analysis) is labelled C-11 to indicate its movement down by semi-tone. The motive of the opening canon is left off here, in favour of the work's primary texture. Burkhart describes it as follows.

> "The typical instrument plays solo for just one half-note, waits, then plays another half-note in another voice, and so on, all parts so disposed as to produce a new instrument combination on every half-note."[336]

The resulting primacy and interrelationship of harmony and tone colour can hardly be overstated. Burkhart's graph of the first two sections (see Figure 164) clearly shows a highly static and vertical organization of pitch content, endlessly re-articulated by a constant and regular flow of voice exchanges[337].

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[334] Cramer, *Klangfarbenmelodie*, 4.

[335] Burkhart, "Farben", 143.

[336] Ibid.

[337] Ibid., 144.

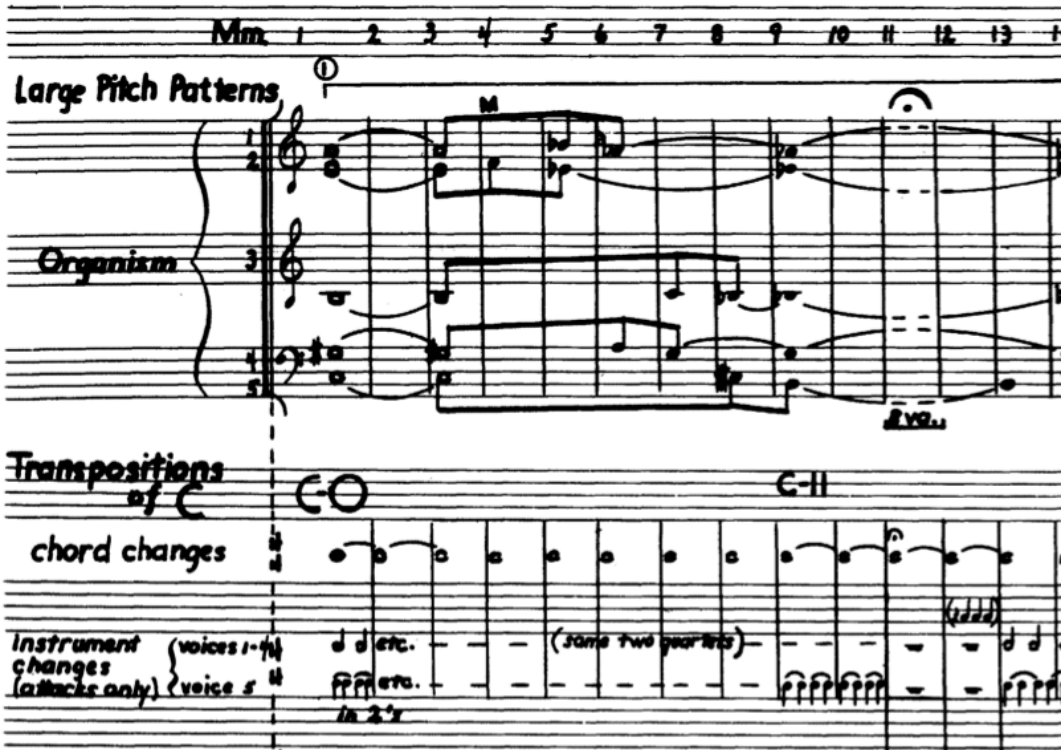

Figure 164 - Schoenberg: Farben (Graph by Burkhart, mm. 1-13)

The graph of Figure 164 shows that while the canon of the first eight measures involves subtle shifts in pitch content, the statement of C-11 at measure nine is sustained for five full bars. During this time, the two lowest rows of the graph show that a full 20 instrument changes have occurred.

Thus, the timbral and harmonic structures of the work begin to take on much more active and interconnected roles following measure nine. While it is the ***relationship*** between the constituent elements (melodic, harmonic, and instrumental) of *Klangfarbenmelodie* that defines the phenomenon, clearly the example of *Farben* is one of a much more vertical nature than those encountered previously. It is this vertical quality that defines the harmonic nature of Schoenberg's *Klangfarbenmelodie.* However, the integration of a melodic canon into the opening section of the movement illustrates how interrelated the various elements of musical texture can remain in examples of one particular type. The following example of harmonic *Klangfarbenmelodie* from one of

Schoenberg's most famous students (Alban Berg[338]) however, is much more strictly vertical in conception.

5.3.2 Harmonic Klangfarbenmelodie II – Berg

In 1911-2 Schoenberg's pupil Alban Berg composed five orchestral songs on texts by Peter Altenberg, which have come to be known as the *Altenberg Lieder* (Op. 4). It is of particular interest that 1911 was the same year that Berg was editing the manuscript of Schoenberg's *Harmonielehre,* cited at length above in reference to the first appearance of the term *Klangfarbenmelodie*[339].

In his 1966 article[340] on the *Altenberg Lieder*, Mark Devoto produced a chart (see Figure 165) describing the distribution of the unusual harmonic content at the beginning of the third song[341].

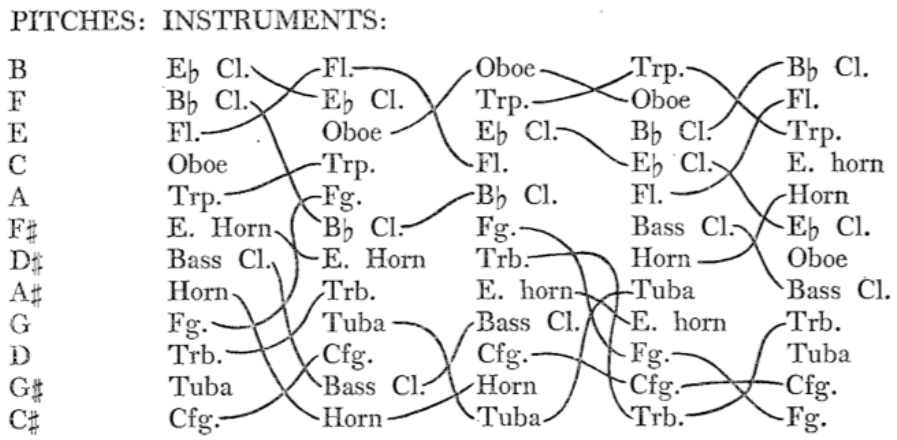

Figure 165 - Berg: Op. 4, No. 3 (Graph by Devoto, mm.1-7)

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[338] For more on the teacher-student relationship between Schoenberg-Berg, see: Donald Harris, . "Some Thoughts on the Teacher-Student Relationship between Arnold Schoenberg and Alban Berg," *Perspectives of New Music,* Vol. 15, No. 2 (April 1977): 133-44; Alban Berg and Arnold Schoenberg, *The Berg-Schoenberg Correspondence: Selected Letters*. Edited by Juliane Brand, Christopher Hailey, and Donald Harris (New York: Norton, 1987); and Bryan R. Simms (ed.), *Schoenberg, Berg, and Webern: A Companion to the Second Viennese School* (Westport, Conn.: Greenwood Press, 1999).

[339] In the 1975 talk published in *Perspectives of New Music* and cited in the previous footnote, Donald Harris cites one of Berg's letters from the 1911 editorial process, noting the extreme subservience of Berg to his teacher: "…it becomes ever more clear to me that this work has been written in service of the divinity the more often I read it, the more deeply I penetrate into it. That we poor mortals may partake of it is our supreme good fortune. For this we thank you, *beloved* Herr Schoenberg." Harris, "Some Thoughts", 134.

[340] Mark Devoto, "Some Notes on the Unknown *Altenberg Lieder,*" *Perspectives of New Music*, Vol. 5, No. 1 (Fall-Winter 1966): 37-74.

[341] Devoto, "Altenberg", 74.

Though the appearance of the complete chromatic aggregate in five consecutive, sustained, chords is noteworthy, it is the method of presentation that is of primary importance to the present inquiry. Though the top and bottom voices trace tritone outlines (B and F in the top voices, C# and G in the lower), the harmony is essentially static in all five iterations. All twelve pitch classes are presented and sustained, without doublings, for each of the five statements. Furthermore, with the exception of the contrabassoon, no two adjacent chords present the same pitch in the same instrument. These tendencies are summarized in Figure 166 below[342].

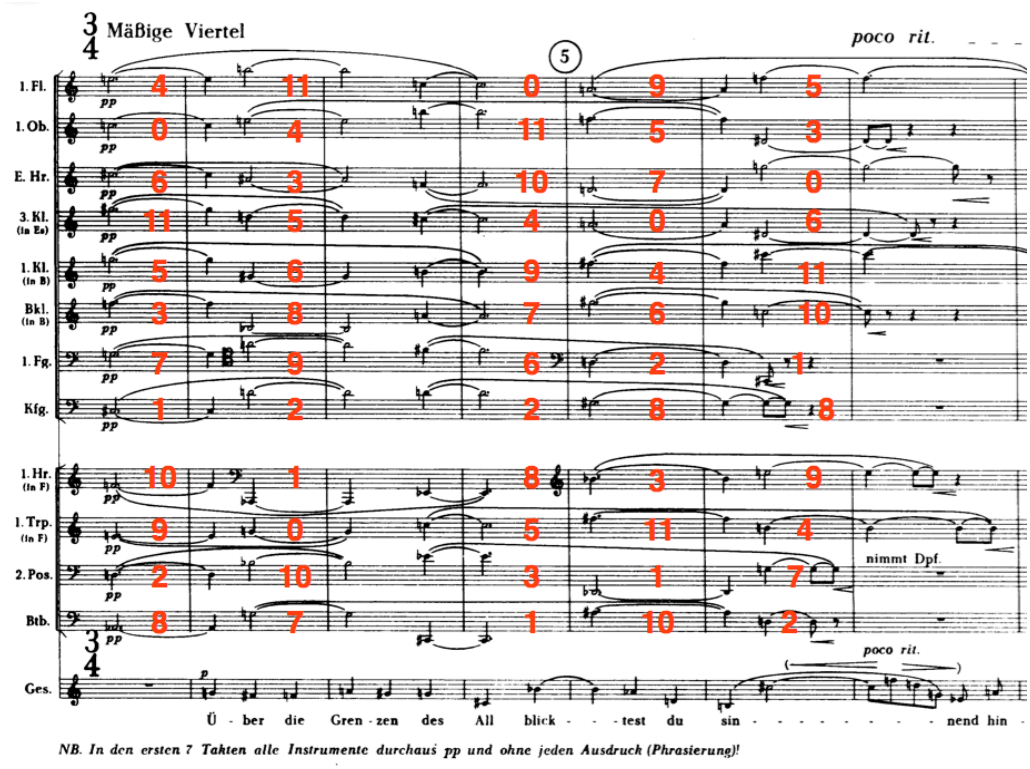

Figure 166 - Berg: Op. 4, No. 3 (Annotated Score, mm. 1-7)

[342] Alban Berg, *Fünf Orchesterlieder, Opus 4* (Wien: Universal Edition, 1953), mm. 1-7.

While its identity as an example of *Klangfarbenmelodie* of the harmonic type seems unambiguous, one might still consider other possible interpretations. For instance, the swapping of pitches between instruments might also be interpreted in terms of the melodic *Klangfarbenmelodie* timbral transformations seen earlier in Wagner and Mahler. Consider for example the trajectory of the pitch class F# through the available instrumental resources shown in Figure 167.[343]

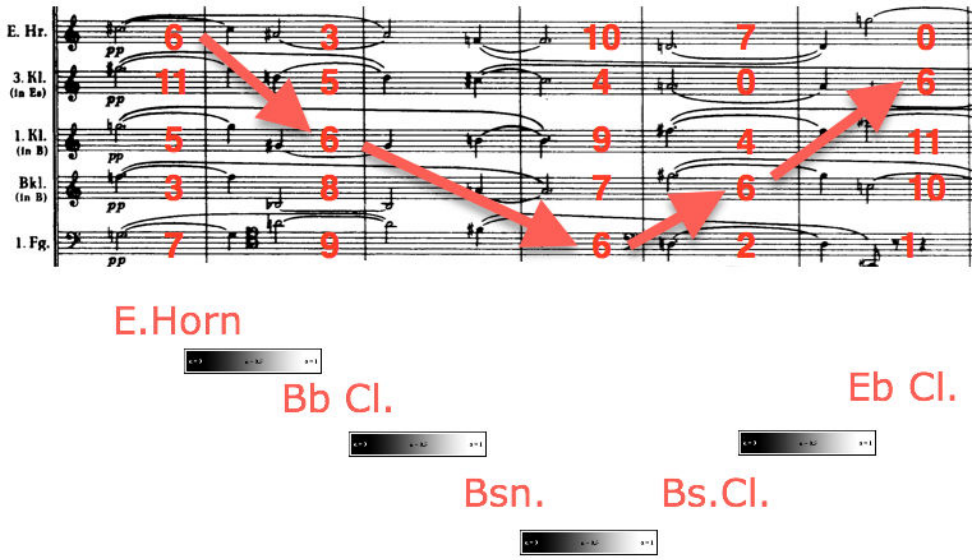

Figure 167 - Berg: Op. 4, No. 3 (Melodic Interpretation, mm. 1-6)

According to a melodic reading, each pitch class could be interpreted as undergoing a gradual transformation of timbral colour with four distinct stages. In the case of F#, the transformations would occur from the english horn, to the B-flat clarinet, to the bassoon, to the bass clarinet, and finally to the Eb Clarinet.

However, the density of harmonic information, the use of sustaining instruments, the presence of rhythmic unisons, and the static harmonic content, all contribute to a much more vertically unified impression. As such, this example typifies the "harmonic" variety of *Klangfarbenmelodie* even more acutely than the Schoenberg example from opus 16 (with its quasi-hidden canonic structure).

[343] Berg, *Opus 4*, mm. 1-6.

While the *Altenberg* example is clearly *Klangfarbenmelodie* of the harmonic type, the exercise of considering potential alternatives is an important one. This fact will be illuminated through consideration of the final category of purely acoustic manipulation of timbre. For while the canonic/harmonic (Schoenberg) and proto-dodecaphonic (Berg) pitch structures of the two previous examples anchor them firmly in *Klangfarbenmelodie* traditions of the past, it would be difficult to suggest that timbre is not manifest as a primary musical parameter for overall structure. It is the aim of the following section however to address cases in which the ability to transform instrumental and vocal timbres becomes ***the*** primary procedure of musical composition (as opposed to instances clouded by earlier pitch-based paradigms).

5.4 Timbre as Primary Compositional Material

In Chapter 3 acoustics (the science of sound), was described in enough detail to facilitate a discussion of digital audio morphing technologies. However, for the following examples it is sufficient to acknowledge Schoenberg's assertion that "pitch is nothing else but tone color measured in one direction."[344], and to note the importance of a given pitch's harmonic structure (the strength of its partials) in shaping its timbre[345].

The most intuitive illustration of the relationship between pitch, timbre, and harmonic structure is the phenomenon of vocal formants[346]. A knowledge of acoustics is not necessary to understand that different vowels can be distinguished from one other even when spoken or sung on a common pitch. The varied presence and intensity of the partials for a given pitch (see Figure 168) are responsible for the identity of the vowel (and sometimes speaker) perceived, regardless of the pitch (fundamental frequency).

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[344] Schoenberg, *Harmonielehre,* 421.

[345] If the acoustic terminology of the following section is unclear to the reader, skipping ahead to the introductory materials of Chapter 5 will address any confusion.

[346] For a thorough account of vowel perception and production, see: B.S. Rosner and J.B. Pickering, *Vowel Perception and Production* (New York : Oxford University Press, 1994).

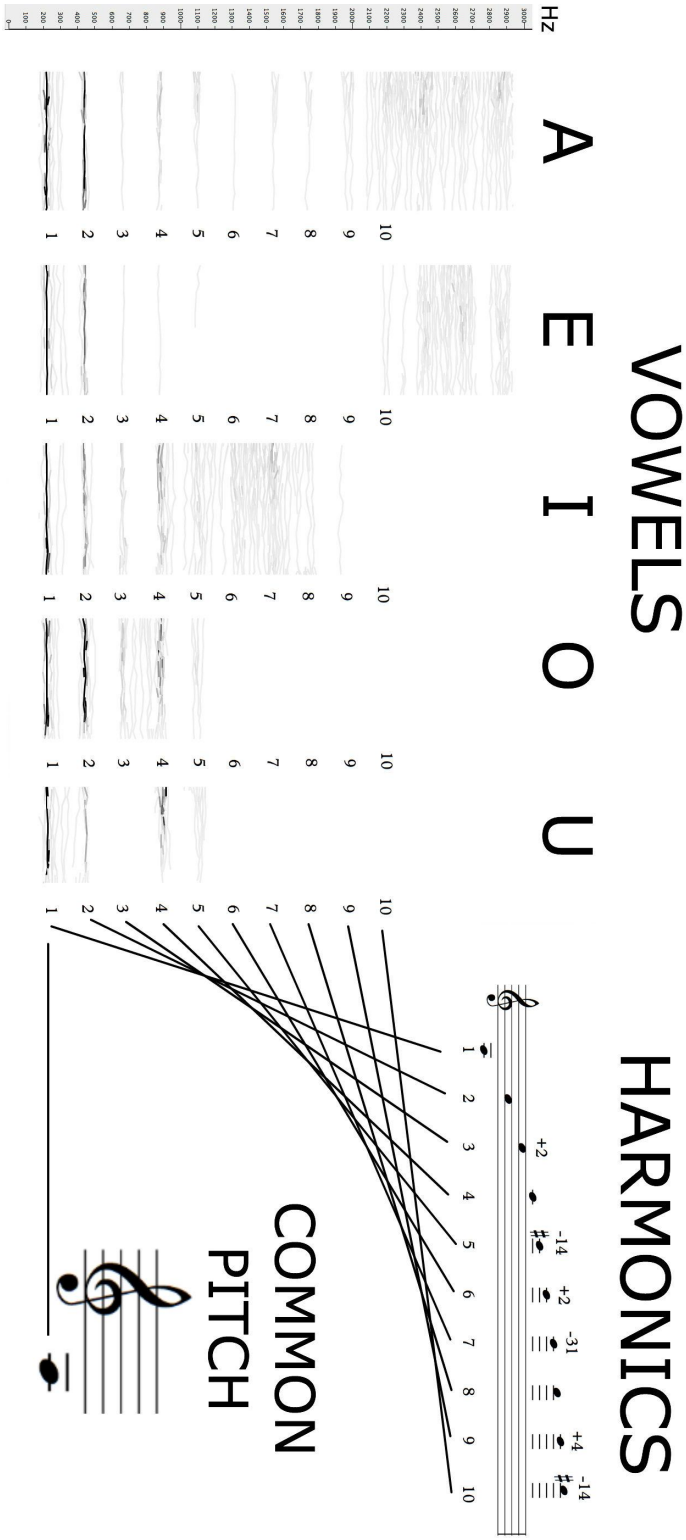

Figure 168 - Spectrogram of Author's Singing Voice: Five Vowels

In the above example, the harmonics (and inharmonic partials – to be explained further in Chapter 5) that contribute to a given vowel's identity are plotted along a spectrum of audible frequencies (labeled in cycles per second on the left). As described in the previous chapter, the audible spectrum (measured in frequency rather than discrete pitches) took on structural importance for the organization of pitch content in several mid-20th century works[347]. The following examples from Stockhausen, Messiaen, and Grisey will show that this trend coincided with the emergence of works in which the spectral contents of individual sounds were employed as the basis for compositional structure. The term spectral music has been applied to music in which the spectrum of a given sound(s) takes on a fundamental role in the creation of musical material and form[348]. As the subsequent discussion of Gerard Grisey's music will note, such techniques gave rise to an entire school of compositional activity in late 20th century France. Fellow French spectralist and Grisey colleague Tristan Murail has explained how this development was at least partially a consequence of new (20th century) tools for audio analysis[349].

However, spectral music can also be traced back to several proto-spectral techniques, including those of the *Klangfarben* compositions discussed above. Writing in 1911, some fifty years prior to the development of digital tools for detailed audio analysis, Schoenberg expressed a willingness to explore the medium of timbral composition purely intuitively:

> "The evaluation of tone color (*Klangfarbe*), the second dimension of tone, is thus in a still much less cultivated, much less organized state than is the aesthetic evaluation of these last-named harmonies. Nevertheless, we go right on boldly connecting the sounds with one another, contrasting them with one another, simply by feeling; and it has never yet occurred to anyone to require here of a theory that it should determine laws by which

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[347] In addition to the works cited in Chapter 2 as examples of pitch space being treated as an unsegmented continuum of frequency (Xenakis' *Mikka-S* and Tenney's *Koan*), one might also (more broadly) consider composers who ascribed structural importance to pitch materials' frequencies of vibration (for instance, Varèse), and composers who experimented with alternate divisions of pitch space (such as Ives, Bartók, and Partch for example).

[348] Julian Anderson. "Spectral music," *Grove Music Online*. Oxford Music Online. Oxford University Press, accessed October 9, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/50982.

[349] For more on the role of audio technology in this development, see: Murail, "Complex Sounds" .

> one may do that sort of thing. Such just cannot be done at present. And, as is evident, we can also get along without such laws....
>
> ...For the present we judge the artistic effect of these relationships only by feeling. How all that relates to the essence of natural sound we do not know, perhaps we can hardly guess at it yet but we do write progressions of tone colors without a worry, and they do somehow satisfy the sense of beauty. What system underlies these progressions?" [350]

5.4.1 Timbre as Primary Compositional Material I – Messiaen

A musical bridge between Schoenberg's intuitive approach, and one that is rooted more firmly in the science of acoustics, can be found in several works by Olivier Messiaen[351]. Though a highly influential French composer (and teacher[352]) of the mid-late 20th century, Messiaen is rarely mentioned in the context of the French spectral tradition (to be discussed shortly). Despite this fact, Messiaen was working in a proto-spectral medium as early as 1956-8 in his 7 Volume *Catalogue d'Oiseaux* for solo piano.

Though other materials are used throughout the *Catalogue* to evoke the atmosphere of the locations in which Messiaen transcribed his birdsongs, the songs themselves form the core of the anthology's musical content. In rendering these songs, Messiaen strove for precision, as he describes in his 1967 conversations with Claude Samuel.

> "Personally, I'm very proud of the exactitude of my work; perhaps I'm wrong, because even people who really know the birds might not recognize them in my music, yet I assure you that everything is real"[353]

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[350] Schoenberg, *Harmonielehre*, 421.

[351] While the *Catalogue d'Oiseaux* will follow as a particularly demonstrative example, the principles of timbral composition enumerated by Messiaen could just as easily be applied to his many other works involving birdsong. For more on the role of acoustics in these works, see: Robert Fallon, . "The Record of Realism in Messiaen's Bird Style," in *Olivier Messiaen: Music, Art, and Literature*, ed. Christopher Dingle and Nigel Simeone, 115-136 (Farnham: Ashgate, 2007); and David Kraft, *Birdsong in the Music of Olivier Messiaen* (London: Arosa, 2013).

[352] It is worth noting that two of Messiaen's most celebrated students were Pierre Boulez and Karlheinz Stockhausen, both of whom are closely associated with technologically assisted investigations into acoustics (Boulez at IRCAM and Stockhausen throughout his entire career). Messiaen's influence as a teacher is documented in: Pierre Boulez and George Benjamin, "Messiaen as Teacher," in *The Messiaen Companion*, ed. Peter Hill, 266-268 (London: Faber and Faber, 1995). For more on Messiaen's influential analysis class, see: Vincent Benitrez, "A Creative Legacy: Messiaen as Teacher of Analysis," *College Music Symposium*, Vol. 40 (2000): 117-139.

[353] Messiaen, *Musique et Couleur*, 94.

Obviously, with the sound production methods of birds and pianos differing so greatly, certain alterations to the material were necessary:

> "I write one, two, or three octaves lower. And that's not the only adjustment: for the same reasons I'm obliged to eliminate any tiny intervals that our instruments cannot execute. I replace those intervals, which are on the order of one or two commas, by semitones, but I respect the scale of values between the different intervals… all are enlarged, but the proportions remain identical, and as a result, what I restore is nevertheless exact. It's a transposition of what I heard, but on a more human scale."[354]

In addition to preserving the proportions of his melodic intervals, Messiaen was also quite diligent in approximating the timbral characteristics of his transcriptions. In fact, he went so far as to invent an entirely new harmonic practice (that closely anticipated the French spectral tradition). In Messiaen's own words, the harmony is in complete service of timbre:

> "In order to translate these timbres, harmonic combinations are absolutely necessary. Even in very fast movements... each note is provided with a chord, not a traditional chord, but a complex of sounds destined to give the timbre of that note. There are as many invented chords as there are notes, which is to say, for a bird piece comprising one or two thousand notes, there are one or two thousand invented chords."[355]

Though a wide variety of chords are invented for each melodic pitch, it is not surprising that certain characteristic harmonic intervals recur within the call of an individual bird. The opening figure of *Le Courlis Cendré* from Vol. 7 of the *Catalogue*[356] for instance (see Figure 169), makes almost exclusive use of Forte set class number 3-3[357] (a minor third on top of a minor second). The first chord of the piece is the only exception, as is not included in the bird call proper (Messiaen labels the start of the call one eighth note later in the upper register).

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[354] Ibid., 95.

[355] Ibid.

[356] Olivier Messiaen, *Catalogue d'oiseaux 7e livre*, (Paris: Leduc, 1964), mm. 1.

[357] For more on set class numbers, see (the previously cited): Straus, *Post-Tonal Theory*.

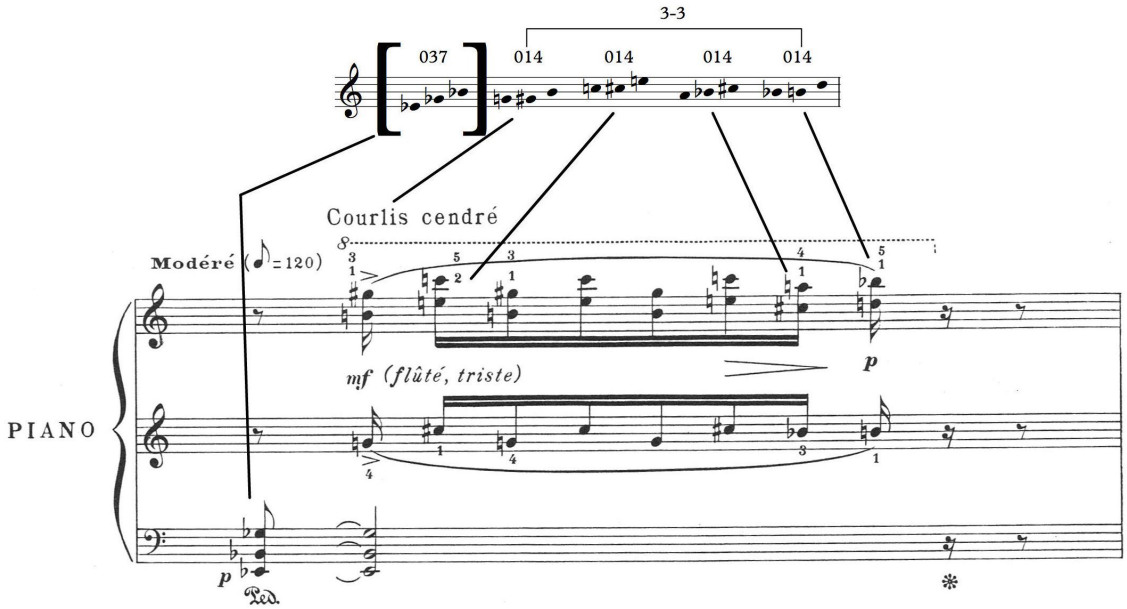

Figure 169 - Messiaen: Catalogue D'oiseaux, Vol. 7, Le Courlis Cendre (m. 1)

Similarly, the call of the Goéland Cendré that appears on page 9 of *Le Courlis Cendré*[358] is primarily supported by the very similar Forte set class numbers 4-5 and 4-6 (both of which prominently feature an F#-C# dyad) as seen in Figure 170 below.

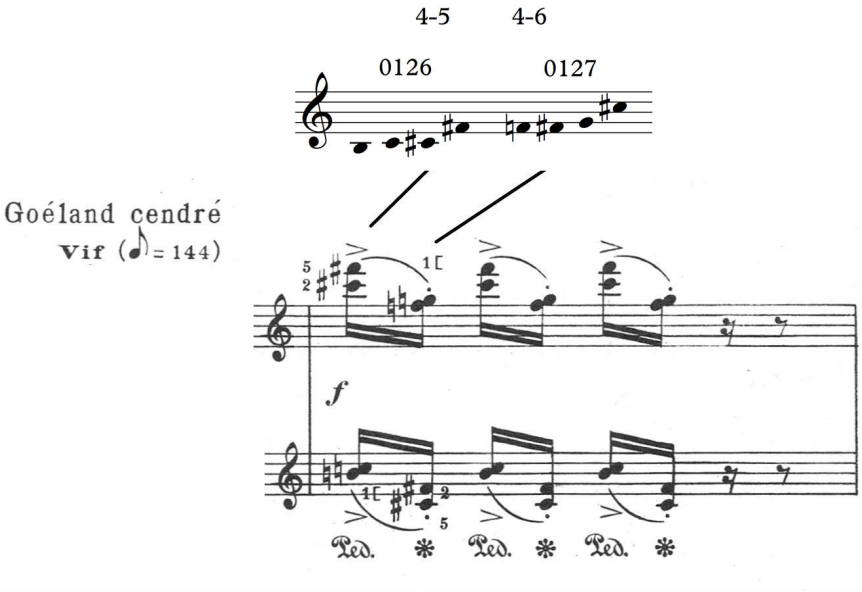

Figure 170 - Messiaen: Catalogue D'oiseaux, Vol. 7, Le Courlis Cendre (p. 9)

[358] Messiaen, *Catalogue*, 9.

This consistency of set class usage within the call of each bird (and its diversity from bird to bird) is clear evidence that Messiaen did in fact derive his harmonies according to timbral concerns.

Given the importance of register in spectral harmony[359], it is also useful to consider how intervals are treated in terms of their spacing. During the page 7 call of the *Huîtrier pie*[360], Messiaen uses virtually nothing outside of Forte set class number 3-1 (two minor seconds stacked to build a major second). This three note chromatic cluster also appears as both of its constituent dyads: the internal minor second, and the major second outlined by their stacking (Figure 171).

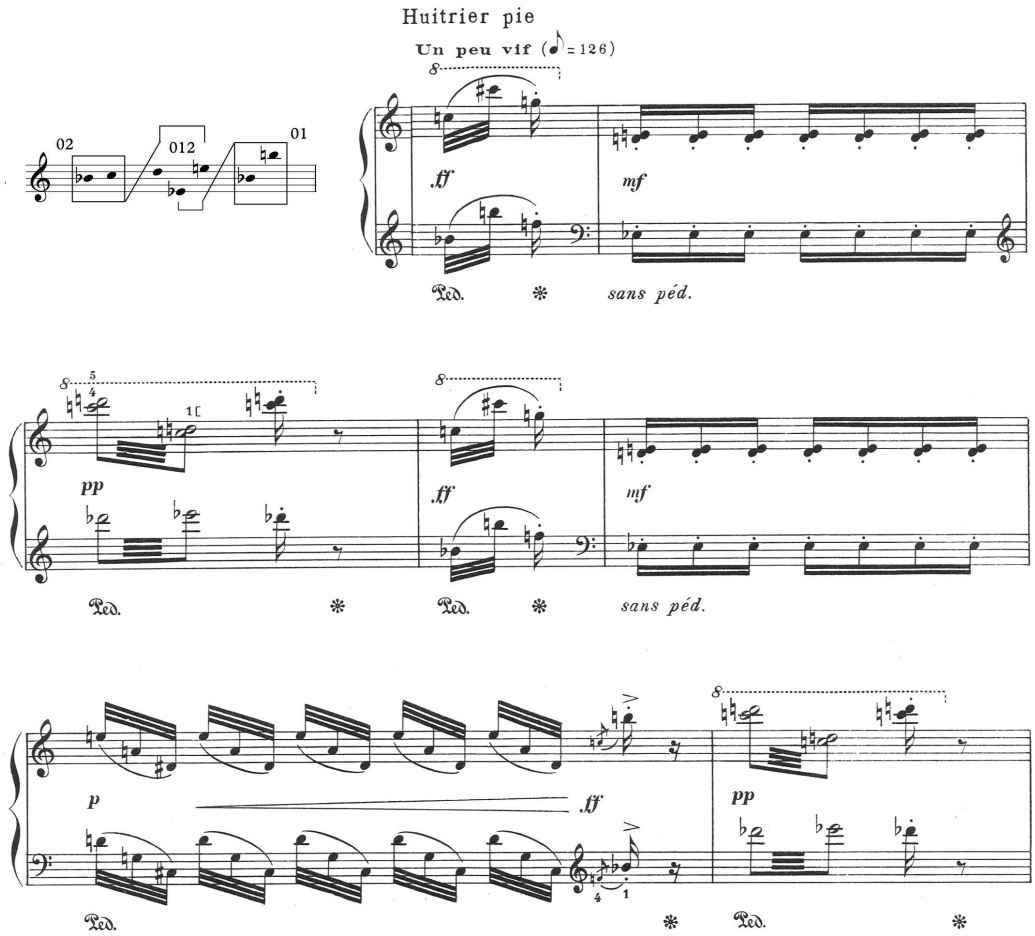

Figure 171 - Messiaen: Catalogue D'oiseaux, Vol. 7, Le Courlis Cendre (p.7)

[359] Due to the non-linearity of western pitch space, higher instances of the same interval are separated by greater and greater numbers of cycles per second. As a result, the upper harmonics of a harmonic pitch are packed tighter and tighter together in pitch space as one ascends the series.

[360] Messiaen, *Catalogue*, 7.

The spacing of the reduction in Figure 171 shows that while the major seconds are presented in their most compact form, all minor seconds are separated by the spacing of a ninth. Though irrelevant to pitch class set classification, this registral characteristic has a substantial effect on timbre. The potentially harsher dissonance of the minor second is always broken up and buffered by the span of an octave.

5.4.2 Timbre as Primary Compositional Material II – Stockhausen

The systematic exploration of spectral phenomena found in German composer (and former Messiaen student) Karlheinz Stockhausen's 1968 vocal sextet *Stimmung*[361] stands in contrast to the intuitive transcriptions of timbre found in Messiaen's *Catalogue.* Whereas Messiaen worked entirely by ear, Stockhausen's harmonies were largely derived through acoustic research[362] first conducted in the electronic music studios of the West Deutsche Rundfunk (WDR) and then continued at the Heinrich Stroebel Studios of the Sudwestfunk (today the Experimentalstudio of the SWR). Despite this fact, the work is entirely acoustic (save for the possible amplification of the singers).

The manipulation of vocal partials, such as those responsible for the perception of vowel sounds analyzed earlier, constitutes the musical material of the entire hour-long work. The pitches chosen as fundamental frequencies over which the overtone manipulation occurs, were themselves chosen from the harmonics of a low Bb.

The score consists of diagrams outlining both global and localized activity. The former indicates which singer is to lead each section, and which pitch is to be used as a fundamental (see Figure 172)[363]. The latter is a series of "models" that provide rhythmic and frequency information for the changes in vowel production.

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[361] Karlheinz Stockhausen, *Stimmung für 6 Vokalisten: Nr. 24*, (Wien: Universal Edition, 1969).

[362] For more on this aspect of Stockhausen's acoustic research, see the (previously cited): Stockhausen, "Four Criteria".

[363] Stockhausen, *Stimmung*, 1.

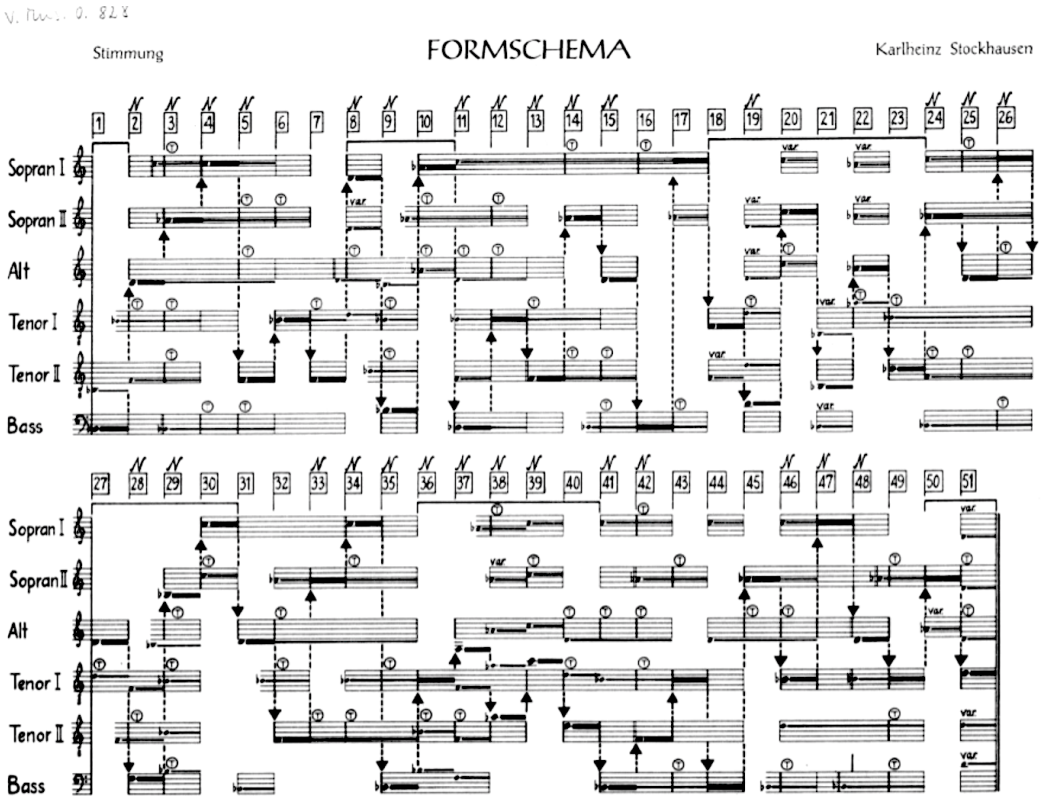

Figure 172 - Stockhausen: Stimmung (Global Form)

The global activity as described previously is specified by the above *Formschema*, while the local (rhythmic and timbral) "models" are notated on sheets labeled *Modelle*, such as the following example reproduced in Figure 173.[364]

[364] Stockhausen, *Stimmung*, 2.

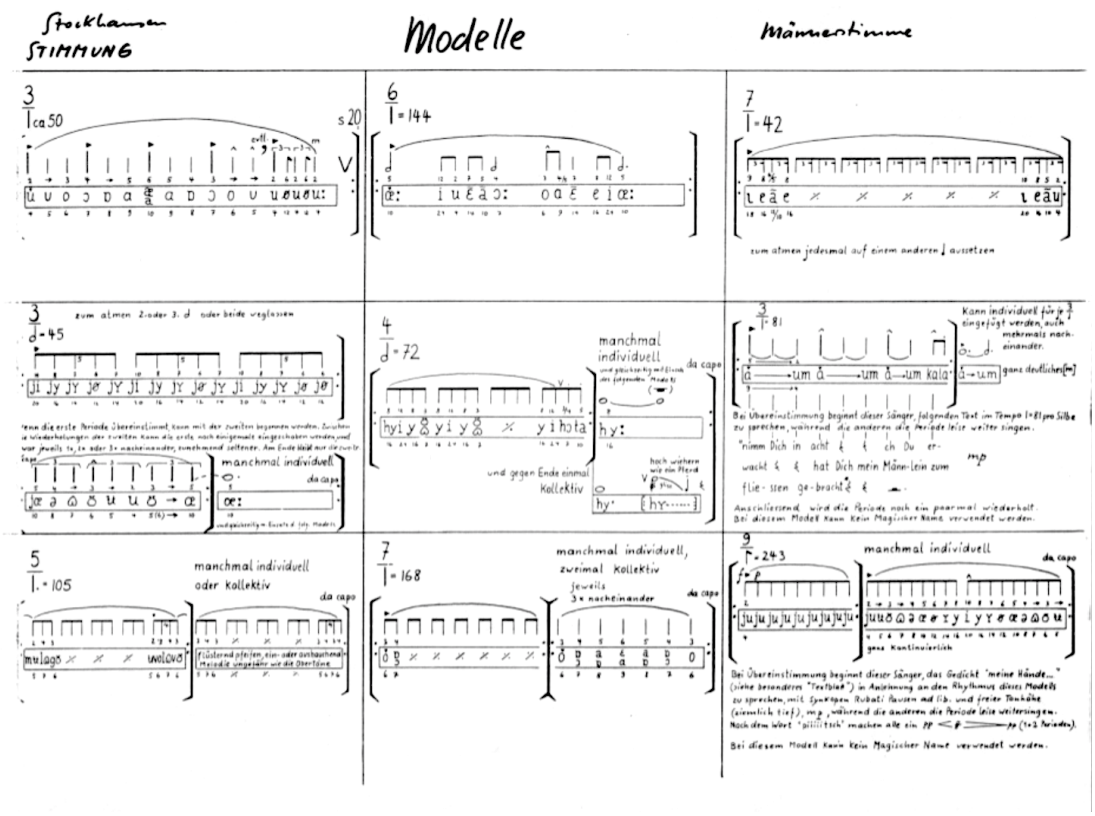

Figure 173 - Stockhausen: Stimmung (Models)

In addition to the International Phonetic Alphabet symbols associated with each vowel sound, Stockhausen also supplies the actual integer multiple of the harmonic being emphasized (see Figure 174). Of greatest relevance to the acoustic manipulation of timbre however, is the fact that changes between groups of partials are almost always continuous. Because of the flexibility of the human vocal apparatus, one sung timbre can seamlessly transform into the next. Below is a spectral analysis of a performance of the model from the top-left corner of Figure 173.

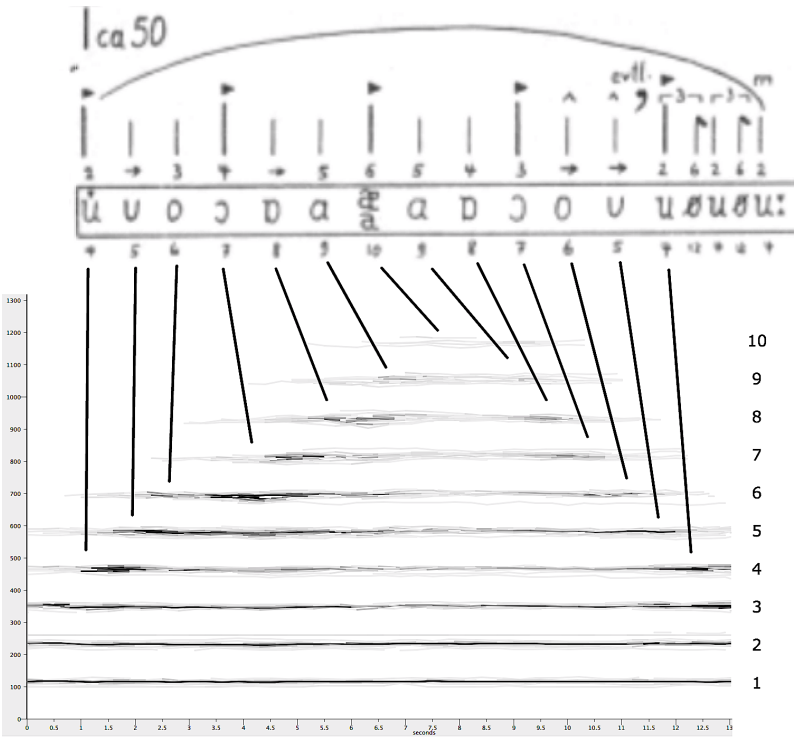

Figure 174 - Stockhausen: Stimmung (Spectral Analysis)

The vocal transformation in the above excerpt can be interpreted on multiple levels according to the Caetano morphing index.

Figure 175 - Stockhausen: Stimmung (Possible Morph Interpretation)

According to the interpretation of Figure 175, the individual transitions between the vocal timbres that emphasize harmonics four through ten each constitute a timbral transformation. In Figure 176 however, the overall trajectory of the gesture is viewed as a single transformation from a timbre emphasizing the fourth harmonic to one that emphasizes the tenth harmonic.

Figure 176 - Stockhausen: Stimmung (Alternate Morph Interpretation)

The intermediate timbres emphasizing harmonics five through nine are here interpreted as the continuum of connective sonority linking the vowels sounds ʊ and æ. Regardless of how one interprets these timbral changes, the salient point is that the spectra of the various vowel sounds in the composition are ***continuously*** transforming into one another.

5.4.3 Timbre as Primary Compositional Material III – Grisey

Despite the anticipation of spectralism in the K*langfarbenmelodie* of the late 19th and early 20th centuries, Messiaen's birdsong transcriptions of the 1940-50's, and Stockhausen's structural exploration of spectral characteristics in this major 1968 work; spectralism proper is generally considered to have begun in France during the 1970's[365]. In a special 2010 edition of *Contemporary Music Review* on the subject of spectral music, Joshua Fineberg states this claim explicitly and mentions by name the two figures most prominently associated with the discipline.

> "The musical school referred to as 'Spectral Music' was begun in France in the early seventies by Tristan Murail and Gérard Grisey and has become one of the most important schools of composition in contemporary music."[366]

[365] In his 2014 biography of Canadian composer Claude Vivier, Bob Gilmore notes other possible proto-spectralists, and describes the aesthetic climate to which Grisey and his colleagues were reacting: "Because the whole spectral approach is so profound, any history of its precursors (who might stretch as far back as Rameau, and include Debussy, Varèse, Scelsi, Messiaen, and many others) becomes immense. Yet whatever its lineage, the new French spectral music was a reaction in part against the prevailing norms of the day: against the serial aesthetic that was still rampant in Paris in the 1970s, and against aleatoric music, improvisation, and collage techniques. Murail has often cited the music of figures like Ligeti and Xenakis as more important in the development of his own thought than the music of Boulez or Barraqué, Cage or Stockhausen." Bob Gilmore, *Claude Vivier: A Composer's Life* (Rochester: University of Rochester Press, 2014): 164.

[366] Joshua Fineberg, "Spectral Music," *Contemporary Music Review*, Vol. 19, No. 2 (2000): 1-5.

While several other composers were also involved in the birth of the movement described by Fineberg[367], French composer Gérard Grisey is practically synonymous with spectralism in the general consciousness. A former pupil of both Messiaen[368] and Stockhausen[369], Grisey was instrumental in the creation and dissemination of spectral music in Paris during the 1970's through his founding of Ensemble L'Itinéraire. Grisey was also recognizable as a composer of spectral music due to the acoustically derived titles given to several of his most well-known works. *Les Espaces Acoustiques* is a cycle of six compositions for various forces spanning over a decade in compositional activity. Due to the didactic unfolding of its opening gesture, 1975's third instalment: *Partiels*[370] constitutes and exceptionally clear illustration of the spectral method[371].

Much as in *Stimmung*, the harmonic structure of a low pedal tone (in this case E = 42.1 Hz) is treated as the primary material for the composition. In Grisey's case, the original source material was a spectral analysis of the pedal E being played by a trombone. Included in the special volume of *Contemporary Music Review* on spectralism cited above, is a copy of the spectral analysis (Figure 177) employed in the composition of *Partiels*[372].

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[367] Paul Griffiths also points out the involvement of Michaël Lévinas, Hugues Dufourt, and Roger Tessier in: Paul Griffiths, *Modern Music and After: Directions since 1945* (Oxford: Oxford University Press, 1995): 339.

[368] Julian Anderson. "Grisey, Gérard," *Grove Music Online. Oxford Music Online*, Oxford University Press, accessed October 10, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/45479.

[369] David Bündler, "Interview with Gérard Grisey (January 18, 1986)", accessed October 10, 2014, http://www.angelfire.com/music2/davidbundler/grisey.html.

[370] Gérard Grisey, *Partiels: pour 18 musiciens* (Milan: Ricordi, 1978).

[371] In the 2014 biography cited in a previous footnote, Bob Gilmore summarizes the spectral method with specific recourse to its origins in the studio activities of Grisey and Murail: "The essence of *la musique spectrale* is its search for compositional models based on sound, rather than on mathematics, or language, or visual imagery. In 1982 Grisey would famously declare: "We are musicians and our model is sound, not literature; sound, not mathematics; sound, not theatre, or the plastic arts, or quantum physics, or geology, astrology or acupuncture!" The permutation of notes was replaced by a scrutiny of the inner life of sounds, which then became models for compositional forms. In the mid-70s Grisey and Murail undertook computer-aided analyses of the waveforms of complex sounds, studies that were sophisticated given the technology of the time but quite primitive in view of the means available today. The natural harmonic series was one such object of study." Gilmore, *Vivier*. 164.

[372] Fineberg, "Spectral Music", 116.

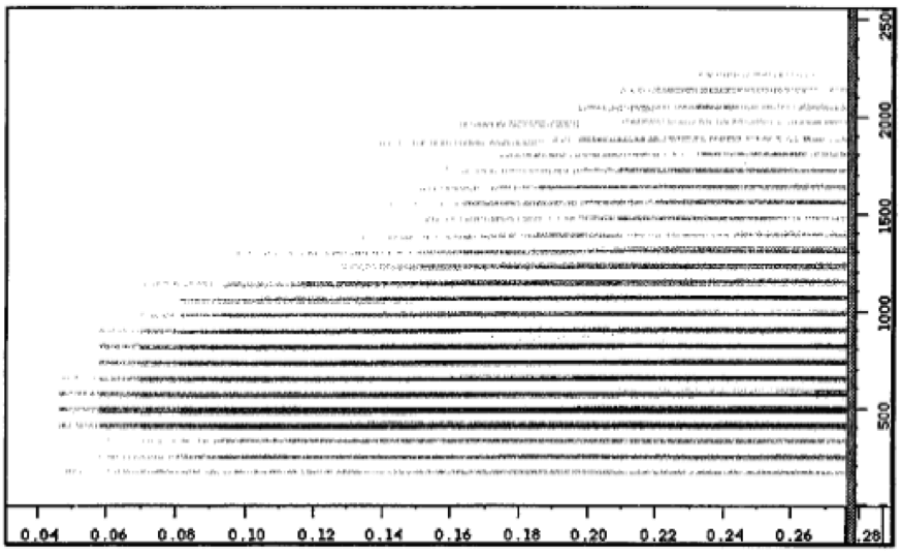

Figure 177 - Sonogram of E = 41.2 Hz

Unlike Stockhausen's use of the human vocal apparatus to selectively filter a complex spectrum, Grisey orchestrates the partials (the horizontal lines from the above figure) individually, by assigning them to the instruments of his ensemble (Figure 178). The following copy of the first page from *Partiels*[373] is annotated with the harmonic number being assigned to each instrument[374].

[373] Grisey, *Partiels*, 1.

[374] Analysis taken from: Darren Miller, *Spectralism* (University of Victoria: PhD Comprehensive Exam Research Paper, 2010).

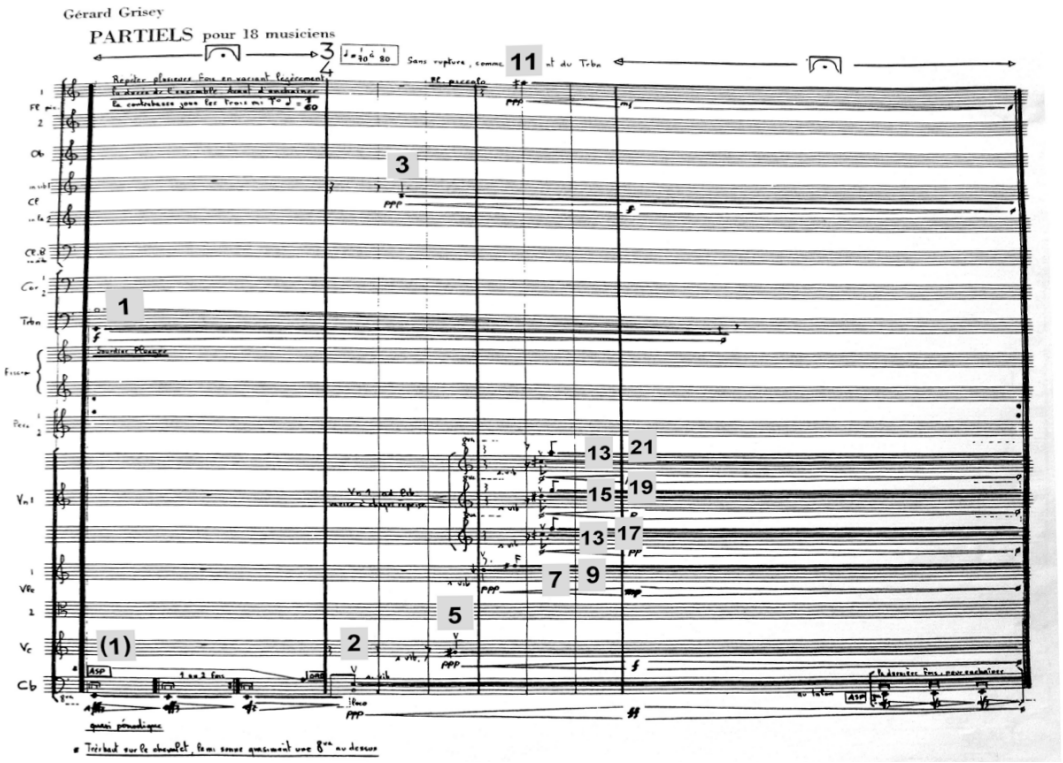

Figure 178 - Grisey: Partiels (Annotated Orchestration of Trombone Note, mm. 1-4)

Though performed on conventional orchestral instruments, Grisey observes the just intonation of the harmonic series within the scope of an eighth-tone level of resolution. Grisey goes on to repeat the same pedal E in 11 different spectrally-derived harmonizations, which exist as an analogy to the electronic manipulation of timbre in the acoustic domain. As described by François Rose in his 1996 article on the French spectral school[375], these repetitions involve the downward shifting in register of remote upper harmonics so as to gradually create a highly inharmonic spectrum[376]. Rose illustrates this progression, included below with a Caetano inspired morphing continuum (Figure 179). Note that the open noteheads signify harmonic partials (frequencies at integer multiples of the fundamental frequency) while the closed noteheads represent inharmonic partials (frequencies not related to the fundamental by an integer factor).

[375] Francois Rose, "Introduction to the Pitch Organization of French Spectral Music," *Perspectives of New Music*, Vol. 34, No. 2 (Summer, 1996): 6-39.

[376] As will be described fully in Chapter 5, inharmonic partials are those whose frequencies are not integer multiples of the fundamental.

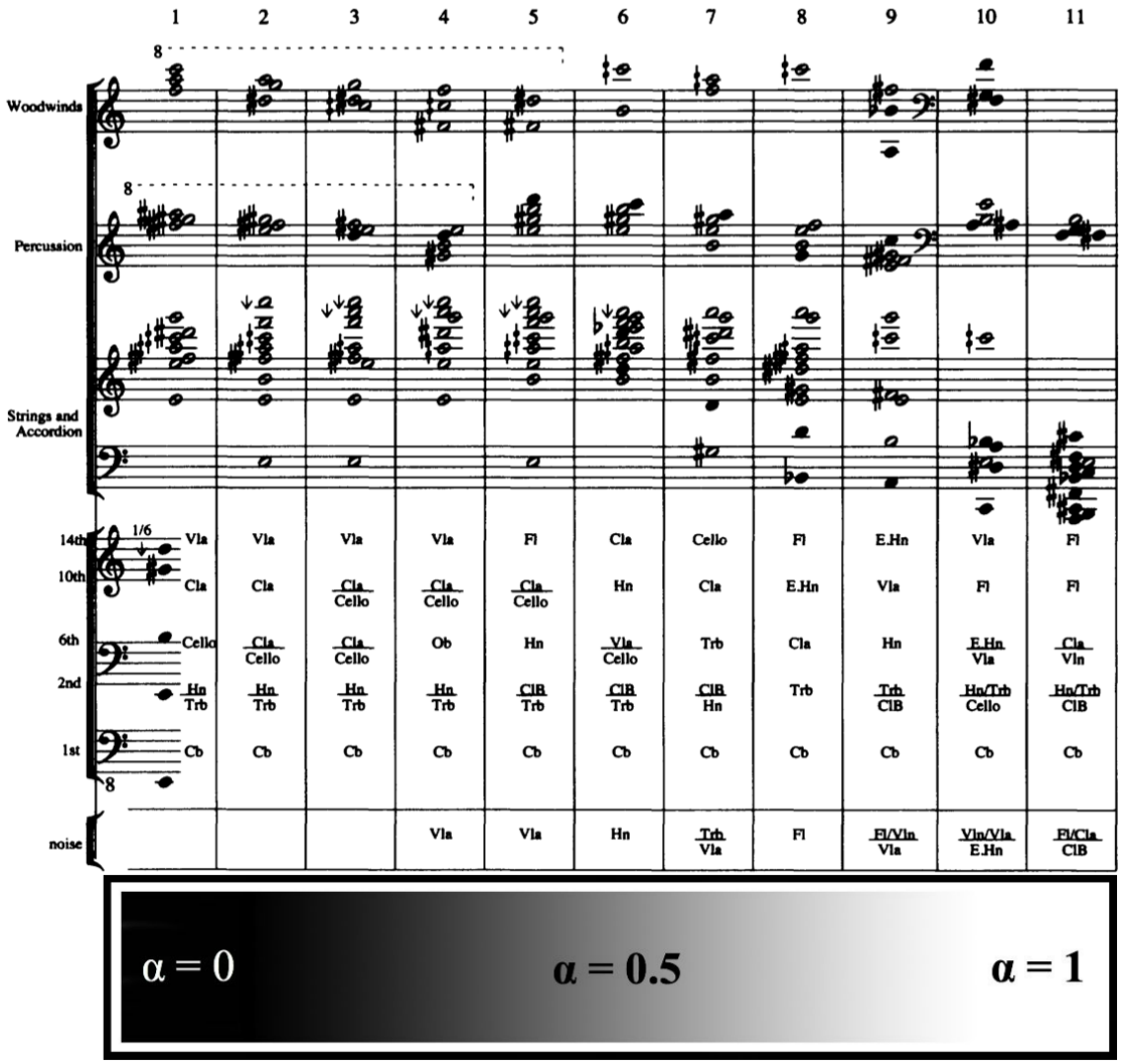

Figure 179 - Grisey: Partiels (First Eleven Chords Analyzed by Rose)

An alternate notation is supplied in Figure 180, to clarify the crossing clefs resulting from the densely packed harmonies in Rose's original diagram. The light grey background represents the grid of harmonics for E = 41.2Hz, black bars represent harmonic partials found in Grisey's chords, and red bars represent inharmonic partials.

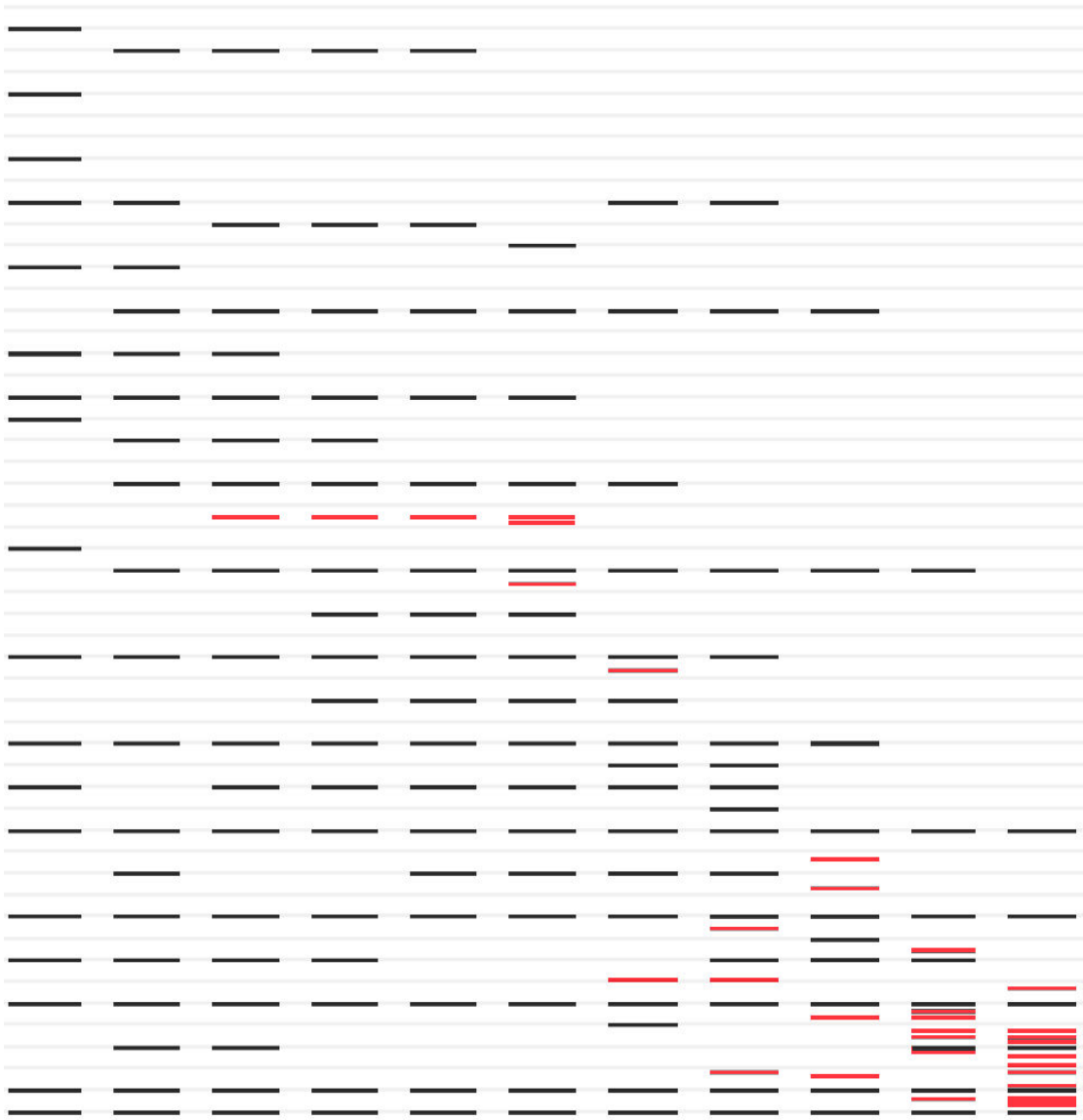

Figure 180 - Grisey: Partiels (Alternate Graphic Rendering of Rose's Analysis)

The steadily increasing presence of red bars in the above graph indicates the transformation from a harmonic to an inharmonic spectrum.

Though presented "out of time" above, the temporal aspects of the opening section are also of note. Whereas Stockhausen's *Stimmung* presented a similar process of spectral transformation over the course of a few seconds, the duration of the above excerpt from *Partiels* is over four minutes in length. Even over such a long duration, the careful concentration of material employed by Grisey in this section allows for the

perception of a single continuous transformation. However, the extended timeframe involved in the opening of *Partiels* does bridge the acoustic manipulation of timbre with the subject of the following chapter: the morphology of form[377].

5.5 Conclusions

In Chapter 4, the tendency of expansion observed in historical systems of pitch organization culminated in the treatment of pitch as frequency, and pitch-space as an un-segmented continuum encompassing the entire audible spectrum. The acoustic manipulation of timbre in the spectral and proto-spectral compositions of Messiaen, Stockhausen, and Grisey relied on such an understanding of tone and tone colour. However, it has also been shown that composers such as Wagner, Mahler, Schoenberg, and Berg were able to pursue this medium intuitively in the *Klangfarben* compositions of the late nineteenth and early twentieth centuries. However, with the development of new analytic tools, spectral composers began to treat timbre as a primary compositional resource based on empirical and verifiable acoustic data. The use of such techniques over periods lasting anywhere from several minutes to the entire duration of a given work, raises the question of how form itself might relate to morphology and various kinds of sonorous transformations. The following chapter will address such concerns through investigations and analyses at the structural level of musical form.

As emphasized during the analysis of my own work in Chapter 2, the application of the principles underlying audio morphing and musical morphology to the global scale of form was a primary structural concern in *for chelsea smith*.

[377] For more on Grisey's own thoughts regarding time, see his article: Gérard Grisey, "*Tempus ex Machina*: A Composer's Reflections on Musical Time," *Contemporary Music Review*, Vol. 2, No. 1 (1987): 239-75.

6 Morphology and Form

6.1 Introduction

The many examples of morph-like transformations included in the past two chapters have generally had two things in common: 1) they have been realized using purely acoustic instrumentation, and 2) they have required only a few seconds (or in extreme cases a few minutes) to reach completion. While Chapter 3 dealt with the former, it is the goal of the present chapter to expand the scope of the latter. These analyses will involve cases in which musical transformation might best be considered in relation to the large-scale level of form.

One is able to immediately perceive local distortions and transformations of pitch material (suspensions, resolutions, mode mixture, modulation, etc.) and tone colour (instrumental crossfades, timbral developments on a single pitch, thematic transferences of material between instruments, etc.). This immediacy of perception allows the listener to remain conscious of both the origin and arrival points of the transformed sonority. The morphology of form however is by its very nature a much more time consuming perceptual activity, in that the vast majority of musical forms being considered in the present study have durations ranging from roughly ten minutes to upwards of an hour or more.

Thus is it time to reintroduce the dichotomy between musical ***morphology*** and musical ***morphing*** that was discussed at length in Chapter 1. To summarize this distinction, the verb morphing indicates the sort of local level continuous transformation of sonic material described in Chapters 4 and 5, while the noun morphology indicates "the history of variation in ***form*** [emphasis mine]."[378] The primary focus of this dissertation is the investigation of sonic morphing and the influence of various other instances of transformation on music composition. This investigation into relationships between microphenomena and their consequences at macro levels (those of musical form) has an inherent connection to the author's compositional research and creation. This correspondence between structures of the micro and macro levels has been explored

[378] The term morphology appeared in biological discourse much earlier (early 19th century) than it was used in a more broadly understood general sense (late 19th and early 20th centuries). See: OED, "Morphology, n."

in relation to common practice repertoire[379]. As such, the following chapter on large-scale morphology will not only investigate new forms that correspond to the techniques of sonic morphing, but will also survey key writings dealing with the morphology of Classical, Romantic, and 20th Century music (see Table 12).

Eras/Styles	Writers/Composers	Morphological Principles
Classical	Koch, Sulzer, Reti, Haydn, Cleland	Transformation
Romantic	Dahlhaus, Adorno Brahms, Wagner	Variation and Sequence
Post-Traditional Materials/Morphologies	Attali, Rancière	Music as Composition, and the Aesthetic Regime of Art
Post-Traditional (Acoustic Instruments)	Russolo, Lachenmann	Purely Acoustic Analysis, Classification, and Arrangement
Post-Traditional (Plastic Media I – Film)	Benjamin, Stravinsky, Grisey	New Manipulations and Arrangements via Plastic Media
Post-Traditional (Plastic Media II – Tape)	Schaeffer, Reich	New Manipulations and Arrangements via Plastic ***Audio*** Media
Post-Traditional (Digital Media)	Hackbarth	Analysis and Concatenation

Table 12: Overview of Chapter 6

6.2 Motivic Transformation and Theories of Form in the Classical Period

The main focus of the present study is the immediate sonic effect of continuous and perceptible change between sonorities. In short: morphing. The compositional motivations behind this investigation however, demand (or at the very least suggests) the development of large-scale forms that respond and/or correspond to the new techniques of sonic transformation.

[379] In addition to the early musicologists cited in the following sections, one might also consider the work of the influential Austrian music theorist Heinrich Schenker. Arguably ***the*** 20th century framework for analysing music of the common practice period, Schenkerian Analysis is described in reference to a correspondence between structural levels, by Charles Burkhart in his 1978 article cited below: "Central to Heinrich Schenker's theory of music is his concept of hierarchically ordered structural levels (*Schichten*). According to this concept, a level expressing a given degree of reduction governs-that is, provides the structure of-the next most elaborate level, and is therefore "higher" in rank to it... Schenker was much more interested in those… in which the motive was expressed on *different* structural levels-both low and high-or, as is often said, expressed "in the small" and "the large."" Charles Burkhart, and Heinrich Schenker, "Schenker's "motivic parallelisms"," *Journal of Music Theory*, Vol. 22, No. 2 (Autumn 1978): 145-175. [above quotation found on p.145-6]

The literature that deals with this relationship between materials and their suggested forms is much older than the technique of audio morphing. One particular manifestation can be found in 18th century writings on motivic transformation, as it applies to the compositional practice of the Classical era. American theorist Kent Cleland's 2003 doctoral dissertation[380] deals with the concept of temporality in the writings of French philosopher Henri Bergson, with the aim of extending it to encompass musical transformation (a subject that Bergson never explicitly wrote about[381]). In order to lay the foundation for this project, Cleland first presents a survey of writings on musical transformation, particularly from the pedagogical literature that shaped the Classical era. Especially well represented among these writings are excerpts from German theorist Heinrich Koch's 1782 *Introductory Essay on Composition:* a sort of instruction manual for composers of the period. Cleland cites an excerpt in which Koch states that the realization of a successful large-scale form:

> "requires mainly two things: (1) a sufficient variety of phrases, or enough modification and adaptation of the main ideas, joined with connective phrases, phrases made up of fragmented ideas, or subsidiary ideas, and (2) a close and completely appropriate connection of all these ideas."[382]

Thus are notions of variety, transformation, and coherence central to Koch's understanding of successful formal design. It is worth noting that the term "connection" is mentioned in both clauses of the above statement, highlighting the role of formal and material connective tissue.

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[380] Kent Cleland, *Musical Transformation as a Manifestation of the Temporal Process Philosophies of Henri Bergson* (Doctoral Dissertation: University of Cincinnati, 2003).

[381] Winner of the 1927 Nobel Prize for Literature, Bergson's contribution to 20th century phenomenology can also be gauged through his influence on subsequent generations of philosophers. Notable among them is Gilles Deleuze, who has written the following work on Bergson's thought: Gilles Deleuze, *Bergsonism* [1966], trans. Hugh Tomlinson and Barbara Habberjam (New York: Zone Books, 1988). Austrian sociologist Alfred Schütz was also deeply influenced by Bergson, applying his phenomenological concepts both to his own field of study (giving rise to the discipline of social phenomenology), and also to music, especially in: Alfred Schutz, *Collected Papers II: Studies in Social Theory*, ed. Arvid Brodersen (the Hague: Martinus Nijhoff, 1964). For more on Bergson see: Jacques Chevalier, *Bergson*, trans. Lilian A. Clare (New York: AMS Press, 1969).

[382] Cleland, *Musical Transformation*, 19 - citing Koch from the source: Nancy Kovaleff Baker and Thomas Christensen, eds., *Aesthetics and the Art of Musical Composition in the German Enlightenment: Selected Writings of Johann Georg Sulzer and Heinrich Christoph Koch* (Cambridge: Cambridge University Press, 1995): 189.

The importance of transformation and connectivity for Koch is rooted in his desire for a strong sense of aesthetic unity within a given work. He defines such unity as the primary condition of art, and this perspective results in an understanding of thematic material that resonates with the principles of audio morphing that have informed my own compositional practice.

> "A continued principal idea properly can beget only a subsidiary idea; this subsidiary idea must always be composed so that it leads us back to the main conception, so that it again necessitates the succession of another principal idea... All works of fine art must have unity. To reach that unity in our piece of music, this newly entering idea must necessarily follow immediately after a principal idea, or must make necessary the succession of a principal idea."[383]

Koch is clearly discussing music of the western tradition's Classical era in the following description of techniques for ensuring thematic unity. One could however, quite easily translate such techniques into the language of modern composers, particularly those working in electronic music studios where the cutting and connecting of materials are the principle techniques of composition.

> "In the realization, the composer must be careful to bring the principal phrases defined in the plan in different configurations. He may cut them up, he may clothe them with connective phrases suitable to the main subject and in different periods and in keys related to the main key. Thus a sufficient variety and alternation in the succession of main and subsidiary ideas will be produced."[384]

Cleland also explores writings by one of Koch's greatest influences: Swiss mathematician, physicist, philosopher, and lexicographer: Johann Georg Sulzer. Born in Winterthur in 1720, Sulzer had no musical training despite the wide breadth of his academic pursuits[385]. His pioneering work of aesthetics[386] however had a deep influence

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[383] Cleland, *Musical Transformation*, 21.

[384] Ibid., 19.

[385] Howard Serwer. "Sulzer, Johann Georg," *Grove Music Online. Oxford Music Online*, Oxford University Press, accessed October 14, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/27105.

[386] Johann Georg Sulzer, *Allgemeine Theorie der schönen Künste in einzeln, nach alphabetischer Ordnung der Kunstwörter auf einander folgenden Artikeln abgehandelt* (Leipzig, 1771–4).

on Koch. Cleland points out that Koch even quoted directly from Sulzer's work[387]. These writings (as summarized here by Cleland) describe ideal relationships between material, transformation, and form. Again, the importance ascribed to unity and thematic interrelationship is emphasized by Sulzer (via Cleland).

> "Sulzer proposed that the artist must begin with knowledge of the completed artwork and how the basic elements that comprise it relate to one another. From this, he or she then "fills in the details" using a myriad of creative ideas that come to mind during the creative process."[388]

Cleland's survey of literature dealing with motivic transformation in the common practice era concludes with the writings of the Serbian-born American musicologist: Rudolph Réti (1885-1957)[389]. Cleland's discussion of Réti involves the emergence of the Classical style from that of the Baroque, based on Réti's 1951 book *The Thematic Process in Music*.

> "He further defined the shift in compositional style from the Baroque to the Classical periods as the increasing ability to derive outwardly non-conforming material from the components of a small number of seminal ideas."[390]

Similar in perspective to the pedagogical writings of Koch and Sulzer, Réti's retrospective assessment of the period also highlights the role of developing surface contrast through the carefully planned transformation of initial materials. Again, this process of transformation is in service of overall unity, to be achieved through the careful compositional planning of thematic morphology.

> "The spirit of the form is fulfilled only if these shapes are transformed in such a way that the new theme *seems* to be entirely different from the one from which it is derived."[391] [emphasis Réti's]

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[387] Cleland, *Musical Transformation*, 14.

[388] Ibid.

[389] Also a theorist and pianist, Réti was responsible for the premiere of Schoenberg's opus 11, as described in: Paula Morgan, "Réti, Rudolph," *Grove Music Online. Oxford Music Online*, Oxford University Press, accessed October 15, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/23259.

[390] Cleland, *Musical Transformation*, 28 - citing Rudolph Réti, *The Thematic Process in Music.* (New York: The Macmillan Co., 1951): 56.

[391] Cleland, *Musical Transformation*, 28 - citing Réti, *Thematic Process*, 56.

A clear case in which the second theme of a Classical composition is only *seemingly* different from its predecessor can be found in the first movement of Joseph Haydn's *Piano Sonata* number 21 in C Major. British musicologist Matthew Riley highlights the extreme structural similarities shared by both themes in the following diagram (Figure 181) from his 2011 article on Haydn's thematic idiosyncrasies[392].

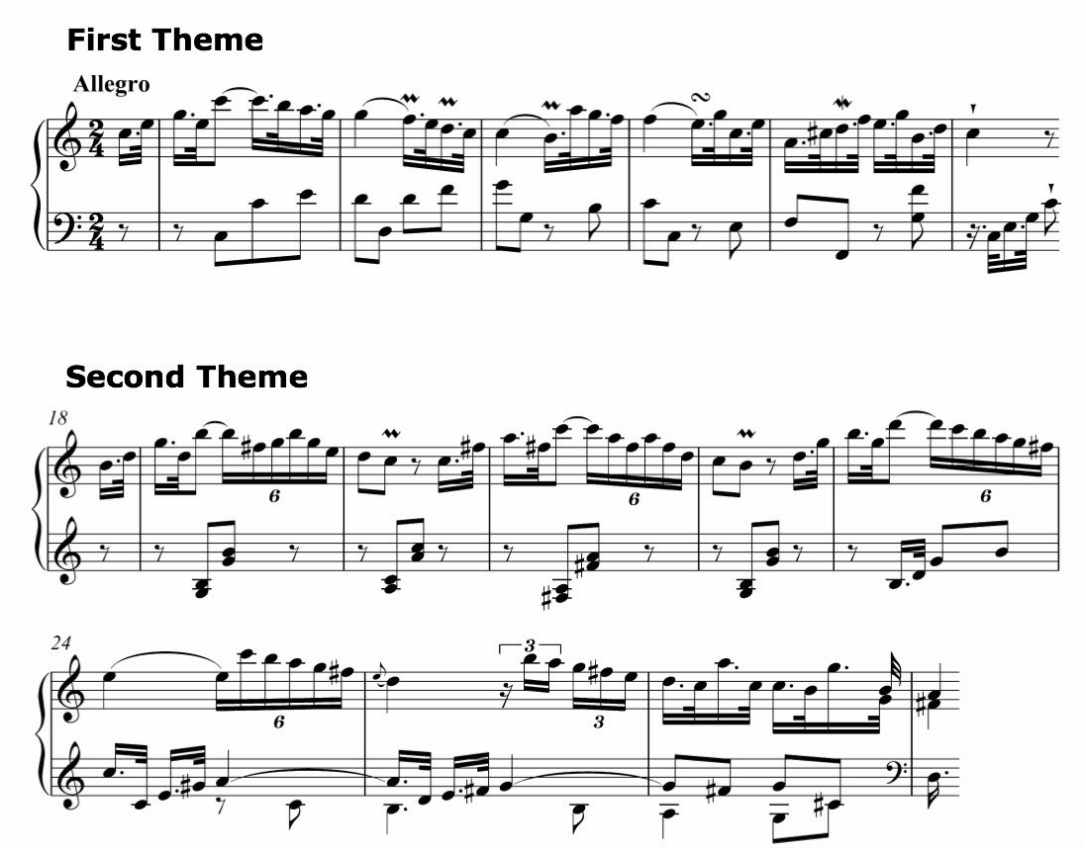

Figure 181 - Haydn: Piano Sonata 21, i (Thematic Analysis by Riley, mm. 1-6, 19-26)

Out of context, the similarities between the two themes *seem* overwhelming. The dotted figures comprising the first three eighth note beats of the first theme are clearly the basis of mm.18-9, 20-1, and 22-3 in the second. While the left hand textures and the tonal centres have both changed (to the expected dominant) at measure 19, the recurrence of the dotted figure might suggested a sort of mono-thematicism. However, when the listener arrives at the second theme – having heard the intervening measures shown in Figure 182 – the overall effect is indeed one of subtle transformation.

[392] Matthew Riley, "Haydn's Missing Middles," *Music Analysis*, Vol. 30, No. 1 (2011): 37–57.

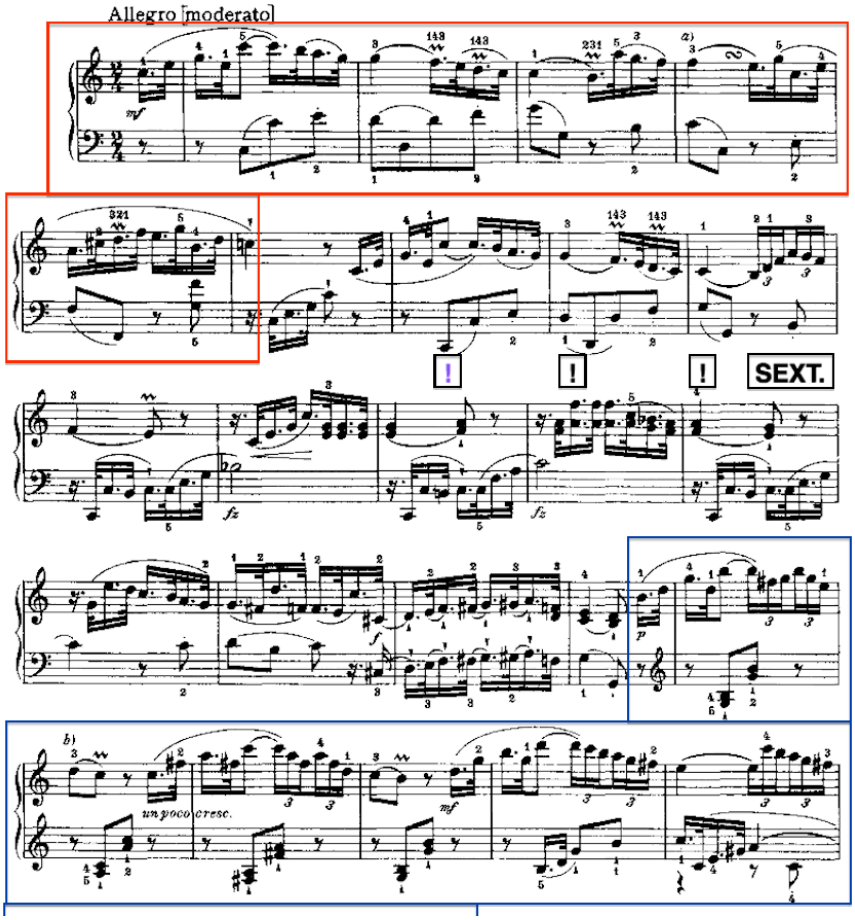

Figure 182 - Haydn: Piano Sonata 21, i (Score, mm.1-24)

Measures 7 to 17[393] reveal only three brief interruptions (indicated with exclamation marks above) of the dotted figures that characterize the first theme. The sixteenth-note sextuplets that constitute the second theme's opposition to this rhythmic hegemony are introduced in measure 9 following the last of these interruptions (indicated as "sext." above).

It is also worth noting the complete absence of left hand dyads (with the exception of the cadence that rounds out the first theme) until the beginning of the second theme at measure 18. A slight thickening of the texture does occur prior to this point in the right hand at measures 11-4, foreshadowing the eventual introduction of the second theme's left hand figures. Thus does this expository material substantiate the assessment of Réti cited above whereby "shapes are transformed in such a way that the new theme *seems* to

[393] Joseph Haydn, *Sonaten für Klavier zu zwei Händen* [Hob.XVI:21] (Leipzig: C.F. Peters, 1937), mm. 1-24.

be entirely different from the one from which it is derived". The Classical ideal of unity is reinforced in that new material only *seems* new, despite its clear derivation from earlier passages.

Dealing with musical experience in a more general sense, Cleland's own observations on Classical transformation are also of note. In these passages, the phenomenological relationship between transformation and form is focused through the lens of Cleland's studies of Bergson's writings. He begins by defining musical (in this case, motivic) transformation along a continuum (reminiscent of Caetano's morphing index described in Chapter 1) and explores the notion of total homogeneity embodied by one extreme limit of this continuum.

> "Related musical objects can be described in terms of their differentiation from each other expressed along a continuum stretching from complete homogeneity to complete variety. At either extreme of the continuum is a constructive state...."[394]

Cleland goes on to describe the end of this continuum associated with direct repetition.

> "Furthermore, if temporality is an essential property of existence, then one must acknowledge that the flow of time creates a state of constant change, even if all other characteristics of an object remain continuous. Therefore, literal repetition is impossible because any subsequent occurrence, no matter how similar it is to a previous occurrence, will always be "colored" by the memory"[395]

Thus do time and memory act as agents of motivic transformation, even when dealing with identically repeated materials. Cleland explores the role of memory at the other (more transformation based) end of the homogeneity-variety continuum.

> "Transformations are heard in relation to expository material. As such, they are reliant on the conscious memory of the listener as well as on the internal memory of the process of transformation. Thus, memory can provide the context for recognition of repetition and transformation. Elements of specific musical objects are experienced as being more or less like expository elements. This similarity exists along a continuum from clearly recognizable to completely unrecognizable."[396]

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[394] Cleland, *Musical Transformation*, 116.

[395] Ibid.

[396] Ibid., 117.

Serious importance is ascribed to motivic transformation through Cleland's synthesis of readings from Bergson and Carl Dahlhaus. By means of this merger "the process of transformation" gains "aesthetic significance" over the raw materials on which they are acting.

> "Dahlhaus emphasizes a continual process of transformation. Specific musical moments not only remember each other but, more importantly, their transformations interpenetrate each other in a manner that more closely resembles Bergson's description of emotional states. Thus, ***aesthetic significance becomes the process of transformation itself*** rather than the recognition of transformed constituent elements through memory." [emphasis mine][397]

By bringing together Dahlhaus and Bergson, Cleland infuses the process of continual transformation with the musically essential phenomena of memory and time. For his own part, Dahlhaus has dealt with this relationship between transformation and time through an in-depth analysis of large-scale form in the late Romantic period.

6.3 Romantic Forms – The Motive as Generator of Morphologies

Continuous transformation and form are two important topics in Dahlhaus' 1974 book on Romantic music: *Between Romanticism and Modernism*[398]. Dahlhaus sees the importance of transformation in this period as a fundamental shift away from the emphasis on formal schemes encountered during the Classical era. Citing the opening of Beethoven's *Third Symphony*, Dahlhaus asserts that in the Classical period:

> "the motto is not so much stated or expounded and then developed as brought forth by the symphonic process in which it has a function to fulfill.... the musical "idea" is the symphonic process itself, not the theme."[399]

Echoing the emphasis on unity cited previously in the literature of the era, Dahlhaus describes the role of a given work's formal architecture in Classical practice. Form in the Classical period is so dominant according to Dahlhaus, that even seemingly generative thematic materials are subject to greater concerns of overall structure.

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[397] Ibid., 185.

[398] See previous citation of: Dahlhaus, *Romanticism and Modernism.*

[399] Dahlhaus, *Romanticism and Modernism*, 41.

> "As yet the single idea was still understood primarily as a corollary of the whole, and not as the essential sustaining substance, whose individuality or conventionality determined the overall form and was the only grounds on which its quality might be judged. Both Wagner and Schoenberg complain about the mere padding to be found in Mozart's music, even in some of his principal themes"[400]

The "mere padding" mentioned by Dahlhaus is the material employed to round off expository statements to conform to period structure – the generally symmetrical building blocks of classical form[401]. Dahlhaus elaborates on the cult of originality alluded to in the previous citation while explaining the contraction of motivic material in the Romantic period.

> "The fact that thematic material was reduced during the course of the nineteenth century from the period to the motive was the result, as has been said, of the principle that a musical idea, to be worthy of the name, had to be original and meaningful throughout"[402]

This new motivic paradigm of the 19th century had major consequences for form:

> "In Beethoven formal ideas and melodic detail come into being simultaneously: the single motive is relative to the whole. By contrast, in the later nineteenth century ***the melodic idea acted as a motive in the literal sense of the word, setting the music in motion***, and provided the substance of a development in which the theme itself was elaborated. Musical form now presented itself primarily (though by no means exclusively) as a consequence drawn from thematic ideas, not as a system of formal relations."[emphasis mine][403]

In addition to shaping material, proportions, and overall form, the Romantic emphasis on originality also influenced harmonic practice according to Dahlhaus.

> "Harmony.... underwent a radical alteration in its formal significance during the later nineteenth century. The emphasis shifted from the general and structural to the particular and instantaneous, from providing a

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[400] Ibid., 43.

[401] The New Grove entry on "Period" describes it as: "a musical statement terminated by a cadence or built of complementary members, each generally two to eight bars long and respectively called 'antecedent' and 'consequent'." Leonard G. Ratner, "Period," *Grove Music Online. Oxford Music Online*, Oxford University Press, accessed October 22, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/21337.

[402] Dahlhaus, *Romanticism and Modernism*, 53.

[403] Ibid., 42.

> framework, which was its principal function in Mozart and, still, in Beethoven, to the individual characterization of detail, the harmonic "idea.""[404]

The picture that Dahlhaus paints of the 19th century, with its emphasis on original motivic (in a literal sense) material, resulted in two distinct schools of composition with individualized techniques of transformation. On multiple occasions Dahlhaus is careful to explain that – though the camps associated with Wagner and Liszt on the one hand and Brahms on the other were stylistically distinct – they were both confronting the same issue.

> "It is the sameness of the problem which marks the second half of the nineteenth century as an essentially unified epoch in musical history, in spite of the stylistic contrasts it embraced"[405]

> "The latent unity of the music of the age is demonstrated by the fact that essentially the same problem faced Wagner, Liszt *and* Brahms; it is not reflected in stylistic unity or uniformity, however, since individual stylistic traits, which develop in the course of working out solutions, are not contingent on separate initial problems."[406]

The "problem" referred to by Dahlhaus is the attempt to generate and sustain increasingly large-scale forms using the reduced thematic materials of the age. This paradox led Nietzsche to refer to Wagner as the greatest of miniaturists, in reference to "the contradiction between the brevity of the musical ideas and the monumentality of the formal designs."[407].

The connection between morph-like transformations, form, and this late romantic problem, is that both the Wagener/Liszt and Brahmsian camps adopted compositional strategies rooted in the continuous transformation of material. In the case of Wagner, it is the leitmotif (a short fragment with dramatic associations) and the process of real sequence (as described in Chapter 4) that develop and transform brief seminal materials into large-scale forms. Dahlhaus draws a distinction between leitmotivic technique and the earlier Classical treatment of themes.

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[404] Ibid., 75.

[405] Ibid., 64.

[406] Ibid., 47-48.

[407] Dahlhaus citing Nietzsche in *Der Fall Wagner*, Ibid., 40-1.

> "Leitmotivic technique plays a formal, structural role in Wagner equivalent to that of regular periodic structure in other music: ***the leitmotivs create the framework*** of the form instead of being interpolated, for dramaturgical reasons, into a structure that rests on other foundations."[emphasis mine][408]

The resulting form is one in which the interplay of the various constituent materials results in a connective fabric of interleaved or "woven" threads, in contrast to previous practice.

> "It took a long time for anyone to acknowledge that musical form can be a polythematic network, a "web" or "woven fabric" (*Gewebe*) as Wagner called it himself, instead of having to be either architectural or the extended elaboration of a few thematic ideas."[409]

Though the technique of real sequence was described in relation to pitch in Chapter 4 (specifically pitch transformations in the opening of *Tristan*), Dahlhaus' description of the technique also has implications for the morphology of a large-scale form:

> "Real sequence is an expository procedure, a means of elaborating a musical idea which in itself—like the Yearning motive in *Tristan*—needs no continuation and would not tolerate conventional "rounding-off" in a closed period... it seems as though ***the sequential structure is not a product of the unusual form but, on the contrary, the form is a consequence of the sequential structure***, which is itself motivated by the brevity of the musical ideas."[emphasis mine][410]

Thus is the manipulation of leitmotivic material through real sequence, juxtaposition, and motivic transformation responsible for the generation of new, expansive, Wagnerian forms. This assessment was shared[411] by German sociologist and philosopher Theodor

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[408] Ibid., 60.

[409] Ibid., 59

[410] Ibid., 46-47.

[411] A 1963 talk by Adorno on the subject of Wagner - Theordor Adorno, "Wagner's Relevance for Today" [1963], in *Essays on Music*, translated by Richard D. Leppert, 584-602 (Berkeley: University of California Press, 2002), addressed concerns that had emerged since his previous book on the subject: "Almost thirty years ago I wrote a book, *In Search of Wagner*… Today I would formulate many things in the book differently." Adorno, "Wagner's Relevanc", 584. In fact, Adorno addresses his previous characterization of sequence in Wagner's music directly: "It has been customary to emphasize the principle of the sequence in the mature works of Wagner; I myself did so at one time. By sequence is meant the repetition of abbreviated motifs—in Wagner the leitmotifs—on a higher level, generally with dynamic, intensifying effect. The spinning out of the music, its essential fiber or texture, thus works more or less with the

Adorno (1903-1969) who also identified a connection between Wagner's use of sequence and the actual makeup of his leitmotifs: specifically, their reliance on minor seconds.

> "The sequence principle in Wagner is by no means a crutch. It follows from the chromaticism, the prevalence of the minor second that pervades the entire musical material…chromaticism itself embodies something not altogether dissimilar to the sequential principle; the repetition of the smallest intervals corresponds to the repetition of individual musical events as they follow each other within the sequence."[412]

The example that Adorno cites to substantiate this connection between the repeating of intervals (minor seconds) and the repeating of leitmotifs (yearning and desire) is the opening of *Tristan*[413] (Figure 183), also alluded to by Dahlhaus above.

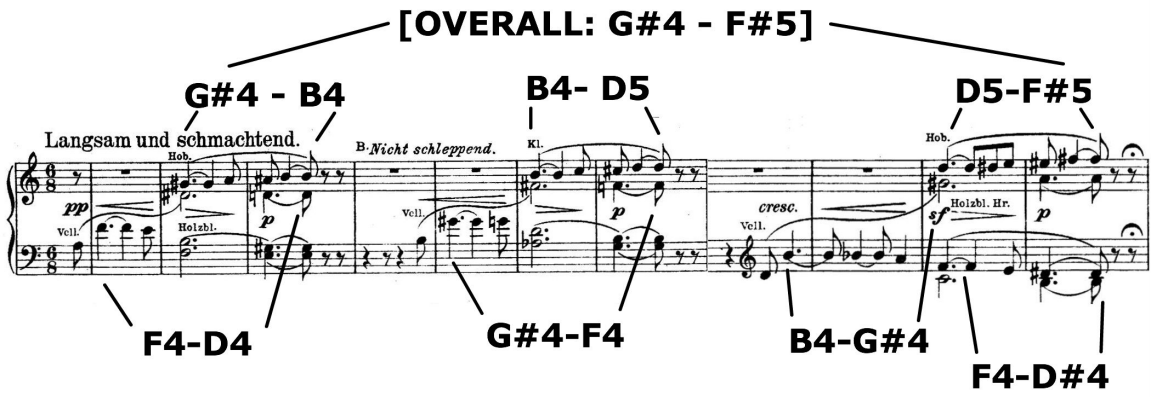

Figure 183 - Wagner: Tristan und Isolde (Annotated Score, mm. 1-11)

Figure 183 identifies the degree to which the intertwining of these two levels of repetition (intervalic and motivic) generate Dahlhaus' "unusual forms". Virtually all melodic motion occurs by semi-tone, and the overall trajectory of the top voice traces an uninterrupted progression of half-steps spanning nearly and octave. Together with the repetition at the level of motive, this intervalic repetition defines the structure of the passage.

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repetition of given elements… But however many sequences there are in Wagner, they by no means represent the sole principle; and above all, they are already varied, frequently and with great subtlety, in themselves." Ibid., 591.

[412] Ibid.

[413] Richard Wagner, *Prelude from Tristan and Isolde* (New York: Norton, 1985), mm. 1-11.

As cited in the previous footnote, Adorno's 1963 talk on Wagner contends that the style of variation associated with Johannes Brahms is actually a facet of Wagner's music as well: "...above all, they [Wagner's materials] are already varied, frequently and with great subtlety"[414]. Dahlhaus however, considers this question of technique to be a fundamental difference between the respective schools associated with each of the two composers.

> "With Brahms, on the other hand [in contrast to Wagner], the elaboration of a thematic idea is the primary formal principle, on which depends the integration of the movement as a whole.... motives develop out of earlier motives like ideas, each of which is a consequence of its predecessors."[415]

In his 1947 essay "Brahms the Progressive", Schoenberg cites the following passage (Figure 184) from Brahms' *First Sextet*, Op. 18, in order to illustrate the asymmetrical and irregular phrase lengths characteristic of the work[416].

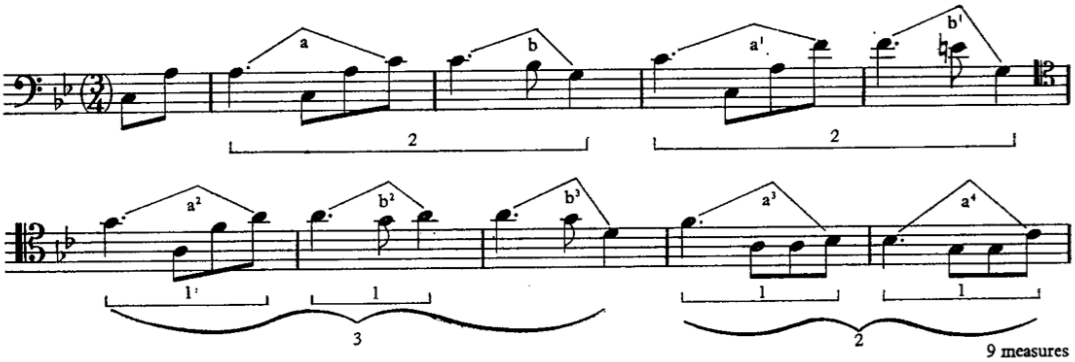

Figure 184 - Brahms: Op. 18, i (Thematic Analysis by Schoenberg, mm. 84-93)

Schoenberg identifies two distinct motivic cells, labelling them "a" and "b" and indicating their continually changing identities through the use of super-script digits 1-4.

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[414] Adorno, "Wagner's Relevance", 591.

[415] Dahlhaus, *Romanticism and Modernism*, 50.

[416] Arnold Schoenberg, "Brahms the Progressive," in *Style and Idea,* translated by Leo Black, 398-441, (Berkeley: University of California Press, 1985): 417.

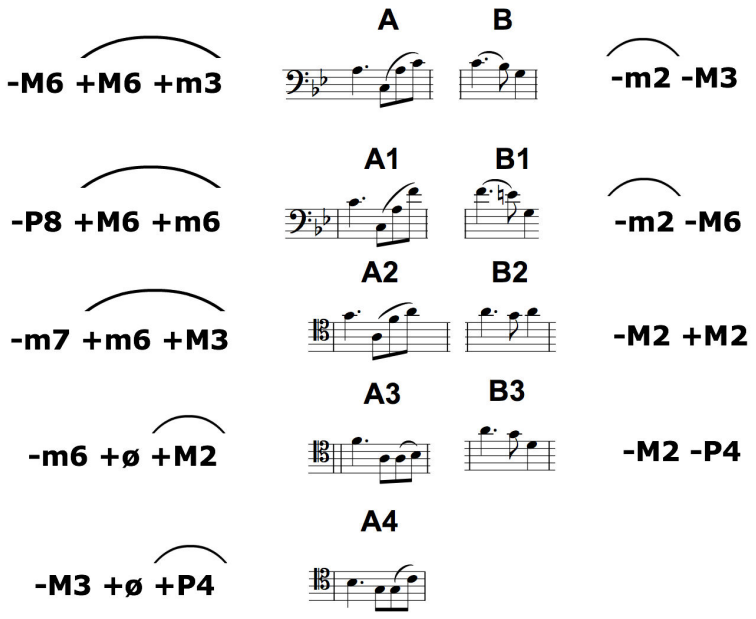

Figure 185 - Brahms: Op. 18, i (Intervalic Content of Cello Material, mm. 84-93)

Figure 185 reveals that no permutation of intervals recurs at any point in the theme, despite the fact that it consists of only two cells. In addition to these motivic transformations, consider as well the changes in phrasing (placement of slurs) that take place within each cell. Finally, the original context of the second theme (Figure 186) reveals that the harmonies (and their functions) are changing with nearly every appearance of a given cell[417].

[417] Johannes Brahms, *Sextet für 2 Violinen, 2 Violen und 2 Violoncelli, Opus 18* (New York: Peters, 1900), mm. 82-93.

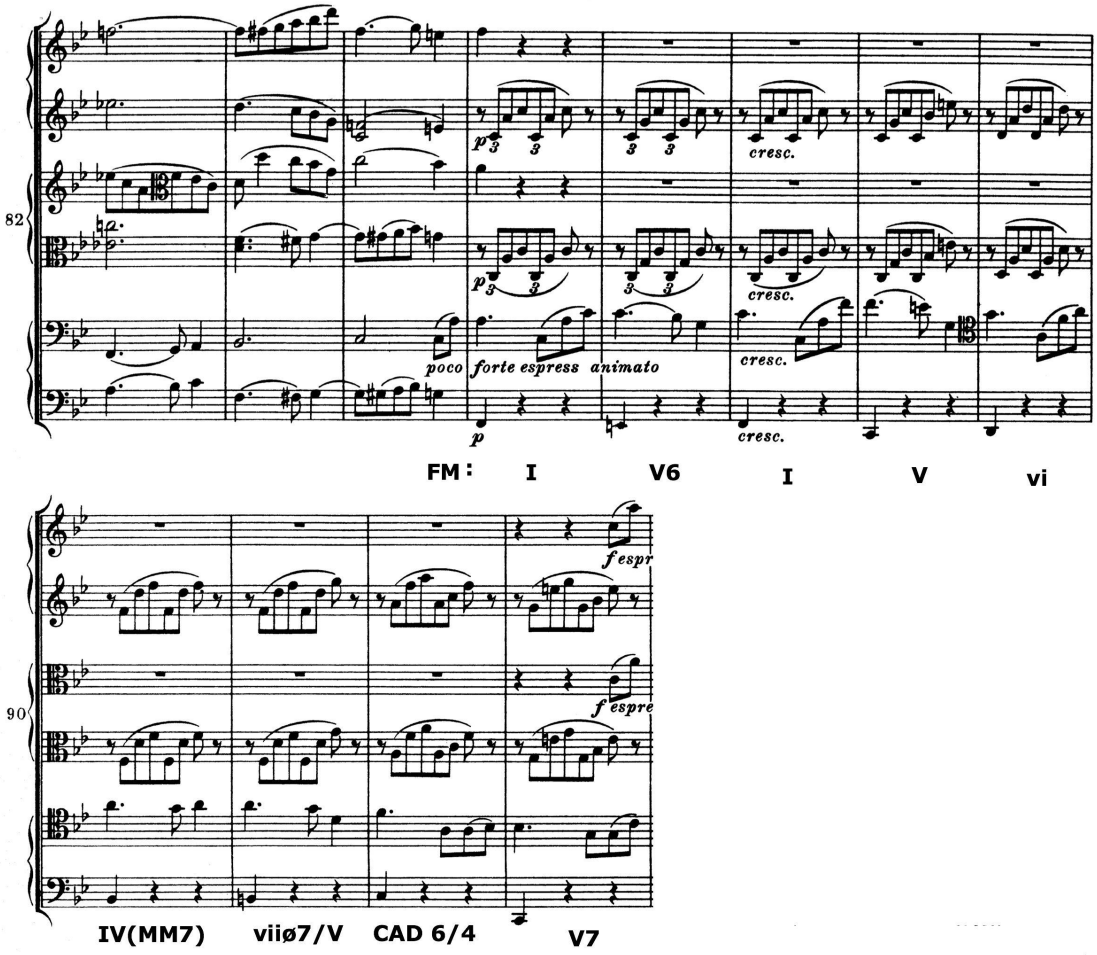

Figure 186 - Brahms: Op. 18, i (Harmonic Analysis, mm. 82-93)

All of the above factors contribute to what Schoenberg identified as the important quality of developing variation in the music of Brahms[418]. Employing the term 27 years later, Dahlhaus elaborates on the formal and phenomenological consequences of this sort of transformation:

> "The process of developing variation bestows on both the basic motives and the material derived from them—insofar as it is recognizable as such—a meaning that they would not have in themselves, as isolated figures. ***The whole significance of the musical instant, unimportant in***

[418] Walter Frisch, *Brahms and the Principle of Developing Variation*. Berkeley (University of California Press, 1984): xiii.

> ***itself, is that it points the way forward to something greater***."[emphasis mine][419]

Thus, not only is form a consequence of the transformational process, but so too is the cumulative and potential "significance of [each] musical instant". As such, the sonorous connective tissue generated through motivic transformation in Romantic music is of both perceptual and formal significance.

This heightened importance for morphology (literally: the study of ***variation*** in ***form***) will carry through into the music of eras that followed late romanticism. The terminology of musical transformation employed by Koch, Sulzer, Cleland, Reti, and Dahlhaus in their discussions of common practice music however, will give way to new terms associated with new analytical paradigms.

6.4 The Emergence of New Materials and Their Morphologies

The principle of transformation (in its most general, etymological sense) is ahistorical. However, ***motivic transformation*** (in the specialized context of the compositional techniques described above) is inseparably tied to music of the common practice period. This era of western art music – in which a common practice (while certainly fluid and evolving) could be said to have existed among disparate composers – has clearly been over for quite some time. What then, are the conditions of the present era, and how does transformation (again, in its most general sense) relate to these conditions? Or, to root the question within the context of the present chapter: what do morphology and form mean in a post-traditional context?

Writing long after the end of the common practice period, French economist and writer Jacques Attali (born 1943) referred to the abandonment of tonality as the initial push towards the present sound world in his 1977 book *Noise*[420].

> "Like science, music has broken out of its codes. Since the abandonment of tonality, there has been no criterion for truth or common reference for those who compose and those who hear. Explicitly wishing to create a

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[419] Dahlhaus, *Romanticism and Modernism*, 49.

[420] Jacques Attali. *Noise: The Political Economy of Music* [1977], trans. Brian Massumi (Minnesota: University of Minnesota Press, 1985).

> style at the same time as the individual work, music today is led to elaborate the criterion of truth at the same time as the discovery "[421]

Attali points out that this moment was not only the initial impetus behind the outward explosion of aesthetic boundaries in recent years, but also suggests that such a creative environment emphasizes the act of context building for both listeners and composers alike. Within a sound world that is – if not truly limitless then at the very least expanding at an exponential rate – the role ascribed to meaningfully constructed form, contextualization, and arrangement of materials (in short – composition) becomes paramount. When Attali goes so far as to assert that "music is becoming *composition*"[422] he is expressing what French philosopher Jacques Rancière (born 1940) described as the aesthetic regime of art in his 2004 book *Aesthetics and its Discontents*[423].

> "The property of being art refers back not to a distinction between the modes of doing, but to a distinction between modes of being. This is what 'aesthetics' means: in the aesthetic regime of art, the property of being art is no longer given by the criteria of technical perfection but is ascribed to a specific form of sensory apprehension."[424]

Both Rancière and Attali assign chief importance to the compositional acts of selection, classification, and arrangement. For his part, Rancière employs examples from the visual arts, citing throughout *Aesthetics and its Discontents* recent exhibitions in which found materials have been carefully and meaningfully assembled (in opposition to the "indifference" of Duchampian readymades[425]).

In addition to his own comments on arrangement and composition, Attali also emphasizes perception in describing the equally altered role of the listener: "Sitting in front of his set, he behaves like a sound engineer, a judge of sounds."[426] Thus, for both Attali and Rancière, the stakes are equally high for the modern audience when it comes to the tasks of analyzing, categorizing, and contextualizing aesthetic materials. The result is

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[421] Attali, *Noise*, 113.

[422] Ibid., 20.

[423] Jacques Rancière, *Aesthetics and its Discontents* [2004], trans. Steven Corcoran (Cambridge: Polity, 2009).

[424] Rancière, *Aesthetics*, 29.

[425] For more on Duchamp and indifference, see: Moira Roth, *Difference/indifference: musings on postmodernism, Marchel Duchamp and John Cage* (Amsterdam: G+B Arts International, 1998).

[426] Attali, *Noise*, 106.

a paradigm of global morphology rooted not in a common practice of transformation (as described previously in this chapter), but rather in a multiplicity of highly individualized schemes of analysis, categorization, and contextualization for diverse, personalized, and non-traditional materials.

The chapter of *Noise* in which Attali both describes the end of the common practice period while likening listeners and composers to audio engineers, is primarily concerned with the technologies of sound recording ("Repeating"). This relationship between recent audio technologies and new paradigms of analysis/contextualization for creators and audiences alike, will be illustrated in the following descriptions of post-traditional musical morphology. Many personalized approaches will be discussed with varying degrees of overlap, and varying levels of technological influence. Given the non-linearity of the former and the important role of the latter, individual composers and writers will be discussed chronologically under four separate headings: acoustic sound families, plastic visual media, plastic audio media, and digital audio media. This overarching progress of technological development will serve as the historical narrative for post-traditional morphologies; even when the works and writings cited therein may occasionally deviate somewhat from a completely linear chronology. The central roles of perception, analysis, classification, and arrangement cited by Attali and Rancière however, will also form a gravitational core for the divergent body of post-traditional morphologies described in the following sections.

6.4.1 New Morphologies and Acoustic Sound Families

Ironically, the first steps towards the establishment of an art form based on the manipulation of real-world sounds occurred *prior* to the development of the audio recording and editing technologies capable of such manipulations. As the foremost Italian Futurist concerned with music, Luigi Russolo's (1885-1947)[427] drew his musical

[427] The *Oxford Dictionary of Art and Artists* makes brief mention of Russolo's style of painting, and points out that he had signed both 1910 futurist painters' manifestos. However, the bulk of Russolo's entry – even in this visual arts reference work – describes his activities primarily in terms of musical contributions. See: Ian Chilvers, "Russolo, Luigi," In *The Oxford Dictionary of Art and Artists*: Oxford University Press, http://www.oxfordreference.com.ezproxy.library.uvic.ca/view/10.1093/acref/9780191782763.001.0001/acref-9780191782763-e-2153.

materials from the soundscape of a modern urban setting, as described in his 1913 manifesto: *Art of Noises*[428].

> "We will delight in distinguishing the eddying of water, of air or gas in metal pipes, the muttering of motors that breathe and pulse with an indisputable animality, the throbbing of valves, the bustle of pistons, the shrieks of mechanical saws, the starting of trams on the tracks, the cracking of whips, the flapping of awnings and flags. We will amuse ourselves by orchestrating together in our imagination the din of rolling shop shutters, the varied hubbub of train stations, iron works, thread mills, printing presses, electrical plants, and subways."[429]

As evident from the publication date of *Art of Noises*, no suitable recording technologies existed to satisfy the Futurists' desire for "orchestrating together" the many sounds they found musically interesting. To this end, mechanical devices (*intonarumori*) were invented to recreate the sounds of the industrial world, and assembled as instruments in a noise orchestra. Unfortunately, only a single page of Russolo's music has survived in score form[430]. In a 1914 issue of the short-lived Florentine journal *Lacerba*, the first page of Russolo's score for *Risveglio di una città* (see Figure 187) was published as an example of futurist music[431].

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[428] Luigi Russolo, *L'arte dei Rumori* [1913], trans. Barclay Brown (New York: Pendragon Press, 1986).

[429] Russolo *Rumori*, 26.

[430] *Lacerba* is also the source of a second surviving fragment of music utilizing the *intonarumori:* two pages of a sketch from Russolo's fellow futurist Francesco Balilla Pratella (1880-1955). This excerpt is reproduced in: Mark A. Radice, "Futurismo: Its Origins, Context, Repertory, and Influence," *The Musical Quarterly*, Vol. 73, No. 1 (1989): 1-17.

[431] Luigi Russolo, *Risveglio di una città* (excerpt) from *Lacerba* (March 1st, 1914): 72-73. Image and citation from: "Inventing Abstraction: 1910-1925," The New York Museum of Modern Art official website, accessed November 4, 2014, http://www.moma.org/interactives/exhibitions/2012/inventingabstraction/?work=240.

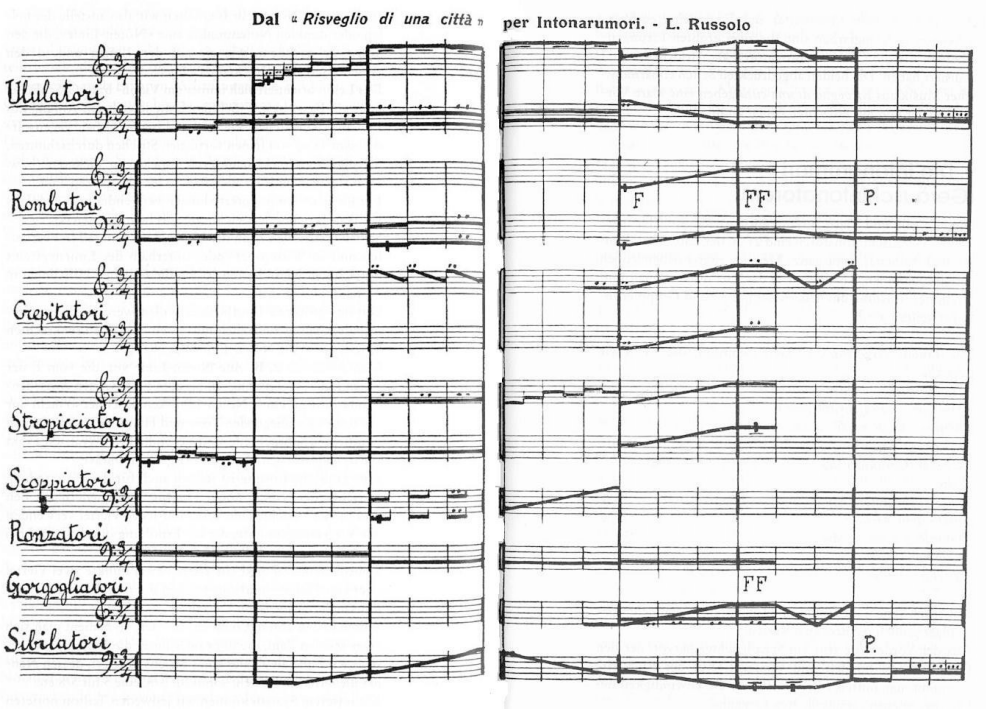

Figure 187 - Russolo: Risveglio d'una cita (Fragment, mm. 1-7)

Of the listed *intonarumori*, four are notated on grand staves (the *Ululatori, Rombatori, Crepitatori,* and *Stropicciatori*); three are notated with the bass clef (the *Scoppiatori*, *Ronratori*, and *Sibilatori*); and one is notated on a treble clef (the *Gorgogliatori*); indicating a substantial range and control of pitch. The relatively quick (quarter note or faster) changes of pitch found in the parts of all *intonarumori* except the *Ronratori* and *Sibilatori* indicate even more precise control over this dimension of sound. Finally, the presence of specific dynamics in measures 5-7 indicate that the volume of sound could also be controlled to a relatively rigorous degree.

The systematic harnessing of complex timbres is of particular historical significance in light of the subsequent developments of: *Musique concrète* [432], sound synthesis, the field of Spectromorphology (described in Chapter 1), and even the use of extended performance techniques on traditional western instruments[433]. In these

[432] Schaeffer states that: "Musical sonority must be expanded to accommodate an extended roster of timbres. The evolution of timbres must gain expressive value, and pieces must be composed whose structures derive from other factors than the interplay of pitch." Donna Zapf, *Musique concrète: a Translation and Analysis of Two Essays of Pierre Schaeffer: L'experience Concrète en Musique, La Musique Écartelée* (Masters Thesis: University of Victoria, 1980): 62.

[433] A more immediate and direct influence on mainstream compositional activity in the 20th century was identified in Radice, "Futurismo". Radice mentions concerns of orchestration: "Luigi Russolo's noise

contexts, Russolo's enumeration of the principles behind noise-instrument design is particularly significant.

> "*We want to give pitches to these diverse noises, regulating them harmonically and rhythmically.* Giving pitch to noises does not mean depriving them of all irregular movements and vibrations of time and intensity but rather assigning a degree or pitch to the strongest and most prominent of these vibrations. Noise differs from sound, in fact, only to the extent that the vibrations that produce it are confused and irregular. *Every noise has a pitch, some even a chord, which predominates among the whole of its irregular vibrations.* Now, from this predominant characteristic pitch derives the practical possibility of assigning pitches to the noise as a whole. That is, **there may be imparted to a given noise not only a single pitch but even a variety of pitches without sacrificing its character, by which I mean the timbre that distinguishes it**. Thus, some noises obtained through a rotary motion can offer an entire chromatic scale ascending or descending, if the speed of the motion is increased or decreased." [italics Russolo's, bolded emphasis mine][434]

The technological implications of Russolo's statement are multifaceted. The similarities to *Musique concrète* (to be addressed in a subsequent section of this chapter) are overwhelming – save the mode of presentation: tape vs. noise instruments. Consider also the development of synthesizers and computer signal processing software. In both cases timbre and its development are the primary foci, with control data (most often from a piano-style keyboard – much like that of the *Russolofono*) changing the pitch(es) "which predominate among the whole of its irregular vibrations", in the prescient words of Russolo cited above. The development of such devices and programs have been made possible through the study of spectral data over time (the foundation of Spectromorphology).

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tuners were used or imitated in works by other composers… In Paris in 1929 Edgard Varèse (1883-1965) introduced the *Russolofono*, the most elaborate of the noise tuners and the only one equipped with a keyboard. Between 1930 and 1933, Varèse completed his score of *Ionisation*, which includes mechanical sirens in the ensemble. Varèse utilized high (*sirène claire*) and low (*sirène grave*) sirens in much the same way that Russolo divided most of his *intonarumori* in the exceprt from *Risveglio di una citta*." (Radice, "Futurismo", p.13); and also describes the development of new compositional ideas founded on Russolo's notational depiction of continuous pitch change (as described at length in Chapter 2 of the present study): "Russolo's new notation does indeed facilitate correspondingly new musical ideas, particularly insofar as transformations of vertical sonorities are shown in what we might call analogue fashion. Since Russolo's time, important compositions employing transformations rather than progressions have appeared – Bartok's *Music for String Instruments, Percussion and Celesta* (1936) and Penderecki's *Threnody for the Victims of Hiroshima* (1960) are two well-known examples." Radice, "Futurismo", 16.

[434] Russolo, *Rumori*, 27.

Before moving on to such technological implications however, one might also consider the application of these principles to music of the western tradition that employs only conventional instrumentation. The string quartet for instance, is one of the most firmly established instrumental arrangements in western art music. In describing his 1971/76/88 composition *Gran Torso*, German composer Helmut Lachenmann states:

> "My conception of a *musique concrète instrumentale...* had in *Gran Torso* to confront for the first time such a traditionally comprised sound apparatus as the string quartet, which has become almost forbidden by its very familiarity."[435]

This confrontation led Lachenmann to the realization that:

> "The received playing style itself had to be expanded, rendered alien. The habits of hearing and performance implied by my chosen ensemble created a resistance--'their' resistance—to my initial ideas about poetics and sound syntax."[436]

The expansion and rendering alien of the received playing style was achieved through the nearly exclusive use of extended playing techniques for string instruments. Consider an excerpt from the cello part found in mm.61-4 of *Gran Torso*, and reproduced as Figure 188 below[437].

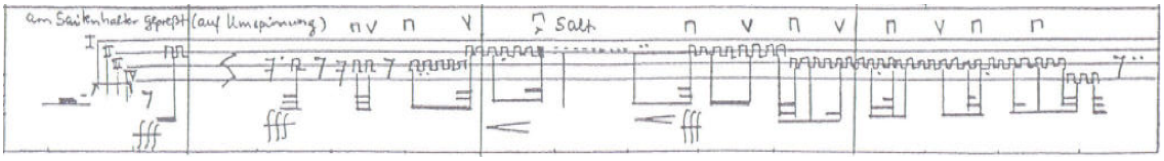

Figure 188 - Lachenmann: Gran Torso (Cello, mm. 61-4)

The rectangular noteheads and square waves indicate a playing style in which the bow pressure is intentionally much more forceful than typically employed during conventional playing. The result is a serrated, grinding, and distorted tone (sounding incidentally, quite similar to a synthetically generated square-wave – to which it also bares a graphical

[435] Helmut Lachenmann, "On My Second String Quartet 'Reigen seliger Geister' (1994-5)," translated by Evan Johnson, *Contemporary Music Review*, Vol. 23, No. 3/4 (September/December 2004): 59-79.

[436] Lachenmann, "On My Second", 60.

[437] Helmut Lachenmann, *Gran Torso* (Wiesbaden: Breitkopf & Härtel, 1980), mm. 61-4.

resemblance). By indicating changes of string through the use of a tablature-like notation system, Lachenmann alters the fundamental frequency of the square waves, while preserving their characteristic timbre. In this way he is "assigning pitches to the noise as a whole" (in the words of Russolo cited earlier) through a system of notation that bares a striking resemblance to that of the surviving repertoire for *intonarumori*.

The similarity between Lachenmann and the Italian Futurists[438] extends beyond their shared mapping of complex timbres onto pitches assigned to new (or re-contextualized) instruments. They both exhibit an analysis, classification, and arrangement paradigm that will be seen to unite a great deal of post-traditional musical morphology.

Both *Musique concrète instrumentale* according to Lachenmann (Table 13), and futurist music according to Russolo (Table 14), break down the entirety of acoustic phenomena into sub-groups known as sound families[439]. Furthermore, the characteristics of these respective sound families have a great deal in common[440]. Consider for instance the application of Lachenmann's *Kadenzklang* family to Russolo's fifth and sixth families, or the *Texturklang* qualities found in Russolo's second and third families.

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[438] The important differences between the Italian Futurists and Lachenmann should also be noted, most obviously their fascist and marxist political leanings (respectively). For more on the relationship between Italian Futurism and fascism, see: Walter L. Adamson, "Avant-garde modernism and Italian Fascism: cultural politics in the era of Mussolini," *Journal of Modern Italian Studies*, Vol. 6, No. 2: 230-248. British/Australian musicologist Richard Toop describes the diametrically opposed orientation of Lachenmann with reference to his teacher Luigi Nono in: Richard Toop, "Concept and Context: A Historiographic Consideration of Lachenmann's Orchestral Works," *Contemporary Music Review*, Vol. 23, No. 3-4 (September/December 2004): 125-143. "Describing the period prior to Lachenmann's use of a text by Red Army Faction prisoner Gudrun Ensslin in his opera *Das Mädchen mit den Schwefelhölzern* Lachenmann largely shared Nono's Marxist convictions, but not their projection into overtly communist work agendas. To date, his most politically explicit work title is that of the two-guitar piece *Salut für Caudwell*, in the course of which a passage from the English Marxist writer is 'spoken' by the guitarists." Toop, "Concept and Context", 128-129.

[439] The first chapter (1966/1993) of Lachenmann's collected writings on music introduces five main sound families. (Lachnemann, *Klangtypen*).

[440] There are also striking similarities between Lachenmann's sound families and the descriptions of contemporary musical material found in Tristan Murail's 1980 Darmstadt presentation: "The Revolution of Complex Sounds" (Murail, "Complex Sounds")

"Cadence-Sound" (*Kadenzklang*)	**"Colour-Sound" (*Farbklang*)**	**"Fluctuation-Sound" (*Fluktuations-klang*)**	**"Texture-Sound" (*Texturklang*)**	**"Structure-Sound" (*Struktur-klang*)**
-an impulse with a decay that is unique to the sound -the sound's duration is determined by its physical characteristics	-pure tone colour of one or more sounds occupying a space between timbre and harmony -no characteristic duration, must/may be cut to size	-colour-sound that is active either internally (ie. trills between fixed limits) or externally (ie. repeating ostinato or figuration)	-a detailed composite of statistically predictable activity with a high level of local entropy -no characteristic duration, must/may be cut to size	-indivisible composite of essential and carefully proportioned elements -can vary in scale from micro sounds to an entire work

Table 13: Lachenmann's Five Sound Families[441]

"Here are the 6 *families of noises* of the futurist orchestra that we will soon realize mechanically:					
1	2	3	4	5	6
Roars Thunderings Explosions Hissing roars Bangs Booms	Whistling Hissing Puffing	Whispers Murmurs Mumbling Muttering Gurgling	Screeching Creaking Rustling Humming Crackling Rubbing	Noises obtained by beating on metals woods skins stones pottery etc.	Voices of animals and people Shouts Screams Shrieks Wails Hoots Howls Death rattles Sobs
In this list we have included the most characteristic of the fundamental noises. The others are only associations and combinations of these."[442]					

Table 14: Russolo's Six Sound Families

The original 1966/1993 Lachenmann article should be consulted for the complete account of the composer's sound-types including many musical examples. However, the above table reveals that Lachenmann's primary criteria for classification involve how

[441] Condensed from: Lachnemann, "*Klangtypen*", 1-20.

[442] Russolo, *Rumori*, 28.

sounds change over time (ie. their internal morphologies). On the other hand, the Futurists first and foremost classified their sounds according to the bodily conditions of their production mechanisms.

The Futurist approach of classifying sounds according to their corporeal origins does however correspond to the categories utilized compositionally by Lachenmann in his music for string quartet (both the above mentioned *Gran Torso* and 1988-9's *Reigen seliger Geister*), according to a 1994-5 article by the composer.

> "Categories are primarily delineated not by the usual parameters, but rather through the (always differently deployed) bodily energetic aspects"[443]

Lachenmann's analysis and categorization of post-common practice resources in his theoretical writing allows him to arrange these materials in a meaningful way within the context of his music. It is noteworthy that in *Gran Torso* and *Reigen seliger Geister* (in which Lachenmann aimed "to go 'deeper' and… to see into the already-developed landscape more keenly"[444]), this meaningful arrangement is manifest through a series of playing techniques transforming into each other, based on their dense network of physical and sonic characteristics. Lachenmann establishes a continuum between:

> "broader sound categories brought to the fore in ever-varying ways. (Witness, for example, toneless string noise as the clear product of *tremolo* bowing, transformed by extreme slowness, that shifts over the strings all the way onto the bridge; or the *legno battuto* on stopped strings: here as a means of the *pianississimo* articulation of silence, there as an impulse-variant of *pizzicato* and other short attacks, as the product of vertical strikes of the bow against the string, mediated with other, springing, thrown, wiping, stroking forms of bow movement, definable as characteristic noises, but also as precise pitches in an appropriately different context.)[445]

Thus do sounds' internal morphologies serve to guide the work's global morphology.

In the specific case of *Reigen seliger Geister*, the continuum explored is that

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[443] Lachenmann, "On My Second", 59.

[444] Ibid., 60.

[445] Ibid.

between loud, short, and precisely pitched attacks on the one hand; and soft, continuous, and muted presentations of string and bow noise on the other.

> "In terms of sound technique, the work—as a field of categories completing and at the same time transforming itself *poco a poco*—emerges first through *flautato* gestures, while the mapped-out sound world gradually transforms itself into a diametrically opposed landscape of quite differently structured *pizzicato* fields."[446]

The goal of the "poco a poco" transformation described by Lachenmann is the "pizzicato field". Reaching its culmination during the "*quasi Waltzer*" passage (see Figure 189) beginning at measure 296 in the score[447], the end goal of this transformation is a long series of tutti chords played as loudly as possible with plectra.

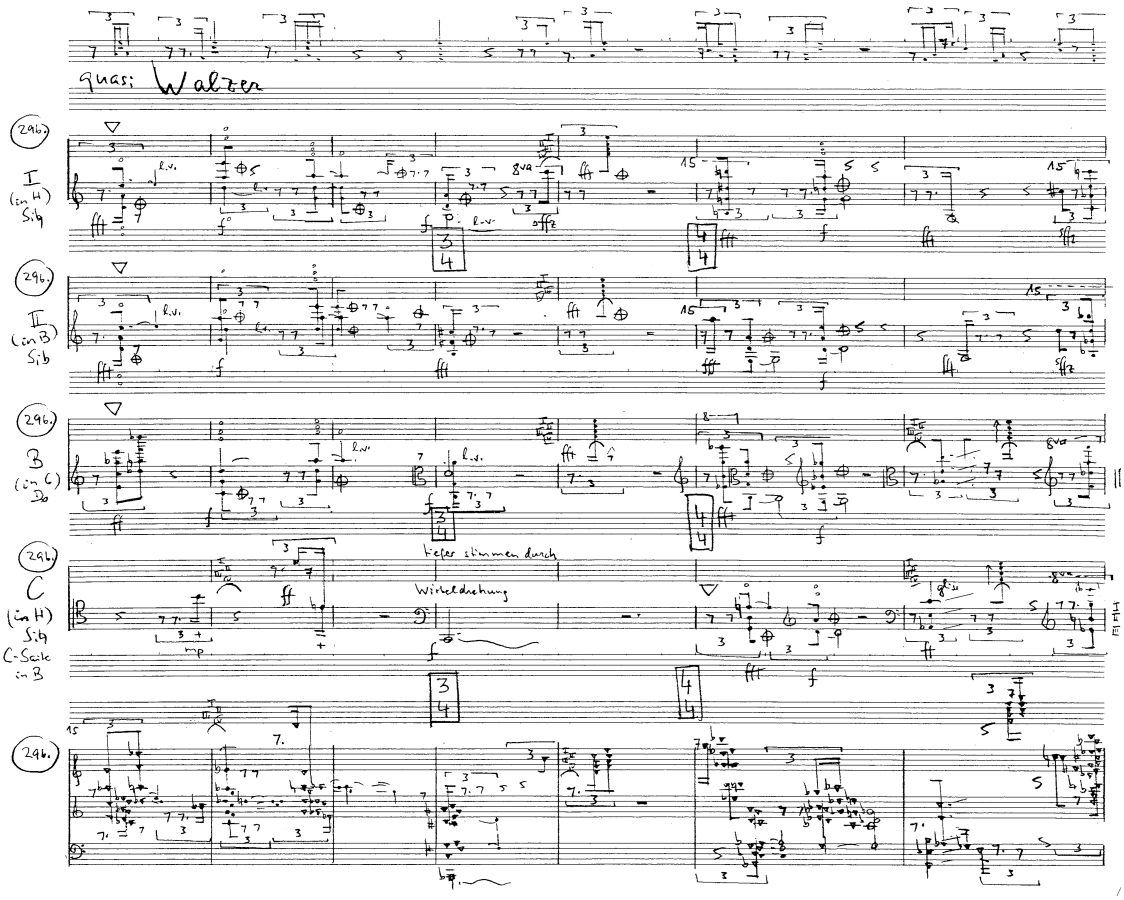

Figure 189 - Lachenmann: Reigen Seliger Geister (mm. 296-302)

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[446] Ibid.

[447] Helmut Lachenmann, *II. Streichquartett Reigen seliger Geister* (Wiesbaden: Breitkopf & Härtel, 1989), mm. 296-302.

The realization of this eventual goal marks a stark contrast to the highly diffuse opening of the quartet. With the exception of a brief and uncharacteristically assertive outburst during measures 49-53, the first section of *Reigen seliger Geister* contains almost exclusively veiled (half-pressed) or muted left hand activity. Articulating this highly reduced "pitch information", is the gradually foregrounded bow motion that itself travels up and down the available length of the string "between the bridge (at the frog of the bow) and the damping finger (at the tip)"[448]. These bowing directions are structurally important enough to be notated on a separate staff for each instrument, as in Figure 190[449].

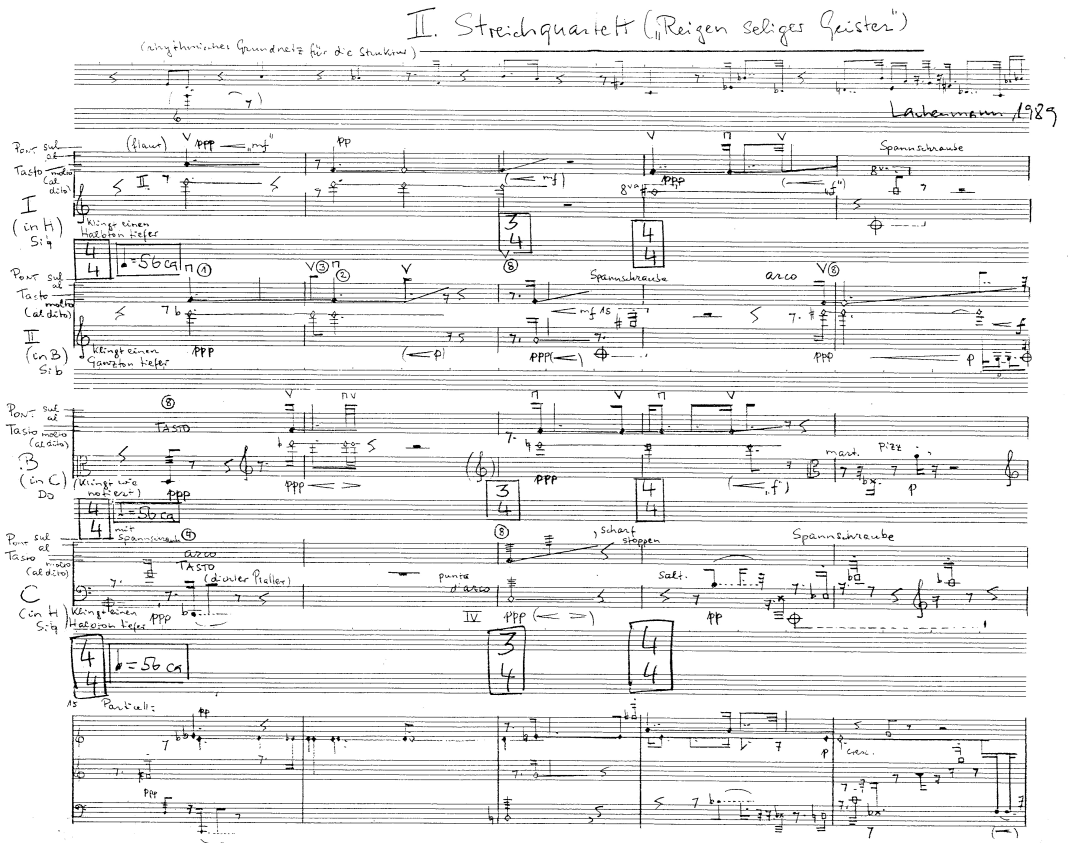

Figure 190 - Lachenmann: Reigen Seliger Geister (mm. 1-5)

[448] Lachenmann, "On My Second", 60.

[449] Lachenmann, *Reigen*, mm. 1-5.

The first substantial step in *Reigen seliger Geister*'s morphology towards the precise pitches and attacks of the pizzicato field occurs just before measure 87. Here, the rise and fall of the longitudinal motion along the fingerboard – previously reserved mostly for the "toneless"[450] motion of the bow – is transferred to the half-pressed notes of the left hand (Figure 191)[451].

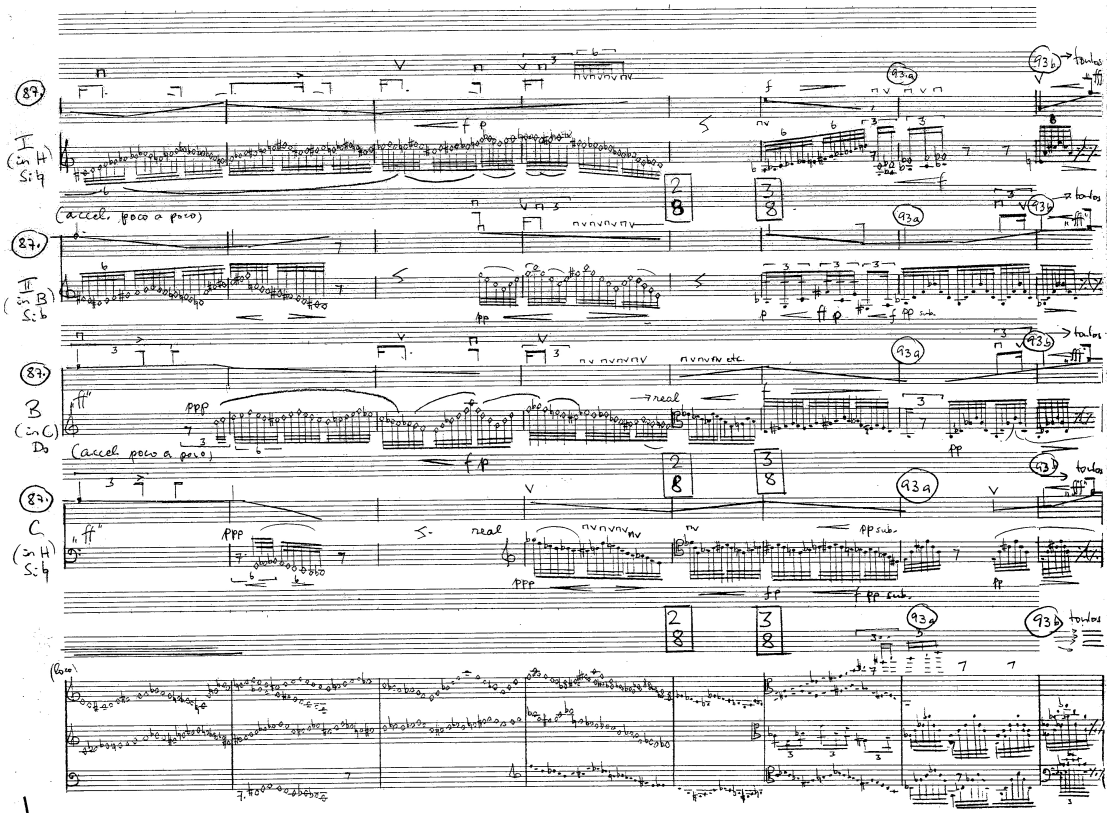

Figure 191 - Lachenmann: Reigen Seliger Geister (mm. 87-93b)

As merely the first step in the long, non-linear morphology tending towards a pizzicato field, the end sonic result is still one of quite veiled pitch content. This first transfer of "bodily energetic aspects" towards materials with more precise attack and pitch profiles is certainly subtle. However, it is merely one increment in a gradual process that continues throughout the entire work, thereby generating its form.

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[450] Of course, the longitudinal motion of the bow is not literally toneless. As Lachenmann points out: "According to the narrowing or widening distance between the bridge and the bowing location on the string, the flautato bow movement itself results in a brightness-glissando." Lachenmann, "On My Second", 61.

[451] Lachenmann, *Reigen*, mm. 87-93b.

The overall form of *Reigen seliger Geister* then, embodies a morphology of post-common practice acoustic materials, made possible through a careful and individualized scheme of analysis, classification, and arrangement. This process of compositional synthesis following an initial sonic analysis is echoed by the studio-based methods of Pierre Schaeffer and Karlheinz Stockhausen[452]. The next step towards these electro-acoustic media however (following the purely acoustic/mechanical examples of Russolo described above and their resonances in the subsequent, conventionally orchestrated works of Lachenmann), is the related field of early visual media, namely: film.

6.4.2 New Morphologies and Plastic Media I – Film

Preceding the invention of audio recording tape by nearly half a century, motion-picture film facilitated the out-of-time assembly of a temporal form through the cutting and splicing of its materials. To 20th century German philosopher and cultural critic Walter Benjamin, this development created a fundamentally new artform. In his 1936 essay: *The Work of Art in the Age of its Technological Reproducibility*[453], Benjamin describes the conditions under which mechanical reproduction can actually alter the course of creative production itself.

> "Technological reproduction is more independent of the original than is manual reproduction... it can use certain processes, such as enlargement or slow motion, to record images which escape natural optics altogether... technological reproduction can place the copy of the original in situations which the original itself cannot attain."[454]

The various techniques that Benjamin mentions throughout the essay could very easily be interpreted as instructions for the creation of a piece of *Musique concrète*. Consider the following descriptions of film production enumerated by Benjamin, and the striking parallels they display to the manipulation of recorded sound that was to become possible in subsequent decades.

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[452] One might also consider Lachenamann's own formative experiences at the IPEM electronic music studios in Ghent, where he composed his only tape piece: 1965's *Szenario*. See: Toop, "Concept and Context", 141.

[453] Benjamin, "Reproducibility" [see previous citation]

[454] Ibid., 21.

> "It is assembled from a very large number of images and image sequences that offer an array of choices to the editor; these images, moreover, can be improved in any desired way."[455]
>
> "The work of art is produced only by means of montage."[456]
>
> "The representation of an action- which on the screen appears as a swift, unified sequence... may be spread over hours in the studio"[457]
>
> "The illusory nature of film is of the second degree; it is the result of editing."[458]

Benjamin goes so far as to equate these new techniques with a new art form:

> "The history of every art form has critical periods in which the particular form strains after effects which can be easily achieved only with a changed technical standard... that is to say, in a new art form."[459]

While early editing techniques do not constitute morphing in the sense of continuous change between – and interpenetration by – two distinct sources of material, they do present new tools for the arrangement of material in time. These new influences on the creation of form do therefore lead to the possibility of genuinely new morphologies (morphology as a noun being defined in Chapter 1 as the history of variation in form). The key element of this paradigm shift is the temporal plasticity of one's materials, made possible through various recording media.

These earliest and simplest manipulation technologies (cutting and splicing) have continued to exert an influence over composers of electronic music from Cage[460] and Schaeffer[461] all the way up to Koonce[462] and Takasugi[463] (and for that matter any modern

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[455] Ibid., 28.

[456] Ibid., 29.

[457] Ibid., 32.

[458] Ibid., 35.

[459] Ibid., 38.

[460] John Cage, *The 25-year retrospective concert of the music of John Cage* (Mainz: Wergo, 1994), compact disc.

[461] Pierre Schaeffer and Pierre Henry, "Symphonie pour un homme seul," in *50 ans de musique électroacoustique au Groupe de recherches musicales* (Paris: INA/GRM, 2001), compact disc.

[462] Paul C Koonce, *Walkabout & back* (New York: Mode, 2000), compact disc.

composer who utilizes audio editing software). However, the paradigm shift described above can also be detected at the level of form in many purely acoustic works as well. For instance, the Edgard Varèse composition *Déserts*[464], and the George Antheil work *Ballet Mécanique*[465] have both been described in terms of their connections to film editing. Figure 192 suggests how one might also interpret the construction of *Symphonies of Wind Instruments* (1947 revision of the 1920 original)[466] by Igor Stravinsky in relation to the (then) emerging visual technology of film splicing.

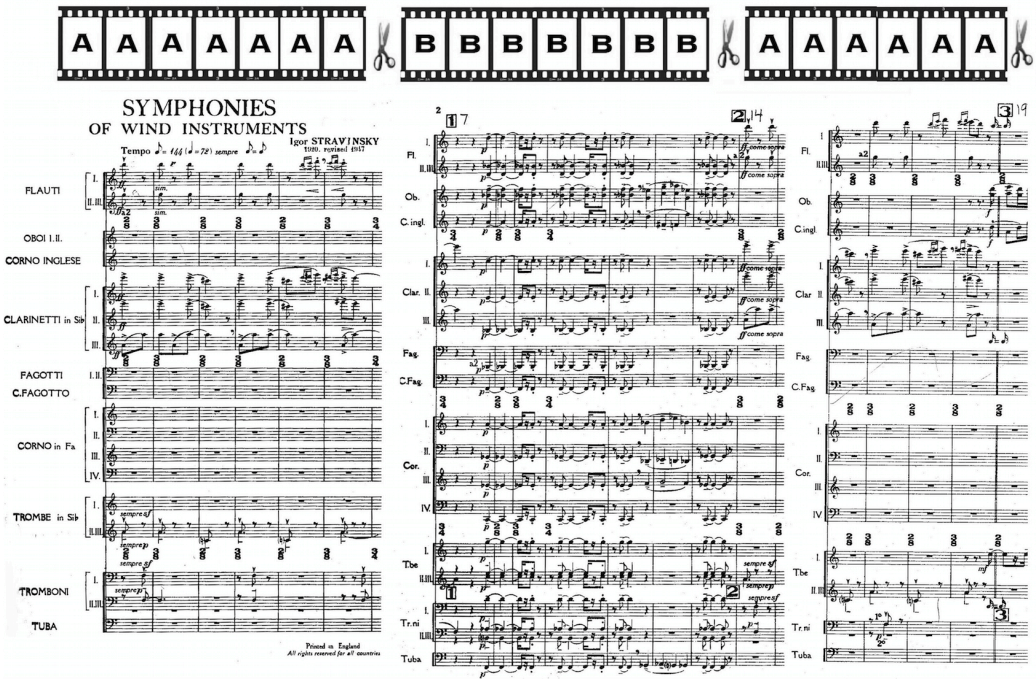

Figure 192 - Stravinsky: Symphonies of Wind Instruments, i (Score, mm. 1-18)

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[463] Takasugi's primary studio technique is a sort of "DIY granular synthesis" in which individual sounds are built up out of tiny clippings of a given sonic material. See: Steven Kazuo Takasugi "Strange Autumn: An Attempt at an Interpretation." In *New Music and Aesthetics in the 21st Century, Vol. 4 – Electronics in New Music*. Edited by Claus-Steffen Mahnkopf, Frank Cox, and Wolfgang Schurig, 207-222 (Hofheim: Wolke Verlag, 2004): 204. Granular synthesis proper is also of relevance to the manipulation of plastic recording media. Invented by Greek composer Iannis Xenakis, this technique was originally executed using only analog recording and editing technologies (ie. the splicing of audio tape). For more on the origins of this technique, see: Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition* (Bloomington: Indiana University Press, 1971). The real-time digital implementation of the technique (facilitating its broader musical adoption) was described by Canadian composer Barry Truax in: Barry Truax, "Real-Time Granular Synthesis with a Digital Signal Processor," *Computer Music Journal*, Vol. 12, No. 2 (1988): 14-26.

[464] See: Marian Van Dijk, "Montage Technique in Edgard Varèse's Déserts," *Tijdschrift voor Muziektheorie*, Vol. 9, No. 2 (2004): 121-130.

[465] See: Maurice Peress, "Sound & Vision: The Player," *Film Comment*, Vol. 42, No. 1 (Jan. 2006): 16.

[466] Igor Stravinsky, *Symphonies of Wind Instruments* (London: Boosey & Hawkes, 1952), mm. 1-18.

Visually, it is clear that the abrupt cuts indicated above are the result of sharp contrasts in orchestration, rhythmic profile, and density of pitch-spacing. However, a reduction of the first two cuts indicated by the letters A-B-A above (see Figure 193), reveal further contrasts at the level of pitch.

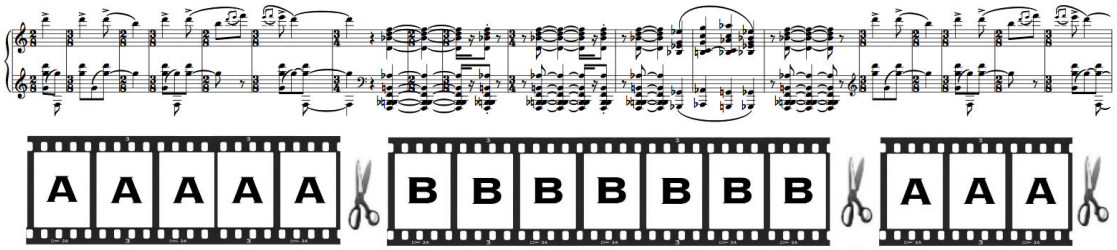

Figure 193 - Stravinsky: Symphonies of Wind Instruments, i (Reduction, mm. 1-18)

Again the dramatic contrasts of density and register are immediately apparent: the high, sparse, melodic writing of the A material as opposed to the low, dense, chordal repetitions of the B material. The treatment of pitch in this passage is also strikingly heterogeneous. The A material presents a simple melody in the mode of G-mixolidian, while the vast majority of the B material is simply a restatement of one complex 11th chord built over a B-flat major triad (with an F in the bass).

These dramatic and sudden changes of material reveal – as in film or *Musique concrète* – the potential creative influence of the editing studio in bringing together disparate sonic entities. The close proximity shared by such divergent materials however, does not generate any connective tissue between A and B, but rather, simply brushes them up against each other. Again, form is achieved additively.

Two paradigms of formal construction resulting in very different characteristic morphologies have thus far been described: the transformation paradigm of common practice form (as described by Koch, Sulzer, Cleland, Reti, and Dahlhaus); and the analysis, classification, and arrangement paradigm that rose to prominence in the early 20th century (as embodied by Russolo – and later – Lachenmann). Furthermore, plastic recording media have also been linked to this paradigm shift (through Benjamin's description of film editing). These technologies however, have heretofore only been

considered in terms of their potential for the novel ***arrangement*** of materials – as opposed to their ***manipulation*** or ***creation***.

In addition to techniques of cutting and splicing however, Benjamin also identified the potential of film to generate forms in which slow, continuous change constitutes the entire architecture of the work. He describes this possibility (or even tendency) in the context of film's seemingly magical ability to transcend daily reality.

> "Our bars and city streets, our offices and furnished rooms, our railroad stations and our factories seemed to close relentlessly around us. Then came film and exploded this prison-world ***with the dynamite of the split second***, so that now we can set off on journeys of adventure among its far-flung debris. With the close-up, space expands, with slow motion, movement is extended. And just as enlargement not merely clarifies what we see indistinctly "in any case," ***but brings to light entirely new structures of matter, slow motion not only reveals familiar aspects of movements, but discloses quite unknown aspects within them***- aspects "which do not appear as the retarding of natural movements but have a curious gliding, floating character of their own.""[emphasis mine][467]

Through recording technologies that allow for the radical manipulation of time, a single (normally fleeting) transformation may be sufficiently stretched so as to assume the conditions of form itself. This technologically facilitated or inspired plasticity of time allows listeners to truly "enter into" a single transformation. Such forms extend the dimensions of a single transformation to the global level of form: morphing becomes morphology.

An example of this "disclosure" of "quite unknown aspects within"[468] through the filmic technique of slow motion was discussed in the previous chapter's citation of *Partiels* (1975) by Gérard Grisey[469].

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[467] Benjamin, "Reproducibility", 37.

[468] Ibid.

[469] For further discussion of this section from *Partiels*, please see Chapter 3.

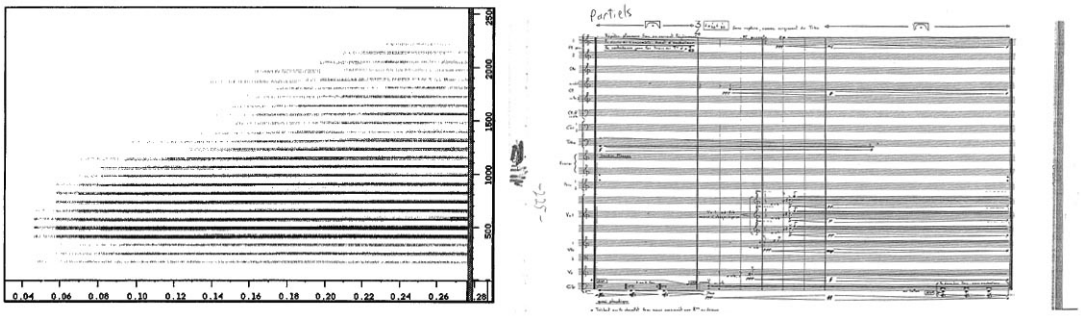

Figure 194 - Grisey: Partiels (Source Material and Score, mm. 1-8)

As noted in Chapter 5, a comparison of the time scales for the two images in Figure 194 reveals a significant discrepancy. An attack which lasts roughly half a second in the spectrogram on the left is stretched out to roughly half a minute in the score on the right. Though it is unlikely that Grisey was consciously pondering techniques of film editing during the composition of *Partiels*, the overall effect of sonic slow-motion is certainly identical to its visual counterpart described above by Benjamin. Furthermore, the lack of similar effects in compositions predating slow motion technology might also suggest the subconscious influence of film.

Benjamin's unknown internal aspects revealed through Grisey's sonic slow-motion take the form of the microtonal inflections corresponding to the precise frequencies of the partial vibrations that make up the analyzed trombone attack, and the independence of loudness and duration in each of these voices. In the words of his fellow spectralist, Tristan Murail: "timbres are split into harmonies, harmonies fuse as timbres"[470].

Though noteworthy in and of itself, this expansion by a factor of roughly 60 constitutes only the beginning of a much more dramatic time stretch. As shown in the analysis of *Partiels* that concluded Chapter 5, this purely harmonic opening is gradually transformed into a densely inharmonic cluster over the course of four minutes (a factor of roughly 240). As noted earlier, the balance between transformational material and a morphology of musical form begins to take on the dimensions of the latter. In the words of Benjamin cited above, the listener is transported out of the world, with its tendency "to

[470] Murail, "Complex Sounds", 135.

close relentlessly around us... with the dynamite of the split second, so that now we can set off on journeys of adventure among its far-flung debris."[471] As noted previously, the world to which the listener escapes during the first half of *Partiels* consists entirely of one long manipulation from the E pedal tone that opens the work to its increasingly inharmonic presentations. This single immersive transformation assumes the dimensions of form by virtue of its duration, and its consistent adherence to a single process.

The "translation" of editing and manipulation techniques from film to music (as applied to the Stravinsky and Grisey case studies cited above) has relevance to the discussion of digital audio morphing found in Chapter 3. After all, the quest for audio morphing is at heart an attempt to cross-modally recreate an effect from the visual realm in sound. Before proceeding to such matters however, one might also consider the influence of sound's own initial plastic medium: tape. Not surprisingly, this aural descendant of film will be seen to share many characteristics with its visual predecessor. However, the direct physical access to any recordable sound also yielded many developments in musical morphology unique to the medium.

6.4.3 New Morphologies and Plastic Media II – Tape

With the development of audio recording on magnetic tape, sound editing obtained the quality of plasticity inherent in film manipulation. While soundwaves had previously been engraved directly onto un-editable cylinders or plates, their conversion into an electric signal that could be stored on various media occurred around 1930[472]. According to the entry on Sound Recording in the New Grove:

> "By about 1929, notably in the 'Blattnerphone', the wire was replaced by a flat steel band, 6 mm wide and 0·2 mm thick, because the round wire was inclined to twist. Such recordings could be edited, and high-frequency erasing and bias were developed about 1927. It was not until flexible coated tapes were introduced that magnetic recording gained real momentum. BASF showed their first tapes and 'magnetophon' recorders

[471] Benjamin, "Reproducibility", 37.

[472] Arthur W.J.G. Ord-Hume, et al. "Recorded sound," *Grove Music Online. Oxford Music Online,* Oxford University Press, accessed October 29, 2014, http://www.oxfordmusiconline.com.ezproxy.library.uvic.ca/subscriber/article/grove/music/26294.

> at the 1935 Berlin Radio Fair. Paper was used at first, then plastic-film-based tapes."[473]

The new plasticity of recorded sound generated many exciting new material and formal possibilities in a fundamentally new medium: electro-acoustic music. The purely acoustic examples from Russolo's futurism and (later) Lachenmann's *Musique concrète instrumentale* reveal that the meaningful arrangement of post-common practice materials requires a pre-compositional step foreign to common practice morphologies. This step, the act of analyzing and classifying one's chosen sonic materials, is also a characteristic of the electro-acoustic school of composition from which *Musique concrète instrumentale* derived its name.

In her 1980 Master's translation of two Pierre Schaeffer (1910-1995) essays, Donna Zapf introduces the founder of *Musique concrète* and describes the historical origins of the movement.

> "The genesis of electro-acoustic music in France can be equated with the experimental work of Pierre Schaeffer (b. Nancy, France, 1910[-1995]). In 1948, with vague aspirations of realizing a comprehensive form of expression through sound, Schaeffer brought noise-makers into the *Studio d'Essai* of the *Radiodiffusion-Télévision Francaise* (RTF) in Paris. His *recherche sur les bruits* became *Musique concrète*. In 1949, he was joined by composer Pierre Henry; within a short period numerous other composers and musicians were associated with the studio. In 1951, the *Groupe de Recherce de Musique Concrète* (GRMC) was incorporated at the RTF. *Concrete music* refers specifically to the initial decade (1948-1958) of electro-acoustic music at the RTF."[474]

The term also implies stylistic characteristics. The New Grove entry on electro-acoustic music breaks down the term *Musique concrète*, and enumerates its stylistic qualities.

> "The word '*concrète*' originally conveyed the idea that the composer was working directly (concretely) with the sound material, in contrast to the composer of instrumental or vocal music who works indirectly (abstractly) using a symbolic system of notation which represents the sounds to be made concrete by instruments and/or voices. In musique concrète sound materials could be taken from pre-existing recordings (including

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[473] Ord-Hume, et al. "Recorded sound."

[474] Zapf, *Musique concrète,* 2.

> instrumental and vocal music) and recordings made specially, whether of the environment or with instruments and objects in front of a studio microphone. These source sounds might then be subjected to treatments before being combined in a structure; ***the compositional process proceeded by experiment***."[475] (emphasis mine)

The final clause of the above summary is one of the most significant aspects of *Musique concrète*. As has been shown, new sounds of all kinds became available to composers of the late nineteenth and early twentieth centuries: from unrestricted use of pitch space (as described in Chapter 4) to the direct compositional manipulation of familiar timbres (as described in Chapter 5), all the way up to the integration of non-traditional acoustic materials within the sphere of concert music (as described above).

It is self-evident that the introduction of audio recording technology (with its ability to capture and store sounds for later or shared use) would dramatically accelerate this expansion of material resources. However, the advent of such technologies also had important consequences at the levels of compositional technique and form. For the first time, tools existed for the development of new morphologies rooted in the scientific and empirical examination of (the new) musical materials. As Schaeffer stated in 1952's *L'experience Concrète en Musique,* as translated by Zapf:

> "As soon as the concept of concrete music arose, however, it was exceeded not only by an abundance of new materials but by an explosion of formal possibilities. But unlike the new instrument makers, concrete music is not seduced by this proliferation. Instead, it demands an enumeration of these haphazardly liberated objects, an inevitability in their use, and a methodology, even if founded only on hypotheses."[476]

Emphasizing the importance of responsive techniques and forms, Schaeffer drew a sharp distinction between *Musique concrète* and the intuitive approaches of earlier composers. In reference to *Klangfarben* composition, he went so far as to suggest that "Schoenberg's timbral melody represent[s a minor aspect] of the composers' work -- experimentation without development."[477] For Schaeffer the emphasis on analysis and

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[475] Simon Emmerson and Denis Smalley. "Electro-acoustic music," Grove Music Online. Oxford Music Online. Oxford University Press, accessed February 17, 2015, http://www.oxfordmusiconline.com/subscriber/article/grove/music/08695.

[476] Schaeffer (via Zapf, *Musique concrète,* 57.)

[477] Ibid., 61.

classification of material marked a radical paradigm shift in western composition – a shift with important consequences for the morphology of post-traditional music. In his 1996 obituary of Schaeffer, French composer and writer Jean de Reydellet summarized *Musique concrète*'s legacy in words he ascribed (without citation) to Schaeffer himself. Though the original source is unknown, Schaeffer/Reydellet described *Musique concrète* as:

> "an opposition with the way a musical work usually goes. Instead of notating musical ideas on paper with the symbols of solfege and entrusting their realization to well-known instruments, the question was to collect concrete sounds, wherever they came from, ***and to abstract the musical values they were potentially containing***" [478] [emphasis mine]

It was also an important aspect of Schaeffer's method that even traditional materials could be incorporated into the new medium:

> "It seems arbitrary and inhuman to forbid known elements from construction in which the results are as yet unforeseen. This is both snobbery and a very modern prejudice to which I do not subscribe."[479]

This openness to familiar sonic elements is both an outgrowth of Schaeffer's own aesthetic[480], and an inherent characteristic of a medium based in the recordings of real-world sound (many of them familiar). In terms of the former, Schaeffer describes his feelings on materials generated through audio synthesis in the Zapf translation of his 1978 article *Musique Écartelée*:

> "I readily admit my predilection for natural materials, my preference for the grain of wood or marble, for the formal properties of a seashell or an agate. I dread a profusion of synthetic materials which are too homogenous, too malleable and suggest no inherent form."[481]

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[478] Timothy D. Taylor, *Strange Sounds – Music Technology and Culture* (Routledge: New York, 2001), cites the following obituary, but notes that Reydellet himself provides no citation: Jean de Reydellet, "Pierre Schaeffer, 1910-1995: The Founder of *Musique concrete,*" *Computer Music Journal*, Vol. 20, No. 2 (Summer 1996): 10-11.

[479] Schaeffer (via Zapf, *Musique concrète,* 63.)

[480] Schaeffer's diaries contain many appeals for an openness to more familiar materials (as opposed to those of the newly emerging post-war serialists). See: Pierre Schaeffer, *In Search of a Concrete Music* (1948-52), trans. Christine North and John Dack (Berkeley: University of California Press, 2012).

[481] Schaeffer (via Zapf, *Musique concrète,* 137.)

Ironically, one of the young composers to have joined Schaeffer's GRMC during the 1950s would go on to work with a great deal of "synthetic materials" in terms of their "inherent form[s]". In his 1971 talk: *Four Criteria of Electronic Music*, Karlheinz Stockhausen describes his earlier activities in Paris under Schaeffer, and how they led him to pursue the synthesis of electronic sound:

> "I started first of all by analyzing all sorts of sounds... I recorded sounds in the Musée de l'Homme, where you can find exotic instruments... I also analyzed sounds and noises which I recorded from daily life, and began to study books in which you can find spectral analyses of the sounds of classical musical instruments... I became very interested in the differences between sounds... ***It was after analyzing a lot of sounds that this second thought came up (it was always implied): if I can analyze sounds which exist already and I have recorded, why can I not try to synthesize sound in order to find new sounds, if possible.***"[482] [emphasis mine]

Stockhausen regarded this activity as a direct outgrowth of the western musical tradition of the early twentieth century. While "the Viennese School of Schoenberg, Berg, and Webern had reduced their musical themes and motifs to entities of only two sounds, to intervals"[483], Stockhausen identified the fact that "it took a little leap forward to reach the idea of composing, or synthesizing, the individual sound"[484]. Though a more complete explanation of Stockhausen's specific techniques of synthesis (additive and subtractive) can be found in Chapter 3, it is sufficient here to note the importance of the first tape-based studios in analyzing and categorizing the vast wealth of new sonic materials.

Most importantly, these technologically influenced methods of analysis lay the foundation for new morphologies of music in the post-common practice period. Form and material become interrelated in a way that Stockhausen describes as virtually inseparable. Thus does the transformation of materials in traditional music give way to the (re-)synthesis of new forms influenced by an analysis of their materials in post-traditional practice.

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[482] Stockhausen, "Four Criteria", 89.

[483] Ibid.

[484] Ibid.

> "We have discovered a new law of relationship between the nature of the sound and the scale on which it may be composed... There is a very subtle relationship nowadays between form and material. I would even go so far as to say that ***form and material have to be considered as one and the same. I think it is perhaps the most important fact to come out in the twentieth century***, that in several fields material and form are no longer regarded as separate, in the sense that I take this material and I put it into that form. ***Rather, a given material determines its own best form according to its inner nature***."[485] [emphasis mine]

The creation of responsive forms through an analysis and classification of one's materials unites the seemingly disparate studio approaches of both Schaeffer and Stockhausen. Furthermore, even the purely acoustic compositional methods of Lachenmann and Russolo have similarly analytical roots in that they both employ sound families to classify and arrange their materials. While these extra steps of analysis and assessment may mark the emergence of new morphologies of form rooted in new musical resources, one might also trace a line back to the "form as a result of motive" paradigm described by Dahlhaus in reference to late Romantic practice. The Grisey example cited above suggests how filmic media might be reflected in a third paradigm of morphology based on gradual (or in visual terms: slow motion) change ***as*** form. In an analogous way, the subsequent plastic medium of audio tape can also be seen to have influenced a new type of form composed of a single gradual change or process.

American composer Steve Reich (born 1936) began experimenting with tape loops – the copying of a short fragment of material onto a literal loop of magnetic tape such that it could cycle through a tape recorder and repeat indefinitely – in the mid-1960s. A fortuitous accident during which the playback speeds of two identical loops began to drift apart very gradually, resulted in what came to be known as phase music[486].

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[485] Ibid., 111.

[486] Steve Reich, *Writings on Music* (Oxford: Oxford University Press, 2002): 20.

The representative tape piece of this era is 1966's *Come Out*, wherein the voice of a preacher speaking the titular phrase is presented in multiple loops that drift in and out of phase (denoted by Ø, signifying one full repetition of the phrase). Excerpts from the first three minutes of the work are shown in a stereo waveform below as Figure 195.[487]

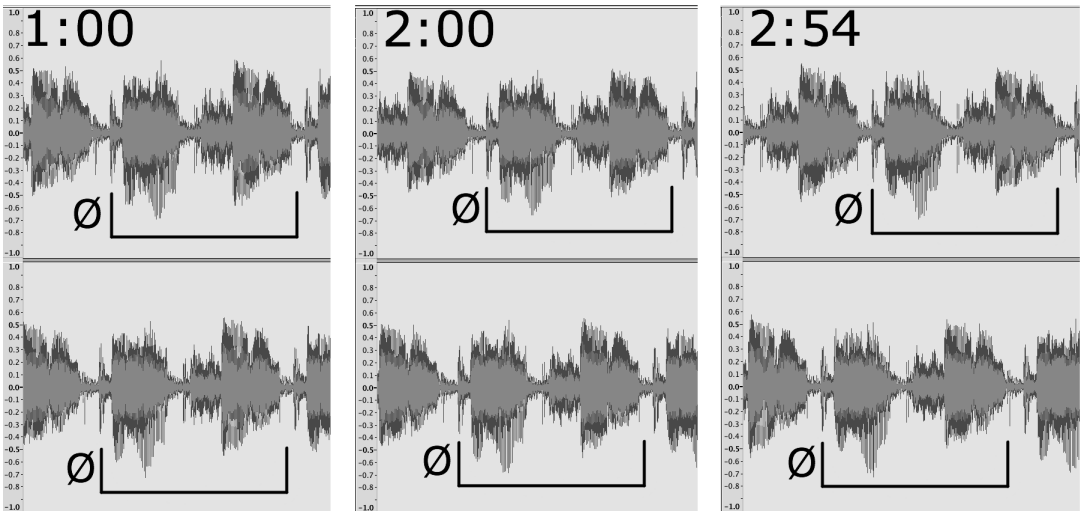

Figure 195 - Reich: Come Out (Phase Analysis at 1:00, 2:00, and 2:54)

As can be seen by comparing the phase brackets of the top and bottom waveforms at 2:54, the top track is further ahead of the bottom track than it was 2:00 and much further ahead than it was at 1:00.

Following this point in the piece, the texture is thickened through the splitting of each channel to produce another two layers of phase relationships, making visualization much more difficult. The aural effect however, is clear. The very gradual change in texture – an extended sonic transformation – is the only musical content of the work, existing as the main perceptive realm for the listener to inhabit. Material again becomes form through immersion within a single, gradual, process. Reich describes the importance of process in his collected writings, published in 2002.

> "I am interested in perceptible processes. I want to be able to hear the process happening throughout the sounding music."[488]

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[487] Steve Reich, "Come Out," in *Works 1965-1995* (New York: Nonesuch, 1997), compact disc.

[488] Reich, *Writings*, 35.

Following his initial experiments on tape, Reich applied these techniques to the composition of purely acoustic works. The opening of 1967's *Piano Phase*[489] (Figure 196) reveals the same technique at play as a determinant of global form in the piano duet.

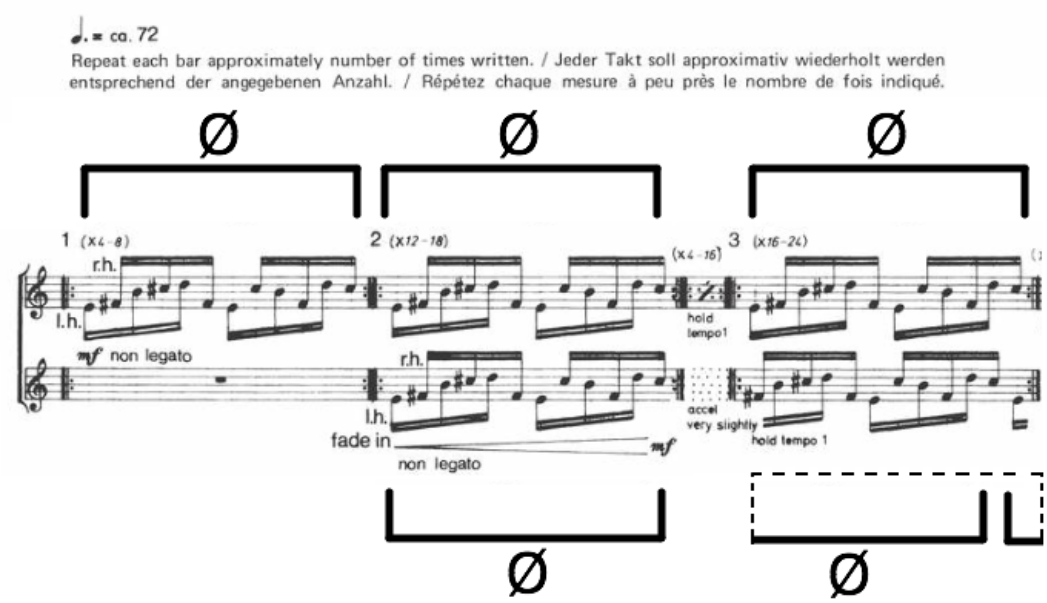

Figure 196 - Reich: Piano Phase (Phase Analysis, mm. 1-3)

The (multiply-repeated) measure in which the slight acceleration is very gradually executed by the second pianist is very small in the score, and in fact, does not even receive a measure number (it is located between the bordering double bar lines of measures 2 and 3). These measures – of slight visual stature – constitute the most important sonic material of the piece. In these measures, the shifting of phase is continuous rather than being quantized in the discrete multiples of sixteenth notes found in the numbered bars.

When the entire cycle of possible phase combinations is completed at measure 14, the second piano drops out (Figure 197)[490].

[489] Steve Reich, *Piano phase* (London: Universal Edition, 1980), mm. 1-3.

[490] Reich, *Piano*, mm. 13-15.

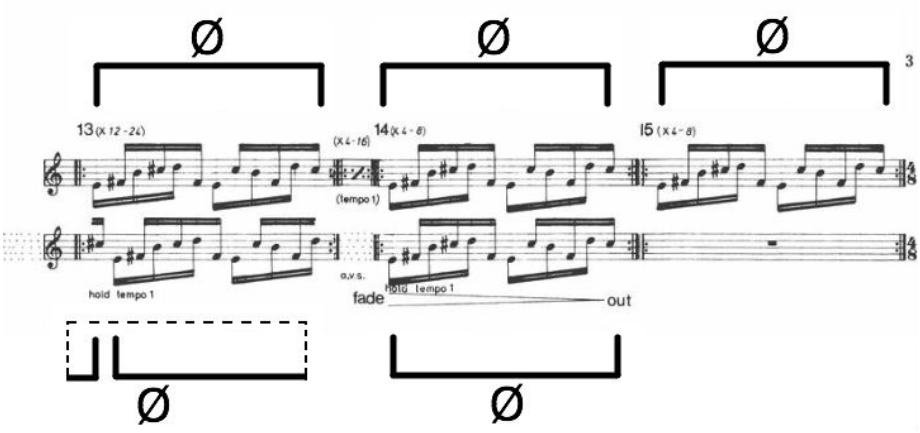

Figure 197 - Reich: Piano Phase (Phase Analysis, mm. 13-5)

When the second piano returns in measure 17, the contents of the numbered measures have been cut in half, with the first piano playing the first half of the measure (plus an additional B4 and C5). The second piano plays an elaboration of the second half of the original numbered measure, with the upper beams now outlining a perfect fourth between E5 and B4 (Figure 198)[491].

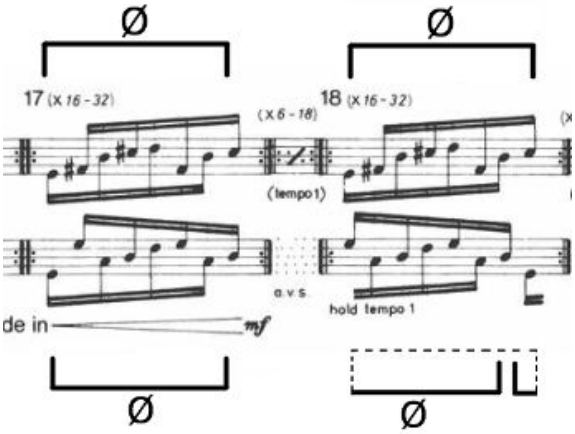

Figure 198 - Reich: Piano Phase (Phase Analysis, mm. 17-8)

[491] Reich, *Piano*, mm. 17-18.

As in *Come Out*, the splitting process occurs a second time. After the first piano drops out at measure 26, the second piano isolates the middle four notes of its previous pattern, which then becomes subject to the usual phasing process until the end of the piece (Figure 199)[492].

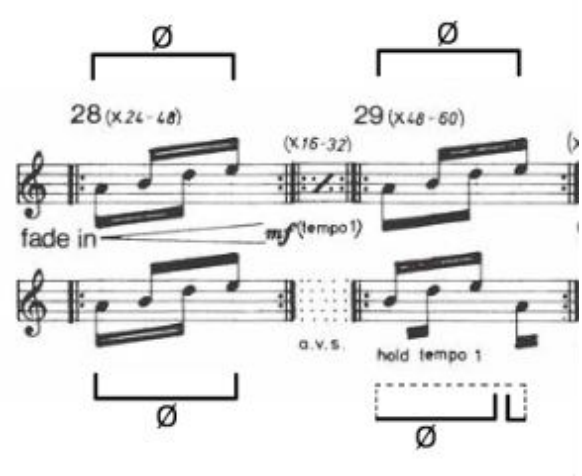

Figure 199 - Reich: Piano Phase (Phase Analysis, mm. 28-9)

The morphing of the material has again become the form. Furthermore, the duration is long enough and the scope of the material is limited enough that the listener can become completely immersed in the process. And though born of experimentation on tape, this dramatically new type of formal morphology is executed in a purely acoustic medium[493].

6.4.4 New Morphologies and Digital Audio Media

A particularly rigorous and analytically intense method – by which forms can be derived from material – has emerged with the aid of recently developed digital recording tools. Dr. Ben Hackbarth is a young American composer concerned with the composition of both acoustic and electroacoustic music. Hackbarth's recent research and software development activities at IRCAM in the field of musical concatenative synthesis

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[492] Reich, *Piano*, mm. 28-29.

[493] For more on the mutual relationship between technology and time in Reich's music, see: Steve Reich, "My Life with Technology," *Contemporary Music Review*, Vol. 13, No. 2 (1996): 13-21; Robert K. Schwarz, "Steve Reich: Music as a Gradual Process Part I," *Perspectives of New Music*, Vol. 19, No. 1 (Spring, 1981): 373-392; Robert K. Schwarz, "Steve Reich: Music as a Gradual Process Part II," *Perspectives of New Music*, Vol. 20, No.1-2 (Winter, 1982): 225-286.

have yielded developmental software known as AudioGuide[494]. Hackbarth describes his compositional motivations in a 2013 article:

> "Freedom is strikingly evident in the plethora of inventive and exacting methods for crafting sound, often permitting the composer to create a seemingly infinite variety of sonic qualities and timbres. However, a majority of software does not aid the composer in ***organizing combinations of sounds intelligently or in structuring sonic relationships across time***."[495] [emphasis mine]

Hackbarth emphasizes the vast freedoms associated with the contemporary soundworld, and the inherent difficulties of operating within such a limitless field. He then goes on to describe the new compositional difficulties that arise at the level of control.

> "While there are many benefits to an increased precision of control, there are also risks. When realizing a musical passage, a task not unlike assembling a sonic jigsaw puzzle, one can become overly immersed in shaping individual pieces without sufficient awareness of how they fit together to create a cumulative image. Consequently, one can lose sight of compositional intuition and intent in a landscape densely populated by choices and details. This type of unmediated engagement with complexity creates two primary aesthetic hazards:
>
> (1) Neglecting the integrity of sonic relationships due to the complexity of crafting individual elements.
>
> (2) The onset of 'creative decision fatigue', resulting in a slowing of compositional metabolism that threatens to undermine inspiration, exploration, and flexibility."[496]

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[494] Hackbarth describes the project as follows: "AudioGuide is a program for concatenative synthesis that I'm currently developing with Norbert Schnell, Philippe Esling and Diemo Schwarz. Work began in 2010 at IRCAM when I was composer in residence for musical research. Written in python [with the help of libsndfile], it analyzes databases of sound segments and arranges them to follow a target sound according to audio descriptors. The program outputs soundfile event lists that can be either synthesized (in csound or Max MSP/Pure Data) or translated into symbolic musical notation (currently, I am using BACH in MaxMSP as a quantizer/visualizer)." Ben Hackbarth, "AudioGuide", Ben Hackbarth's personal website, accessed October 29, 2014, http://www.benhackbarth.com/audioGuide/.

[495] Ben Hackbarth, with Norbert Schnell, Philippe Esling, and Diemo Schwarz, "Composing Morphology: Concatenative Synthesis as an Intuitive Medium for Prescribing Sound in Time," *Contemporary Music Review*, Vol. 32, No. 1 (2013): 49-59.

[496] Hackbarth et al., "Composing", 50.

Hackbarth's solution to this difficulty is the use of concatenative synthesis, a shaper of audio morphologies that weds form and material in a structure determined by the material itself. As with many of the audio morphing technologies described in Chapter 3, musical concatenative synthesis is the application of a technique originally intended to approximate human speech. In the concatenative synthesis of speech, databases (corpuses) of *phones* (units) – the smallest constituent sounds of a language – are used to reconstruct the desired (target) word[497].

Figure 200 shows how one might use concatenative synthesis to approximate the target word "Burma" from a corpus consisting of units obtained through an analysis of the word "Hamburger".

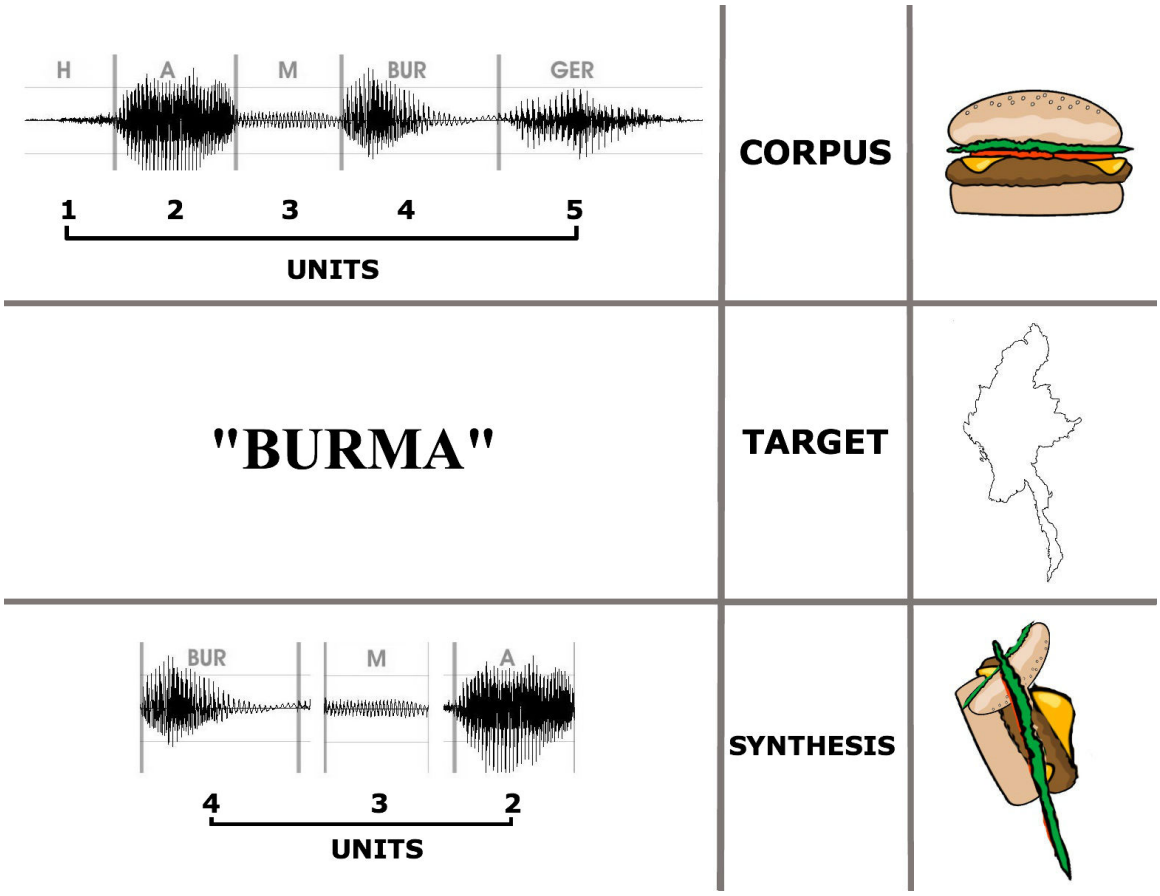

Figure 200 - Concatenative Synthesis Example

[497] For more on concatenative synthesis of speech, see: R. Prudon, *A Selection/Concatenation TTS Synthesis System* (Ph.D. dissertation, LIMSI, Université Paris XI, Orsay, France, 2003).

The accompanying visual analogy of Figure 200 further illustrates how this technique might be understood in an abstract sense. The musical translation of this technique is of course much more complex than the simple illustrations provided above. German software developer and sound artist Diemo Schwarz completed a PhD thesis at IRCAM on the subject in 2004[498]. He describes musical concatenative synthesis as follows.

> "Concatenative data-driven sound synthesis methods use a large database of source sounds, segmented into heterogeneous units, and a unit selection algorithm that finds the units that match best the sound or musical phrase to be synthesised, called the target. The selection is performed according to the features of the units. These are characteristics extracted from the source sounds, e.g. pitch, or attributed to them, e.g. instrument class. The selected units are then transformed to fully match the target specification, and concatenated."[499]

According to Schwarz, the main advantage of concatenative synthesis (over older synthesis models) is the increased level of sonic detail obtained through the use of digital recording technologies.

> "Usual synthesis methods are based on a model of the sound signal. It is very difficult to build a model that would preserve all the fine details of sound. Concatenative synthesis achieves this by using actual recordings. This data-driven approach (as opposed to a rule-based approach) takes advantage of the information contained in the many sound recordings."[500]

This newly obtained advantage involves its own inherent difficulties. Given the present aesthetic validity of all sound (both natural and synthetic), the task of analyzing and classifying the full sonic corpus of modern practice requires a vast wealth of parameters. Describing the development of AudioGuide, Hackbarth mentions this difficulty as a fundamental obstacle.

> "One of the difficulties in strategizing an intuitive form of control of sonic morphology is that qualities such as timbre are not readily disposed to manipulation with physical interfaces like a keyboard, which emphasize the importance of a single dimension. Research has shown that our

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[498] Diemo Schwarz, *Data-Driven Concatenative Sound Synthesis* (PhD Thesis: IRCAM, 2004).

[499] Schwarz, *Concatenative*, ix.

[500] Ibid.

> perception of timbre is best described in higher dimensional spaces (Grey, 1977). Dimensional complexity problematizes compositional control—one must devise a medium where morphology can be intuitively prescribed yet contain the level of detail required to represent the complexity of sound over time."[501]

The "higher dimensions" of timbral classification mentioned by Hackbarth extend all the way up to twenty in the current version of AudioGuide. These qualitative tools of classification are referred to as audio descriptors. Figure 201 from Hackbarth illustrates both the division of a soundfile into the segments that will comprise the corpus (the white sections of the lower graph, separated by bars of grey), and a plot showing three of the twenty audio descriptors as they change over time (indicated in red, green, and blue).

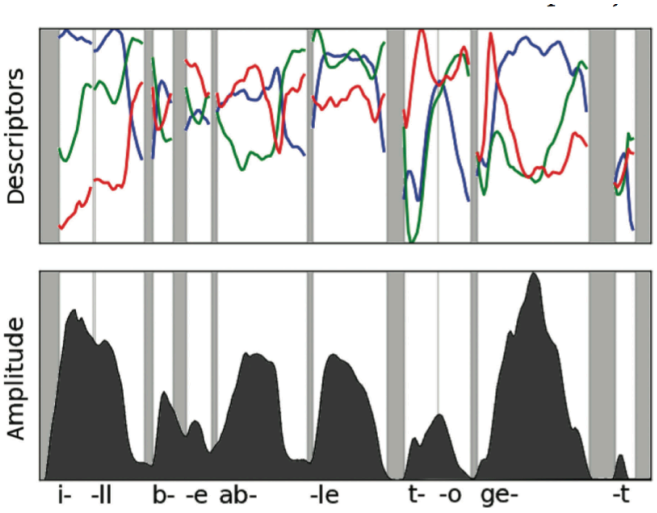

Figure 201 - Hackbarth: Analysis of Spoken Text

> "An Analysis of the First Three Mel-Frequency Cepstral Coefficients for Spoken Text 'I'll be able to Get.'
>
> AudioGuide analyses the target with a variety of formulas which yield time-varying measurements that describe sonic characteristics. AudioGuide provides 20 such measurements, termed audio descriptors, which approximate qualities such as pitch, loudness, and higher dimensional attributes that describe different aspects of timbre. For instance, Figure 1 shows the amplitude of a four second soundfile of speech along with the first three mel-frequency cepstral coefficients, a set of descriptors which describe timbral qualities. The white and grey regions show an algorithmic segmentation of the sound into acoustically viable

[501] Hackbarth et al., "Composing", 52.

> chunks—the grey regions indicate that the sound has fallen below the threshold of audibility."[502]

Having analyzed and classified a source sound according to the 20 audio descriptors, a corpus of short segments is available for the concatenative synthesis of any desired form (target). This involves the analysis or definition of the target's structure, and subsequent mapping of elements from the corpus to the elements of the target. Hackbarth acknowledges the inherent problems of automatically matching descriptors, and describes the strategies adopted by AudioGuide to confront such problems.

> "One of the primary challenges of using concatenative synthesis as a strategy for controlling morphology is that matching descriptor values is largely an automated process. In contrast to being confronted with an overabundance of choices and parameters, many sonic details are created algorithmically, imposing a readymade aura which can prove aesthetically troublesome. In order to give the user a higher degree of control over selection, AudioGuide provides different methods for defining and manipulating computational similarity to both aesthetic and pragmatic ends."[503]

Thus, concatenative synthesis (as embodied by AudioGuide) is a flexible means of generating morphologies of sound according to the characteristics of sonic materials themselves. One sound (target) becomes a sort of blueprint for the arrangement of others (the corpus). The central roles of analysis of classification espoused by 20th century figures such as Russolo, Schaeffer, Stockhausen, and Lachenmann are present as the clockwork enabling concatenative synthesis to function automatically.

It is important to note that the forms generated by this technique still require the influence of the composer to select and manipulate the most desirable outcomes, but like the piano keyboard to the composer of orchestral music "this buffer enables certain types of compositional approaches and explorations that would arguably not survive a scenario in which the totality of choice is confronted in a single moment."[504] Thus, compositional activity assisted by concatenative software unites form and material through analysis and

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[502] Ibid., 52-53.

[503] Ibid., 54.

[504] Ibid., 51.

classification, while still leaving room for the will of the composer. According to Hackbarth, such an approach can:

> "...not only aid in the prescription of pitch, dynamics, and rhythms, but also timbre, morphology, and the spectral connectivity of adjacent sounds. In search of a sufficiently robust medium, our goal was... to create software which permits sonic resource and temporal articulation to be prescribed separately yet to be realized with a degree of integration"[505]

In addition to its relevance within the context of global morphology in electronic music, musical concatenative synthesis is also noteworthy in that it can be used to craft works that employ only acoustic instruments. Supposing that the corpus has been assembled from sounds that can be played and notated on acoustic instruments, there is nothing to stop a composer from utilizing this method as a generator of purely acoustic morphologies.

Hackbarth has pursued this option in his own work, and Audioguide has been integrated with notational software in order to facilitate this variety of concatenative composition. In 2011, Hackbarth composed a trio (*Am I a Particle or a Wave?*[506]) for two percussionists and one "imaginary" pianist (a pre-recorded piano track of exceptional difficulty). An excerpt is shown in Figure 202 below.

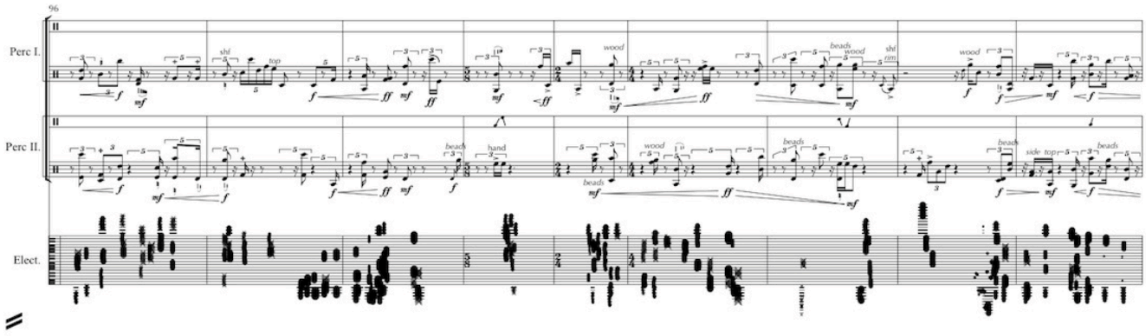

Figure 202 - Hackbarth: Am I a Particle or a Wave? (Study Score Excerpt)

These dense bands of piano material are arranged along a chromatic grid (rather than a traditional staff), while the two human percussionists read from the two staves of

[505] Ibid.

[506] Ben Hackbarth, "*Am I a Particle or a Wave?*", Hackbarth Personal Website, accessed August 13, 2015, http://www.benhackbarth.com/aipow/.

traditional notation. The choice to orchestrate the work exclusively for percussion instruments provides Hackbarth with a spectrally complex and highly malleable corpus.

6.5 Conclusions

The preceding discussion has been organized chronologically according to the media in which the various notions of musical morphology (or in some cases, the literal morphing of musical form) were realized or derived. Beginning with typical instrumental resources of the common practice period; on to the extended acoustic instruments and techniques of the 20th century; through plastic visual media (film); plastic aural media (audio tape); and finally the digital audio resources of the computer age. While this narrative has been technologically linear, the compositions and media through which these new morphologies have been realized are far from sequential.

Furthermore, certain fundamental principles of global morphology have also been shown to transcend era. From the transformation of Classical and Romantic motives, through to the technologically influenced mutations of acoustic material under Reich, Grisey, and Hackbarth; the morphologies of local material and global design have proven to be linked inextricably. This correspondence between micro and macro levels of morphology however, became explicit in the 20th century writings of Russolo, Schaeffer, Stockhausen, and Lachenmann. This preoccupation led to a new paradigm of global morphology based on the: capture/selection, analysis, categorization, and arrangement of one's materials.

In one sense, morphology at a global level involves the temporal expansion of the morphing phenomena described in earlier chapters. On timescales such as those employed in the cited works from Reich and Grisey, material and form become intertwined tightly enough so as to smooth over the distinction between morphology (as a noun) and morphing (as a verb) set out in Chapter 1.

This gradually emerging relationship between form and content – between morphing and morphology – has certainly broadened the scope of my initial inquiry well beyond its projected target. However it has also provided me with far more compositional inspiration than my initially planned investigations into audio morphing software could have ever yielded in isolation.

With such an ever-broadening scope, it is important to keep in mind throughout, that this creative aspect of my research (the compositional application of my findings) is the lens through which all other outcomes are to be viewed.

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Appendix A – for chelsea smith [SCORE]

NOTE:

THE FOLLOWING STUDY SCORE HAS BEEN REDUCED
FROM ITS ORIGINAL SIZE OF 11x17

FOR CHELSEA SMITH

Darren Miller

Performance Notes

GENERAL

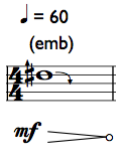
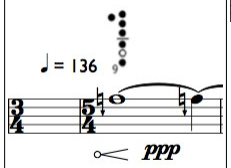
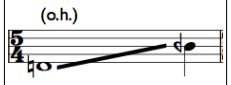
-the passage of time is indicated in one of four ways:

1) traditional meters and metronome markings (see m. 3)
2) "DECAY TIME" measures: following a downbeat from the conductor, the indicated sounds are allowed to die out at which point the conductor will start the next measure (see m.1)
3) measurements in seconds: these may take the form of either a finite number of seconds (see m. 289), an approximate number of seconds (see m. 18), a variable timeframe that will depend on acoustic conditions (see m. 2), or a minimum number of seconds (see m. 244).
4) "MORPH" and other process based measures: these variable-length measures are mostly used to indicated the time required for the electronics to complete a transformation (see m. 177), though occasionally they are used for purely acoustic processes (see m. 290 and piano 1)

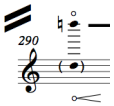
FLUTES

-microtonal materials are notated/performed in one of three ways:

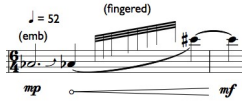
1) by altering the embouchure (abbreviated "emb" and generally accompanied by an arrow) through the rotation of the headpiece to slightly sharped or flatten a traditional fingering.
2) by utilizing alternate fingerings (provided in parts).
3) by partially covering or uncovering the open-holed keys of the instrument (abbreviated "o.h." and generally accompanied by a thick glissando line).

1) embouchure bends	2) alternate fingerings	3) open-hole glissandi
 a four second long, downwards pitch bend that begins from a D#5 with a slight upward bend	an alternate fingering for F5, slightly flat. 	 an open-hole glissando from D4 to a B4 that is a quarter tone flat, over the span of one whole note

-harmonics are indicated through the presence of a fundamental (in brackets), and the desired sounding pitch accompanied by a small circle above the notehead.



-quick chromatic runs are indicated by departure and target notes enclosing a series of headless stems and the word: "fingered".



-variations of tone colour are expressed in terms of "% AIR", referring to the approximate level of airiness (ie. white noise) introduced into a pure pitch.

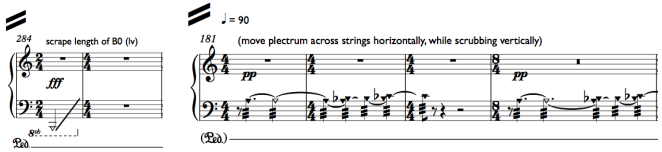
-flutter tongue is indicated with the abbreviation "flz."

-the return to an ordinario playing technique (following a passage of flutter tongue or airy tone) is indicated with the abbreviation: "ord".

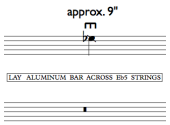
PIANOS

-whenever a tremolo is indicated (for one or more pitches), the goal is to play as fast and consistently as possible (in that order of importance).

-the scraping and scrubbing of strings is done with a very soft plectrum (guitar pick), and is indicated with a triangle-shaped notehead in the score.

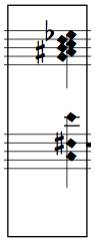


-the mutes indicated in the score are made of 2"x0.5" aluminum bar, and will be provided.

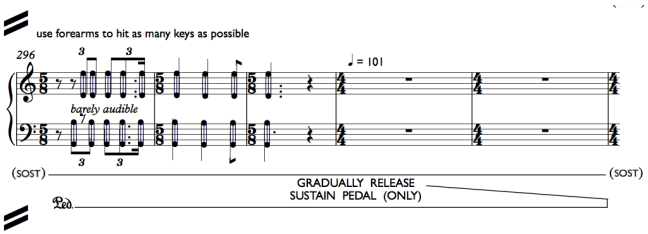


-the precise locations of these techniques for the inside of the piano (in addition to the harmonic in mm.372-3 of piano I) will need to be found and labeled prior to performance/rehearsal.

-the frequent use of diamond-shaped noteheads indicate keys that are to be depressed SILENTLY.



-the full-forearm clusters of rehearsal mark R (and similar sections) should be played as close to inaudibly as possible, such that they should activate the vibration of as many strings as possible, with as little perceptible attack as possible.



CELESTA

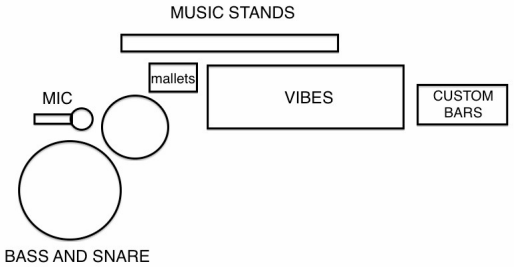
-the celesta part is written an octave lower than the instrument's sounding pitch (as is customary).

-whenever a tremolo is indicated (for one or more pitches), the goal is to play as fast and consistently as possible (in that order of importance).

PERCUSSION I

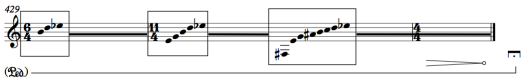
-instruments: snare drum, bass drum, vibraphone, custom-cut aluminum vibraphone bars.
-mallets required: 4 soft yarn mallets, 2 drumsticks, 2 bows, 2 wire brushes, 2 hard rubber mallets

-because the bass drum (rim) and snare drum require a (single) microphone for live electronic processing, and all instruments/mallets should be within reach, the following diagram is supplied as a potential stage arrangement.



-whenever a tremolo is indicated, the goal is to play as fast and consistently as possible (in that order of importance).

-the boxed notation at the end of rehearsal X indicates that the enclosed pitches should be "juggled" as smoothly as possible (with up to 4 soft yarn mallets), so that a diffuse "harmonic cloud" without individual attacks or melodic lines results from the alternation. the essential idea is that all of the pitches should be heard equally with no individual points or lines emerging.



PERCUSSION 2

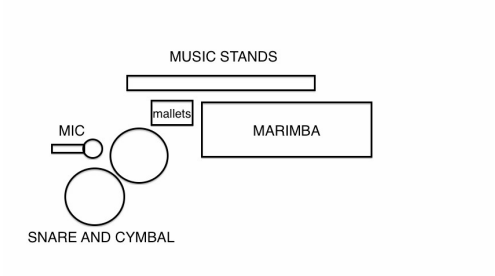
-instruments: medium cymbal, snare drum, marimba
-mallets: 2 soft yarn mallets, 2 wire brushes

-the same soft yarn mallets used on the marimba are used on both the cymbal and the snare drum.

-attempt to balance the timbres/dynamics of the cymbal and snare drum strikes whenever alternating between instruments by using a very careful touch.

-whenever a tremolo is indicated, the goal is to play as fast and consistently as possible (in that order of importance).

-because the cymbal and snare drum require a (single) microphone for live electronic processing, and all instruments/mallets should be within reach, the following diagram is supplied as a potential stage arrangement.



TECHNICAL NOTES

-all of the live electronic processing for the premiere was performed in Max/MSP utilizing a custom patch, which can be obtained from the composer.

-alternate software may be used if desired, provided that the following description (and the recording of the premiere) are taken as strict guidelines.

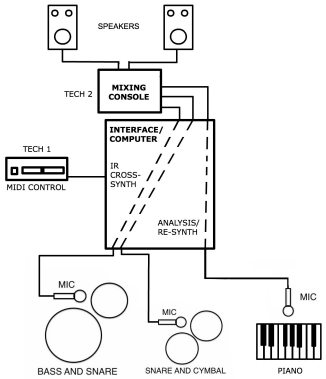
PHYSICAL SETUP

-the following technical resources are required for a performance of *for chelsea smith*:
- -three microphones (AKG 414's or similar)
- -two powered loudspeakers (12" JBL's or comparable)
- -mixing console and cables
- -computer running Max/MSP (or other – see above)
- -audio interface (minimum three balanced inputs and two balanced outputs)
- -a midi controller with at least one slider and at least one button

-one microphone is placed inside the piano

-two microphones are placed on the unpitched percussion instruments (one per player)

-two technicians should operate the live electronics (one for score following/cues, one for output) using the supplied Max/MSP patch, however additional technicians may be required if alternate software is employed (see notes on score following below).



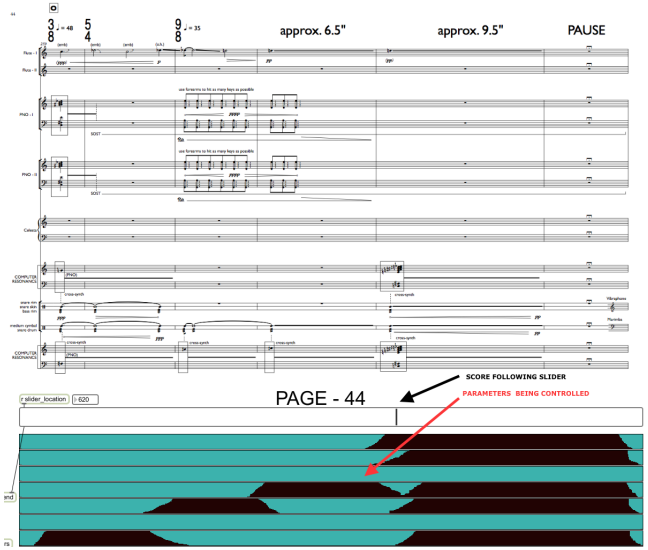
SOFTWARE TECHNIQUES - OVERVIEW

-there are three live electronic techniques employed in the piece:

1) impulse response (IR) cross-synthesis ("cross-synth" in score)
   -selectively applied to percussion signals
2) live analysis/re-synthesis/interpolation of spectral data via oscillator bank ("morph" in score)
   -performed on the signal from the pianist's microphone
3) pitch shifting of variable-speed phase vocoder playback (occurring at measure 248 only)
   -no live input

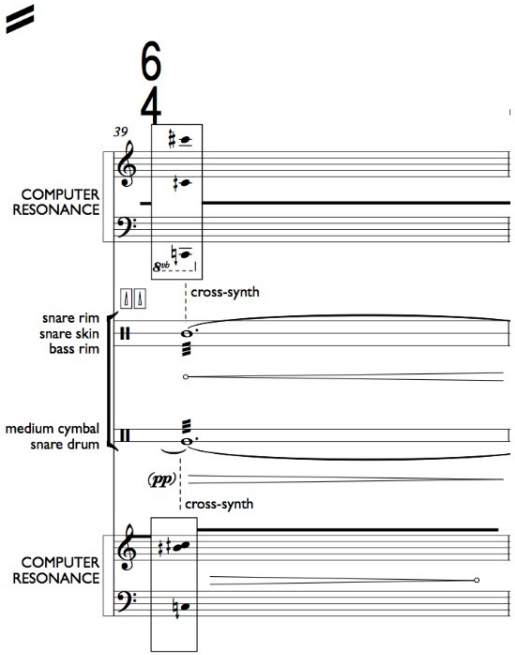
-a manual score follower (the slider of the midi controller) was used at the premiere to control the following parameters: gating and routing of percussion signals for IR cross synthesis, rotation of the IR buffers' contents, page turning of the digital score, progress of sinusoidal morphs (from 0. to 1.), gain levels for the oscillator bank, and pitch-shift levels for the phase-vocoder output.

-the button on the midi-controller is used to capture spectral data from the piano signal when needed.



SOFTWARE TECHNIQUE (1) CROSS-SYNTHESIS

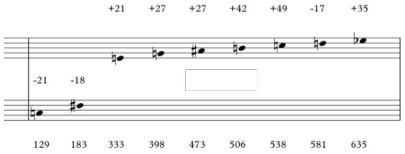
-the [multiconvolve~] object from Alex Harker and Pierre Alexendre Tremblay's *HISSTools Impulse Response Toolbox v1.1* [Huddersfield: CeReNeM - http://www.thehiss.org] was used during the premiere to process the percussionists' signals (indicated in the score as "cross-synth").

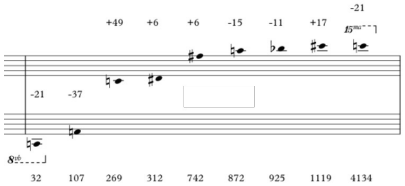


-the individual inputs being controlled by the score follower refer to the INPUT levels of the various inlets of the [multiconvolve~] object.

-regardless of the number of buffers loaded at any given time, the output of the [multiconvolve~] object is monophonic for each player, and these final output levels are controlled by the second technician (using the mixing console).

-the many and varied pitch contents of the IR buffers are all drawn from two collections of nine individual pitches (seen below), six complex sonorities, and one recording of a screaming mink.





-if one is recording their own samples for the IR buffers indicated in the score (as opposed to employing those available from the composer), the attacks should peak at -3dB, and their steady decays should last roughly 6 seconds.

-if the instrumentation of a given IR buffer is not stated explicitly, it is a piano attack, and as such, pitches that are not of equal temperament may be obtained through digital transposition techniques.

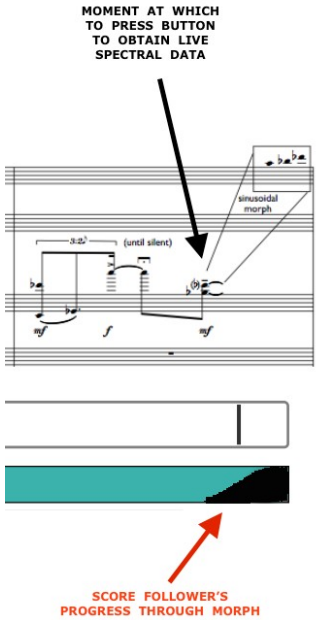
SOFTWARE TECHNIQUE (2) ANALYSIS/RE-SYNTHESIS

-the [sigmund~] object created by Miller Puckette [max/msp externals - http://vud.org/max/] was used during the premiere to analyze the sixteen strongest peaks of the pianist's signal.

-a sixteen voice sinusoidal oscillator bank was used to re-synthesize both the piano data captured live, and also several pre-loaded spectral envelopes.

-if the patch available from the composer is not used, the destination values (16 spectral peaks) for all sinusoidal morphs indicated in the score must be captured prior to performance.

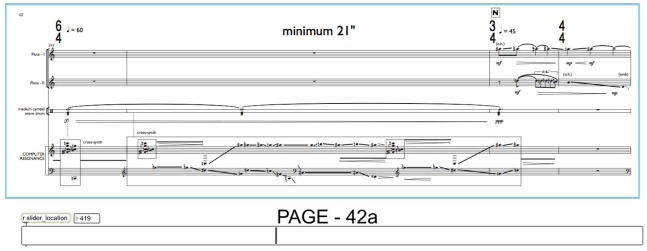
-the live capture of spectral data is achieved with the button on the first technician's midi controller, while the score follower controls the progress through a morph.



SOFTWARE TECHNIQUE (3) PITCH SHIFTING OF PHASE VOCODER PLAYBACK

-the phase vocoder created for max/msp by Cort Lippe and Richard Dudas [The Phase Vocoder Part II from http://cycling74.com/2007/07/02/the-phase-vocoder-part-ii/] was used during the premiere to perform the two moving lines found in measure 248.

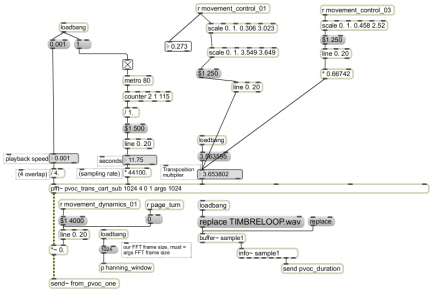
-the melodic progress of measure 248 is controlled by the first technician via the score follower.



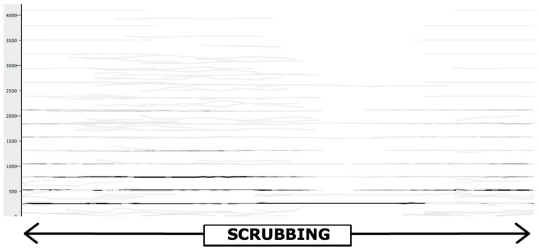
-the output level of this measure is controlled by the second technician using the mixing console.

-the melodic content of measure 248 is prepared in advance, and mapped onto the sub-sliders of the score follower (this data accompanies the patch available through the composer).

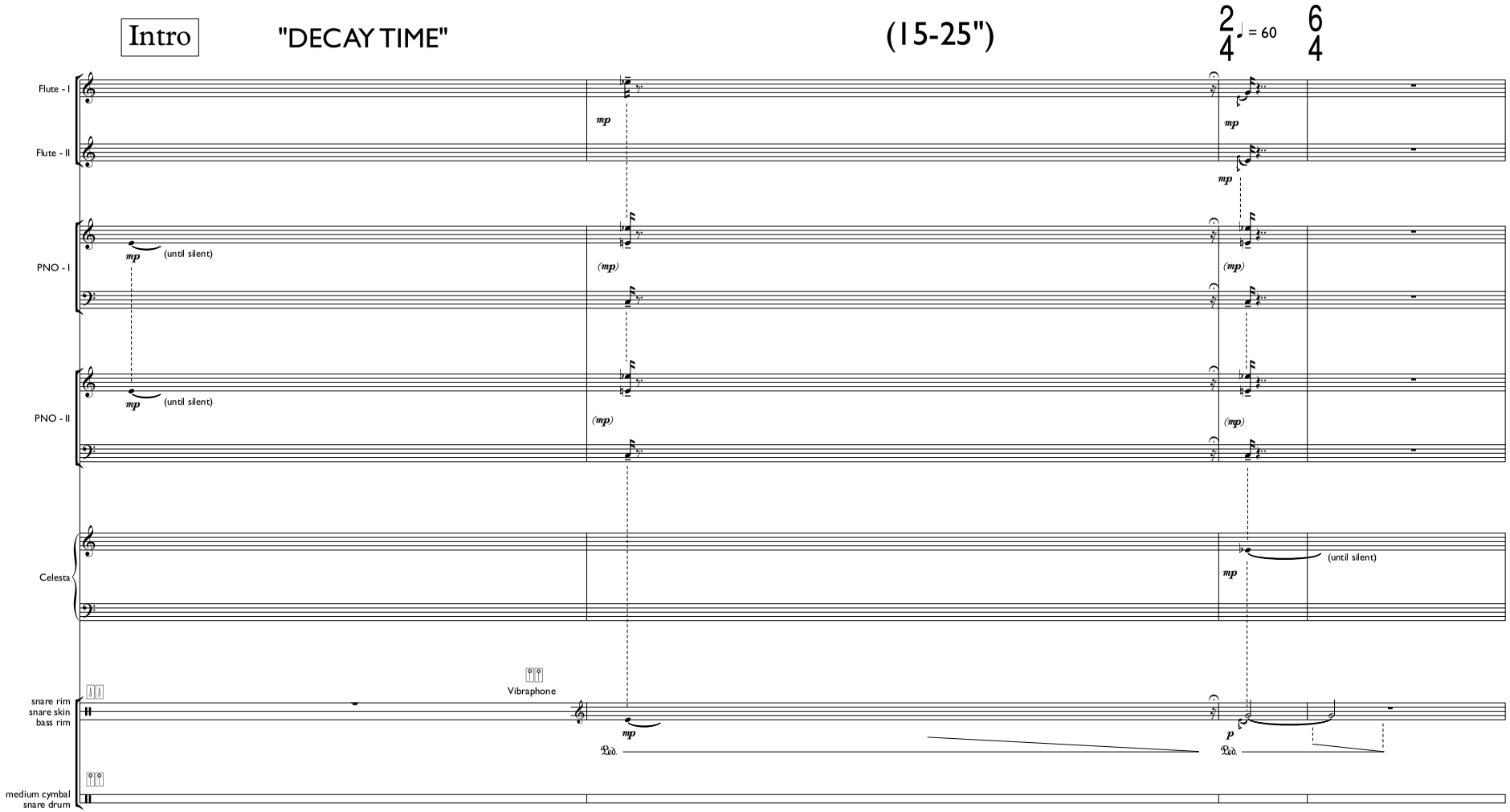
-the melodies are performed by pitch-shifting two voices of phase vocoder output obtained by scrubbing through a single pitch repeatedly.

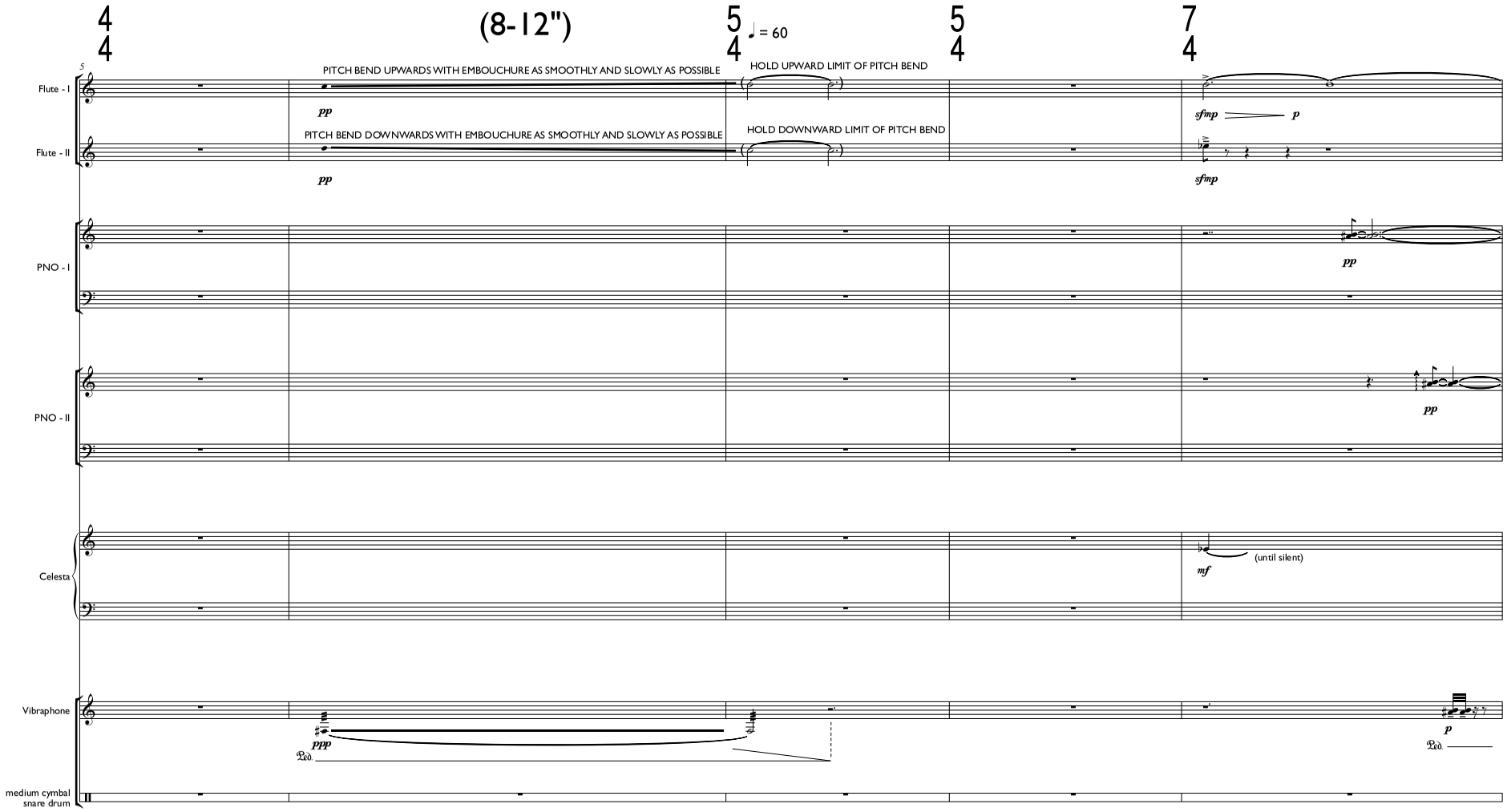


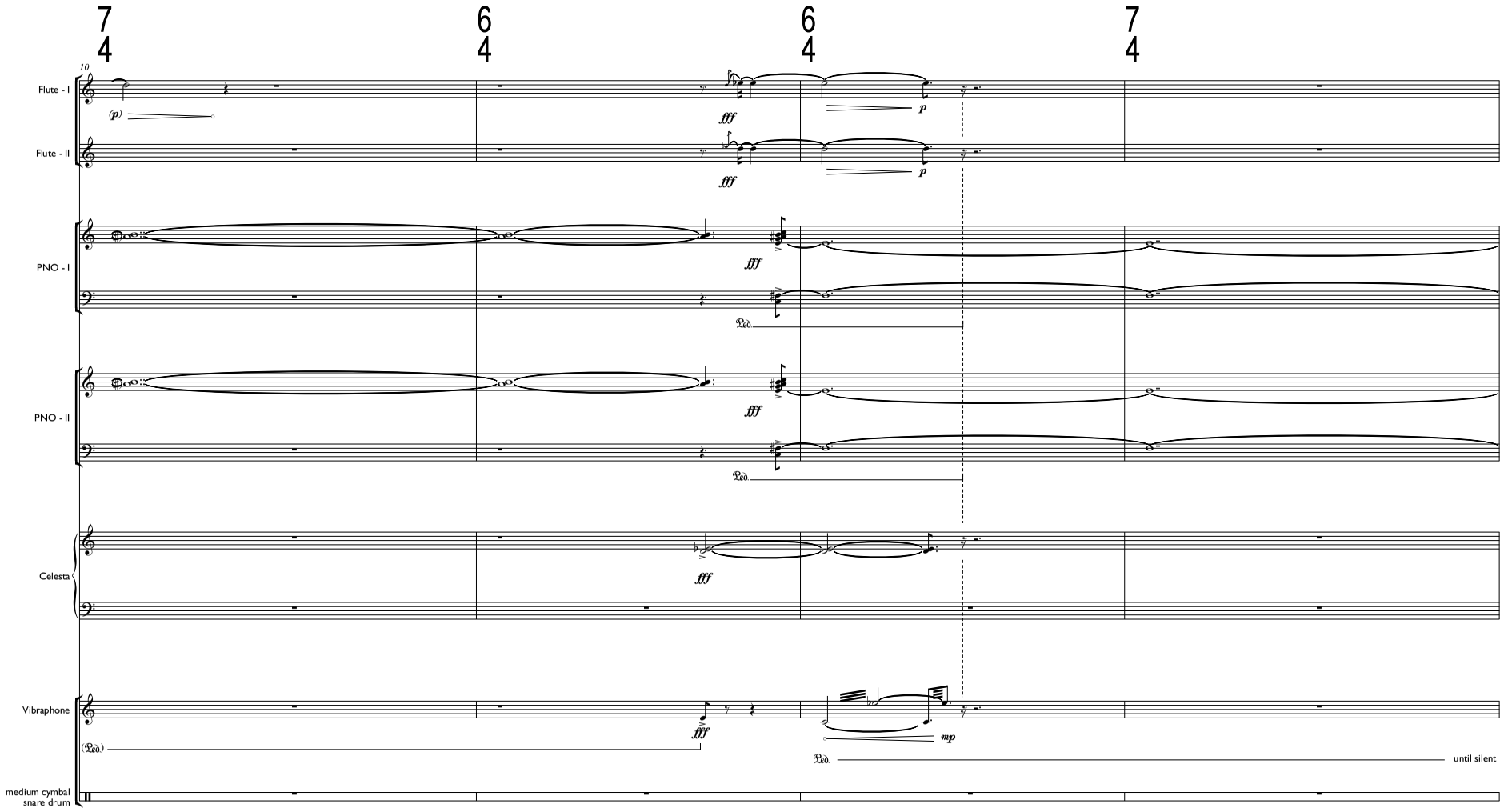
-the single ("all-timbre") pitch must be prepared ahead of time (if one is not using the file supplied by the composer) through linear predictive coding cross-synthesis in which the spectra of each individual instrument of the ensemble morphs continuous morph through the spectra from the individual instruments of the ensemble.

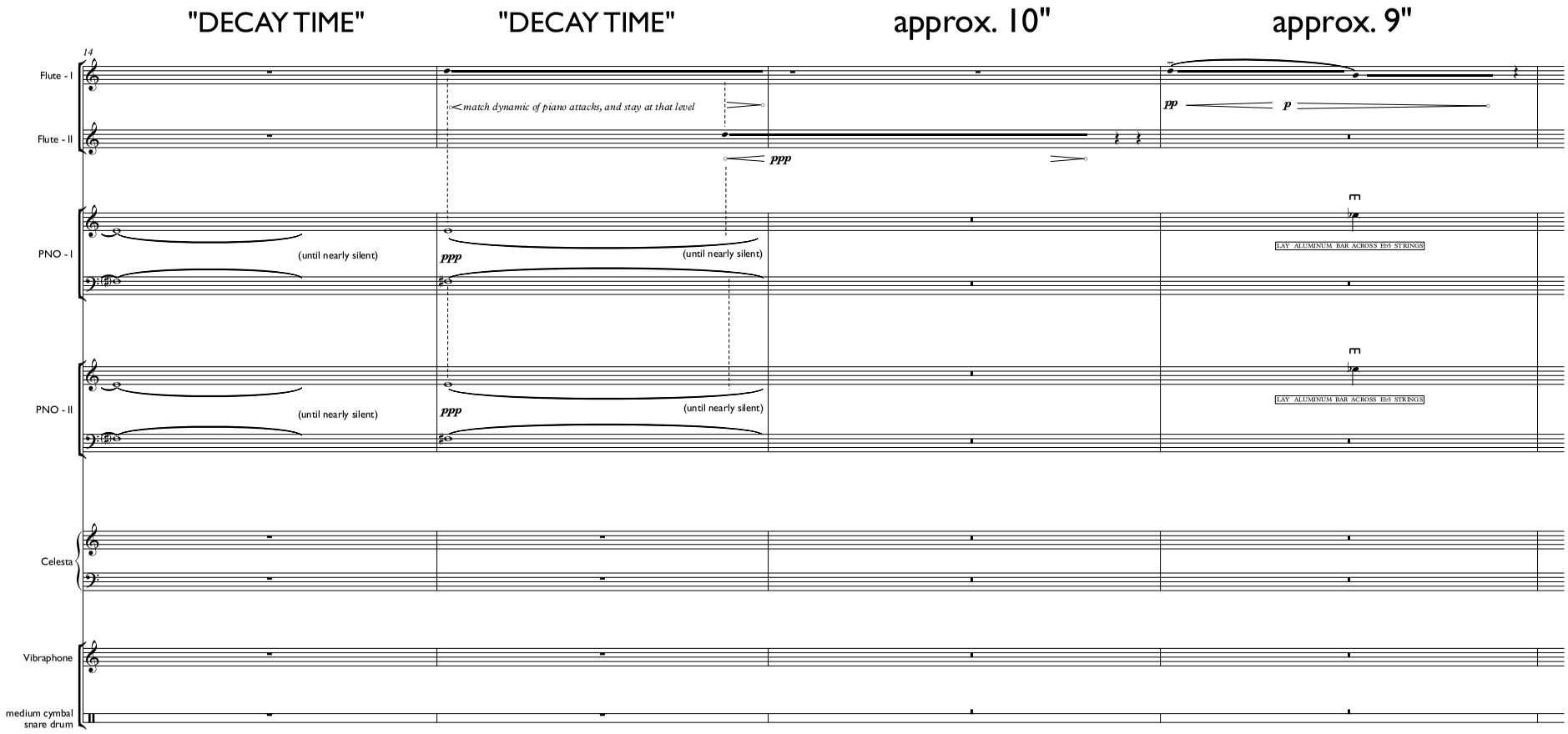


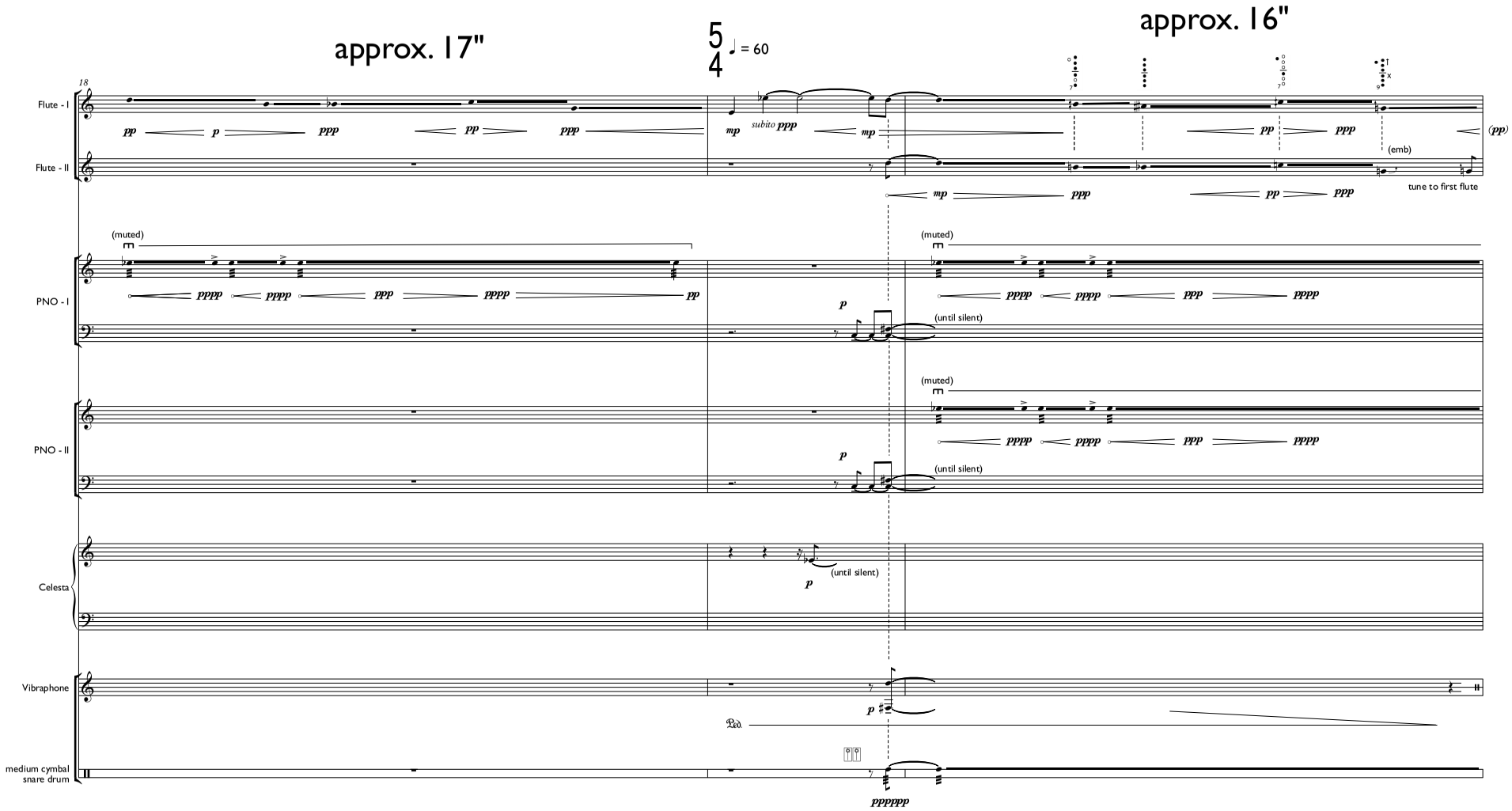
FOR CHELSEA SMITH

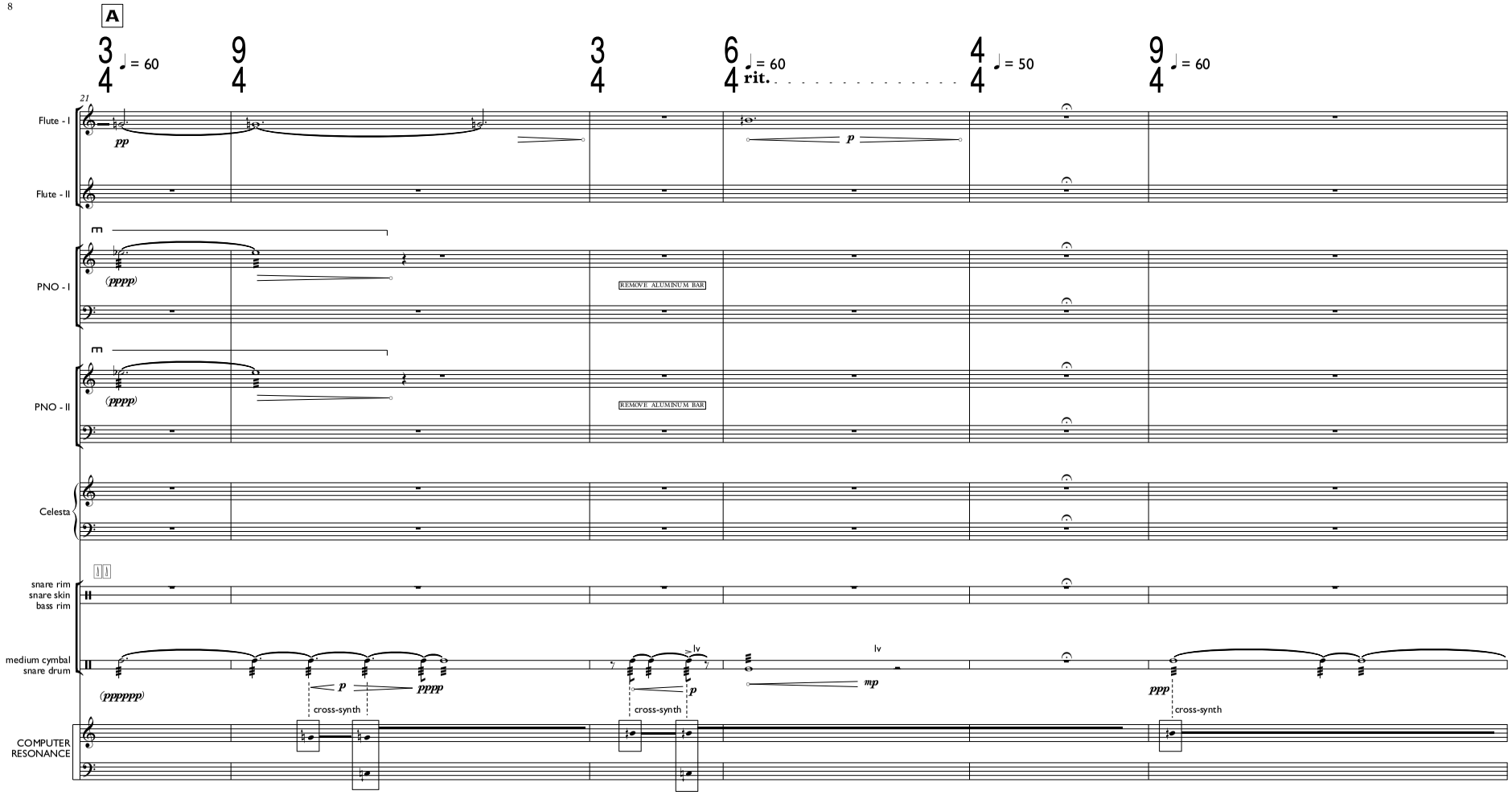


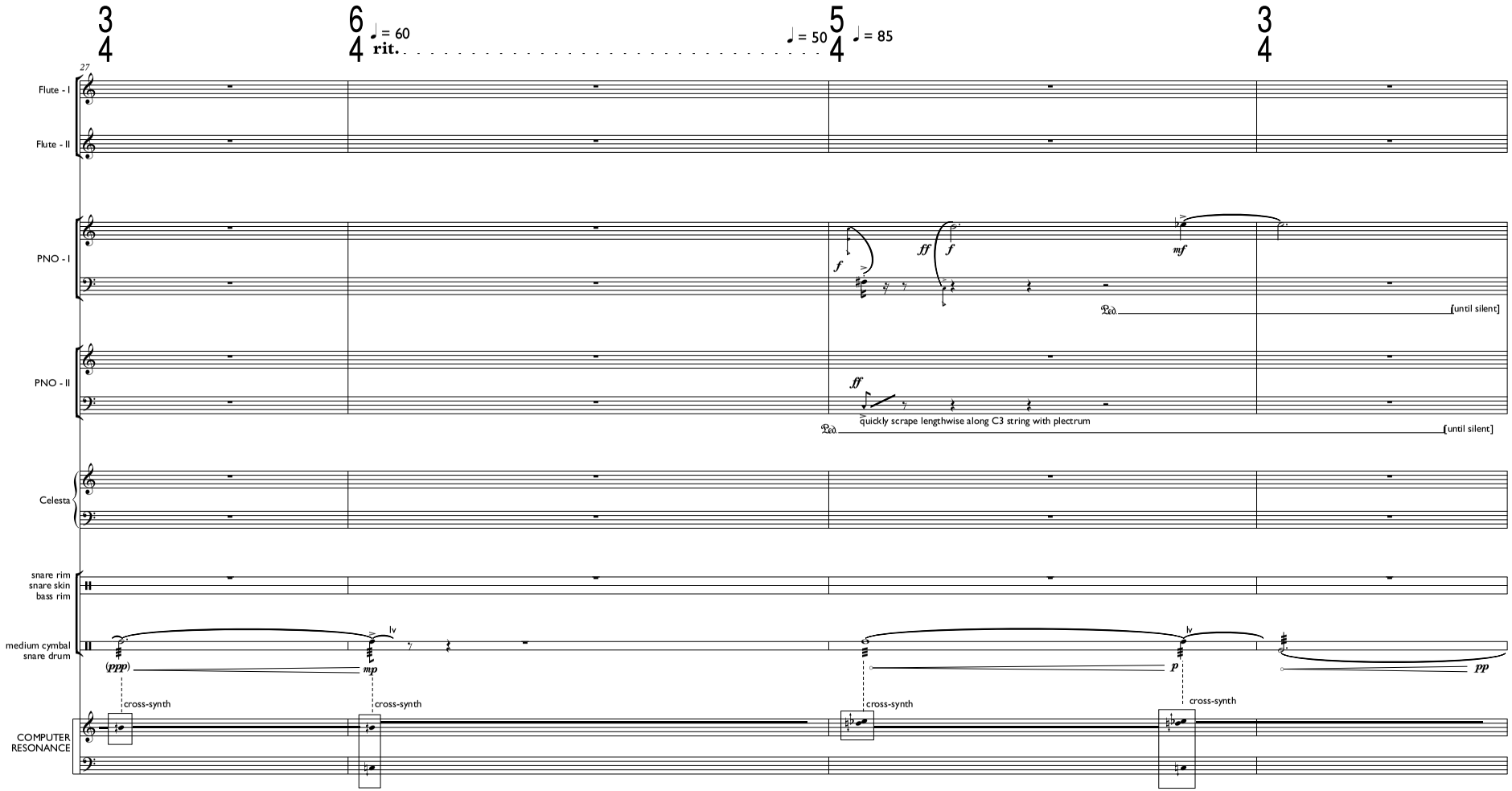

(8-12")
♩ = 60
5
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
PITCH BEND UPWARDS WITH EMBOUCHURE AS SMOOTHLY AND SLOWLY AS POSSIBLE
HOLD UPWARD LIMIT OF PITCH BEND
PITCH BEND DOWNWARDS WITH EMBOUCHURE AS SMOOTHLY AND SLOWLY AS POSSIBLE
HOLD DOWNWARD LIMIT OF PITCH BEND
pp
sfmp
p
ppp
mf
(until silent)
Ped.

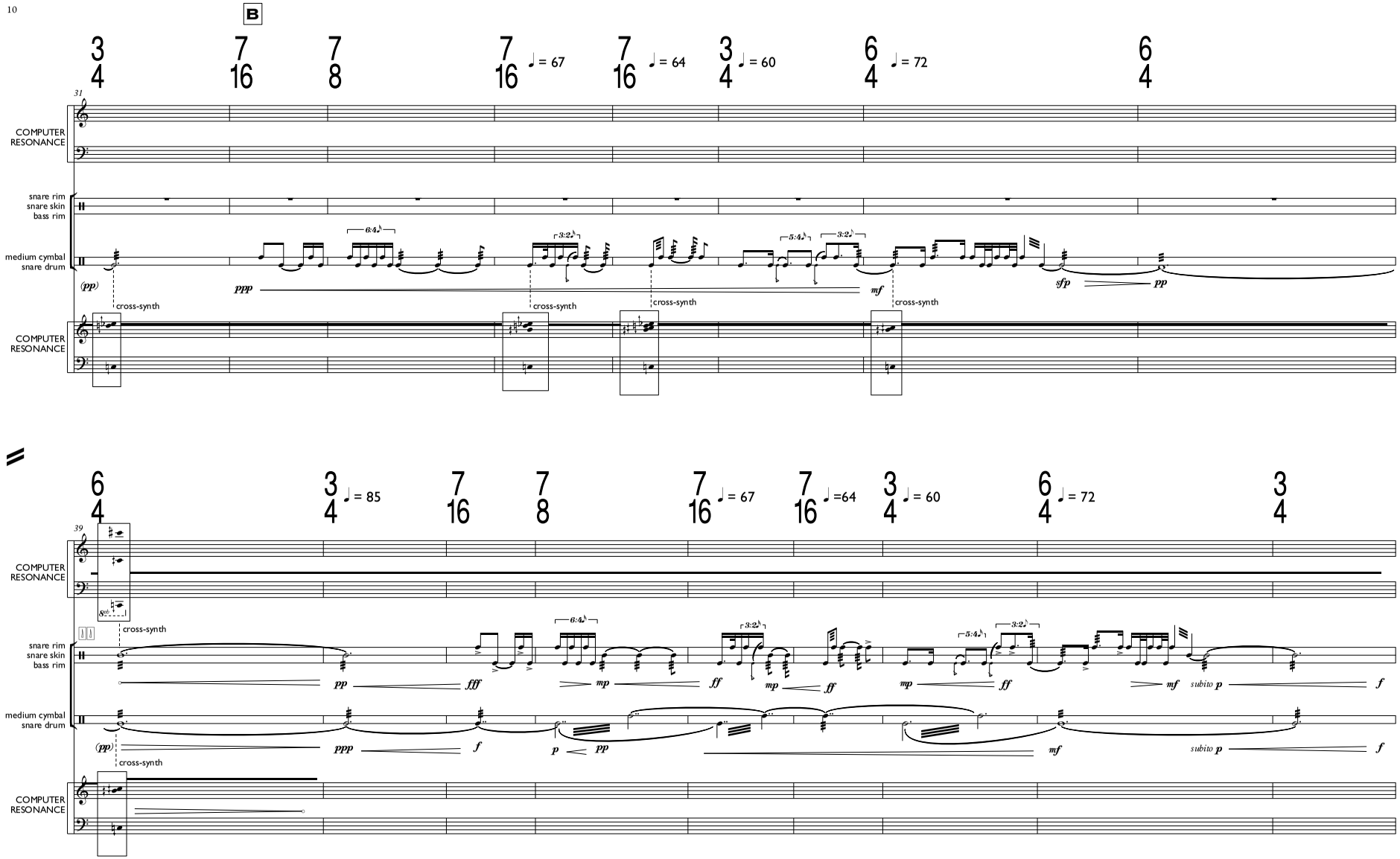

7/4
6/4
6/4
7/4
10
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
(p)
fff
p
mp
until silent


"DECAY TIME"
"DECAY TIME"
approx. 10"
approx. 9"
14
Flute - I
Flute - II
match dynamic of piano attacks, and stay at that level
ppp
pp
p
PNO - I
PNO - II
(until nearly silent)
ppp
(until nearly silent)
LAY ALUMINUM BAR ACROSS Eb5 STRINGS
Celesta
Vibraphone
medium cymbal
snare drum


approx. 17"
5/4 ♩ = 60
approx. 16"
18
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
pp
p
ppp
mp
subito ppp
(pp)
(emb)
tune to first flute
(muted)
pppp
(until silent)
pppppp


A
3/4 ♩ = 60
9/4
3/4
6/4 ♩ = 60
rit.
4/4 ♩ = 50
9/4 ♩ = 60
21
Flute - I
pp
p
Flute - II
PNO - I
(pppp)
REMOVE ALUMINUM BAR
PNO - II
(pppp)
REMOVE ALUMINUM BAR
Celesta
snare rim
snare skin
bass rim
medium cymbal
snare drum
(ppppppp)
p
pppp
cross-synth
lv
p
cross-synth
lv
mp
ppp
cross-synth
COMPUTER
RESONANCE


27
3/4
6/4
♩ = 60
rit.
♩ = 50
5/4
♩ = 85
3/4
Flute - I
Flute - II
PNO - I
f
ff
f
mf
[until silent]
PNO - II
ff
quickly scrape lengthwise along C3 string with plectrum
[until silent]
Celesta
snare rim
snare skin
bass rim
medium cymbal
snare drum
lv
(ppp)
mp
lv
p
pp
cross-synth
cross-synth
cross-synth
cross-synth
COMPUTER
RESONANCE


B
31
COMPUTER RESONANCE
snare rim
snare skin
bass rim
medium cymbal
snare drum
COMPUTER RESONANCE
cross-synth
39
8va
subito p

"DECAY TIME" (LONG)

C

6/4

9/4 ♩ = 50

48

Flute - I

Flute - II

PNO - I

PNO - II

Celesta

snare rim
snare skin
bass rim

medium cymbal
snare drum

Vibraphone

FOLLOW DECAY OF C1 IN PEDAL

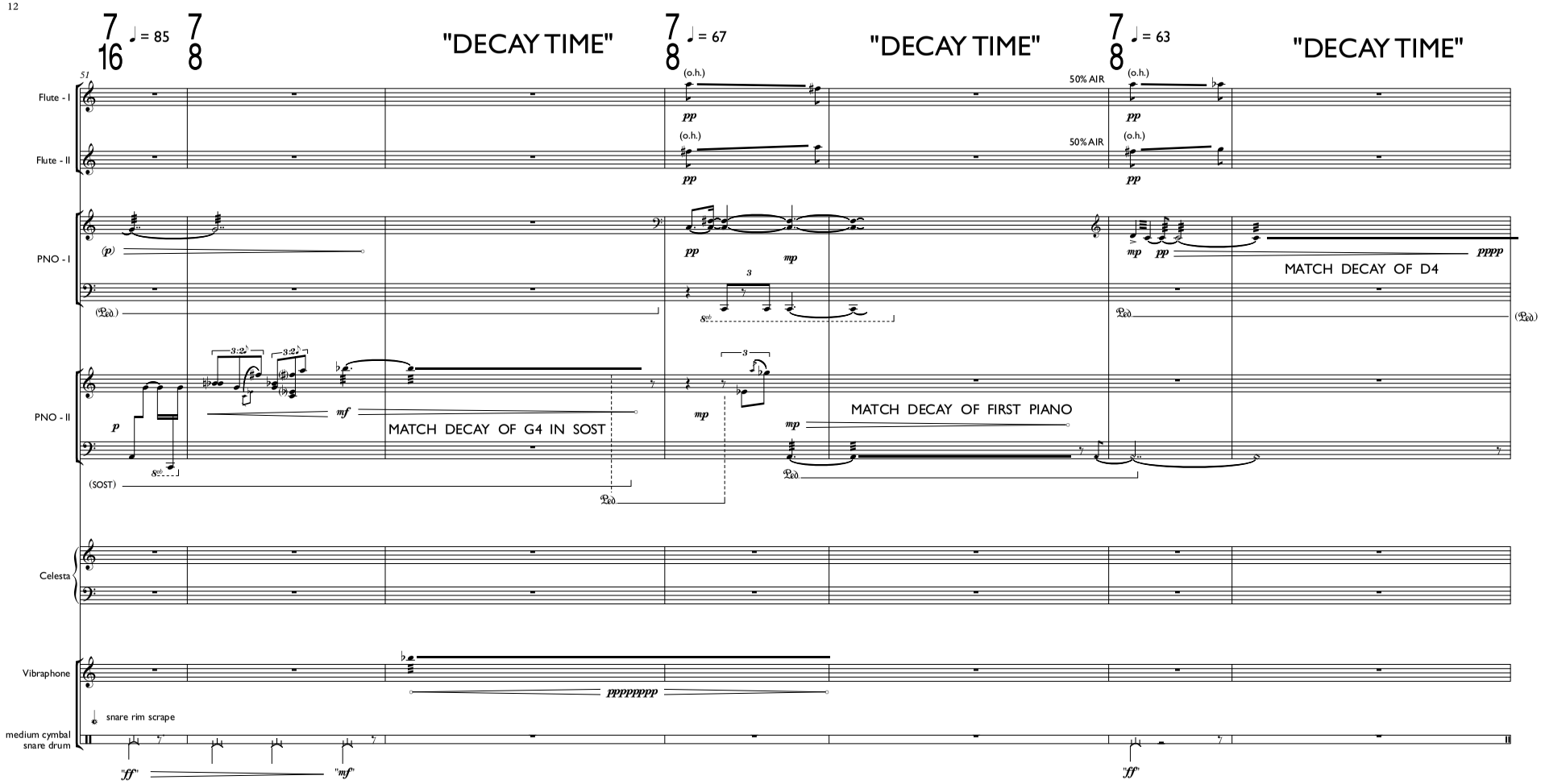
MATCH DECAY OF A2 IN PEDAL

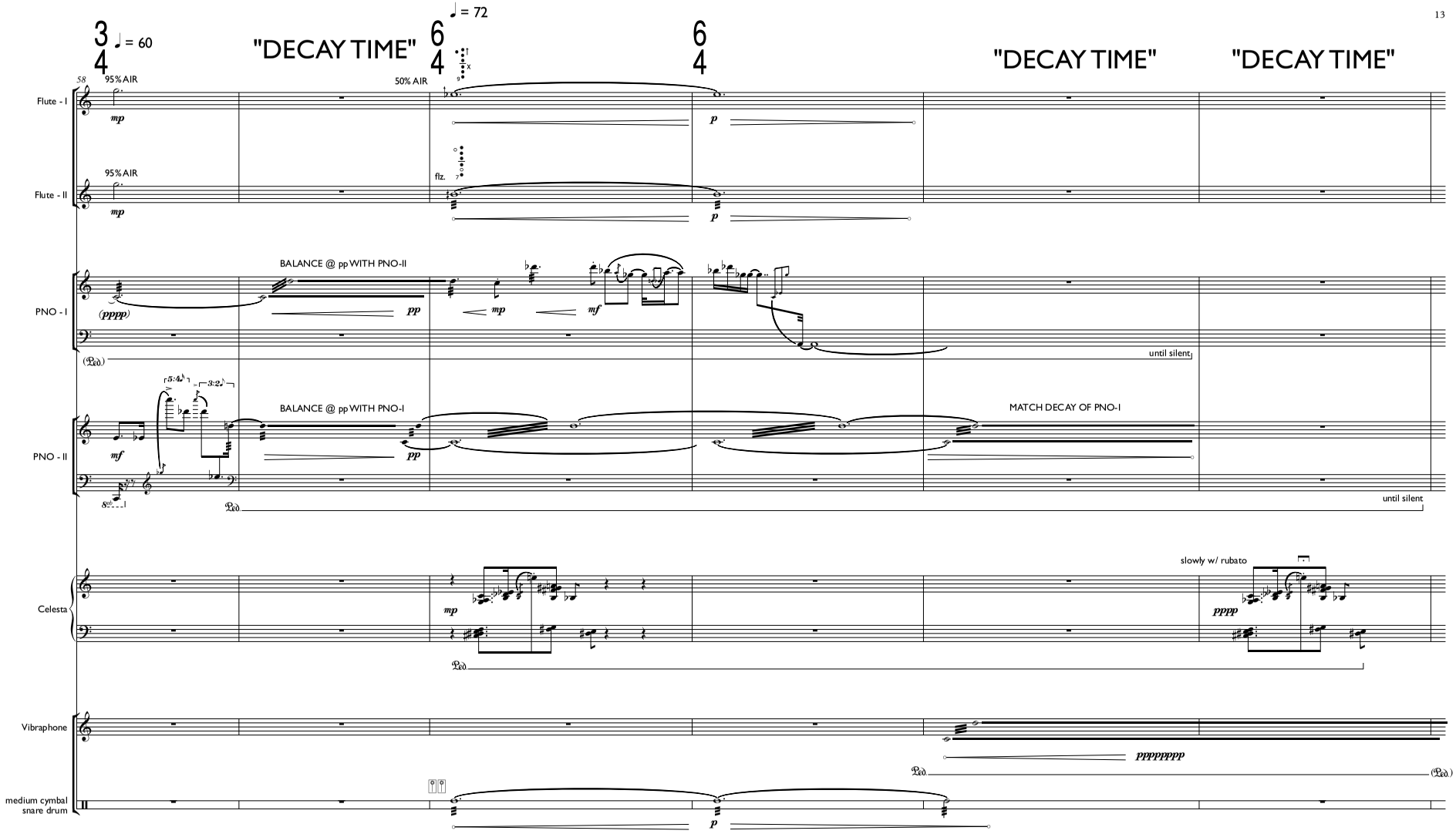
(loco)

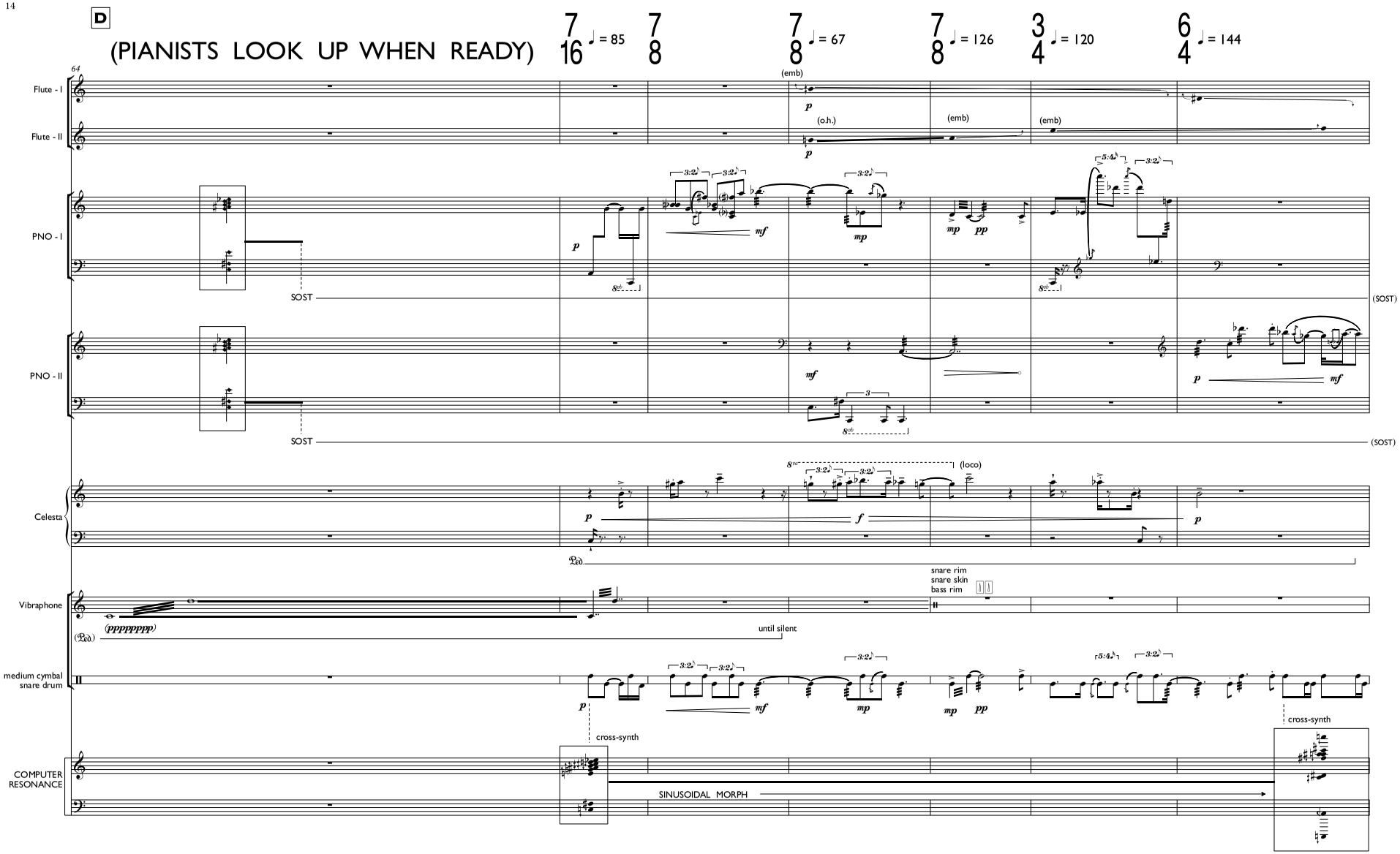
SOST.

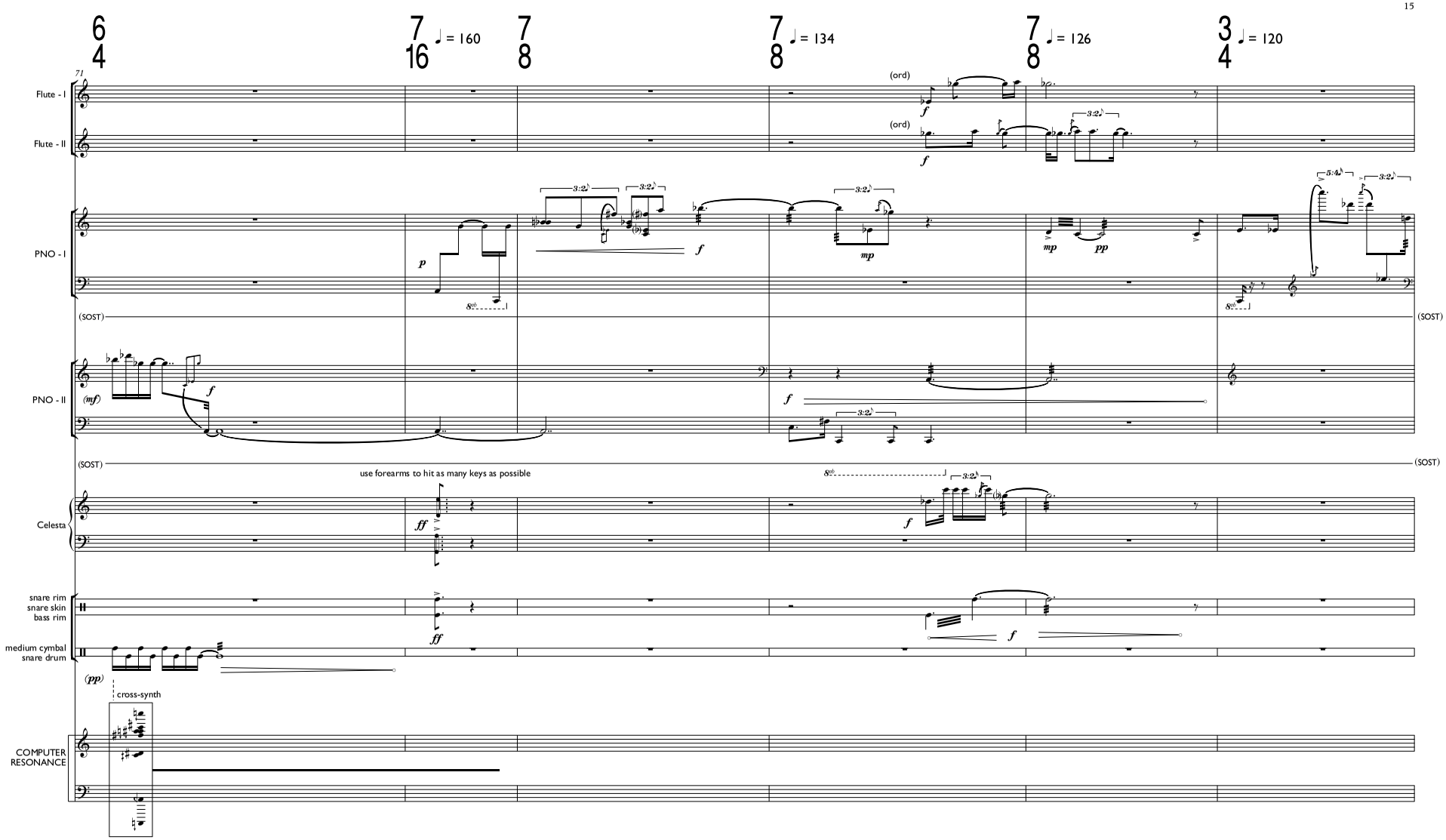
(SOST)

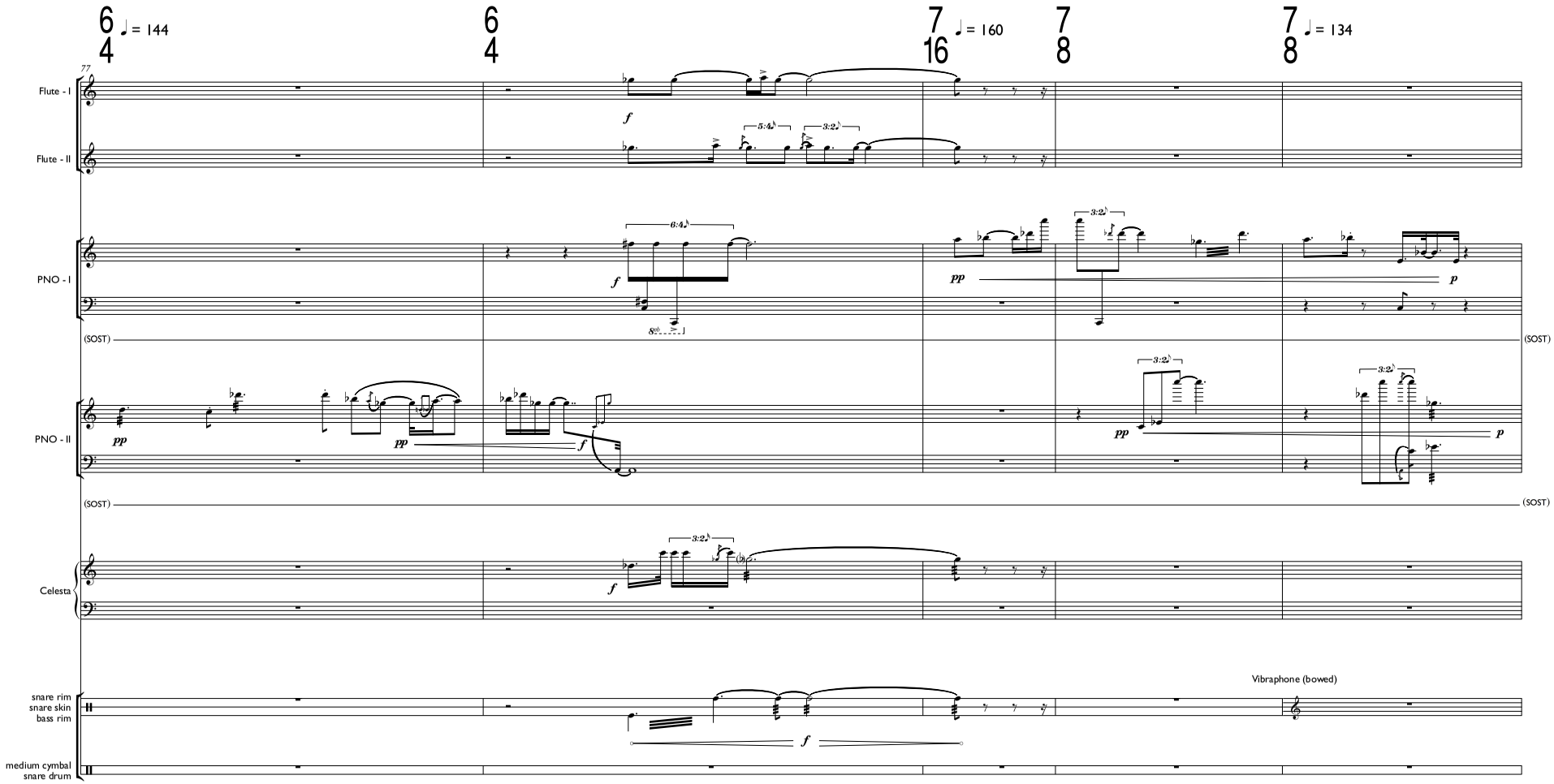
(Ped.)

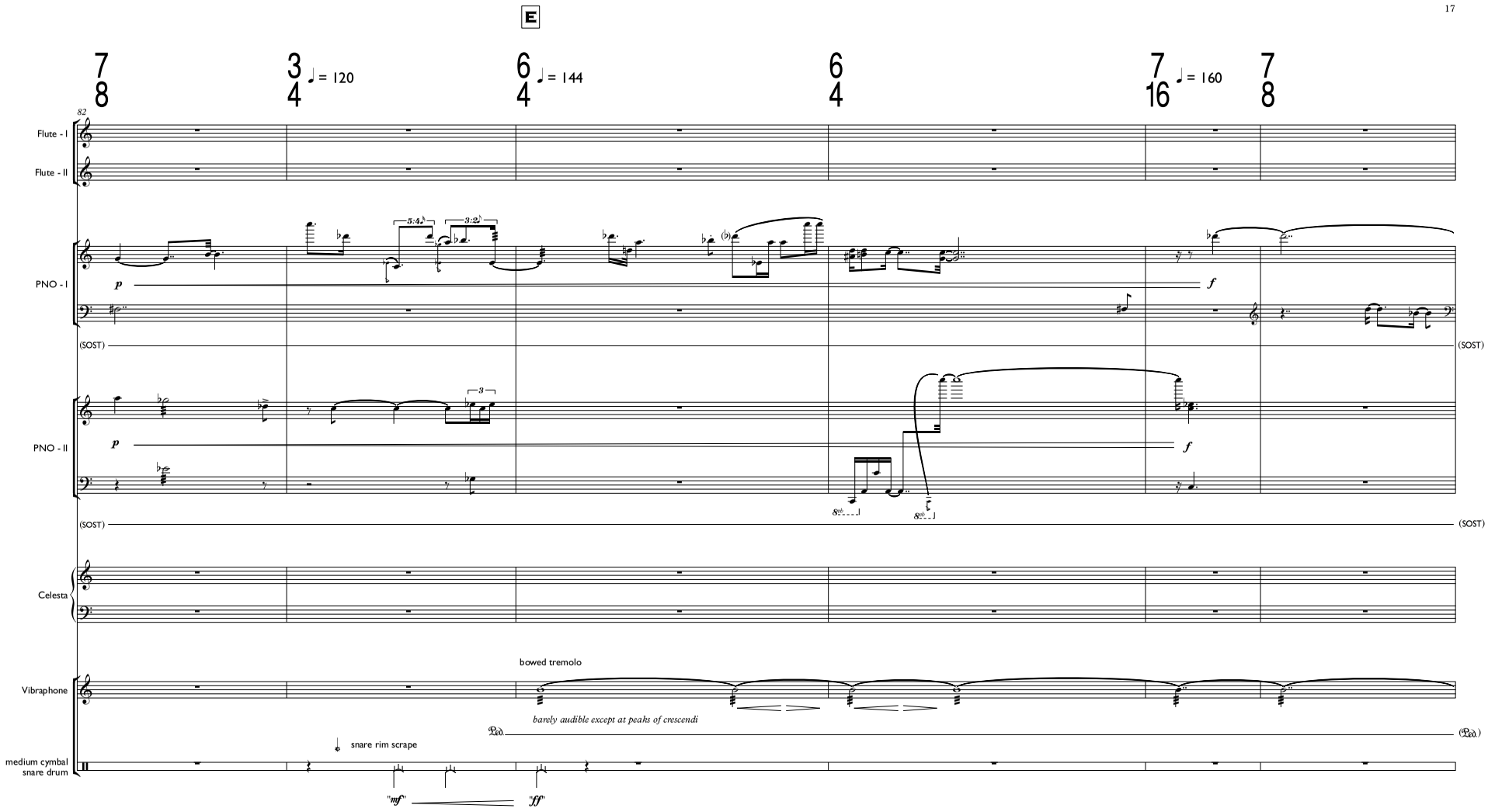

51
♩ = 85
"DECAY TIME"
♩ = 67
"DECAY TIME"
♩ = 63
"DECAY TIME"
Flute - I
Flute - II
(o.h.)
50% AIR
PNO - I
PNO - II
(SOST)
MATCH DECAY OF G4 IN SOST
MATCH DECAY OF FIRST PIANO
MATCH DECAY OF D4
Celesta
Vibraphone
snare rim scrape
medium cymbal
snare drum
"ff"
"mf"

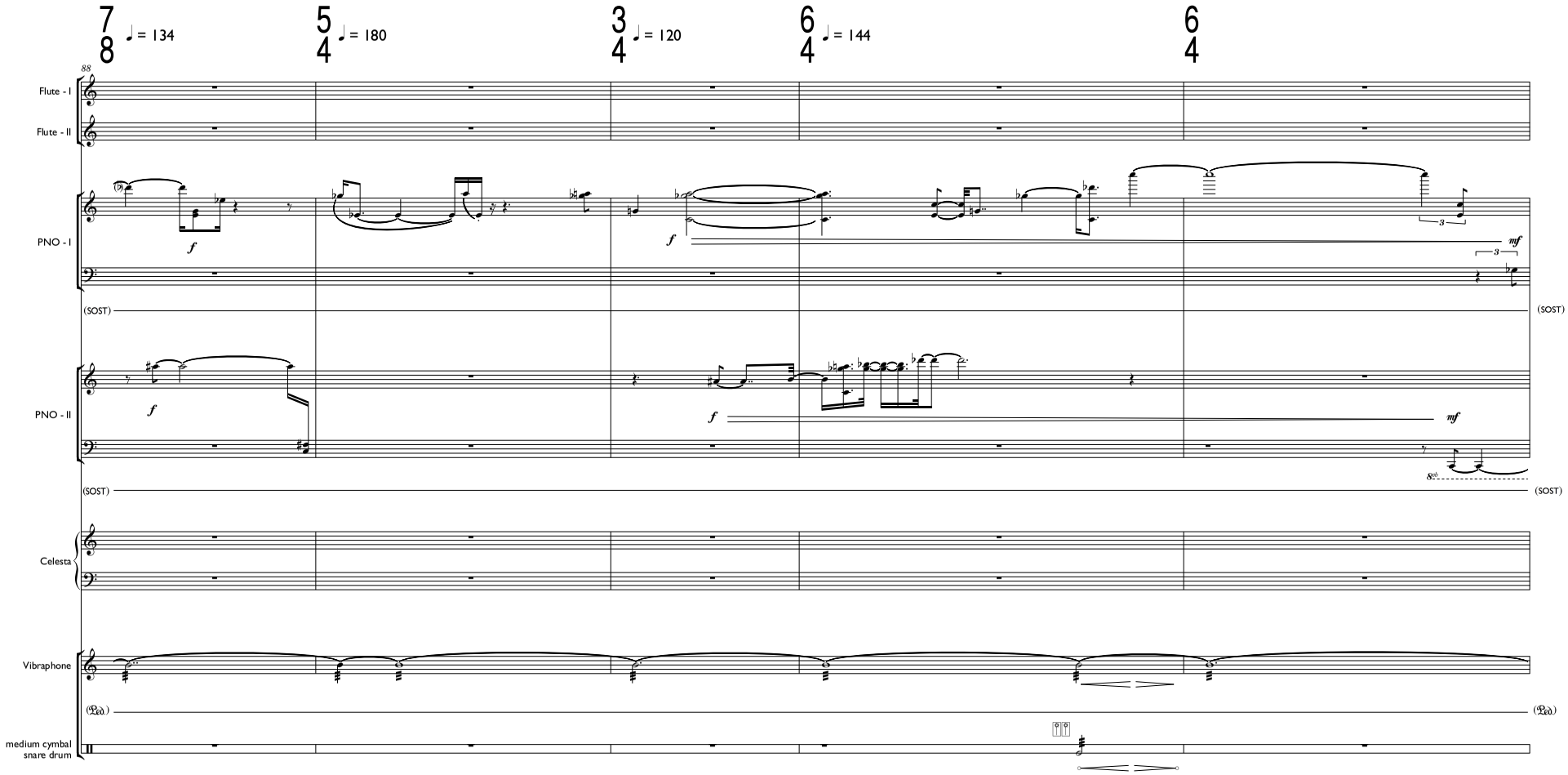

58
3/4 ♩ = 60
"DECAY TIME"
6/4 ♩ = 72
6/4
"DECAY TIME"
"DECAY TIME"
Flute - I
95% AIR
mp
50% AIR
p
Flute - II
95% AIR
mp
flz.
p
PNO - I
(pppp)
BALANCE @ pp WITH PNO-II
pp
mp
mf
until silent
PNO - II
mf
BALANCE @ pp WITH PNO-I
pp
MATCH DECAY OF PNO-I
until silent
Celesta
mp
slowly w/ rubato
pppp
Vibraphone
ppppppp
medium cymbal
snare drum
p

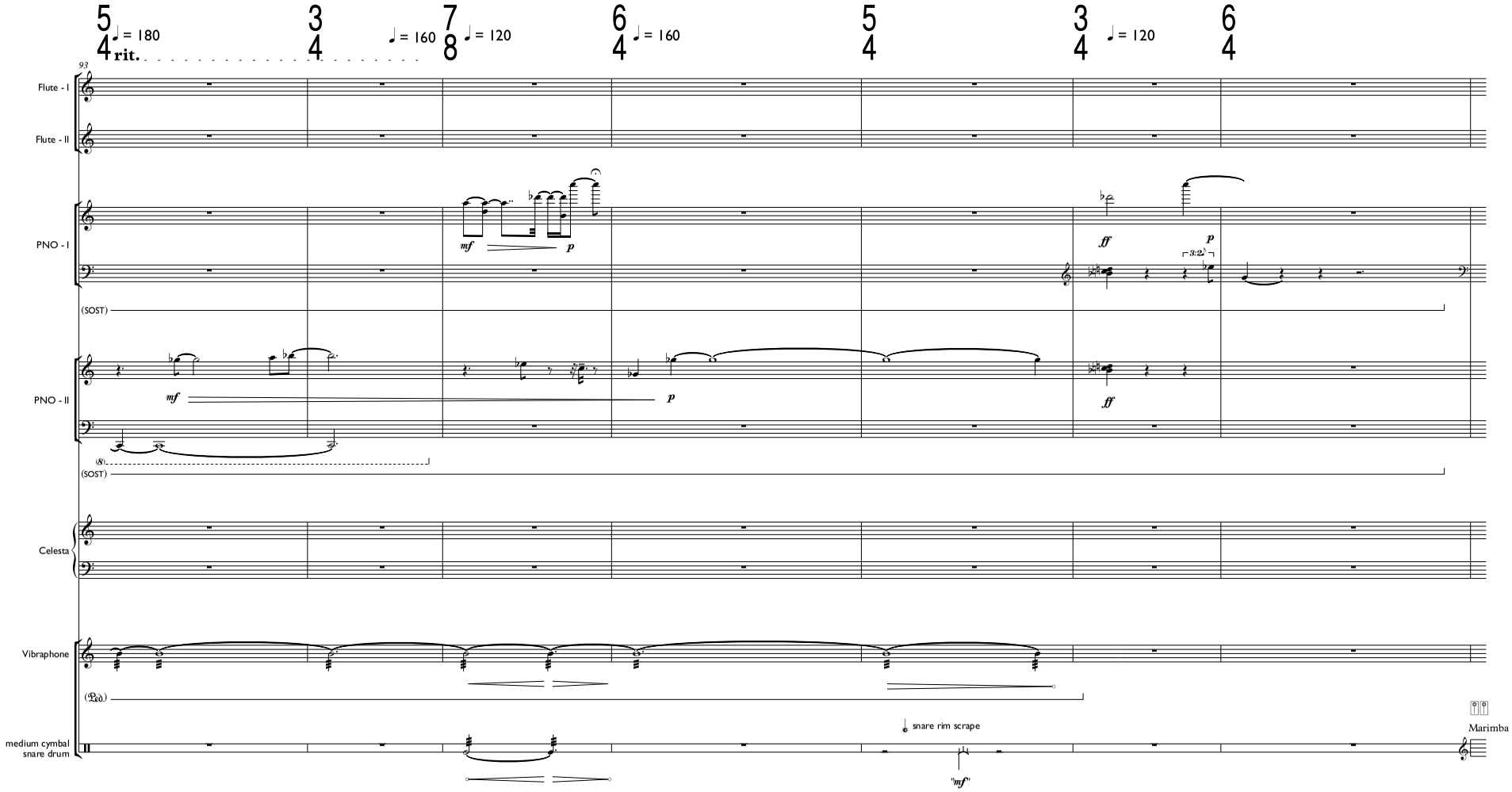

D
(PIANISTS LOOK UP WHEN READY)
64
♩ = 85
♩ = 67
♩ = 126
♩ = 120
♩ = 144
Flute - I
Flute - II
(emb)
(o.h.)
PNO - I
PNO - II
SOST
(SOST)
Celesta
(loco)
Vibraphone
snare rim
snare skin
bass rim
until silent
medium cymbal
snare drum
cross-synth
COMPUTER RESONANCE
SINUSOIDAL MORPH


71
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
snare rim
snare skin
bass rim
medium cymbal
snare drum
COMPUTER RESONANCE
(ord)
(ord)
(SOST)
(SOST)
(SOST)
(SOST)
use forearms to hit as many keys as possible
cross-synth
♩ = 160
♩ = 134
♩ = 126
♩ = 120


6/4 ♩ = 144
6/4
7/16 ♩ = 160
7/8
7/8 ♩ = 134
77
Flute - I
Flute - II
PNO - I
(SOST)
PNO - II
(SOST)
Celesta
snare rim
snare skin
bass rim
medium cymbal
snare drum
Vibraphone (bowed)


E
82
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
♩ = 120
♩ = 144
♩ = 160
p
f
(SOST)
5:4
3:2
3
bowed tremolo
barely audible except at peaks of crescendi
Ped.
snare rim scrape
"mf"
"ff"


7/8 ♩ = 134
5/4 ♩ = 180
3/4 ♩ = 120
6/4 ♩ = 144
6/4
88
Flute - I
Flute - II
PNO - I
(SOST)
PNO - II
(SOST)
Celesta
Vibraphone
(Ped.)
medium cymbal
snare drum


5/4 ♩ = 180
rit.
3/4
♩ = 160
7/8 ♩ = 120
6/4 ♩ = 160
5/4
3/4 ♩ = 120
6/4
93
Flute - I
Flute - II
PNO - I
mf
p
ff
p
3:2
(SOST)
PNO - II
mf
p
ff
(SOST)
Celesta
Vibraphone
medium cymbal
snare drum
snare rim scrape
"mf"
Marimba

F

LONG MORPH

♩ = 40 rit. . . . . ♩ = 30

QUICK MORPH

♩ = 40 rit. . . . . ♩ = 30

MEDIUM MORPH

100

COMPUTER RESONANCE

sinusoidal morph

sinusoidal morph

sinusoidal morph

PNO - I

f

staccatissimo → tenuto

ff

p

staccatissimo → tenuto

ff

p

♩ = 40 rit. . . . . ♩ = 30

LONG MORPH

(PIANIST LOOK UP WHEN READY)

108

COMPUTER RESONANCE

sinusoidal morph

PNO - I

staccatissimo → tenuto

ff

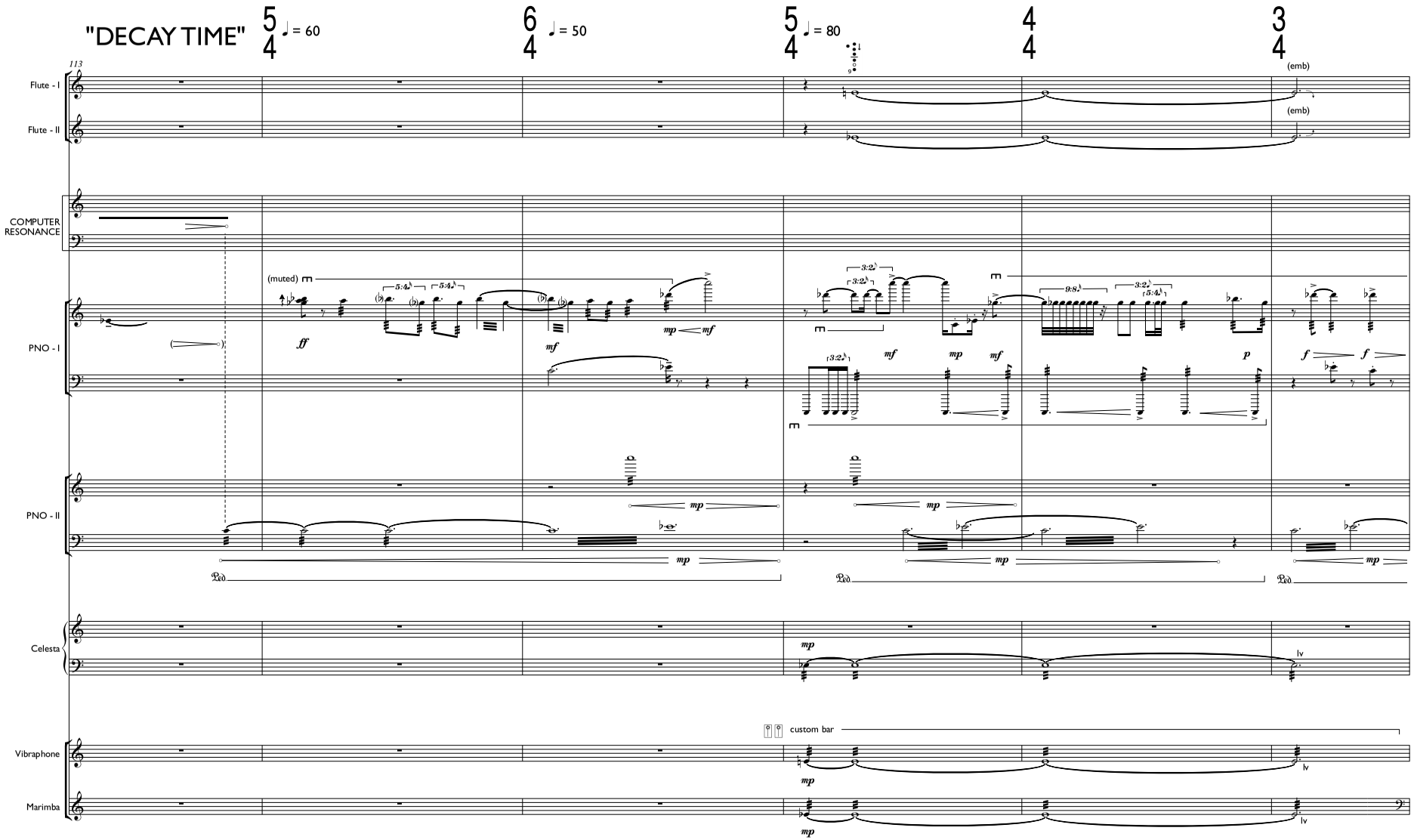
p

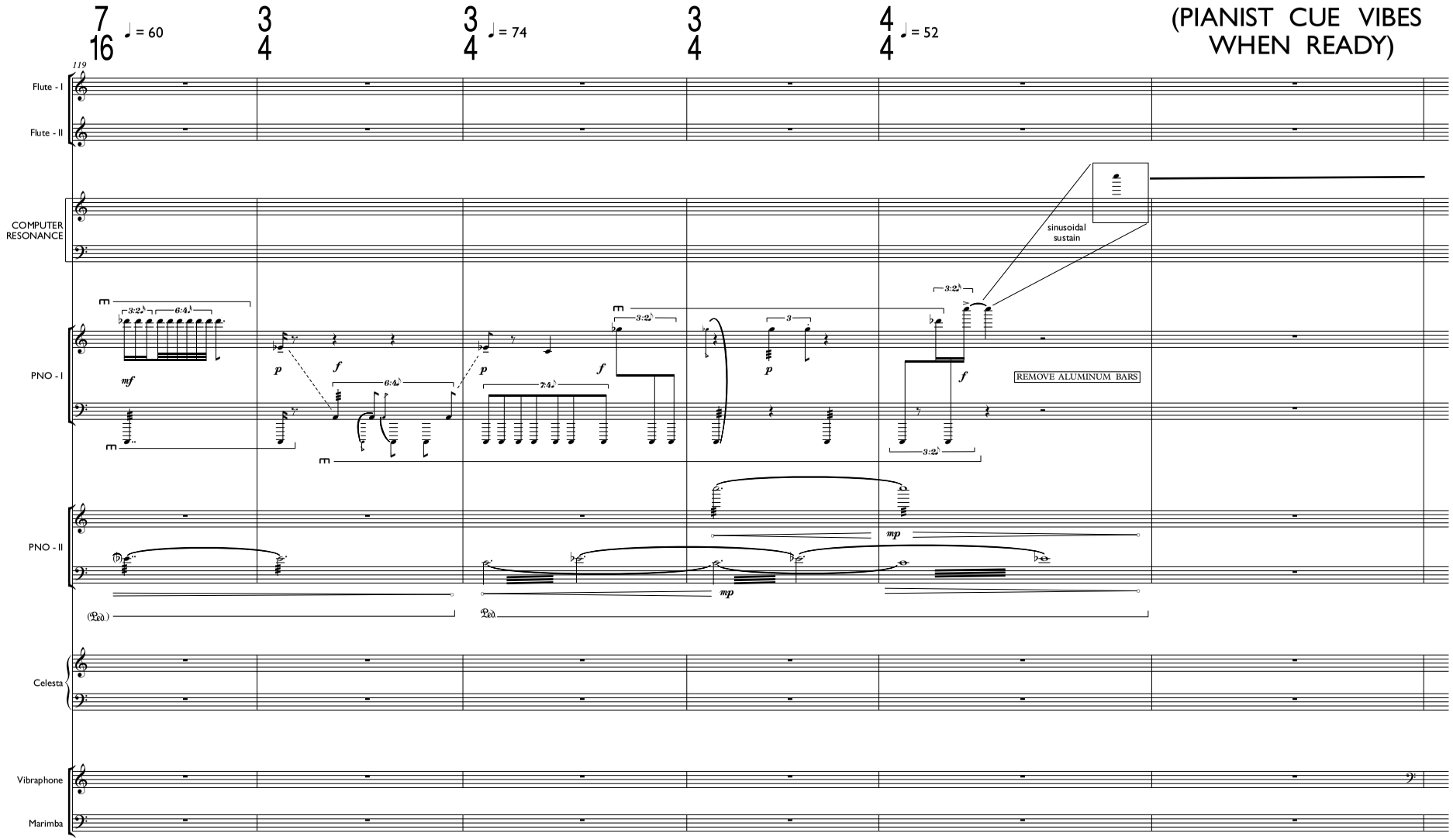
LAY 3 ALUMINUM BARS ACROSS THESE STRINGS:

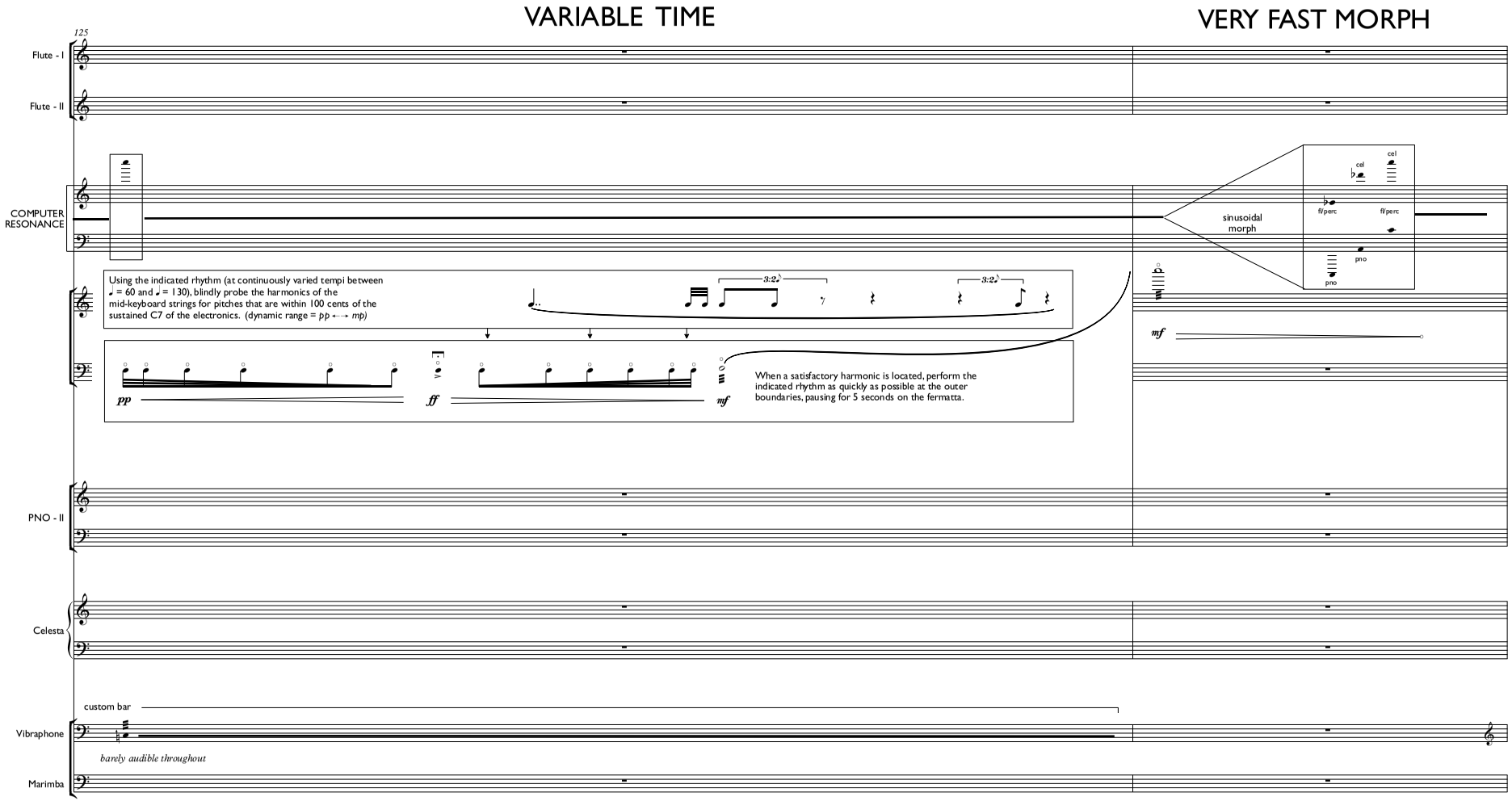
1

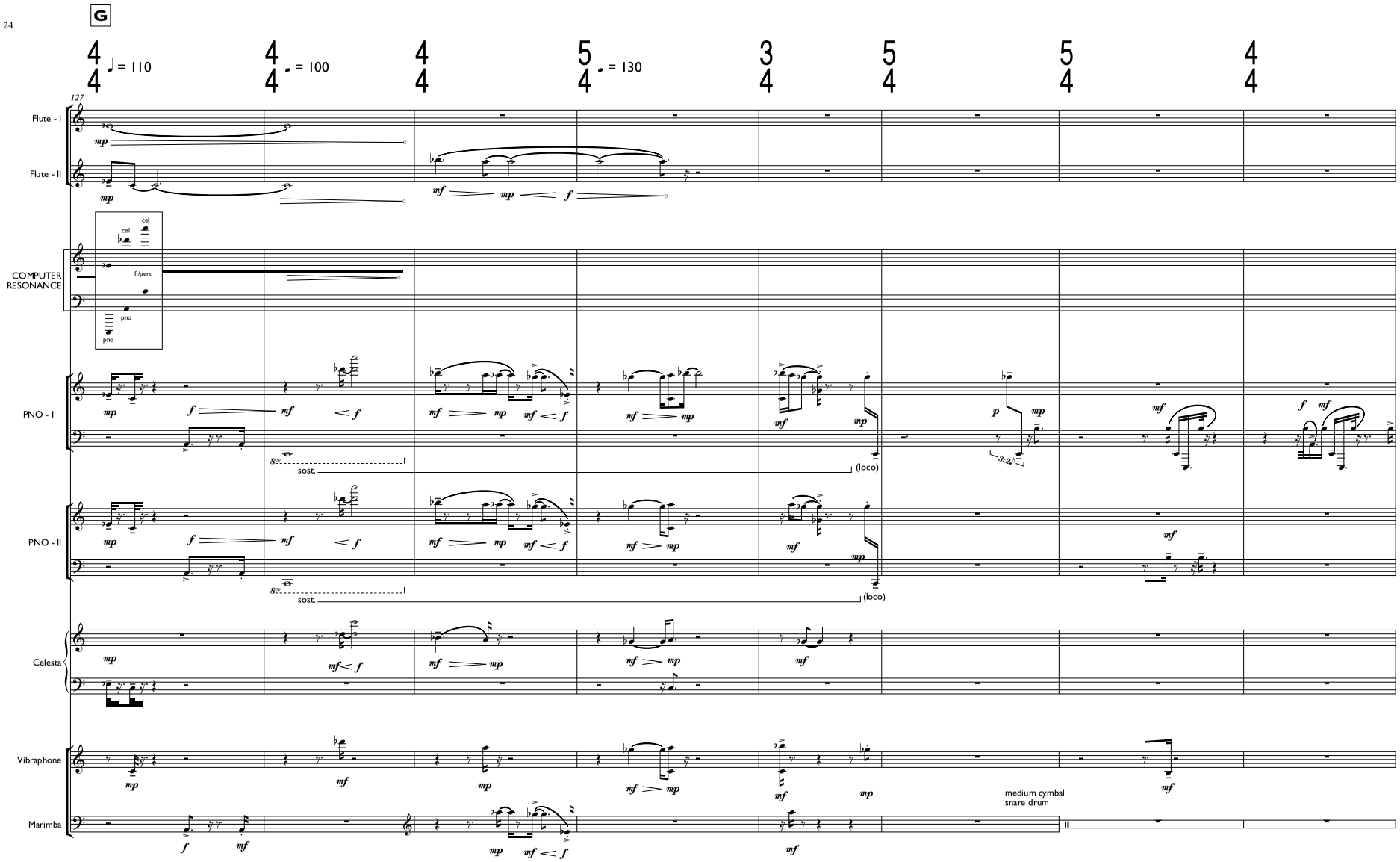
2

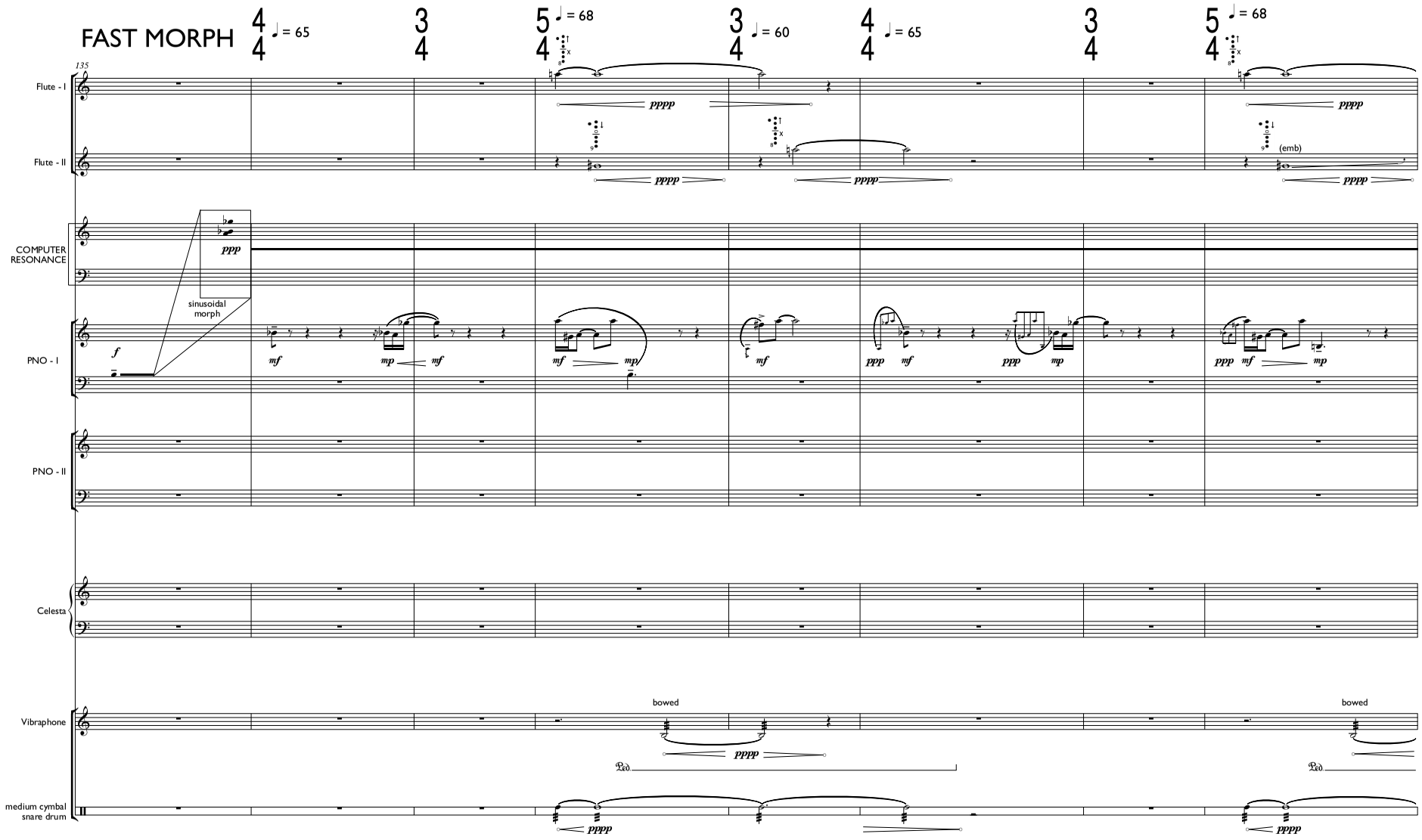
3

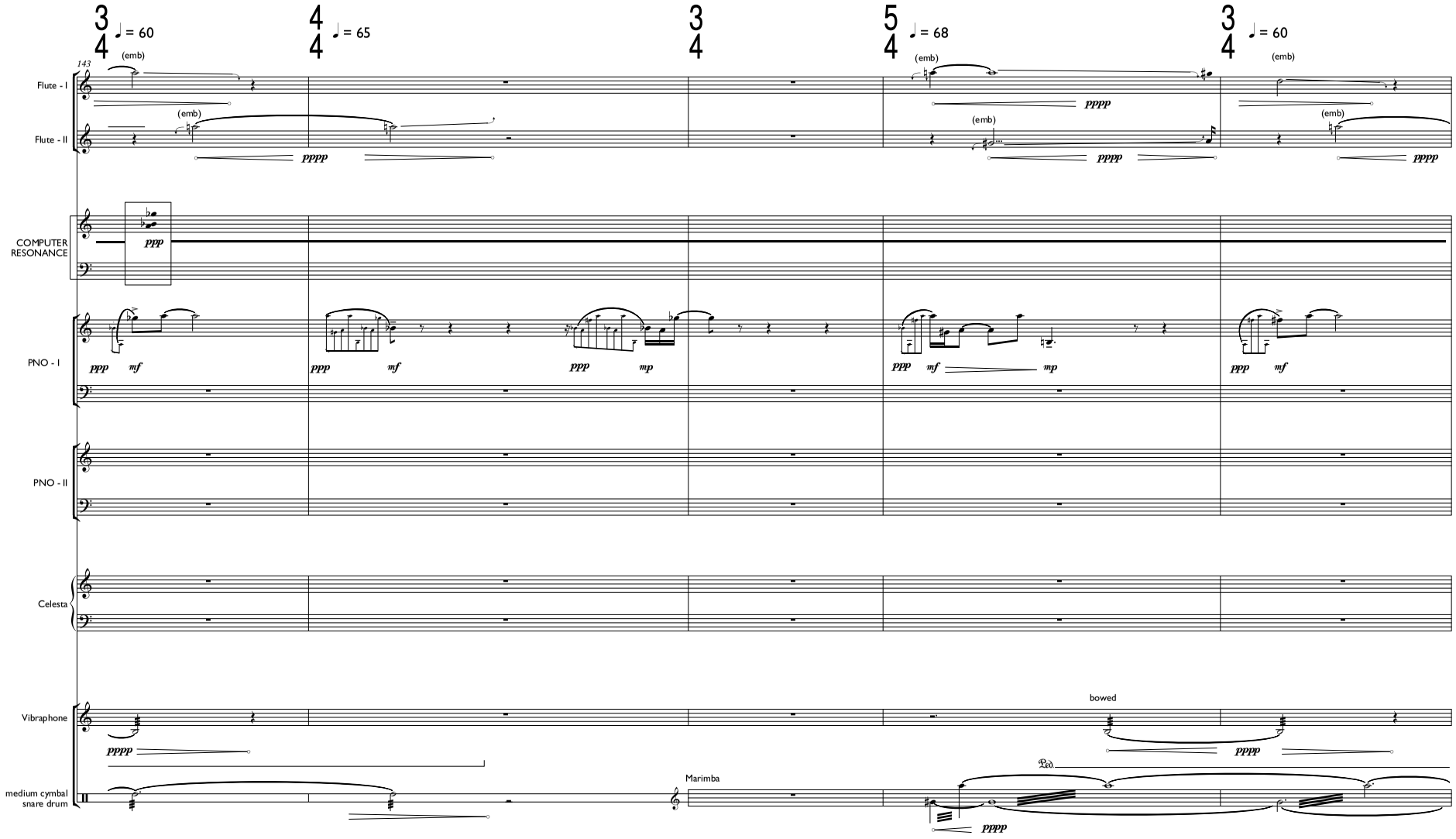

"DECAY TIME"
5/4 ♩ = 60
6/4 ♩ = 50
5/4 ♩ = 80
4/4
3/4
113
Flute - I
Flute - II
(emb)
(emb)
COMPUTER RESONANCE
PNO - I
(muted)
ff
mf
mp
mf
mf
mp
mf
p
f
f
PNO - II
mp
mp
mp
Celesta
mp
lv
custom bar
Vibraphone
mp
lv
Marimba
mp
lv


7/16 ♩ = 60
3/4
3/4 ♩ = 74
3/4
4/4 ♩ = 52
(PIANIST CUE VIBES WHEN READY)
119
Flute - I
Flute - II
COMPUTER RESONANCE
sinusoidal sustain
PNO - I
REMOVE ALUMINUM BARS
PNO - II
Celesta
Vibraphone
Marimba

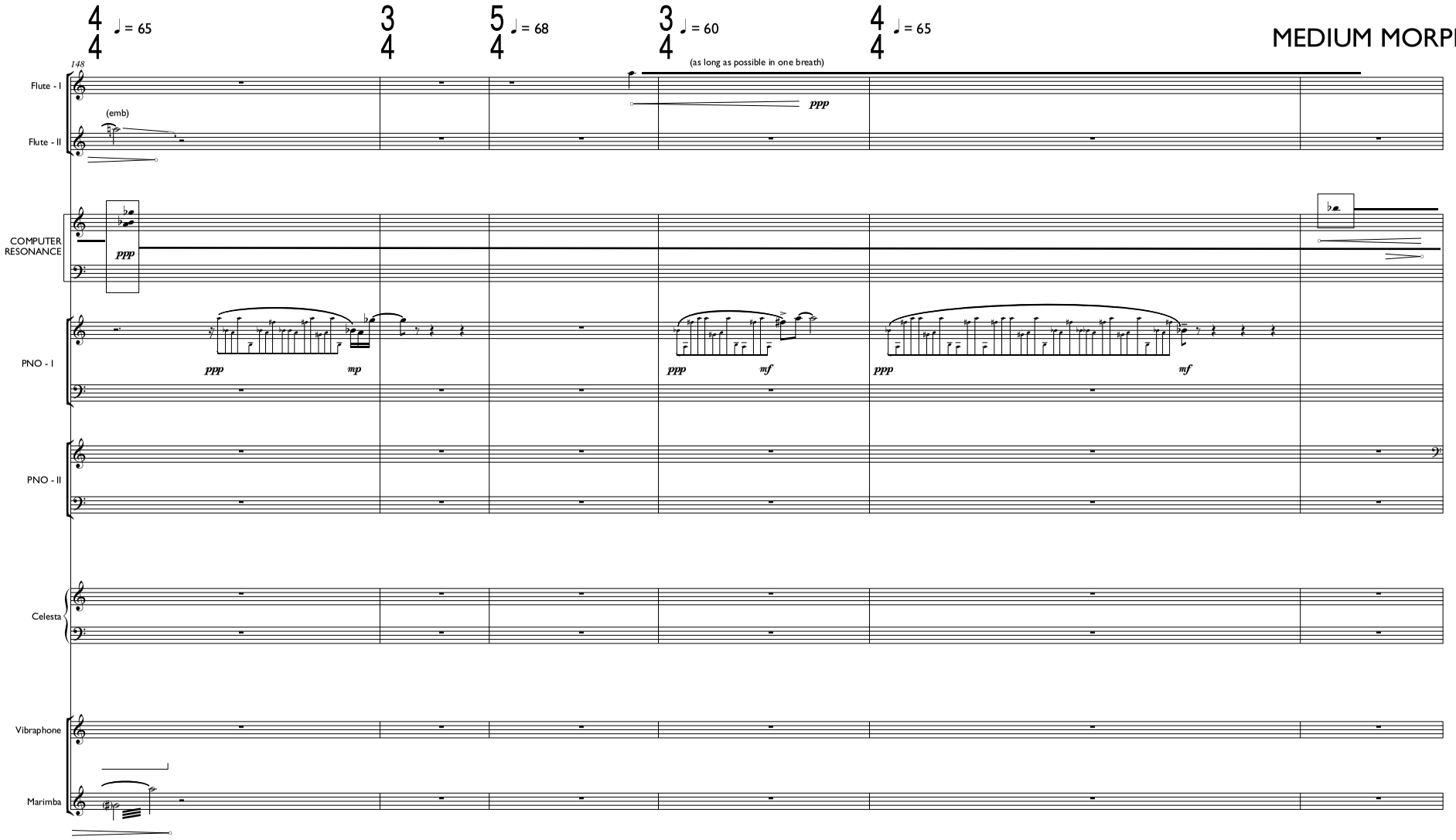

VARIABLE TIME
VERY FAST MORPH
125
Flute - I
Flute - II
COMPUTER RESONANCE
Using the indicated rhythm (at continuously varied tempi between ♩ = 60 and ♩ = 130), blindly probe the harmonics of the mid-keyboard strings for pitches that are within 100 cents of the sustained C7 of the electronics. (dynamic range = pp ←→ mp)
3:2
3:2
pp
ff
mf
When a satisfactory harmonic is located, perform the indicated rhythm as quickly as possible at the outer boundaries, pausing for 5 seconds on the fermatta.
sinusoidal morph
cel
cel
fl/perc
fl/perc
pno
pno
mf
PNO - II
Celesta
custom bar
Vibraphone
barely audible throughout
Marimba

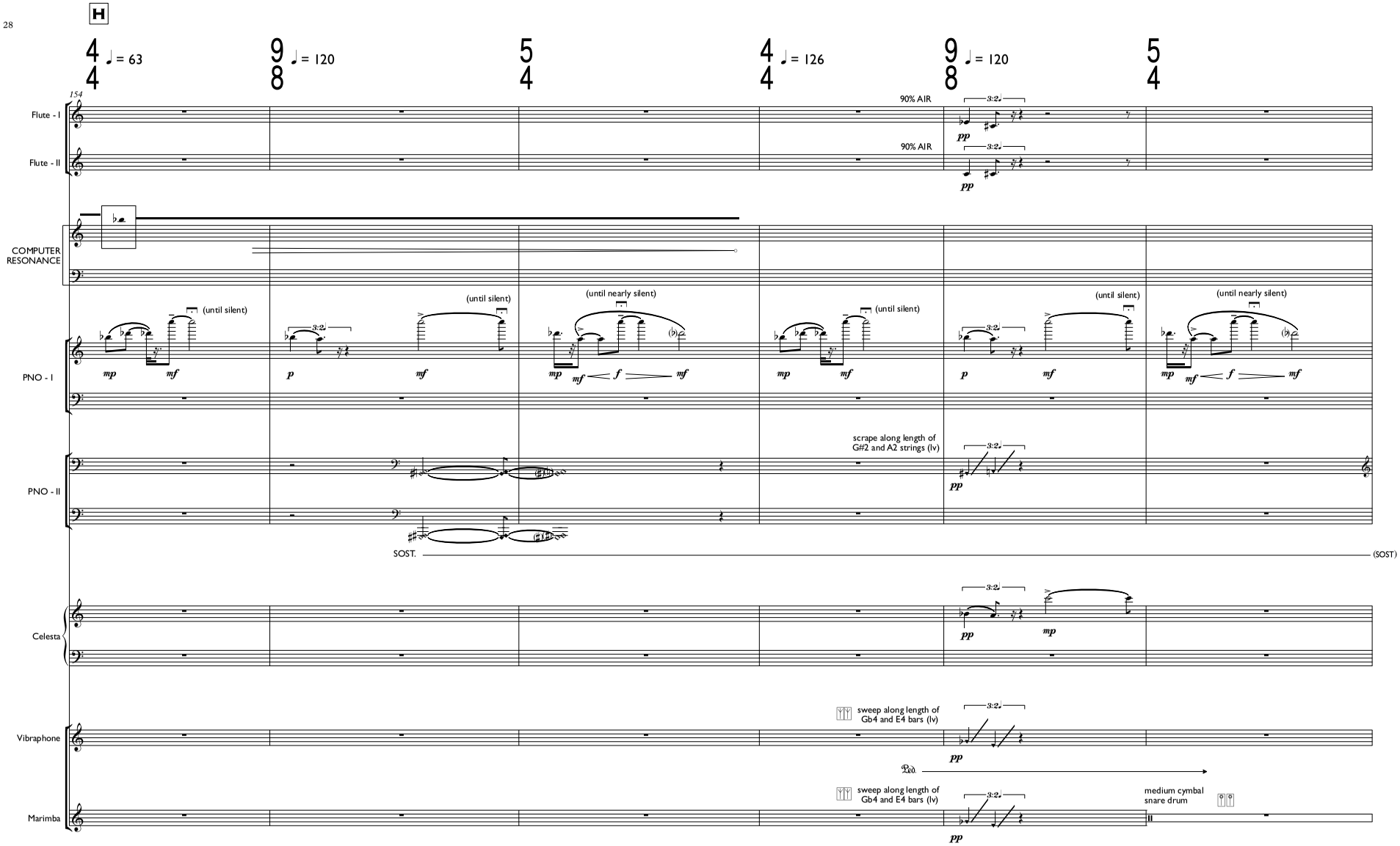

G
♩ = 110
♩ = 100
♩ = 130
127
Flute - I
Flute - II
COMPUTER RESONANCE
cel
fl/perc
pno
PNO - I
PNO - II
sost.
(loco)
Celesta
Vibraphone
Marimba
medium cymbal
snare drum

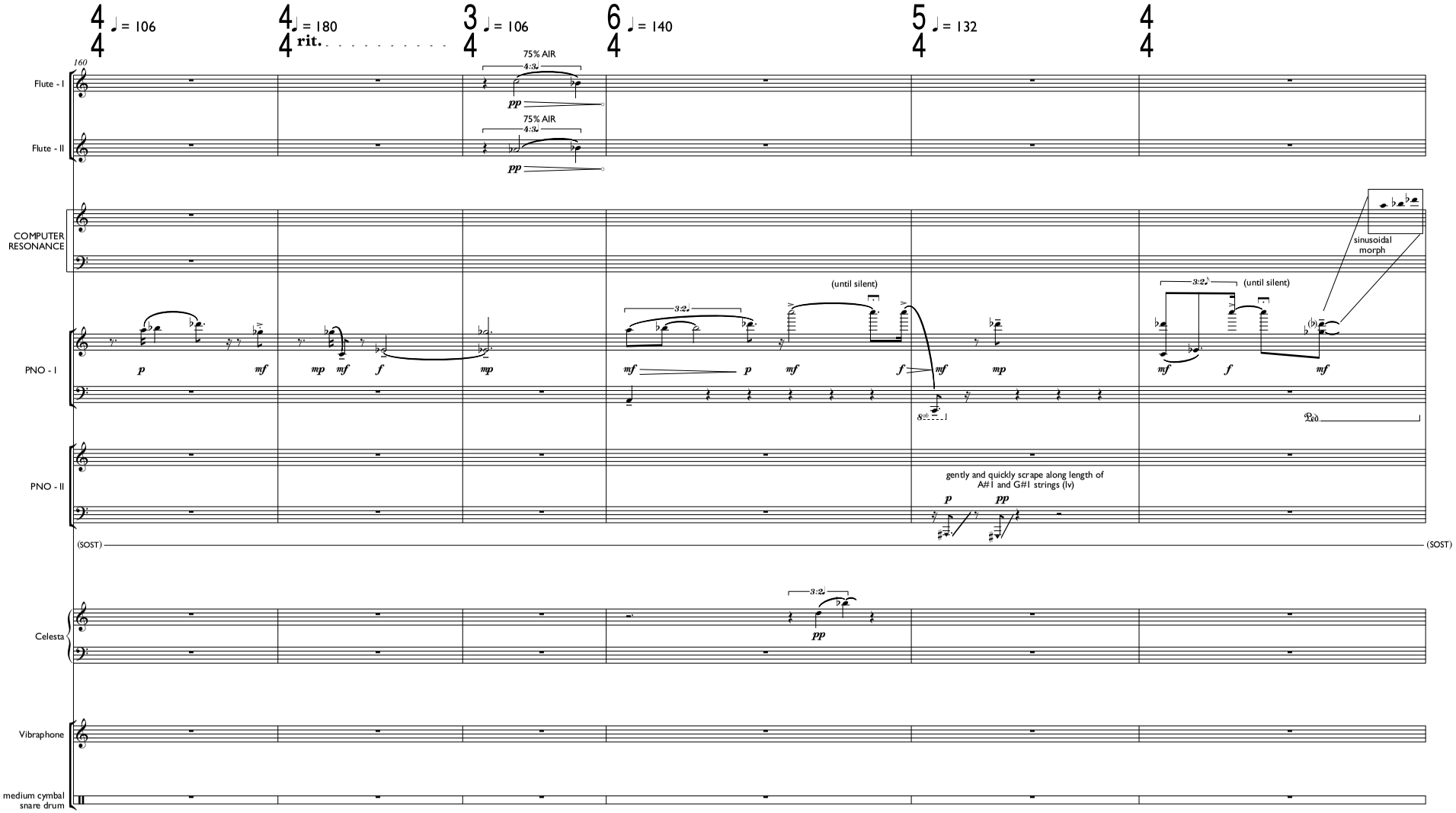

FAST MORPH
135
Flute - I
Flute - II
COMPUTER RESONANCE
sinusoidal morph
PNO - I
PNO - II
Celesta
Vibraphone
bowed
medium cymbal
snare drum
(emb)

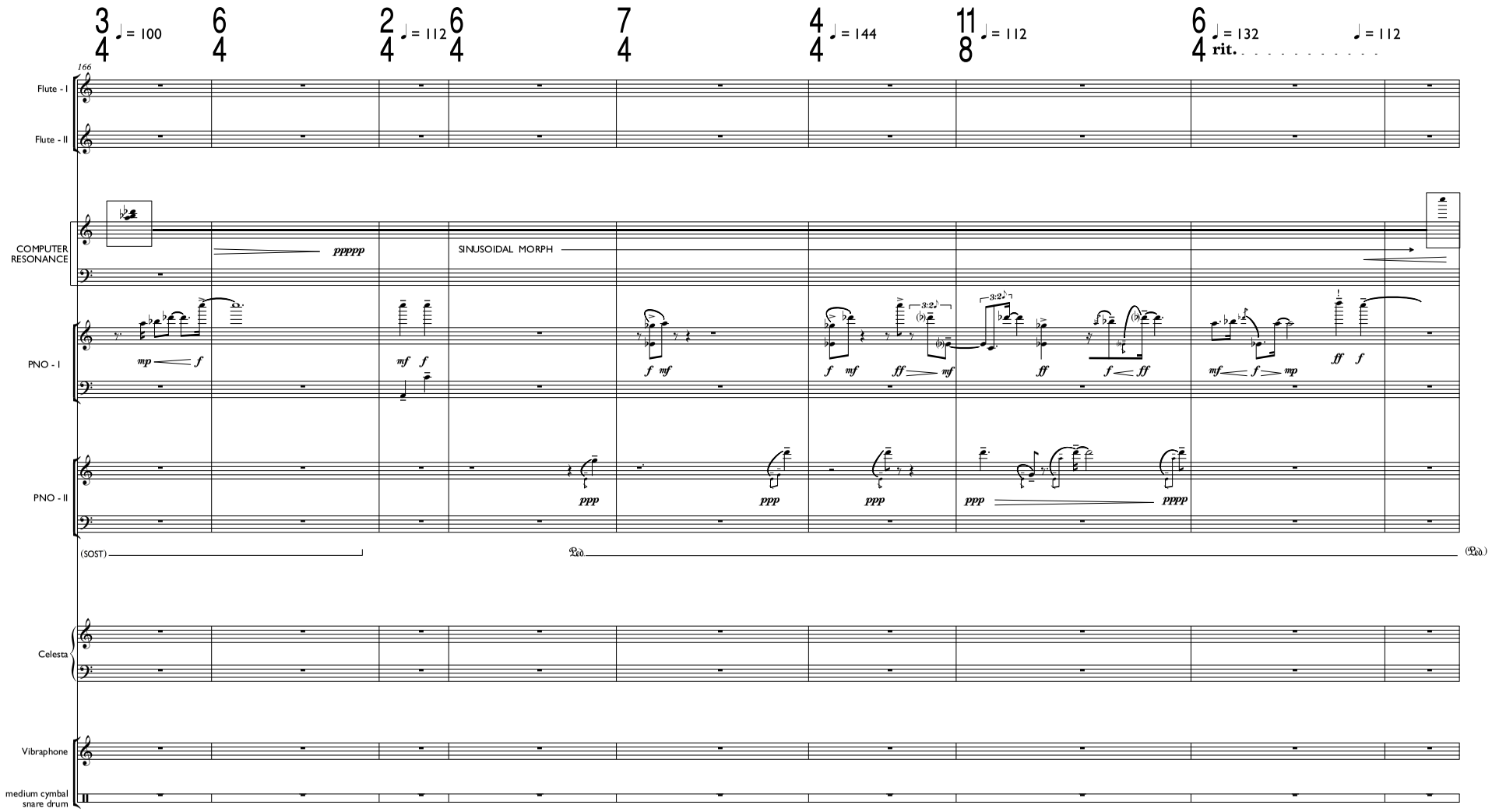

143
♩ = 60
♩ = 65
♩ = 68
♩ = 60
(emb)
Flute - I
Flute - II
COMPUTER RESONANCE
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
Marimba
bowed
pppp
ppp
mf
mp

MEDIUM MORPH




H
♩ = 63
♩ = 120
♩ = 126
♩ = 120
154
Flute - I
Flute - II
90% AIR
90% AIR
COMPUTER RESONANCE
PNO - I
(until silent)
(until silent)
(until nearly silent)
(until silent)
(until silent)
(until nearly silent)
PNO - II
scrape along length of G#2 and A2 strings (lv)
SOST.
(SOST.)
Celesta
Vibraphone
sweep along length of Gb4 and E4 bars (lv)
Marimba
sweep along length of Gb4 and E4 bars (lv)
medium cymbal snare drum


♩ = 106
♩ = 180
rit.
♩ = 106
♩ = 140
♩ = 132
160
Flute - I
Flute - II
75% AIR
4:3
pp
COMPUTER RESONANCE
sinusoidal morph
PNO - I
(until silent)
3:2
p
mf
mp
f
PNO - II
gently and quickly scrape along length of A#1 and G#1 strings (lv)
(SOST)
Celesta
Vibraphone
medium cymbal
snare drum


166
Flute - I
Flute - II
COMPUTER RESONANCE
ppppp
SINUSOIDAL MORPH
PNO - I
PNO - II
(SOST)
(Ped.)
Celesta
Vibraphone
medium cymbal
snare drum
♩ = 100
♩ = 112
♩ = 144
♩ = 132
rit.
♩ = 112

I

FAST MORPH

♩ = 132 ♩ = 90

175

Flute - I

Flute - II

COMPUTER RESONANCE

grainy

sinusoidal morph

PNO - I

PNO - II

SCRUB STRINGS (very soft plectrum)

(move plectrum across strings horizontally, while scrubbing vertically)

Celesta

Vibraphone

medium cymbal
snare drum

MEDIUM MORPH

185

Flute - I

Flute - II

COMPUTER RESONANCE

PNO - I

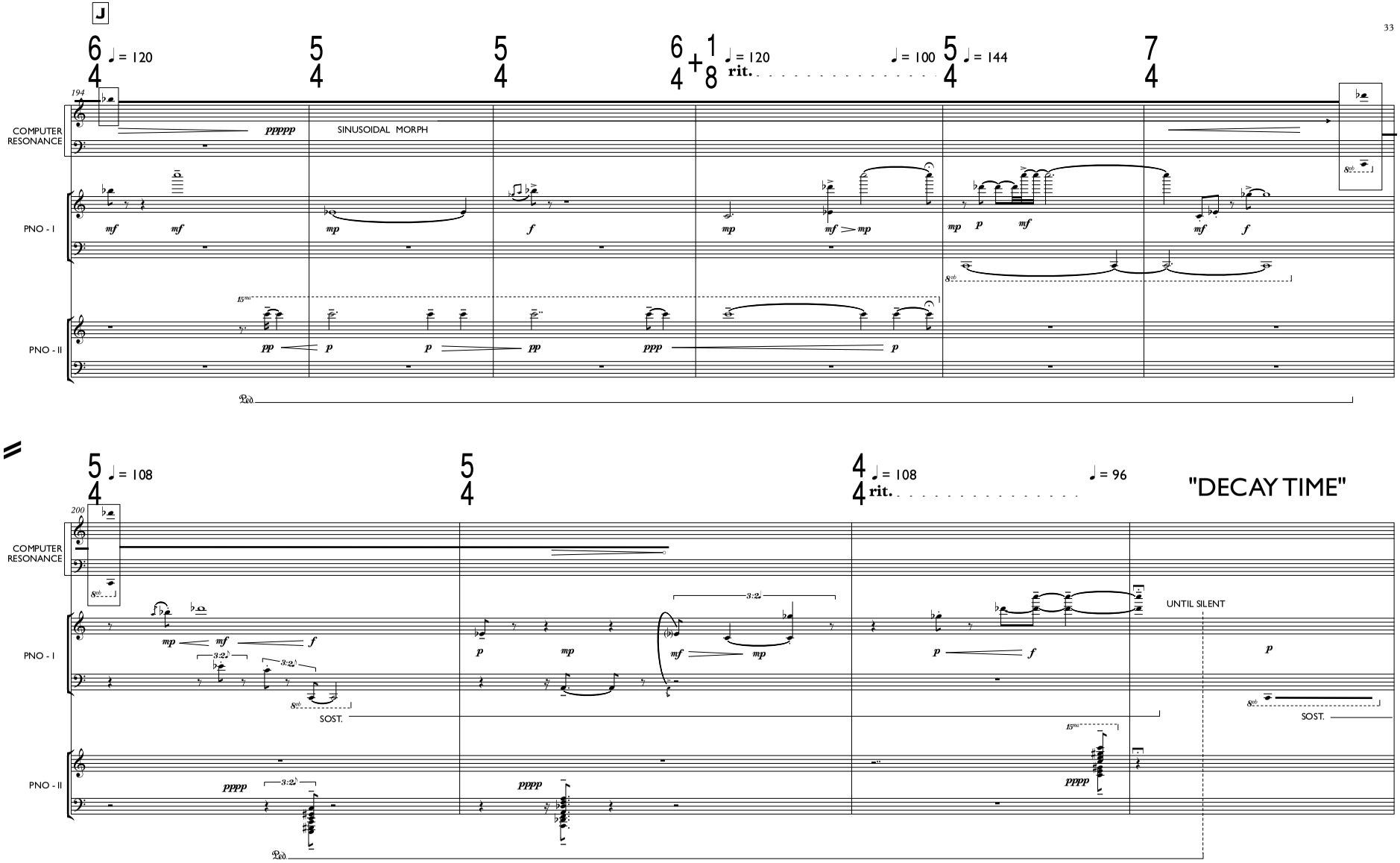
sinusoidal morph

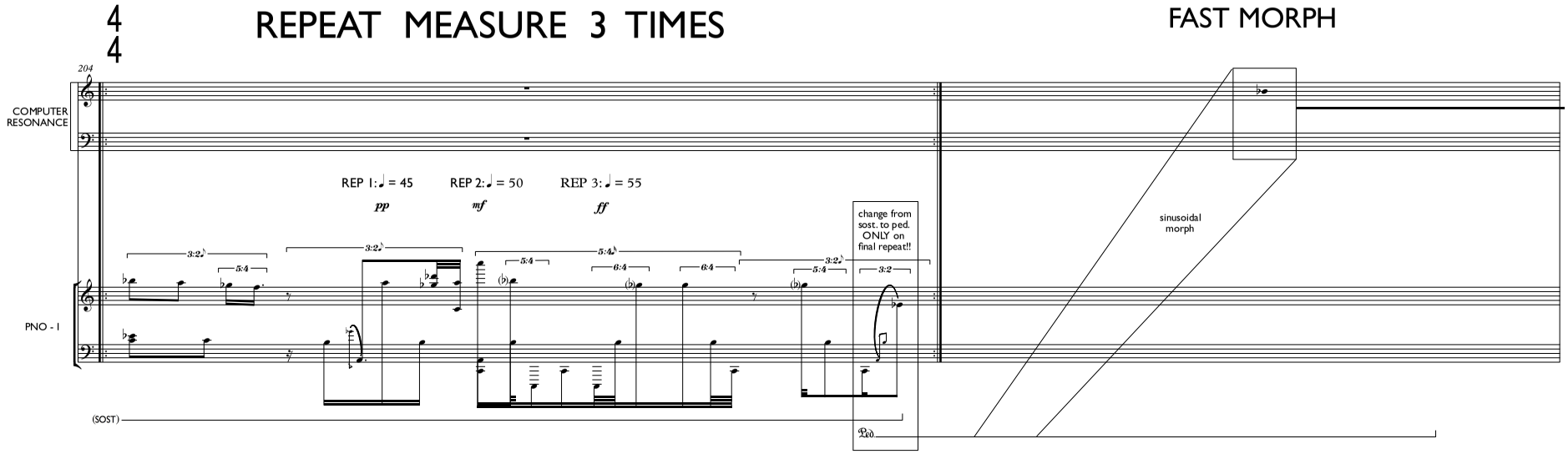
PNO - II

Celesta

Vibraphone

medium cymbal
snare drum


J
194
♩ = 120
rit.
♩ = 100
♩ = 144
COMPUTER RESONANCE
ppppp
SINUSOIDAL MORPH
PNO - I
mf
mf
mp
f
mp
mf > mp
mp
p
mf
mf
f
PNO - II
pp
p
p
pp
ppp
p
Ped.
200
♩ = 108
rit.
♩ = 108
♩ = 96
"DECAY TIME"
COMPUTER RESONANCE
UNTIL SILENT
PNO - I
mp
mf
f
SOST.
p
mp
mf
mp
p
f
p
SOST.
PNO - II
pppp
pppp
pppp
Ped.


4
4
REPEAT MEASURE 3 TIMES
FAST MORPH
204
COMPUTER RESONANCE
PNO - I
REP 1: ♩ = 45
REP 2: ♩ = 50
REP 3: ♩ = 55
pp
mf
ff
change from sost. to ped. ONLY on final repeat!!
sinusoidal morph
(SOST)

K

206

4/4 ♩ = 130 | 3/4 | 5/4 ♩ = 136 | 3/4 ♩ = 120 | 4/4 ♩ = 126 | 9/8 ♩ = 120 | 5/4 | 5/4

Flute - I

Flute - II

70% AIR
flz.

(emb)

COMPUTER RESONANCE

PNO - I

(until silent)

PNO - II

chromatic cluster
from F#6-F#7

slowly scrape lengthwise along B#6, C#6, and D6 strings

(until silent)

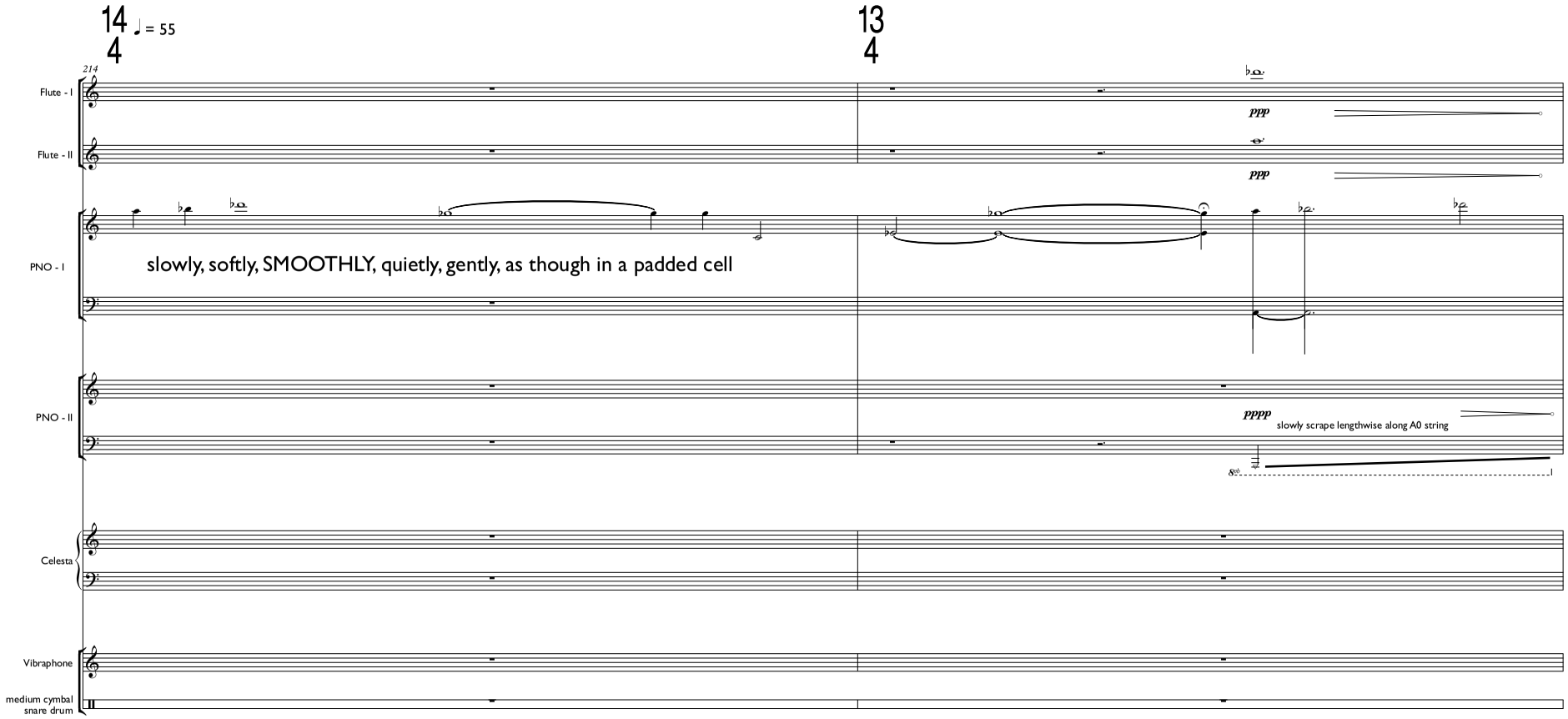
Celesta

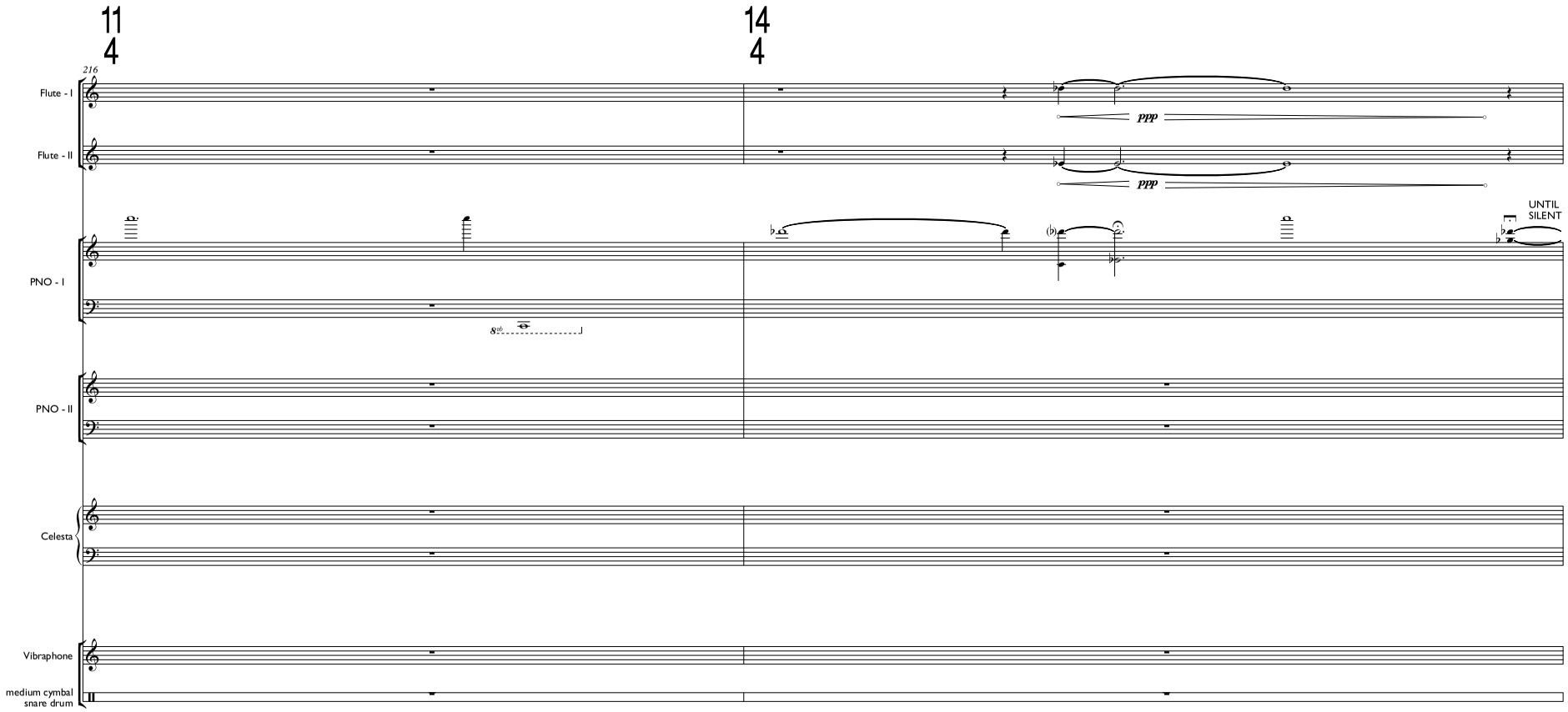
chromatic cluster
from F#5-F#6
[sounding 8va]

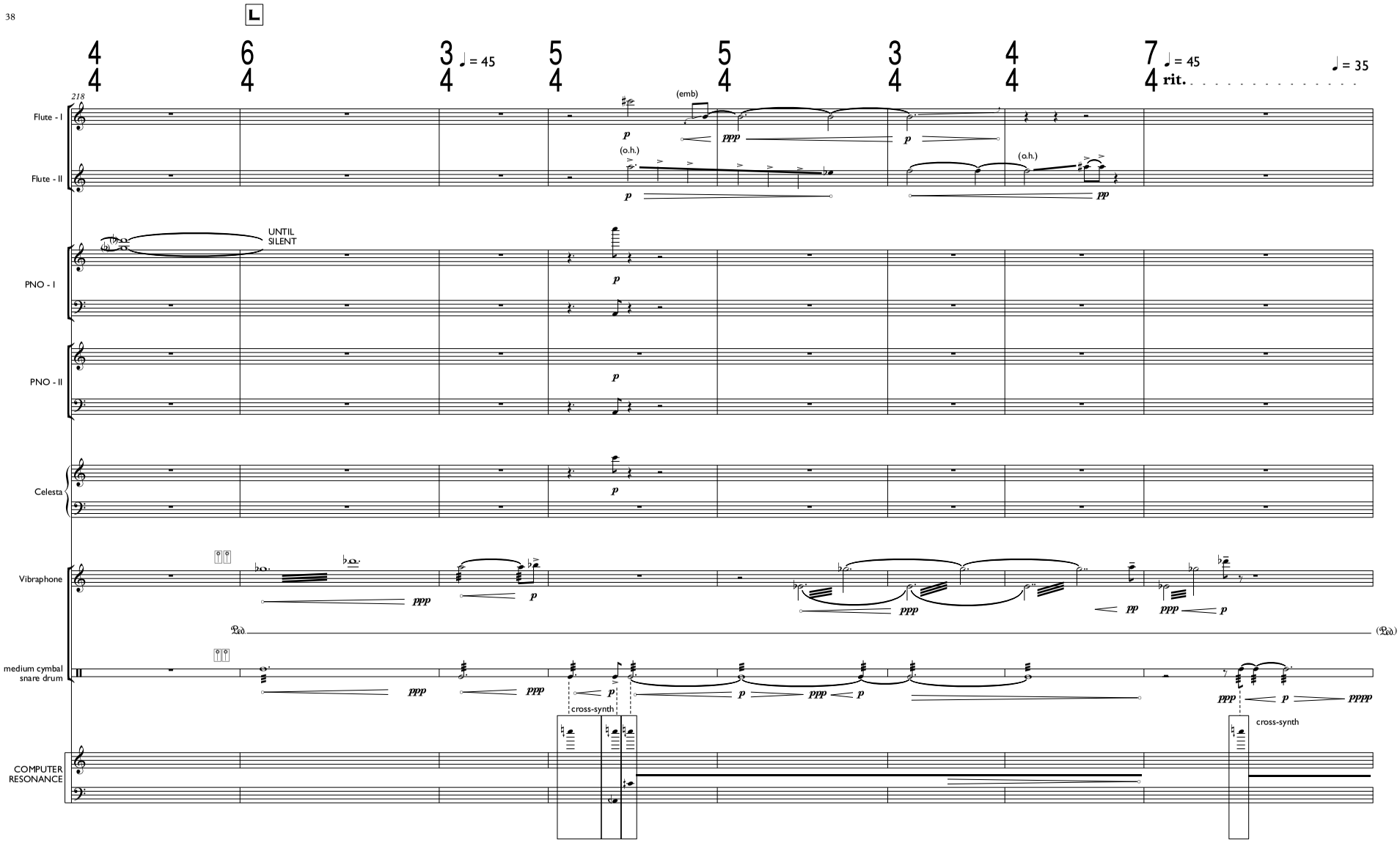
(until silent)

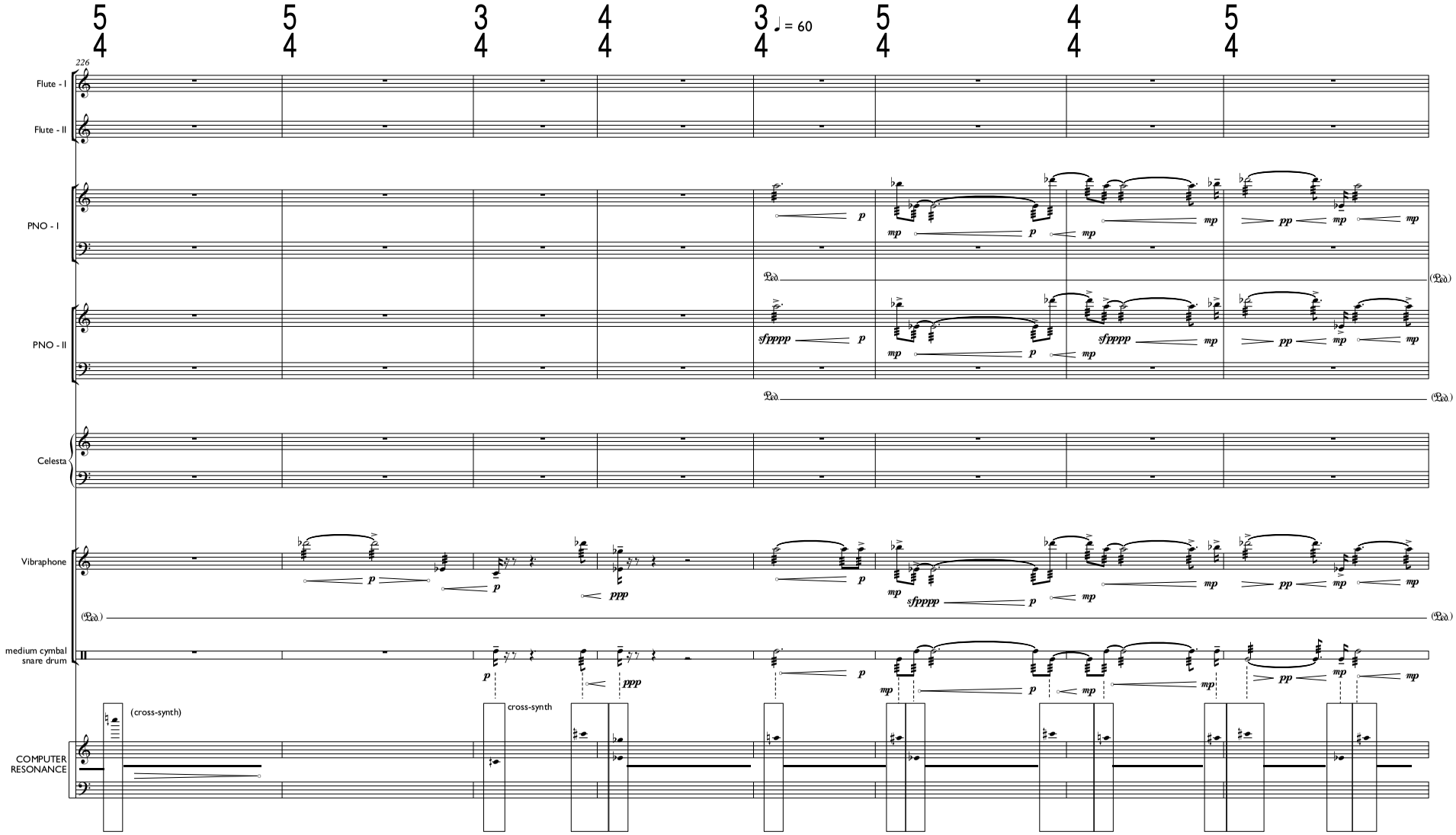
Vibraphone

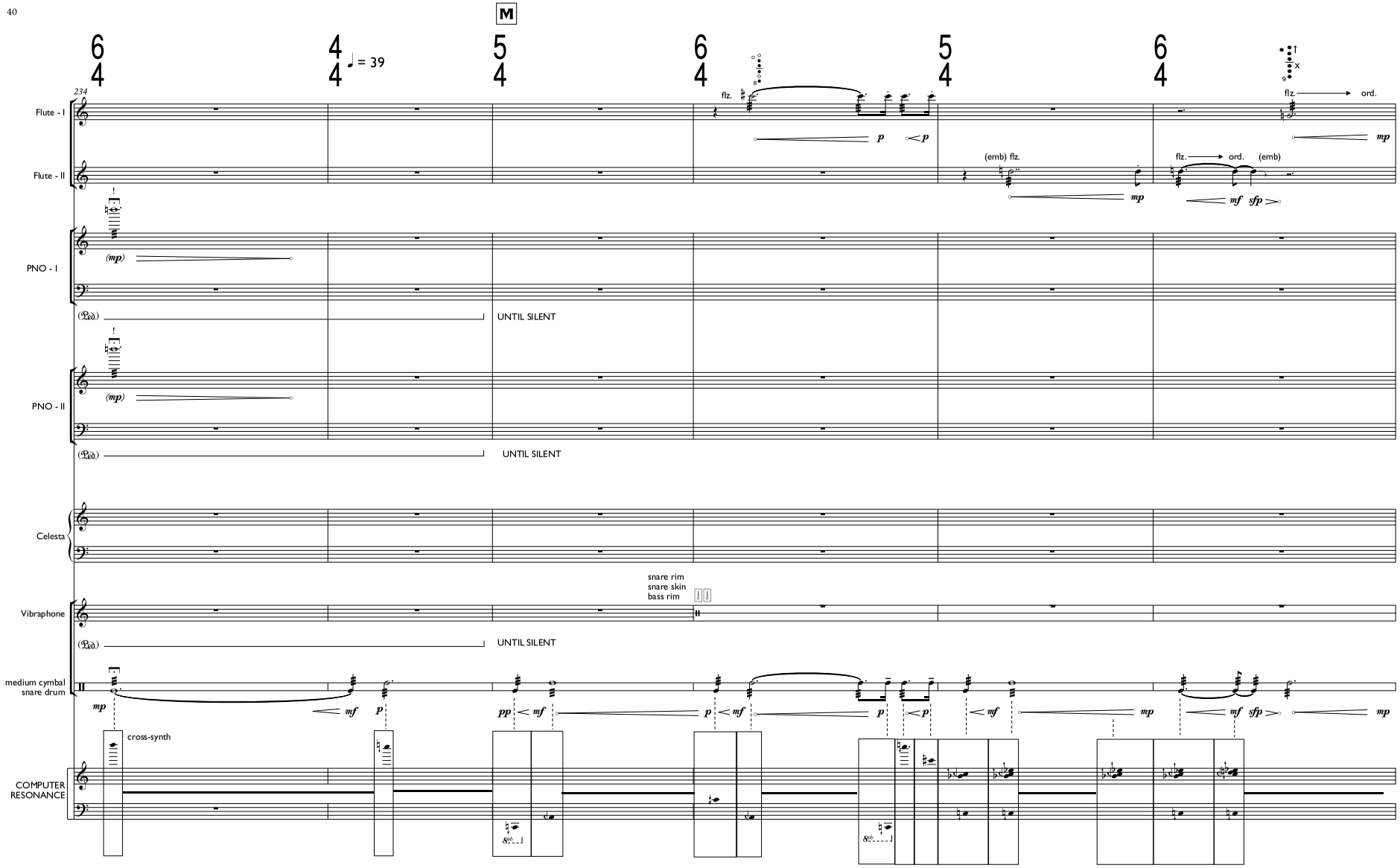
medium cymbal
snare drum

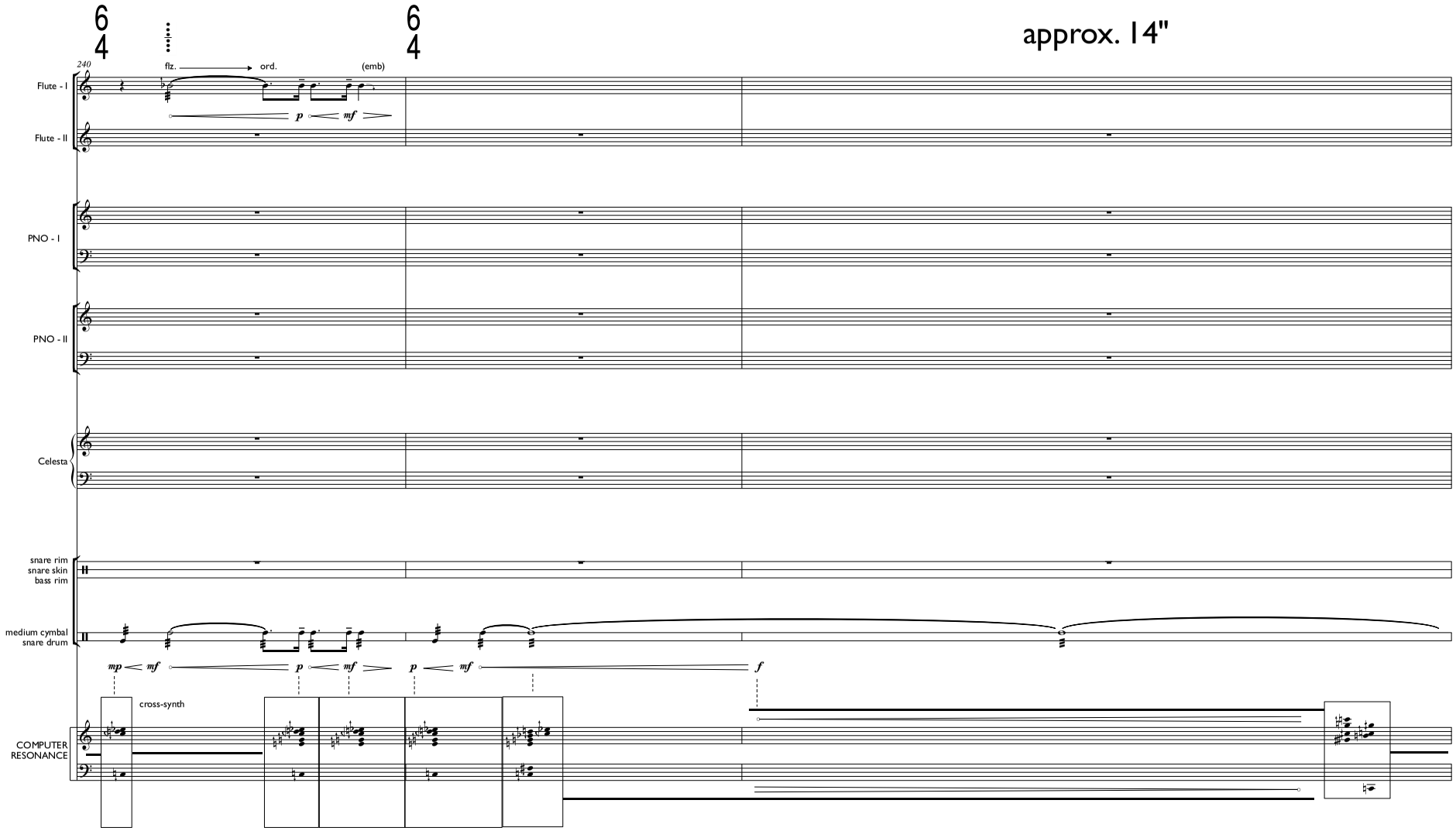

14
4
♩ = 55
13
4
214
Flute - I
Flute - II
ppp
ppp
PNO - I
slowly, softly, SMOOTHLY, quietly, gently, as though in a padded cell
PNO - II
pppp
slowly scrape lengthwise along A0 string
Celesta
Vibraphone
medium cymbal
snare drum

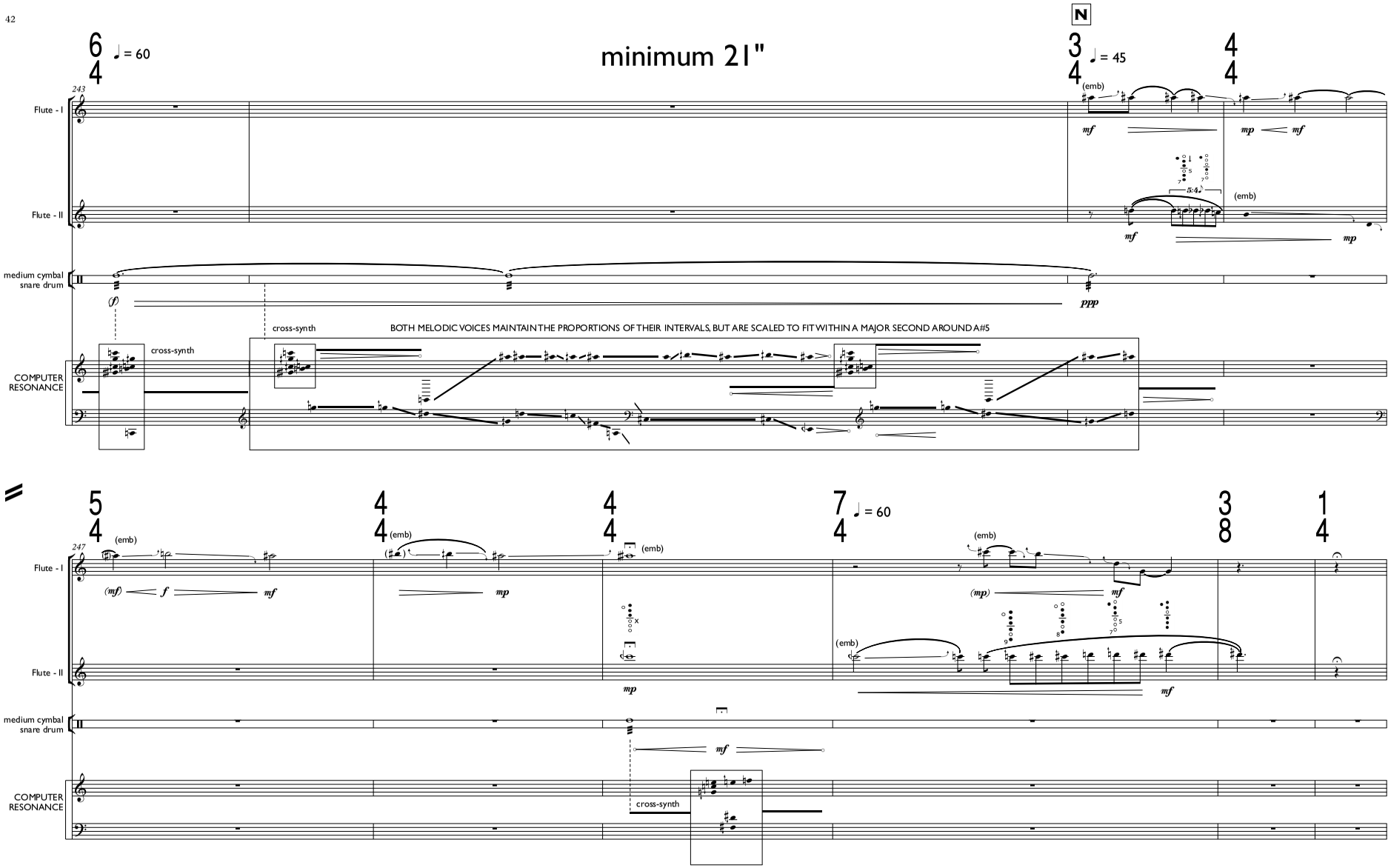

11
4
14
4
216
Flute - I
Flute - II
ppp
ppp
PNO - I
UNTIL
SILENT
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum

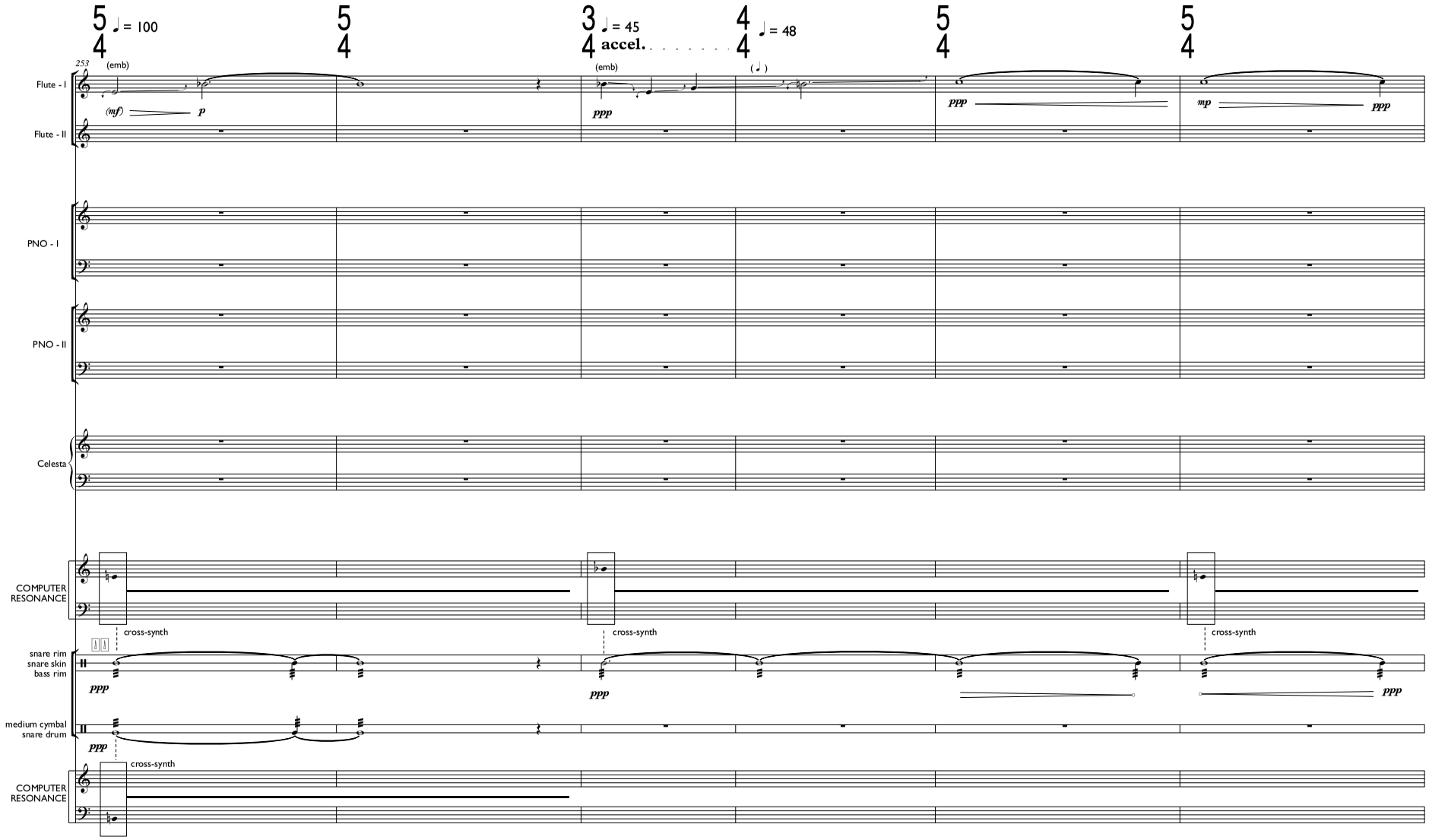

L
218
♩ = 45
(emb)
(o.h.)
rit.
♩ = 35
Flute - I
Flute - II
UNTIL SILENT
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
cross-synth
COMPUTER RESONANCE

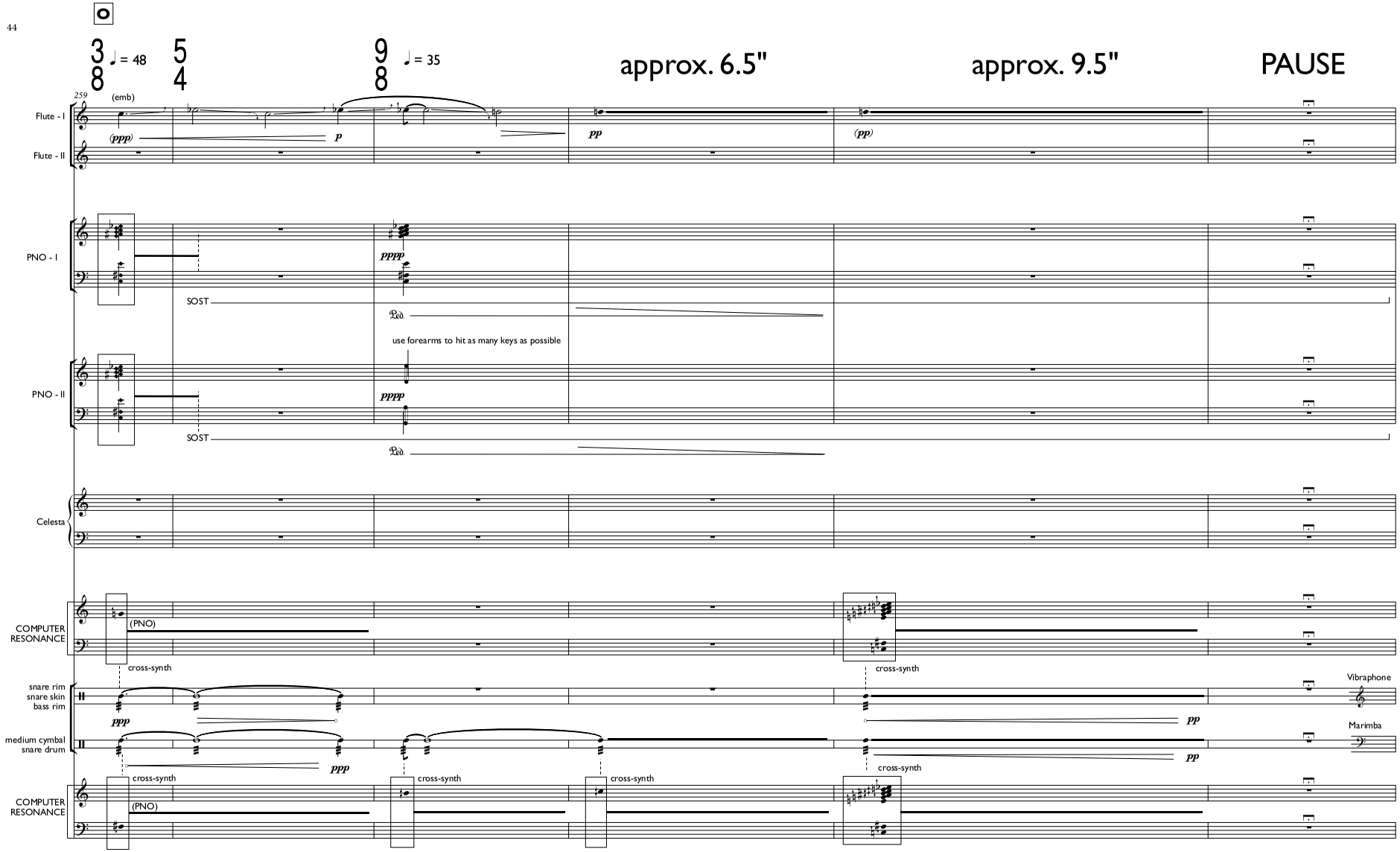

226
♩ = 60
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
COMPUTER
RESONANCE
(cross-synth)
cross-synth

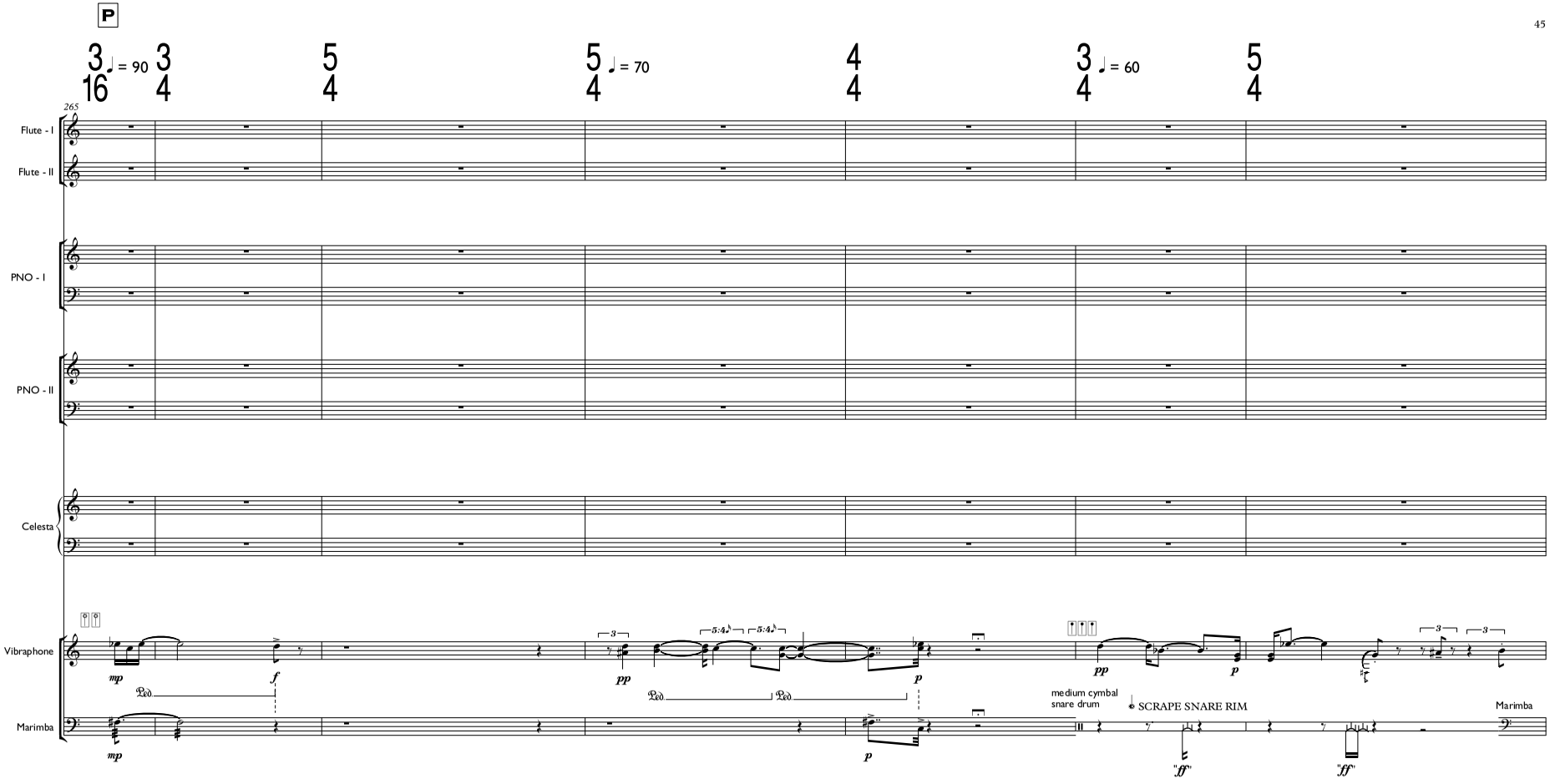

M
234
♩ = 39
Flute - I
Flute - II
flz.
ord.
(emb) flz.
(emb)
PNO - I
PNO - II
UNTIL SILENT
Celesta
Vibraphone
snare rim
snare skin
bass rim
medium cymbal
snare drum
cross-synth
COMPUTER RESONANCE

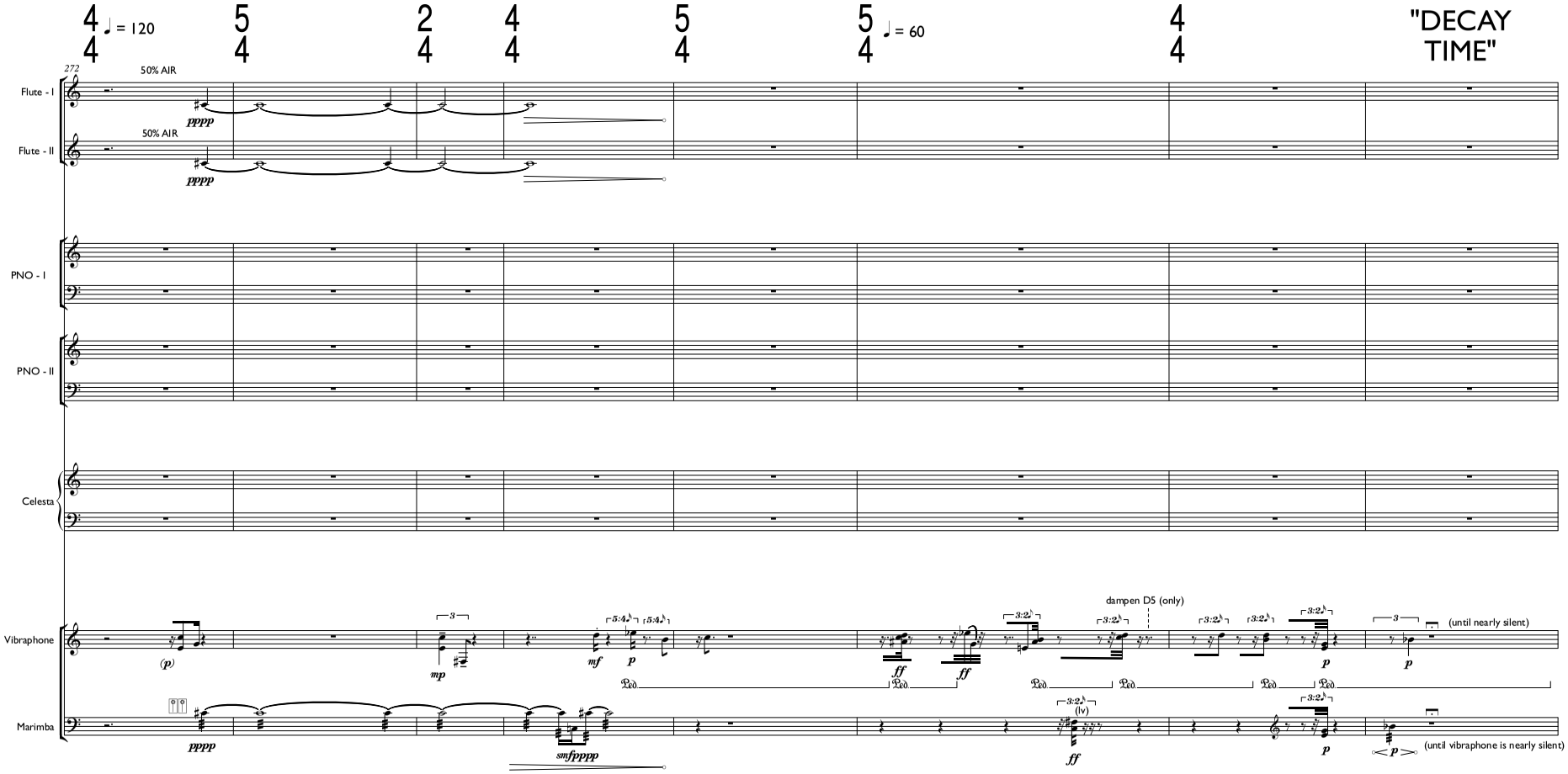

240
flz.
ord.
(emb)
approx. 14"
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
snare rim
snare skin
bass rim
medium cymbal
snare drum
cross-synth
COMPUTER
RESONANCE

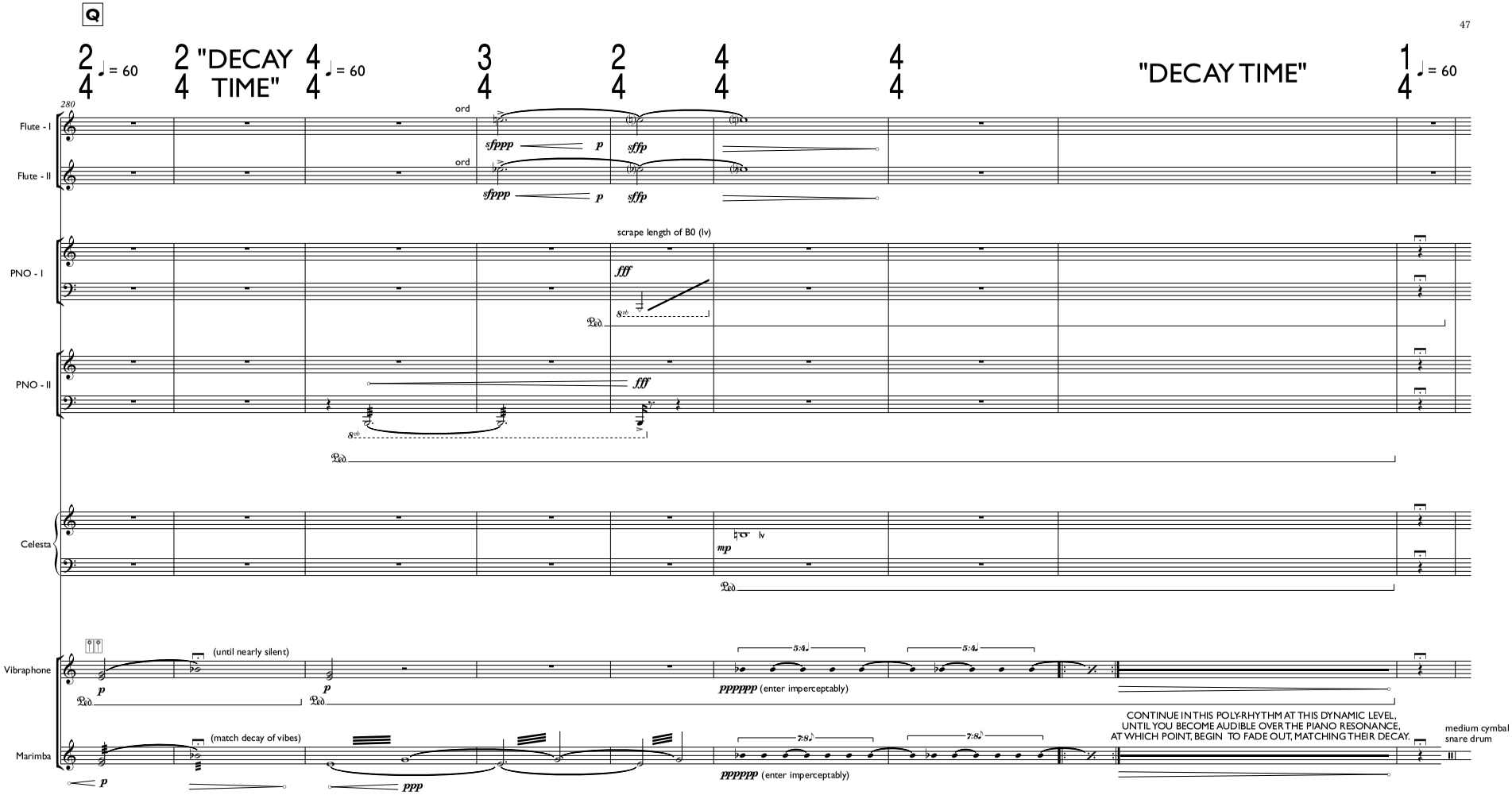

N
minimum 21"
♩ = 60
♩ = 45
♩ = 60
243
247
Flute - I
Flute - II
medium cymbal
snare drum
COMPUTER
RESONANCE
(emb)
mf
mp
ppp
(f)
(mf)
f
(mp)
5:4
cross-synth
BOTH MELODIC VOICES MAINTAIN THE PROPORTIONS OF THEIR INTERVALS, BUT ARE SCALED TO FIT WITHIN A MAJOR SECOND AROUND A#5


253
♩ = 100
♩ = 45
accel.
♩ = 48
(emb)
(emb)
(♩)
Flute - I
Flute - II
(mf)
p
ppp
ppp
mp
ppp
PNO - I
PNO - II
Celesta
COMPUTER RESONANCE
cross-synth
cross-synth
cross-synth
snare rim
snare skin
bass rim
ppp
ppp
ppp
medium cymbal
snare drum
ppp
cross-synth
COMPUTER RESONANCE


3/8 ♩ = 48
5/4
9/8 ♩ = 35
approx. 6.5"
approx. 9.5"
PAUSE
259
(emb)
Flute - I
Flute - II
(ppp)
p
pp
(pp)
PNO - I
PNO - II
pppp
SOST
use forearms to hit as many keys as possible
Celesta
COMPUTER RESONANCE
(PNO)
cross-synth
snare rim
snare skin
bass rim
medium cymbal
snare drum
ppp
Vibraphone
Marimba


P
265
♩ = 90
♩ = 70
♩ = 60
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
Marimba
mp
f
pp
p
medium cymbal
snare drum
SCRAPE SNARE RIM
ff
Marimba


♩ = 120
♩ = 60
"DECAY TIME"
272
Flute - I
Flute - II
50% AIR
50% AIR
PNO - I
PNO - II
Celesta
Vibraphone
Marimba
dampen D5 (only)
(until nearly silent)
(lv)
(until vibraphone is nearly silent)


Q
280
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
Marimba
♩ = 60
"DECAY TIME"
ord
sfppp
p
sffp
scrape length of B0 (lv)
fff
mp
lv
(until nearly silent)
pppppp (enter imperceptably)
(match decay of vibes)
ppp
CONTINUE IN THIS POLY-RHYTHM AT THIS DYNAMIC LEVEL,
UNTIL YOU BECOME AUDIBLE OVER THE PIANO RESONANCE,
AT WHICH POINT, BEGIN TO FADE OUT, MATCHING THEIR DECAY.
medium cymbal
snare drum

4"

approx. 60"

6"

289

Flute - I

75% AIR

barely audible

etc...

Flute - II

75% AIR

barely audible

barely audible

etc...

CONDUCTOR CUTS OFF ENSEMBLE

PNO - I

Using the indicated rhythm (at continuously varied tempi between ♩ = 60 and ♩ = 130), blindly probe the harmonics of the mid-keyboard strings for pitches that are within 100 cents of the D7 (slightly flat) of the electronics. (dynamic range = *p* ⟷ *mf*)

3:2

3:2

mf

ff

mf

When a satisfactory harmonic is located, perform the indicated rhythm as quickly as possible at the outer boundaries, pausing for 5 seconds on the fermatta.

eyes on conductor when sost is ready

SOST

PNO - II

just barely audible

8va

scrape A0 string **extremely** slowly with plectrum, taking 64 seconds to reach your full arm's length.

eyes on conductor when sost is ready

SOST

Celesta

hold first note until silent, and use this duration to set pace/proportions of all following rhythmic values.

6

3

just barely audible throughout

(repeat as/if necessary)

Vibraphone

balance D on vibraphone and D (slightly flat) custom bar for both dynamics and resonance

just barely audible

Ped

eyes on conductor when ready to play marimba

medium cymbal snare drum

lv

pp

cross-synth

mp

ad lib...

COMPUTER RESONANCE

MINK SHRIEK SAMPLE

mp

ad lib...

R

292

♩ = 60

♪ = 90

Flute - I

(emb)

pp

(pp) sempre

Flute - II

come up to match fl. 1

sempre

PNO - I

use forearms to hit as many keys as possible

barely audible

(SOST)

GRADUALLY RELEASE
SUSTAIN PEDAL (ONLY)

PNO - II

Celesta

5:4

Vibraphone

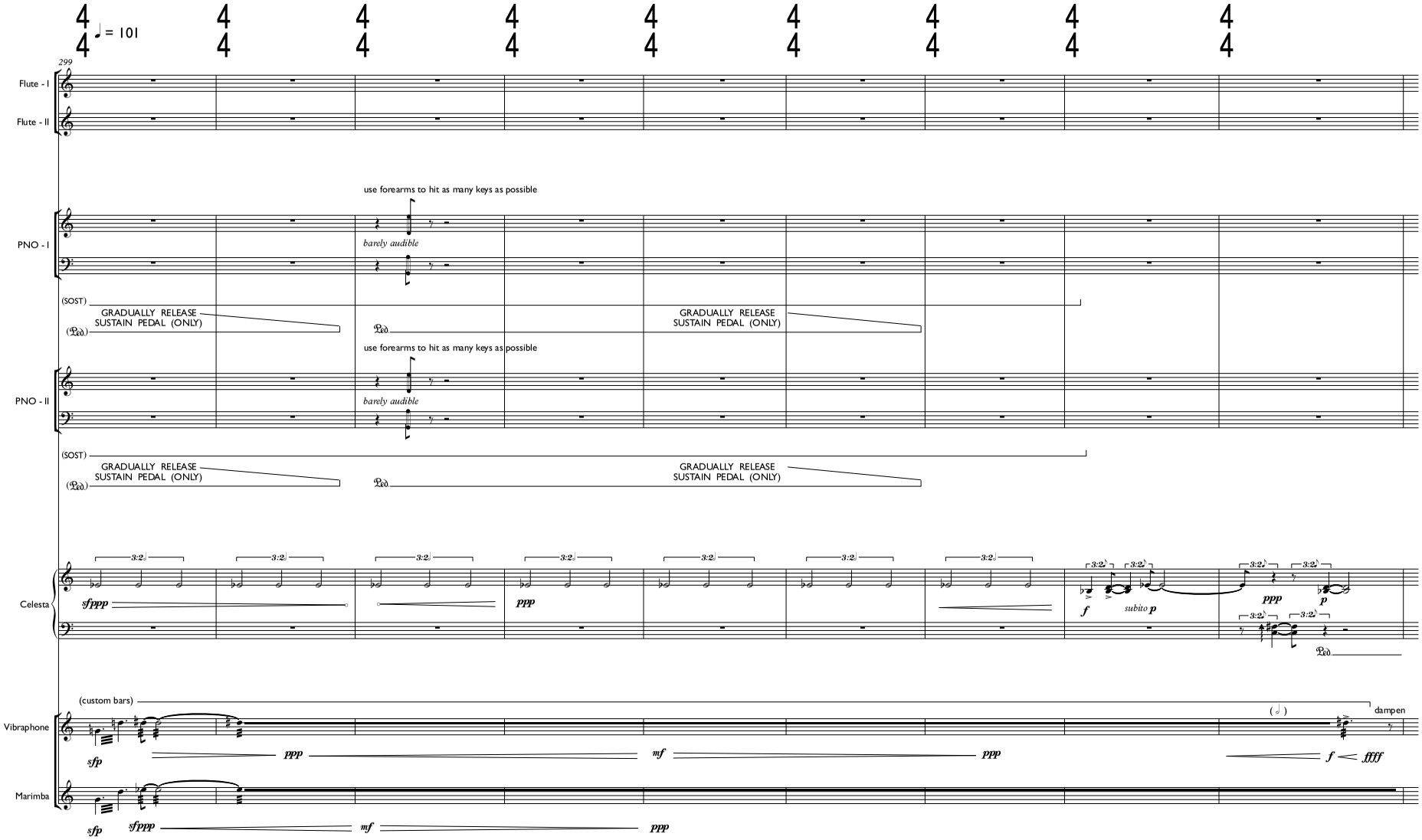
lv throughout
(custom bars)

Marimba

6:4

p

mf


♩ = 101
299
Flute - I
Flute - II
PNO - I
use forearms to hit as many keys as possible
barely audible
(SOST)
GRADUALLY RELEASE
SUSTAIN PEDAL (ONLY)
PNO - II
Celesta
sfppp
ppp
f
subito p
p
Vibraphone
(custom bars)
dampen
sfp
mf
ffff
Marimba

S

"DECAY TIME"

♩ = 101

308

Celesta

Vibraphone

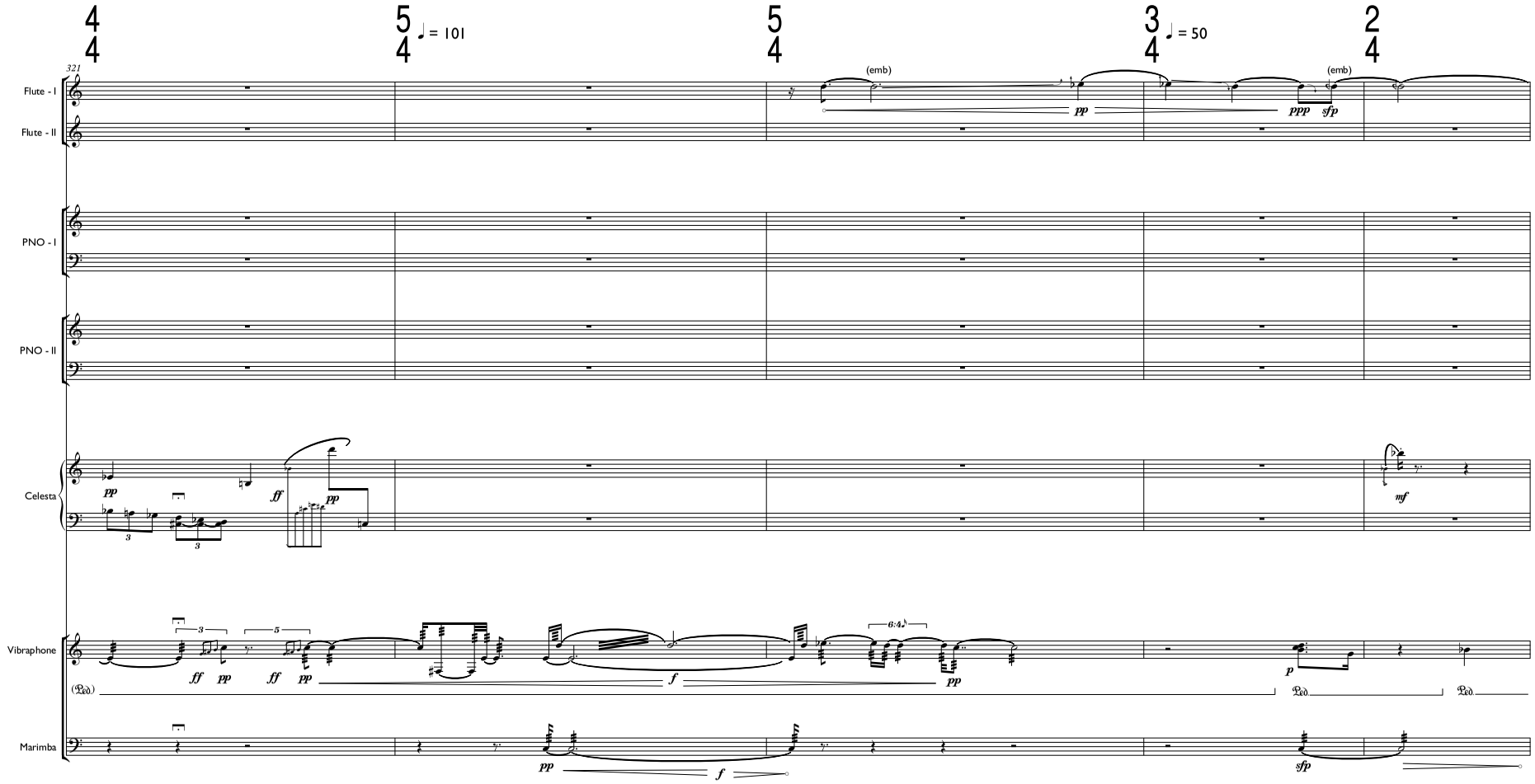
Marimba

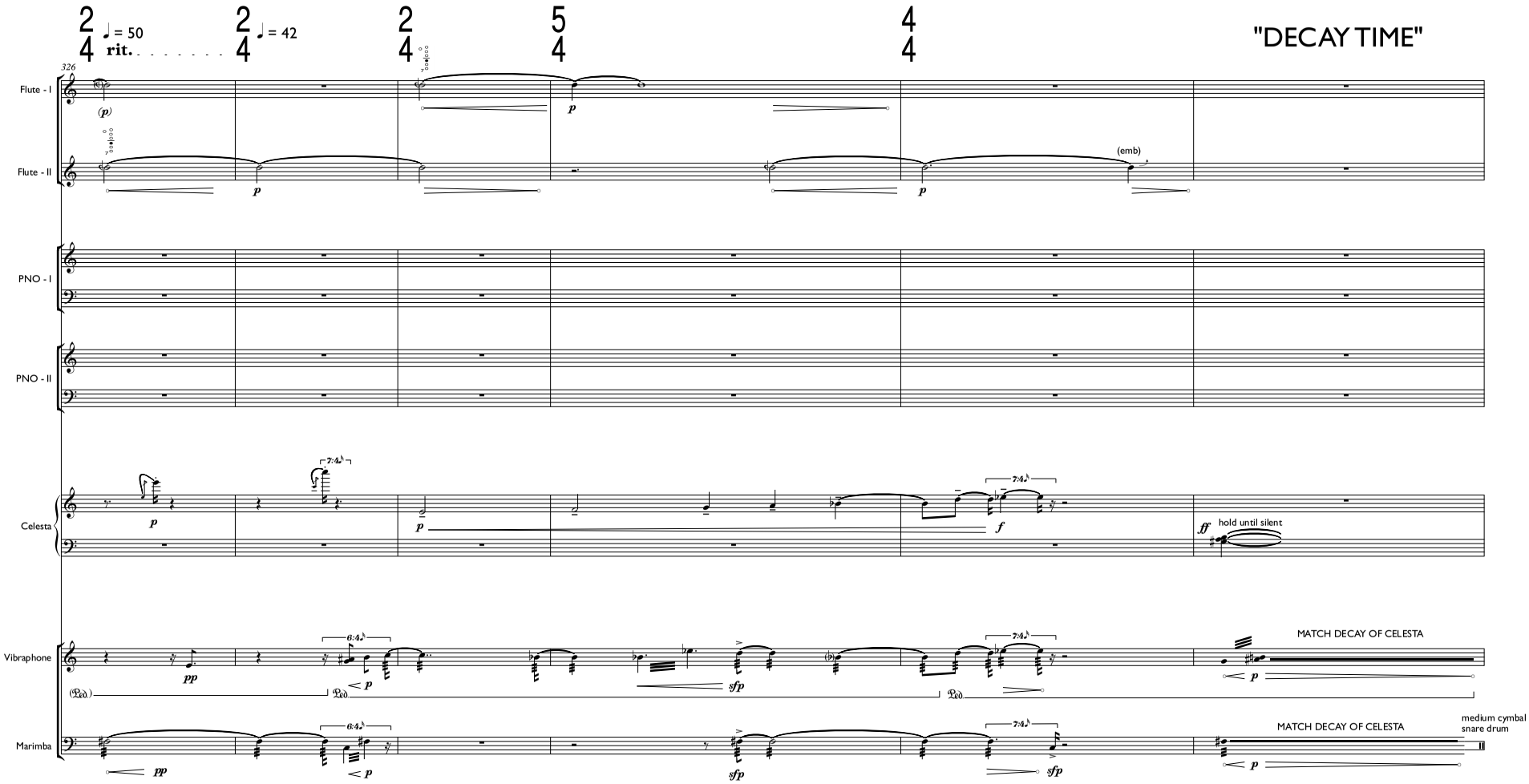
(custom bars)

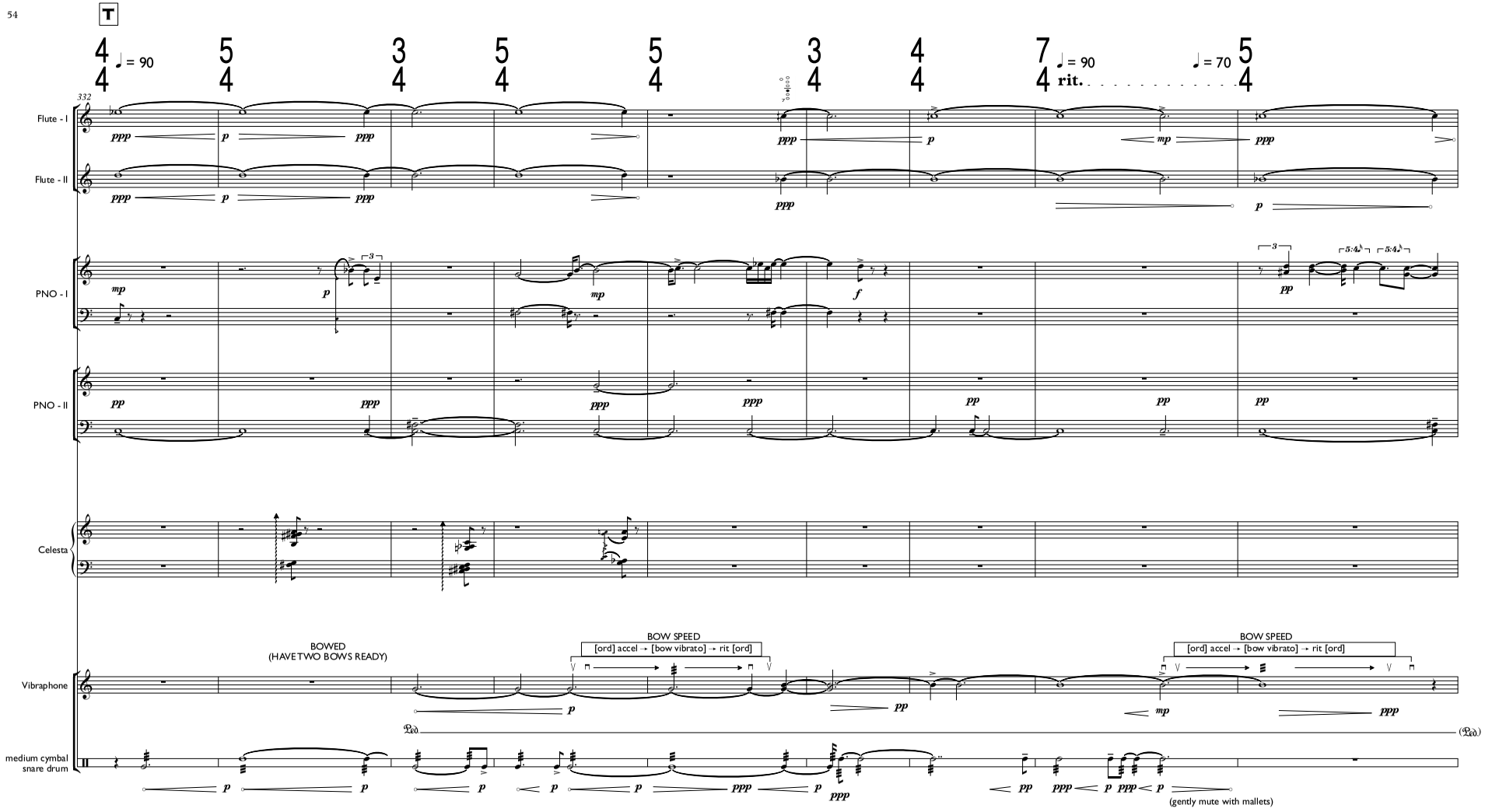
WAIT FOR DECAY OF CELESTA, THEN MOVE ON

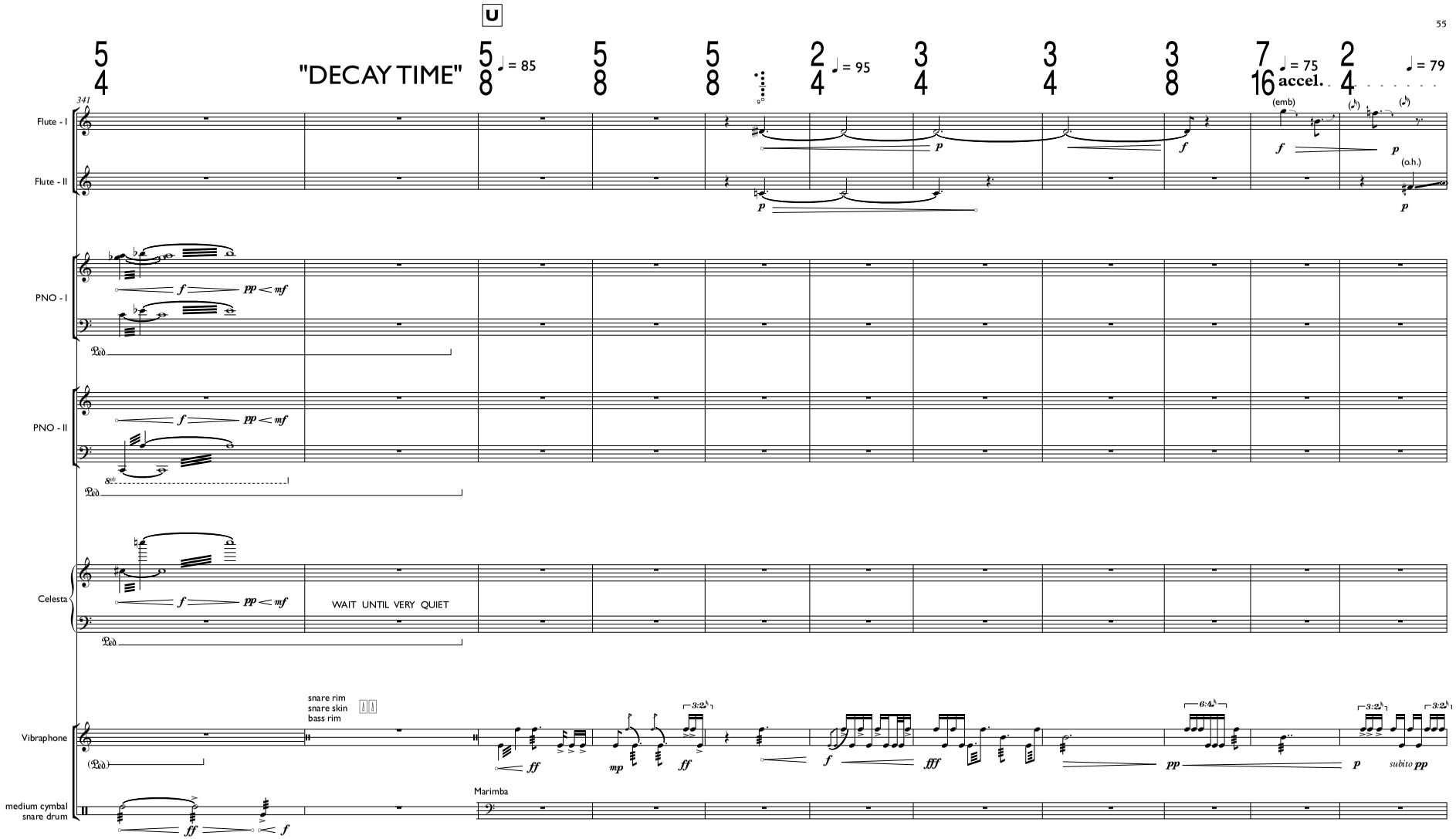
316

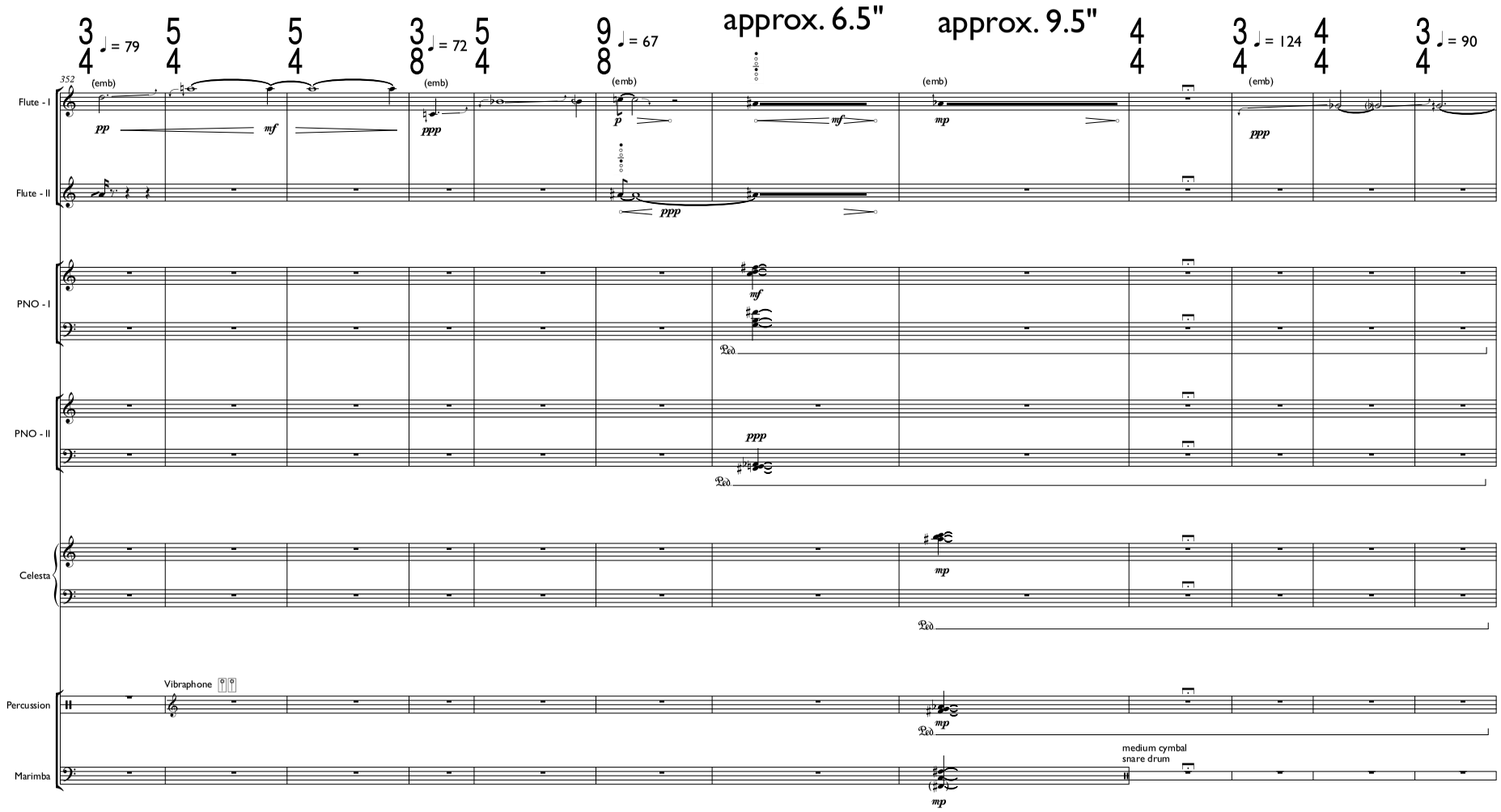
♩ = 69

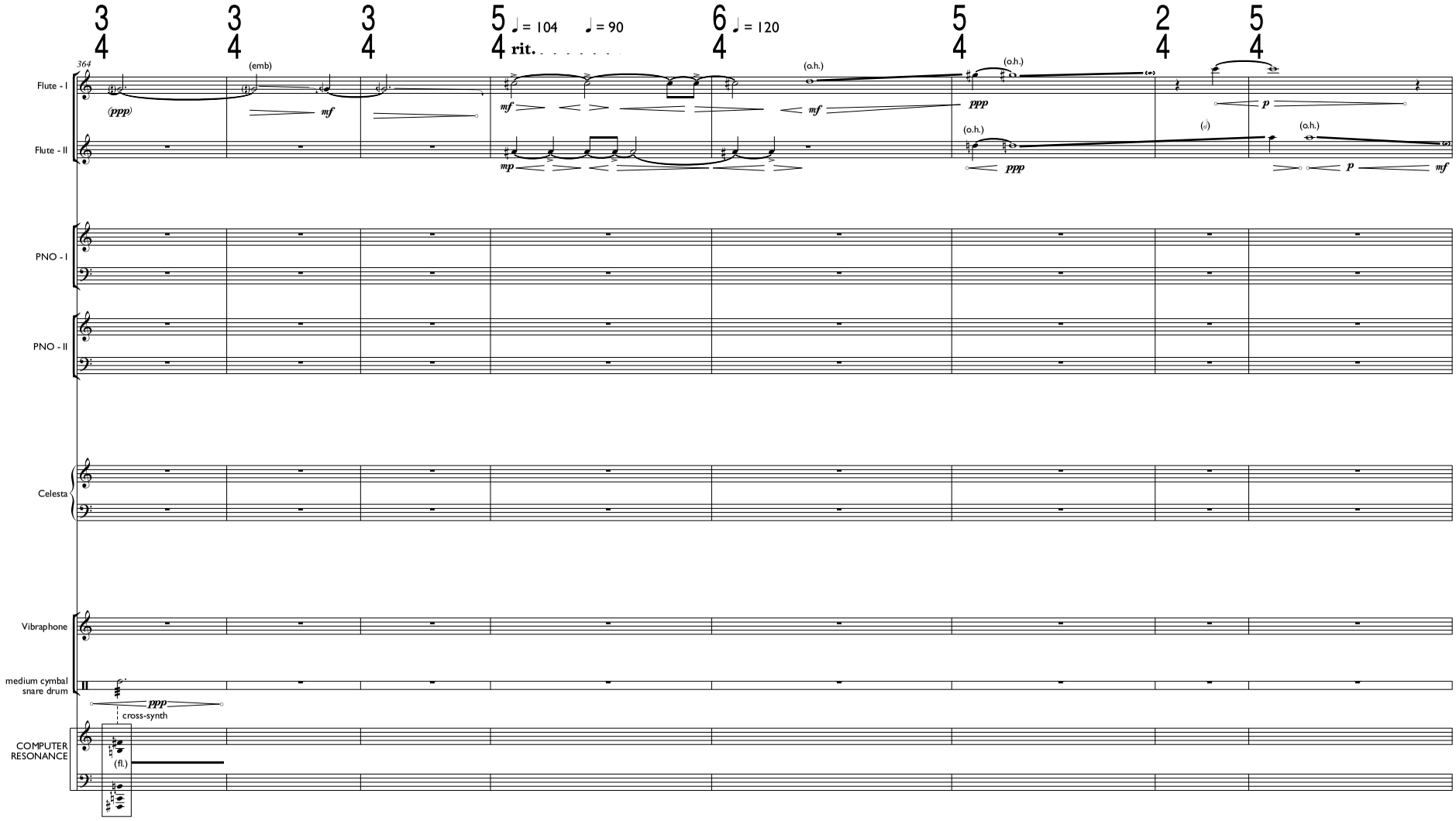

4/4
5/4 ♩ = 101
5/4
3/4 ♩ = 50
2/4
321
Flute - I
Flute - II
(emb)
pp
ppp
sfp
(emb)
PNO - I
PNO - II
Celesta
pp
ff
pp
mf
Vibraphone
ff
pp
ff
pp
f
pp
p
Marimba
pp
f
sfp

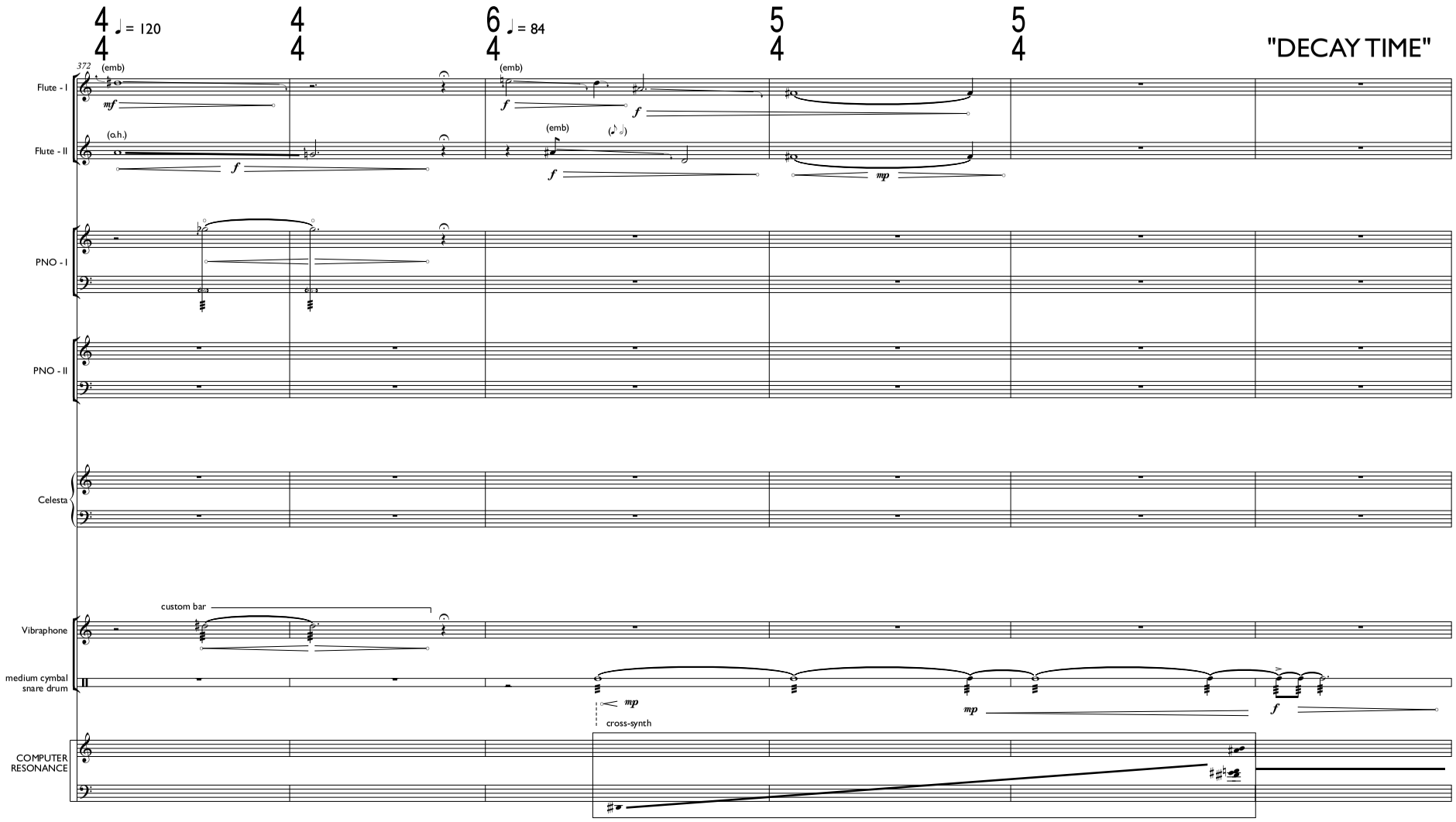

"DECAY TIME"
326
♩ = 50
rit.
♩ = 42
Flute - I
Flute - II
(emb)
PNO - I
PNO - II
Celesta
hold until silent
Vibraphone
MATCH DECAY OF CELESTA
Marimba
MATCH DECAY OF CELESTA
medium cymbal
snare drum

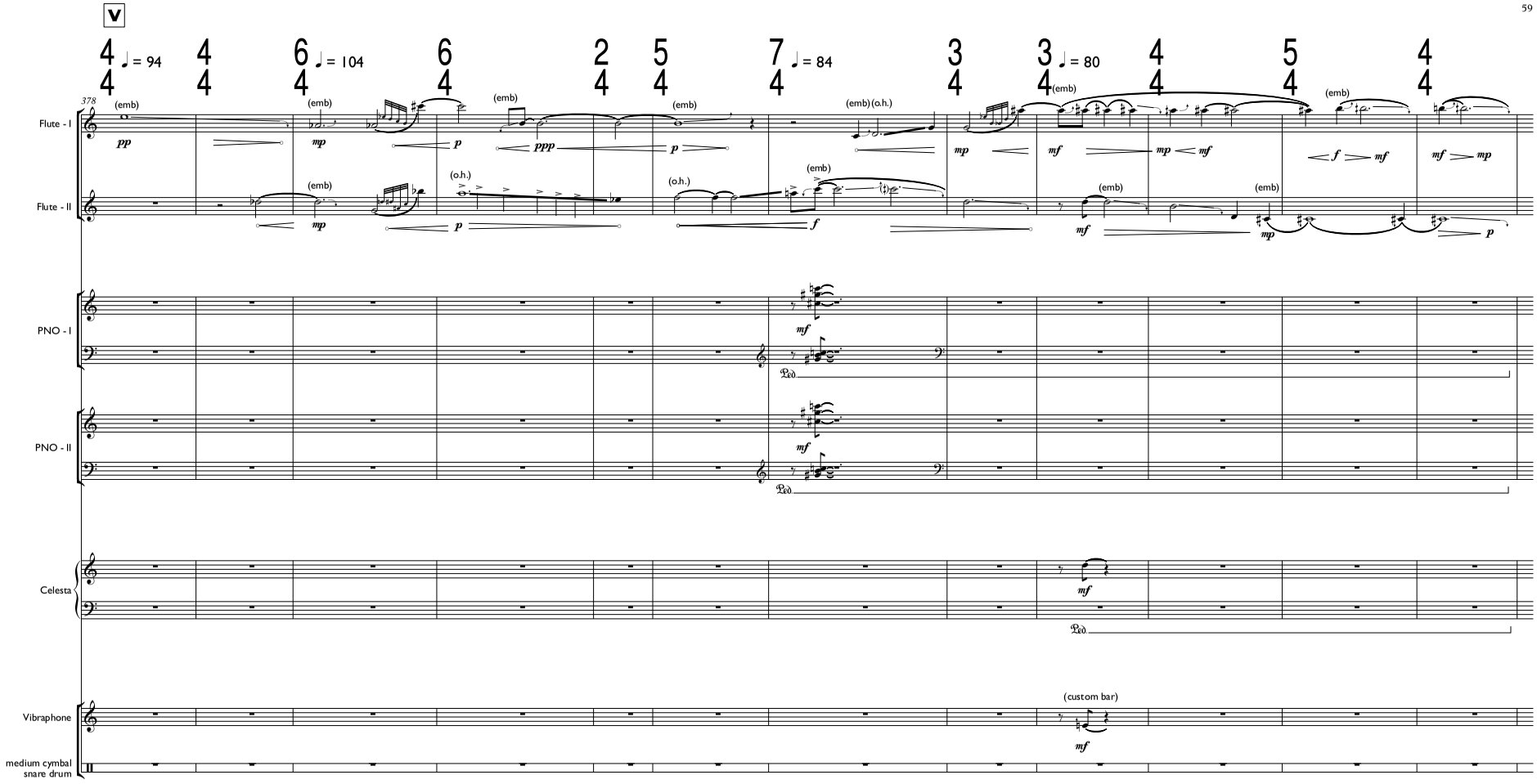

T
♩ = 90
♩ = 90
rit.
♩ = 70
332
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
BOWED
(HAVE TWO BOWS READY)
BOW SPEED
[ord] accel → [bow vibrato] → rit [ord]
BOW SPEED
[ord] accel → [bow vibrato] → rit [ord]
(gently mute with mallets)

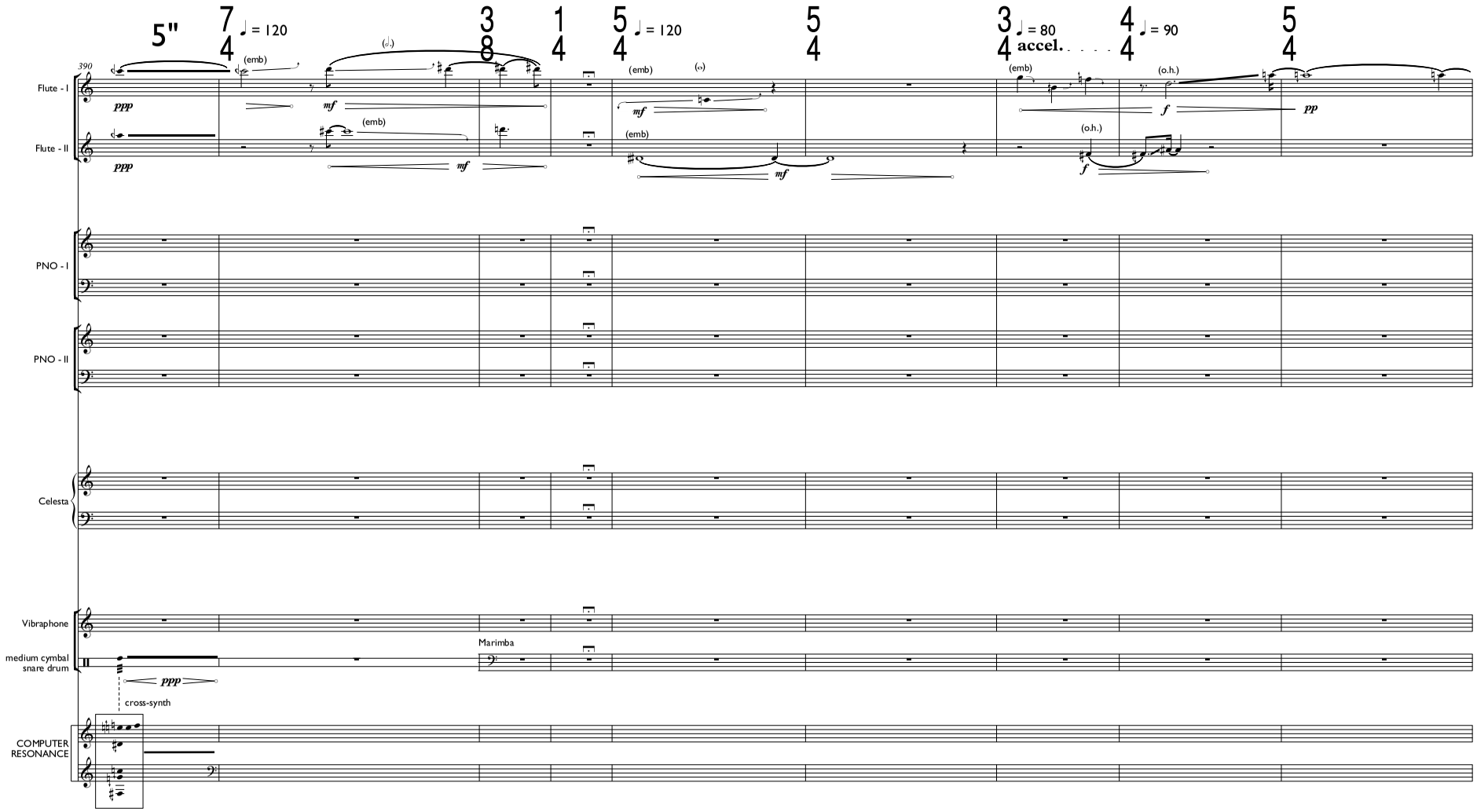

U
"DECAY TIME"
♩ = 85
♩ = 95
♩ = 75
accel.
♩ = 79
341
Flute - I
Flute - II
(emb)
(o.h.)
PNO - I
PNO - II
Celesta
WAIT UNTIL VERY QUIET
Vibraphone
snare rim
snare skin
bass rim
Marimba
medium cymbal
snare drum

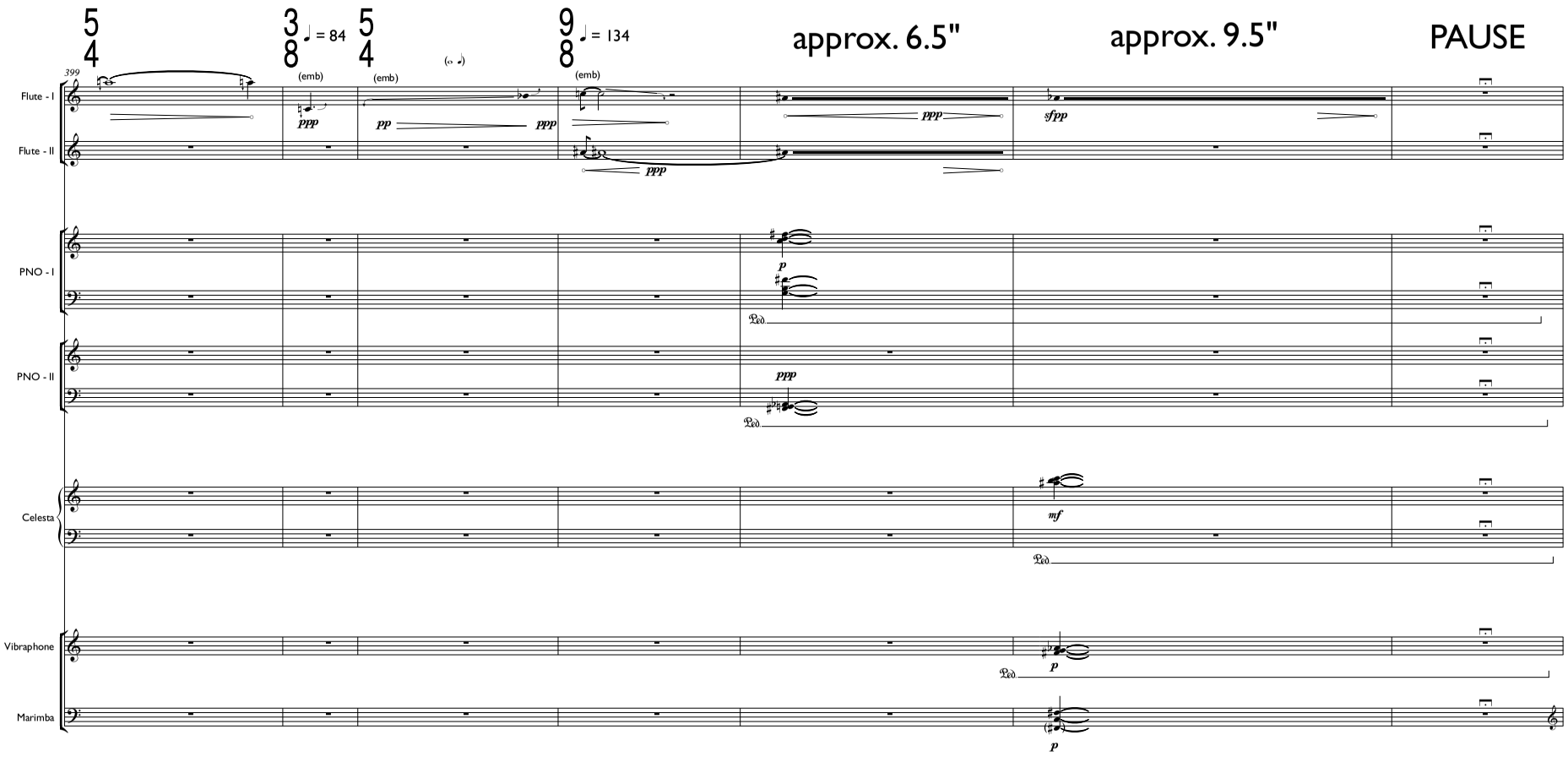

352
♩ = 79
♩ = 72
♩ = 67
approx. 6.5"
approx. 9.5"
♩ = 124
♩ = 90
(emb)
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Percussion
Marimba
Vibraphone
medium cymbal
snare drum

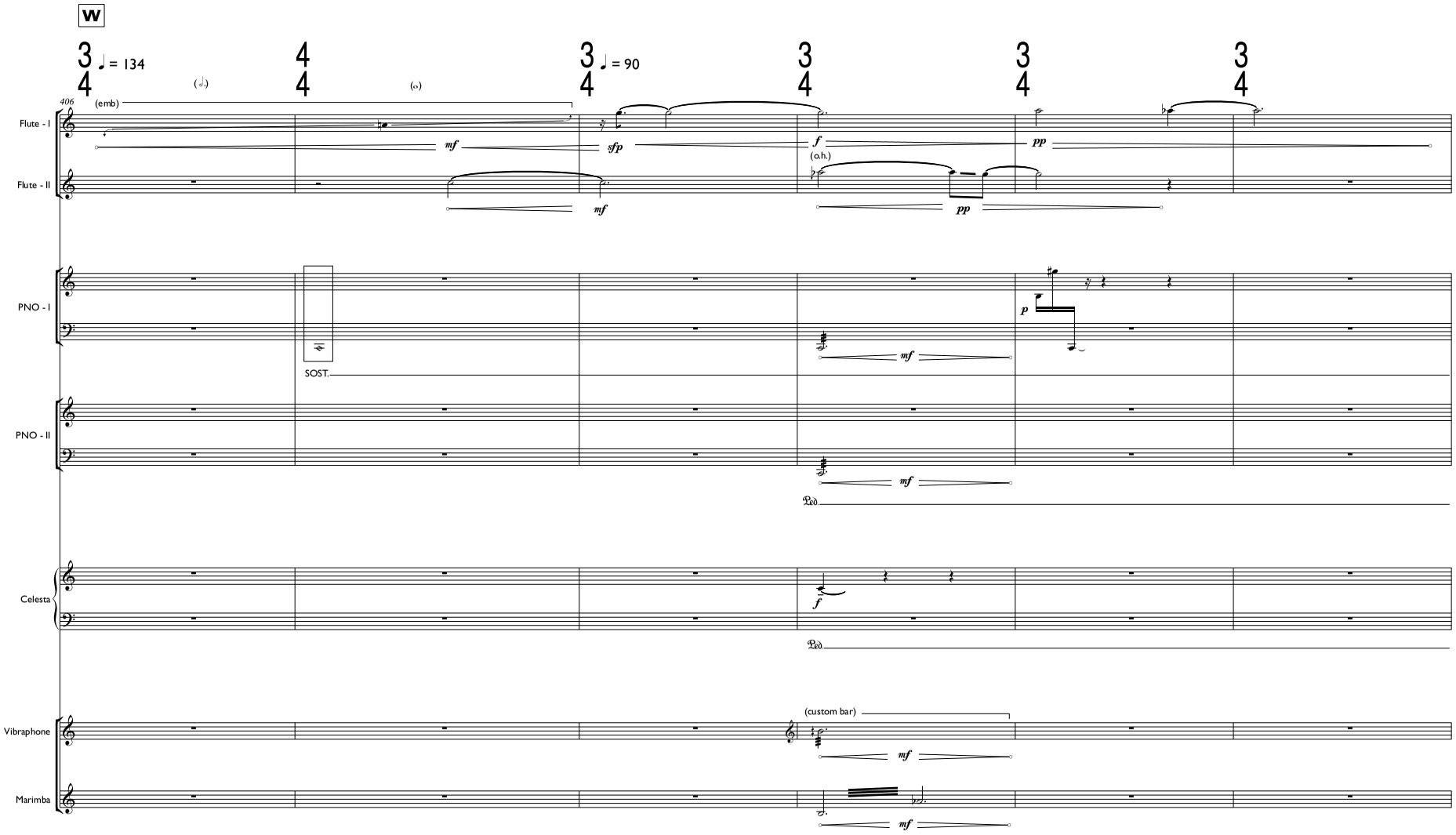

364
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
COMPUTER
RESONANCE
(ppp)
(emb)
mf
mp
rit.
♩ = 104
♩ = 90
♩ = 120
(o.h.)
ppp
p
cross-synth
(fl.)

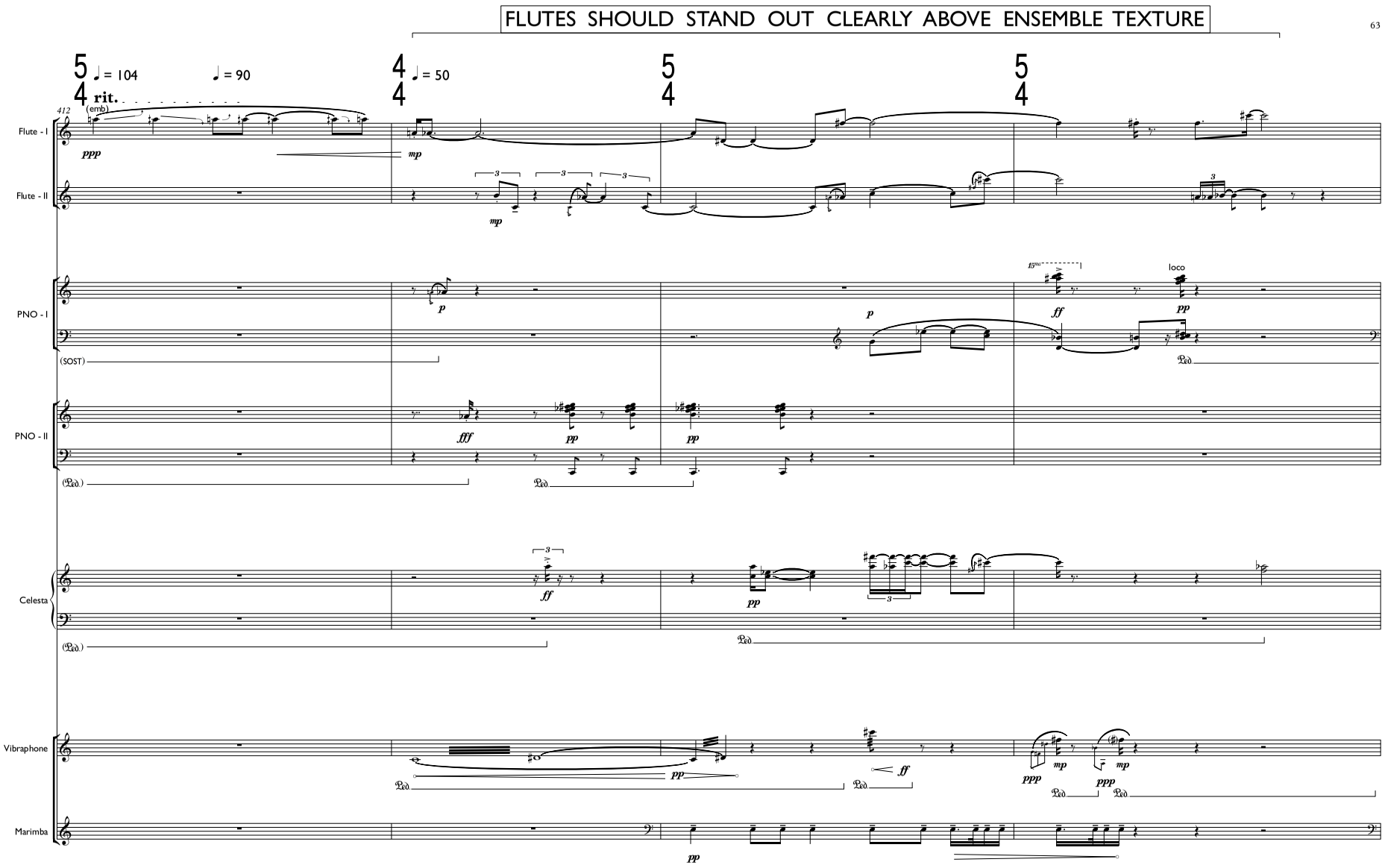

4/4 ♩ = 120
4/4
6/4 ♩ = 84
5/4
5/4
"DECAY TIME"
372
(emb)
(o.h.)
(emb)
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
custom bar
Vibraphone
medium cymbal
snare drum
cross-synth
COMPUTER
RESONANCE

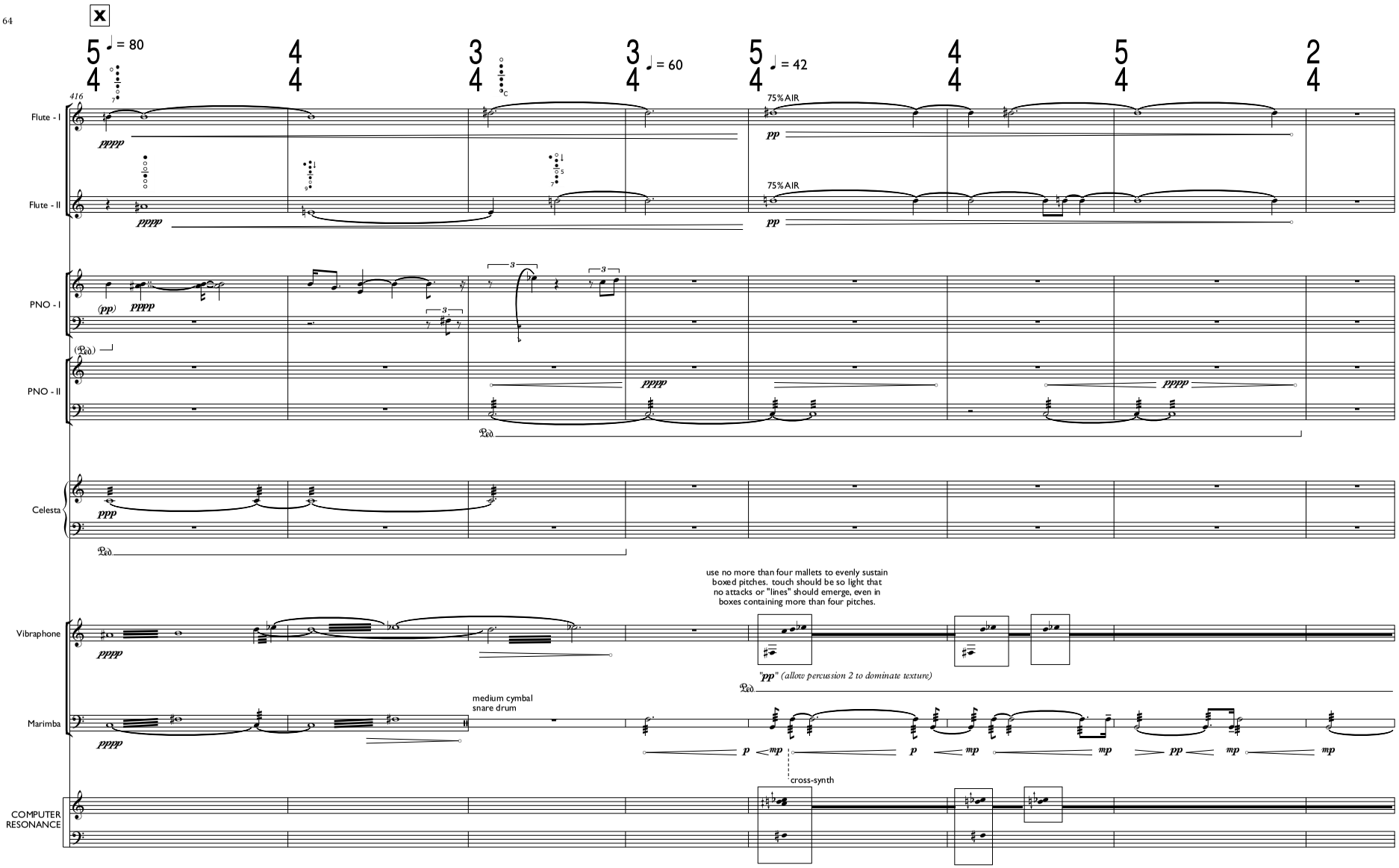

V
378
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
♩ = 94
♩ = 104
♩ = 84
♩ = 80
(emb)
(o.h.)
(emb) (o.h.)
(custom bar)
pp
mp
p
ppp
f
mf

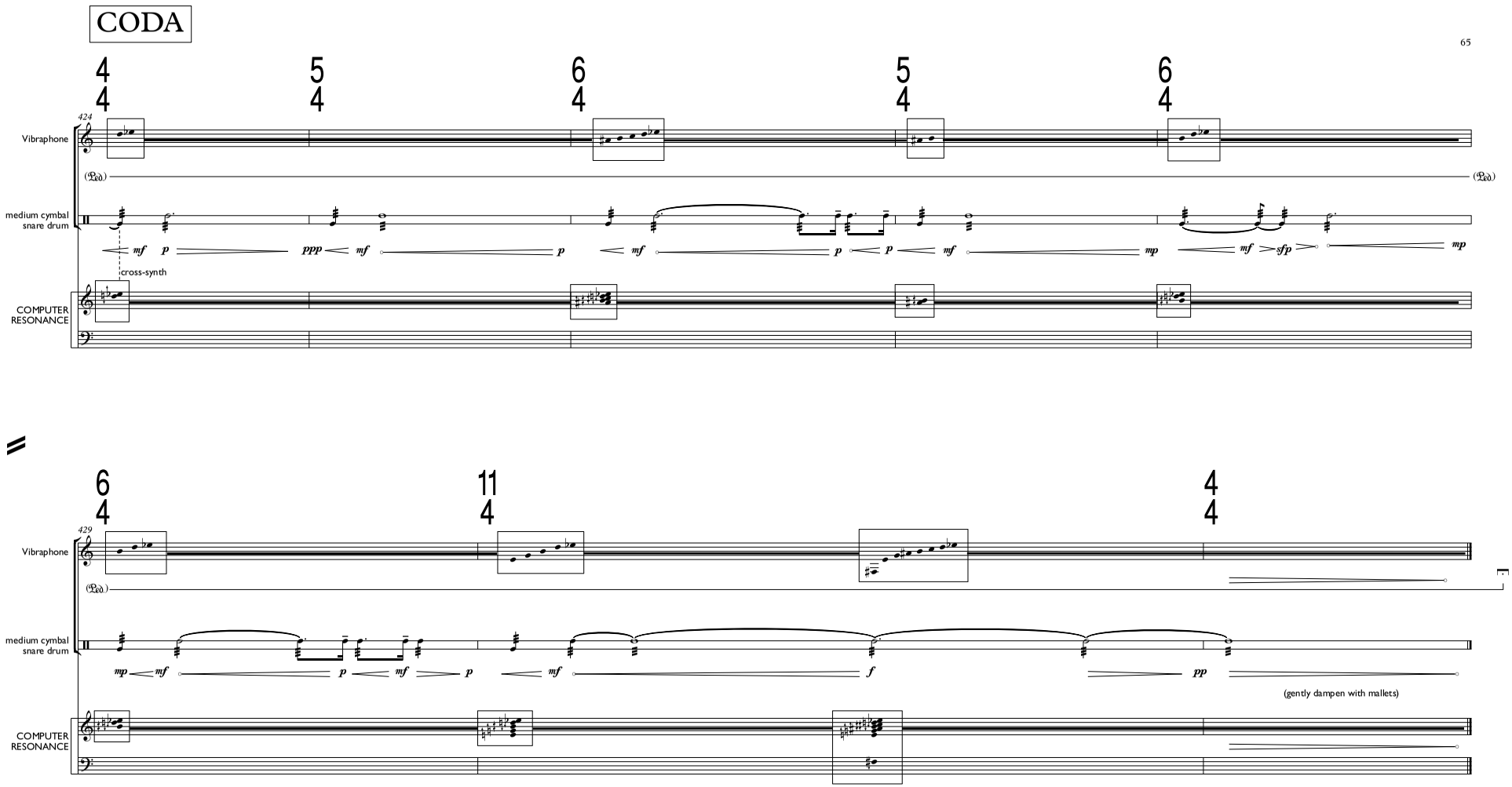

5"
7/4 ♩ = 120
3/8
1/4
5/4 ♩ = 120
5/4
3/4 ♩ = 80
accel.
4/4 ♩ = 90
5/4
390
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
medium cymbal
snare drum
Marimba
cross-synth
COMPUTER
RESONANCE
(emb)
(o.h.)
ppp
mf
f
pp


399
Flute - I
Flute - II
PNO - I
PNO - II
Celesta
Vibraphone
Marimba
♩ = 84
(emb)
♩ = 134
approx. 6.5"
approx. 9.5"
PAUSE
ppp
pp
sfpp
p
mf


W
♩ = 134
♩ = 90
406
(emb)
Flute - I
Flute - II
mf
sfp
f
pp
(o.h.)
PNO - I
PNO - II
p
SOST.
Celesta
(custom bar)
Vibraphone
Marimba


FLUTES SHOULD STAND OUT CLEARLY ABOVE ENSEMBLE TEXTURE
412
♩ = 104
♩ = 90
rit.
(emb)
♩ = 50
Flute - I
Flute - II
PNO - I
(SOST)
PNO - II
Celesta
Vibraphone
Marimba
loco


X
♩ = 80
♩ = 60
♩ = 42
416
Flute - I
Flute - II
75% AIR
PNO - I
PNO - II
Celesta
Vibraphone
Marimba
COMPUTER RESONANCE
use no more than four mallets to evenly sustain boxed pitches. touch should be so light that no attacks or "lines" should emerge, even in boxes containing more than four pitches.
"pp" (allow percussion 2 to dominate texture)
medium cymbal
snare drum
cross-synth


CODA
424
Vibraphone
medium cymbal
snare drum
COMPUTER
RESONANCE
cross-synth
429
(gently dampen with mallets)