Conducting space: An analysis-based approach to spatial sound design in contemporary chamber music performance

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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Abstract

Contemporary chamber music performance practice is often a hybrid that has evolved from the merging of acoustic instrumental performance practice and spatialized, loudspeaker-based acousmatic performance practice. As this hybrid practice continues to evolve, the development of interpretation strategies for performed spatialization based on score analysis can facilitate spatialization design that will clarify the articulation of complex musical structures. This study outlines the development of a spatial performance practice from the perspective of sound designer and audio engineer with the ELISION Ensemble. A framework for the development of this practice is presented through the consideration of a personal perspective on the role of spatiality in the communication of sonic information, examined in the light of published research in auditory communication and both instrumental and acousmatic music performance practice.

Selected spatial performances from ELISION's history are outlined that mark significant aspects of the development of the ensemble's practice. A series of spatial performances undertaken over the course of this research are described that explore the use of a software spatialization system as a tool for spatial performance design for ELISION. A series of spatialization workshops with ELISION performers is described that was conducted with a view to engaging instrumentalists in articulating the spatiality of their performance and enhance the expressiveness of spatialization as an integrated performance parameter. Finally, an analysis-based spatial performance interpretation of a large-scale contemporary chamber work (Richard Barrett's *CONSTRUCTION*) is presented with accompanying spatially rendered audio examples.

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Introduction

This study forms part of a broader research project, *The Spatial Ensemble: Scaling Instrumental Resonance and Morphology for Spatialised Performance*[1], a partnership between ELISION Ensemble and the Spatial Information Architecture Laboratory (SIAL) at RMIT University, supported under Australian Research Council's *Linkage Projects* funding scheme. Chief Investigators for the project were Professor David Forrest and Associate Professor Lawrence Harvey, and Partner Investigators were ELISION Artistic Director Daryl Buckley and composer Richard Barrett.

This study investigates the development of a spatial performance practice for amplified contemporary chamber music from the perspective of the sound designer and audio engineer. I have performed this role with ELISION for twenty-two years, and have over this period been a primary contributor to the ensemble's developed, ongoing and continually evolving spatial performance practice. ELISION is a contemporary chamber music ensemble of varying size and instrumentation that through close collaboration with composers and practitioners in other art forms seeks to engage and challenge audiences through diversity in performance practice.

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[1] This project will be referred to in this exegesis by the abbreviated title *The Spatial Ensemble*, italicized as shown.

The Spatial Ensemble has afforded ELISION the opportunity to reflect on the current state of our spatial performance practice, the development path that has led us here, and how we might look to develop our practice in the future. From the perspective of sound designer and audio engineer, this gives rise to the following research questions –

1. What factors have contributed to the evolution of ELISION's current spatial performance practice?

2. How might this practice be developed in the future?

3. Are there aspects of my spatial sound design process that might be usefully documented as a point of reference for further research?

These questions will be considered in the light of two fundamental principles that are of paramount importance in my approach to performance sound design, and consequently inform every aspect of the design process –

1. Communication of compositional form and detail to the audience.

2. The relationship of the music to the performance environment.

These generalized principles relating to amplified chamber music performance, while not themselves the subject of this study, provide the broader performance practice framework within which the spatialization practice being investigated is situated, and of which it is but one aspect. The following chapters outline the development of ELISION's spatial performance practice, describe development work that has taken place over the course of the study and present an analysis-based score interpretation process for spatial performance sound design that I have refined over the course of this study.

Chapter One provides a personal perspective on aspects of sound and sonic communication that are of significance to this study in that they have informed the spatial sound design practice I have developed, and subsequently realized in ELISION's spatial performances since joining the ensemble in 1990. This chapter also surveys studies of spatiality in music, and identifies examples of spatial performance practice that have contributed to the musicological context in which my performance practice with ELISION has developed, and/or have influenced my approach to spatial sound design.

Chapter Two identifies ELISION performances that exemplify the ensemble's spatial practice and the approaches and methodologies developed and employed therein. The diversity of ELISION's spatial performance projects has necessitated varied approaches to spatial sound design, with a range of strategies employed for different works in different contexts. Five performance case studies are outlined and the features that make them significant in the development of ELISION's spatial performance practice identified.

The research partnership with SIAL Sound Studios brought with it the opportunity to employ the SIAL Sound Spatialization Software System in ELISION spatial performances. Chapter 3 describes the spatial sound design and implementation for a series of four spatialized performances of the Richard Barrett work *codex IX* that were undertaken between 2008 and 2010 and employed the SIAL software spatialization system in performance. The performances took place in a variety of contexts, requiring adaptation of the audio system design and performance control methodologies for each instance. Following on from the *codex IX* performance series, the November 2011 premiere performance of Barrett's *CONSTRUCTION* is described as the culmination of the performance development thread of *The Spatial Ensemble* project.

A parallel research stream resulting from ELISION instrumentalists' perceived lack of engagement with the software-controlled spatialization process was also undertaken, and Chapter 4 describes spatialization workshops conducted with performers to explore a possible technique for engaging instrumentalists more directly in the realization of spatialized performance.

Chapter 5 provides a description of an analysis-based interpretation methodology for Richard Barrett's *CONSTRUCTION* from the perspective of spatial sound design, and example spatial renderings from the work based on this analysis are presented, generated from the 2011 premiere concert recording.

Chapter One: Background

1.1 Experiencing Sound

As a small child, lacking sufficient vocabulary to identify even the most everyday of items, I asked my father what he was going to do with the *gik-gok*. Uncertain how to respond, my father contemplated the hammer he held in his hand and found himself gradually becoming aware of the distant sound of nails being driven rhythmically into the hardwood framing timber that was commonly used in the construction of houses in suburban Australia in the 1960s. The suburb was growing rapidly, and the sound of hammering a constant feature of the soundscape in daylight hours. With the suburb expanding in all directions, the hammering came from all sides and varied distances. Sitting on a swing in the backyard, I was frequently immersed in a 360-degree field of percussive interplay, as random as it was predictable and as unintended as it was purposeful.

I clearly recall how each hammer could be identified from all others purely by the sound, and the various sonic cues that made this possible. Direction would give the first clue – even two framers working on adjacent houses some distance away could be heard to be different in location. With a multitude of hammers in all directions it was easy to differentiate between them by virtue of their angular distribution.

Also discernable was the distance from which the sound of each hammer was coming. If two hammers could not be separated by angle, one was almost always clearly further away than the other. Not quite as loud, but not because the nail was being struck with less force (you could tell). Different in timbre as well – not quite so sharp a sound. No ambiguity as to what the sound *was*, just a slightly different version of it when it was further away. And there was something else, a bit harder to define for a child, but you just *knew* it helped tell you from how far away the sound was coming. A slight incoherence to the sound, like a dozen smaller hammers rather than one full-sized one. You couldn't localize it *quite* so precisely, almost like it was coming from more than one place at a time.

There is a rhythm to hammering, the time it takes to swing the hammer back and strike again. If you get the rhythm right, the mass and momentum of the hammer does a lot of the work and less effort is required to drive the nail. As a child, knowing nothing of the physics, you learned the rhythm. You knew when the next strike was due, from which hammer, from which direction and from what distance. You quickly learned each framer's tempo – they are not all the same, but each mostly constant. Occasionally two would start together and you would hear them drift apart. Other times they would begin apart you would hear them coming into unison.

There was a phrase structure that was also quickly learned. Each nail takes a finite number of hammer strikes to drive in. Not always the same, but within a range. Perhaps five or six strikes, each differing slightly in tone as the nail was driven deeper, with the final strike clearly distinguishable as the hammer struck timber as the nail was driven home. You knew when the last strike was coming, mostly. Sometimes there was ambiguity. You could hear it was close, the next strike would be the last. But wait. Not quite. There would be one more. That's it. Pause to prepare the next nail, next phrase begins. The phrase structure was critical in the comprehension of the soundscape. Striking a nail makes a sound, distinctive enough to be recognizable if you understand the causality, but somewhat meaningless in isolation. When a sequence of strikes clearly indicates the driving in of a nail, the purpose becomes understood, and each strike gains its own significance in the broader context. One was not surrounded by people *hitting* things, one was surrounded by people *making* things, and it was the structure of the nail-phrase that made this clear.

Amid the complex cacophony of hammering from all directions, each nail-phrase could be clearly differentiated. The variables that gave each framer their sonic identity (direction, distance, tempo, timbre) became constants within each phrase, perceptually linking successive strikes together as the phrase unfolded. Between phrases, even from the same framer, there was also variation. The pitch of each phrase would vary dependent on the length of the timbers being nailed, and how each connected to the evolving frame. Longer pieces of timber resonated at a lower frequency (gok), shorter pieces at a higher frequency (gik). Patterns would emerge from each framer as their work progressed. A new length of timber would be introduced, identified by its low pitch, and a sequence of phrases would follow, each ascending in pitch as the timber was nailed to successive cross-members, shortening its resonating length.

The auditory cues that made it possible to comprehend the spatial displacement of framers significantly contributed to the comprehension of the formal structure of the contribution of each framer to the soundscape. This comprehension in turn informed the way the resultant cacophony was heard and could be interpreted. On one level, focusing on a time window shorter than a nail-phrase, one could hear each hammer strike as an isolated event and the resultant soundscape as a pointillistic field of spatialized percussion. Expanding the focal timeframe resulted in the nail-phrase becoming the unit of perceptual significance rather than the individual strikes, and the web of rhythmic and timbral interactions amongst the ensemble of framers gave shape and a degree of predictability to the temporal evolution of the texture. Further expansion of the perceptual time window brought into focus the progression and development of the individual activity of each framer. Each framer's contribution could be comprehended as a line (or sequence of lines) rather than a series of units, resulting in the perception of the overall soundscape as a constantly shifting web of interconnecting threads, all similar yet each identifiable.

The perception and comprehension of individual threads within the texture further enabled the comprehension of relationships between particular threads. Focusing on subgroups of framers (duos, trios, quartets) allowed the intricacies of the relationships between them to be heard in detail. Drifting in and out of phase, rhythmic counterpoint, call/response patterns and the like could all be heard at different times and brought in and out of focus at will. At times such relationships would attract the listener's attention, at other times they could only be heard with concentrated listening. It was easiest in the morning, at the start of the working day. The first blows would be struck, the first nail driven. Gok, gok, gok. Soon, the second part would enter. Gik, gik, gik. Straight away, they would begin to intertwine. Gik-gok, gik-gok, gik-gok. The day would be underway.

Such is my earliest recollection of being consciously attentive to sound, and actively engaged in what Bregman later termed "auditory scene analysis" (Bregman 1990). Fundamental to the comprehension of the auditory scene is the knowledge (or assumption) that sound has a *cause*. Blesser and Salter describe it succinctly:

> All sounds are the result of dynamic action, periodic vibrations, sudden impacts, or oscillatory resonances. (Blesser and Salter 2007, p.15)

Further, they link this causality to comprehension or the search for information conveyed by sound:

> Cognitive processes, containing the individual listener's personal history, transform raw sensation into an awareness that has meaning. (Blesser and Salter 2007, p.13)

And:

> In fact, from a psychological perspective, we do not so much hear sound as perceive sonic events, with sounds transporting events into our consciousness. (Blesser and Salter 2007, p.15)

The untrained ability to sort single sonic events into functional groupings that form perceptual streams enabling comprehension of individual activities and the way they combine into a complex yet comprehensible sonic environment is something I alternately take for granted and marvel at. Bregman's work investigates the processes involved in our ability to perceptually separate the individual streams that make up complex auditory scenes. Bregman's notion of the grouping of single sounds into streams by "clustering related qualities" (Bregman 1990) describes precisely my recollection of being able to attribute sequences of activity to a particular builder by means of identifiable characteristics. Bregman could have been referring specifically to a 'nail phrase' when he wrote:

> events in the world tend to have some persistence. They do not change instantly or haphazardly. It seems likely that the auditory system, evolving as it has in such a world, has developed principles for "betting" on which parts of a sequence of sensory inputs have arisen from the same source. Such betting principles could take advantage of properties of sounds that had a reasonably high probability of indicating that the sounds had a common origin. (Bregman 1990, p.24)

The notion of probability is pertinent. In hindsight, there could never be absolute certainty about the accuracy of interpretation of my childhood sound environment in the absence of visual confirmation. On the other hand, the accumulation of probabilities amounted to compelling circumstantial evidence so long as each perceived stream maintained an internal coherence and made sense in terms of plausible causality. Having been learned, the sound of a hammer with its multitude of subtle variations was entirely self-explanatory. As for the Pythagorean *akousmatikoi* (Levin 1975), the lack of correlated visual information may in fact have heightened aural comprehension, and encouraged more concentrated listening to the sonic detail clearly audible beyond the field of vision. I have no recollection of it ever 'seeming wrong' to be able to hear things you couldn't see. Once a sound was recognized and its causality understood, or plausibly speculated, the acoustic information had a context, hence a place in the scheme of things. Curiosity was immediately sparked if a sound was not familiar, out of context, or not readily interpreted in terms of causality. Unexplained sound meant a part of the world that was not understood and the immediate response was to *attempt* to understand by seeking an elaboration of my world-view that would allow for the new event and place it in a comprehensible context.

The search for understanding through sound implies the knowledge (or at least an assumption) that sound inherently conveys information, a useful model for which is proposed by Truax in what he terms "acoustic communication" (Truax 2001). Building on R. Murray Schafer's study of environmental sound that spawned the field of "Acoustic Ecology" (Schafer 1977, Truax 1999) Truax presents an acoustic model based on *information* as an alternative to the physical sciences' model of sound as *energy* and sound propagation as *energy transmission*. The fundamental difference between the models is that Truax replaces the passive function of *hearing* (our physical, sensory response to exposure to sound energy) with the active role of *listening*, which introduces cognition into the model. In *listening*, sound is not defined by its physical characteristics, rather by how it is interpreted by the listener, a perspective that allows for and takes account of sound having *meaning* to the listener and *context* amongst other sounds and *their* meanings.

It is now clear, looking back to the childhood memory of the suburban soundscape, that the shift from "background listening" through "listening-in-readiness" for the working day to begin to "listening-in-search" (Truax 2001) for the distinctive characteristics and complex interactions of rhythmic structures enacted by the builders was only possible in a "hi-fi soundscape" (Schafer 1977) where, even amid the cacophony of hammering, subtle details could be discerned and comprehended.[2]

Rather than thinking in terms of the distinction between 'hearing' and 'listening', Gaver identifies two modes of listening. "Everyday listening" that focuses on the intrinsic nature of sonic events and what he terms "musical listening" where the focus is on patterns or relations between groupings of sonic events:

[2] Use of the term hi-fi in the context of non-natural soundscape is a variation on Schafer's usage. I use the term to illustrate the ease with which the sounds upon which listening was focused could be discerned against the sonic background.

> It is possible to listen to any sound either in terms of its attributes or in terms of those of the event that caused it. For instance, while listening to a string quartet we might be concerned with the patterns of sensation the sounds evoke (musical listening), or we might listen to the characteristics and identities of the instruments themselves (everyday listening). Conversely, while walking down a city street we are likely to listen to the sources of sounds – the size of an approaching car, how close it is and how quickly it is approaching – but occasionally we might listen to the world as we do music – to the humming pitch of a ventilator punctuated by a syncopated birdcall, to the interplay and harmony of the sounds around us. (Gaver 1993, p.1)

Truax describes sound as mediating link between listener and environment (Truax 2001), and it is the intuitive comprehension of this mediation role that has informed my spatial sound design practice for the articulation of complex music.

What remains clear from my early experience of auditory scene analysis and its inherent acoustic communication is that a significant factor in the ability to comprehend my childhood soundscape and apprehend its constituent acoustic information streams is the role played by the spatiality of sound. Consistent distance and direction were among the more significant "related qualities" (Bregman 1990) that contributed to the grouping of sonic events into perceptual streams. Bregman acknowledges a role for spatial differentiation in stream segregation, but postulates (correctly, I believe) that its contribution only becomes significant in combination with other stream-defining characteristics:

> Maybe we should expect to find that location differences alone will not be powerful influences on grouping, but will have a powerful multiplying effect when they are consistent with other information. (Bregman 1990, p.83)

The capacity to perceptually identify the sonic 'schema' to which Bregman refers relates directly to my experience of learning 'nail phrases' as a child. It was the development of listening acuity that enabled perceptual "feature selection" and learning to comprehend the information communicated by sound that allowed the "feature grouping" of selected nail strikes into a perceived phrase. In Gaver's terminology, I was engaging in "musical listening" to everyday sounds.

1.2 Communicating Music

> A work of music or a recitation creates an auditory scene that is not natural - it is a range of auditory objects plucked out of the flux of acoustic energy as commanded by the composer or performer; it is not a range of objects that is - *in vivo*, as it were - a reliable indicator of significant features of a soundscape. (Matthen 2010, p.87)

The composed auditory scene that constitutes a musical performance by its nature encourages or engenders active listening. In a concert situation, the singular purpose of the event is to frame music for focused listening, and the audience members are seeking an active listening experience. Concert music is crafted to exploit this attentiveness, and seeks to leverage the listeners' capacity for auditory scene analysis and willingness to find structure in and seek meaning from the aural environment presented. The knowledge that one is listening to an artificial, or artistic, construct results in a different mode of listening from even concentrated environmental listening. The formal structures and internal relations between elements are known to be purposeful, along with a planned temporal unfolding mapped by dynamic reshaping of the auditory scene. In known musical genres that subscribe to formal or tonal conventions, the signposts marking structure are readily identified by means of aural memory. These differences aside, however, the cognitive mechanisms for analyzing the auditory scene in search of information are essentially the same for music as any focused listening. Bregman's concepts of "feature selection", "feature grouping" and the apprehension of "schema" all play a role in the comprehension of musical structure (Bregman 1990, Harley 1999).

In his discussion on the role of spatiality in music perception, Lippman reminds us that though listening to music is a unique case in terms of aural experience, it remains but one aspect of a broader range of auditory communication and its uniqueness is in fact *defined* by the broader aural context in which it is framed.

> Of course music represents a level of experience that is markedly different from practical response, and that must be considered in its own terms; but we shall never arrive at a full understanding of its place if we sever it from the rest of human experience and from its context of organic reaction. We must recognize its distinctive character; but its nature is partly constituted by any meaning sound

> may have, however removed and unrelated this may seem. (Lippman 1963, p.32)

The perception of purposefulness in the relationships between elements (simultaneities, melodic sequences or rhythmic relationships) is how we apprehend music as 'structured', and how we comprehend the nature of that structure. As Matthen sees it:

> Crucial to appreciating these works as aesthetic objects is appreciating accidental relations between different auditory objects in this scene— how the rhythm of spoken words interacts with the melody, the contrapuntal harmonies, the merging and separation of voices in a piece. All of these relations are possible only because of the variety of auditory objects that we have discussed in this article. The artist creates these objects and makes them stand in accidental relations. To hear and understand these accidental relations is of the essence of auditory appreciation. (Matthen 2010, p.88)

In tonal music, harmonic conventions provide the listener with a readily learned set of boundary conditions and hierarchical framework to facilitate comprehension (Krumhansl and Shepard 1979). Similarly, music that constrains itself to a rhythmic language consisting of simple durational ratios establishes for the listener a range of probabilities that is easily learned and comprehended (Lerdahl and Jackendoff 1983). In contemporary music, where harmonic conventions are rarely exploited and melodic, harmonic and rhythmic relationships are frequently complex (London 2007), the listeners' task of, as Matthen terms it, "appreciating accidental relations" becomes a challenging one. I use a simple navigational analogy. A tonal centre, once established, provides a point of reference, akin to magnetic north on a compass. However elaborate the detail of the work, its unfolding is framed in the context of a known, unchanging reference. However complex the journey around (or away from) the tonal centre, there is always a sense of where 'home' is, and an expectation that, by some (hopefully) interesting route or other, a way back will be found. The journey is an adventure, but the destination is known (or assumed). There is a comfort that important signposts will be noticed when they arrive, and that even an unexpected turn will indicate a more interesting journey, not a loss of direction.

Complex, non-tonal music presents the listener with an entirely different proposition. In the absence of tonal language, destinations are likely to be unknown until they are arrived at. Even then, what defines them as destinations? Buckley acknowledges the challenges ELISION presents its audiences, and the active role the audience plays in deriving meaning from the work:

> a set of questions could be elaborated as follows: What challenges to systems of knowledge and practices can be posed, how are spaces defined or elaborated in performance, and how does an audience engage in these practices as a co-creator of significance and meaning? (Buckley n.d.)

Buckley emphasizes the exploratory nature of ELISION's performance practice, and the role the performance environment plays in the experience of the work. Blesser and Salter present a generalized view of the integration of sound and environment that echoes Buckley's sentiment, and looks toward my approach to performance sound design:

> Although we usually think of a soundscape as a collection of sonic events, it also includes the aural architecture of the environment. The experience of listening to a sermon in a cathedral is a combination of the minister's passionate articulation and spatial reverberation. A performance of a violin concerto combines the sounds of musical instruments with the acoustics of the concert hall. The soundscape of a forest combines the singing of birds with the acoustic properties of hills, dales trees, and turbulent air. To use a food metaphor, sonic events are the raw ingredients, aural architecture is the cooking style, and, as an inseparable blend, a soundscape is the resulting dish. (Blesser and Salter 2007, p.15)

My role as a sound designer and engineer for contemporary chamber music performance (including ELISION) can be considered the technological manipulation of aural architecture, or "cooking style" to enhance or optimize the audience's comprehension of complex musical forms. My childhood fascination with comprehension of the information conveyed by sound evolved into fascination with the processes of comprehension, then, professionally, into a constructive and creative engagement with the process of clarifying sonic communication by means of sound reinforcement. The auditory spatial intelligence[3] acquired and developed through auditory scene analysis has been the principal driver in the development of skills to enable auditory scene creation or manipulation. (Gardner 2006, Van Schaik 2008)

For ELISION, the role of sound design is frequently more about *occupying* space than dynamically *manipulating* space. Clarity of articulation is paramount, and sound reinforcement functions as a *magnifier*, bringing detail into clearer perspective, as well as an *amplifier*, sonically scaling work to the space. Stockhausen articulated similar intent when describing the performance of *Klavierstücke* in a 1991 lecture:

> Using amplification technique, I project the piano music into the room, high and also as wide as possible, which can help with listening right into the timbres, and with bringing all the nuances closer. …
>
> This is not merely to make the piano *louder*, much more: it should make audible what in the fifties I had composed into the *Klavierstücke.* I have worked a lot with resonances - for instance when you silently depress keys and then strike higher keys, or the reverse. Even people in the last row of seats ought to be able to hear this. At many piano recitals which I have been to here and there, things were such that already by the ninth row the piano sounded

[3] The notion of auditory spatial intelligence is an adaptation of Gardner's concept of visual spatial intelligence. Van Schaik has applied the notion of spatial intelligence to the field of design.

> very distant. And I actually want everyone to hear the piano as the pianist hears it. (Stockhausen 1996, p.81)

Discussing chamber music performance practice more generally in the same lecture, Stockhausen expands on the use of amplification to render compositional detail as clearly as possible:

> I would in every case bring out subtleties, project them with vivid transparency, bring them into physically perceptible proximity, and strive for the audibility of the musicians. I listen to the sound over and over in close proximity to the musicians and I try by means of the sound-projection to render this as a chamber-music experience, in the original sense. (Stockhausen 1996, p.87)[4]

Stockhausen's motivation is the effective communication of his compositional intent - to magnify detail by scaling the instrumental sound "high and also as wide as possible". In employing of amplification to achieve the "vivid transparency" he desires, the primary source of sound for the audience becomes the speakers, not (in the case of *Klavierstücke*) the piano itself. This is a significant factor in the

[4] The singular focus on Stockhausen's use of amplification to magnify sonic detail is not to disregard the significant work of John Cage, David Tudor or others in the area. Stockausen's particular emphasis on the magnification of *instrumental* sound in the context of chamber music performance aligns more directly with the focus of this study.

presentation of the work in that the performance mode shifts from the purely acoustic into the domain of the electroacoustic.[5] The experience for the listener is altered by this shift in a number of ways. Firstly, the cause/effect relationship between the instrument and the sonic result changes. Before a note is played, aural memory (based on prior experience) creates an expectation as to the likely sonic result of any given piano played (unamplified) in any given room. Even without conscious consideration, our learned experience of the behaviour of sound gives us an understanding of the generating capability of a piano, the efficiency of propagation over a given distance and the influence of room acoustics on the audible result. The amplified result could not be caused by the piano alone. Secondly, a spatial dislocation is introduced by the dimensional rescaling of the sonic image. As Stockhausen states, amplification is not being used only to make the piano louder, the intent is also to magnify its scale – the aural equivalent of projecting a close-up visual image onto a screen, resulting in sound sources (speakers) that are not coincident with the 'actual' source and a soundstage that is out of scale with the visual. Thirdly, for the listener to perceive the piano as the source of this disproportionately large and spatially displaced sound requires a more complex auditory scene analysis that allows for the effects of the amplification in establishing causality. The proliferation of recorded, broadcast and amplified sound means listeners are well conditioned to deriving causality for

[5] I use the term electroacoustic in a broad sense as a descriptor of the medium of transmission, with no intended reference to any genre-specific use of the term.

disembodied, speaker generated sound, but a degree of causal abstraction is always present when sound is manipulated electronically. (Wishart and Emmerson 1996)

The process of converting sound into an electrical signal that *can* be amplified has significant implications. Once represented as a signal for transmission via loudspeakers, the sonic material becomes electroacoustic in nature, and the mechanisms for electroacoustic music performance become part of the performance methodology. Beyond the simple case of piano, in an ensemble context this opens the way for signal manipulation to influence or control ensemble balance, instrumental timbre, dynamic shape and spatial placement. These elements can all be varied dynamically to shape the performance of a work and, in the case of works designed for amplification, can become compositional parameters. It is commonplace for composers to include performance directions for amplification, signal processing and spatialization in instrumental scores for this reason.

The employment of loudspeakers in the performance of instrumental (or mixed instrumental/electronic) music blurs the boundaries between instrumental and electronic sound sources. It is possible to compose work (and frame it in performance) such that clear delineation is maintained, but it is equally possible to seek ambiguity in the distinction between acoustic and electronic timbres when both utilize the loudspeaker as the transmission medium (McIlwain 2001). I do not suggest here that all instrumentally generated sound becomes functionally electronic the moment a transducer converts it to voltage, but in the absence of the simultaneous sounding of the acoustic source, it is only aural memory and/or correlated visual information that prevent this. In actuality, there are very few situations I have encountered in amplified chamber music where the acoustic contribution of the instrument is so completely overwhelmed as to be inconsequential, so the combined sonic result is mostly an amplified-acoustic hybrid, as distinct from *acousmatic*.[6]

Performance amplification designed to magnify scale necessarily involves spatial expansion of the soundstage, but in non-spatialized instrumental performances one of the goals of sound design is frequently to achieve the desired scale and articulateness while maintaining a sonic focus that remains spatially coincident with the location of musicians as far as possible. Dislocation between areas of aural and visual focus has the potential to cause distraction if the sonic spatial displacement is *incidental* (or accidental) rather than *functional*, and I seek to minimize it where possible. *Functional* spatial displacement, by which I mean displacement that serves the goal of enhancing the comprehension of the music (Stockhausen's "vivid transparency"), is a purposeful spatial placement that shapes the auditory scene by establishing or defining spatial *relationships* between elements that serve to clarify or articulate aspects of musical form or structure.

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[6] *Acousmatic* is used here in the Pythagorean sense of sound emanating from an unseen source.

Much contemporary repertoire, and much of ELISION's repertoire, is structurally complex and can be difficult to comprehend without repeated listening (Imberty 2000, London 2007). The scarcity of performances of such music makes repeated listening in live performance unlikely in many cases. In amplified performances, sound reinforcement can play a role in facilitating *comprehension* of the music by assisting in the *apprehension* of the sonic detail that articulates compositional structure. In this respect, the role of sound designer/audio engineer shares certain characteristics with the role of conductor in that both require a global perspective on the structure and detail of the composition to articulate the formal construction and clarify salient detail for the audience as effectively as possible. The mechanisms employed in the respective roles to achieve this end are clearly different, and a conductor is required to formulate a more detailed interpretation of many aspects of the score, but the perspective required is fundamentally similar. In conversation with Maria Anna Harley, Xenakis outlines an inherent difficulty for conductors:

> The conductor hears the orchestra in a certain way during the performance, he has certain instruments to the right or to the left, he has the string orchestra around him, then the woodwinds and brass farther away, followed by the percussion. The listener in the auditorium does not have the same sound image as the conductor, and the conductor has to conduct for the listener, not for himself. How can he do that when he is not there? He should conduct from the auditorium and listen to the orchestra from that place. (cited in Harley 1999, p.148)

In amplified performance, the role of "conduct(ing) for the listener" is in practice shared between the conductor guiding musicians' performance and the engineer performing the audio mix. Stockhausen provides a composer's perspective on the relationship between the roles of conductor and what he calls the "sound projectionist":

> The sound projectionist in the middle of the hall has - depending on the piece - a great responsibility as well. The traditional conductor synchronizes and balances what he hears from the podium. The sound projectionist, on the other hand, is ultimately responsible for what the people in the hall actually hear. If, in a work with orchestra-mikes, he amplifies something too little or too much, then you will not hear what the conductor shaped from the podium. So, it is an incredibly demanding profession. The sound projectionist must on the one hand be a conductor – must have a conductor's training - in order to read the score precisely so as to be able to correct the musicians in rehearsals. However, he must also have learned his craft through long years of recording, mixing, rehearsing, and performing electroacoustic music. (Stockhausen 1996, p.82)

Stockhausen alludes to one of my fundamental principles in sound design for chamber music performance – that the role is an interpretive one as much as it is a technical one, and the interpretation is critical to communicating musical structure and detail effectively.

1.3 Studies of Spatiality in Music

Articulation of compositional design through sound spatialization has been employed in the composition and performance of acoustic music since at least the 16th century, and electroacoustic and acousmatic music since their advent. It is beyond the scope of this study to detail this history and comprehensive work on the subject has been done by a number of scholars, several of whom have been influential in shaping the approach taken herein.

A succinct historical overview is provided by Zvonar (Zvonar 2005) that contextualizes this study and the development of ELISION’s spatial performance practice both musicologically and technologically. Extensive studies on the role and implementation of spatiality in music performance have been undertaken by Harley (Harley 1993, 1994, 1999) and Bates (Bates 2009), both of whom consider instrumental, electroacoustic and acousmatic spatial works. Harley’s analysis of auditory stream segregation in spatial music in the context of Bregman’s auditory scene analysis was influential in shaping the process of reflecting on and evaluating the development of my own spatial performance practice, specifically the process of deriving spatial design from inherent characteristics of the music. Bates (2009) provides a summary of the psychoacoustics of spatial auditory perception and surveys and evaluates technological approaches to spatialization in performance. Bates’ overview represents a useful complement to this study in that it focuses on aspects of loudspeaker-based spatialized performance that, while not the subject of this study, are fundamental to spatial sound design in any context. Kendall and Malham (Kendall 1984, Malham 2001) offer relevant insights into spatial hearing with particular reference to loudspeaker reproduction, while Lippman and Reynolds (Lippman 1963, Reynolds 1978) discuss the inherent spatial characteristics of musical sound and have informed the analysis presented in Chapter 5.

Composers of spatial music have written extensively on the subject of spatialization, including Brant on spatialized acoustic music (Brant 1967, 1979), Stockhausen and Boulez on spatialized acoustic and electroacoustic music (Boulez 1971, Stockhausen 1996), and Bayle, Smalley, Wishart, Emmerson and Barrett on spatialized acousmatic music (Wishart and Emmerson 1996, Emmerson 1999, Barrett 2002, Bayle 2007, Smalley 2007). Stockhausen's discussion of the use of amplification to clarify compositional detail, in particular, parallels my performance practice philosophy. Further, his consideration of the role of 'sound projectionist' in amplified chamber music performance is the only published work I have encountered that effectively conveys the interpretive nature of my performance practice.

Smalley's concept of 'gestural space' refers to the local spatial field of a performer, which in Chapter 4 of this study is investigated as a source of spatial information that might be exploited by instrumentalists as a means of directly engaging with the spatialization of their performance. Smalley also describes 'ensemble space' and the 'nesting' of individual gestural spaces within it, a relationship that becomes a variable performance parameter when the technique explored in Chapter 4 is placed in the context of the ELISION ensemble.

1.4 Summary

The design and implementation of spatial sound design represents an interpretive mediation between performers and audience. Conductors and performers mediate between composer and audience, and spatial amplification can be considered as part of that same mediation, or an additional layer of mediation between performers and audience. The acoustic environment is also a mediator, and spatial amplification can equally be part of that mediation.

Sound design for ELISION performs a variety of functions:

1. Facilitating intelligibility of compositional form and detail.

2. Sonically scaling work to the performance environment.

3. Defining a perspective relationship between collaborating artforms.

4. Articulating placement and/or spatial motion of sound.

In my spatial performance practice, I seek to perform these functions through performance design and execution strategies that result from leveraging spatial intelligence to facilitate the comprehension of complex music by clarifying the perception of differentiated auditory objects. This practice has developed partly in the context of ELISION's spatial performances, and it is from this work that the analytical approach outlined in Chapter 5 has evolved.

Chapter Two: ELISION Spatial Performance

2.1 Introduction

This chapter traces a series of ELISION projects using spatialized sound reinforcement spanning a seven-year period from 1995 to 2002. A number of other spatial sound projects took place before, during and after this time, but a full description of all of them would be beyond the scope of this project, and largely redundant in charting the development of ELISION's spatial practice in that not all performances represented a clear or significant advance in the development of the practice. Each of the works selected for this chapter represents some kind of milestone or turning point in the development of the practice, and collectively they chart the lead up to *The Spatial Ensemble* project and highlight the reasons the project came into being.

A brief outline of each work is presented that identifies aspects of the work that informed the spatial sound design for the performance. The performance context and environment are described, and the resultant spatialization design considered with reference to its role in communicating the work to the audience in each setting. The technical implementation employed to realize the spatial sound design is explained in conceptual terms, and as much relevant technical detail as can be recalled. Due to the site-specific nature of the performances described, the precise technical details of the sound design implementation were not documented, as any subsequent performance would necessarily entail a complete redesign for a different environment. Significant technical aspects of the selected works can be recalled readily, as they have directly informed and influenced subsequent practice and represent significant markers in the evolutionary development of the ensemble's performance practice.

An evaluation of the spatial sound design for each performance is discussed in terms of its contribution to the framing and/or communication of the work and also in terms of the practicality and effectiveness of the spatialization design and its implementation. Finally, the particular significance of each of the projects described is evaluated with respect to its role in the evolution of ELISION's spatial performance practice.

2.2 Performance Case Studies

2.2.1 *Bar-do'i-thos-grol*

Midland Railway Workshops, Perth, 5-12 March 1995

Bar-do'i-thos-grol is a collaborative work between composer Liza Lim and visual artist Domenico De Clario based on *The Tibetan Book of the Dead* (Evans-Wentz and Lopez 2000). The ensemble consisted of two cellists, one saxophonist and one clarinetist each playing a variety of instruments, and soprano and countertenor voice, with the saxophonist, clarinetist and one of the cellists also vocalizing at times. The work is a cycle performed over seven nights at seven discrete locations around the performance site, with a unique performance at each location. The cycle is developmental in nature, with the audience for each performance being led along a route that passed through the locations of the previous performances, which were lit as they had been for performance. The commencement times for each performance were staggered at two hourly intervals spanning the period from sunset to sunrise, symbolizing a journey from death to rebirth.

The Midlands Railway Workshops was in 1995 a disused industrial site, and is located 17 km east of Perth, Western Australia. The Workshops operated from 1904 until their closure on 4 March 1994. The site is occupied by numerous buildings originally housing a diverse range of activity – power station, foundry, stores, blacksmiths' shop, carriageworks etc. The performance locations chosen reflected this diversity – some were indoors, some were outdoors, and some were a combination of both.

The sound spatialization in this work served several purposes. Firstly, sonically occupying the space. In unfavourable acoustic environments, and even more so outdoors and from a distance, some vocal and acoustic instrument sound does not carry well, and in a large industrial site the acoustic sound output of a small ensemble can struggle to match the spatial scale of the performance environment. In attempting to transform the selected locations into sonically charged performance environments, the opposite was desirable. The goal was to completely occupy the space(s) with sound, not subtly infiltrate it. Amplification was essential in achieving this, and the ability to sonify in three dimensions by means of spatial sound reinforcement contributed significantly to the sonic occupation of the space(s).

Secondly, from the perspective of ensemble balance, spatialized reinforcement was essential to the effective articulation of the work. Musicians were, at times, scattered far and wide, amongst and around the area occupied by the audience, and sometimes at a distance or out of sight. There is no correct ensemble balance in such a situation, in that the perspective differs for each audience member, but without amplification it would be possible for some performers to go completely unheard by some sections of the audience. The spatialization of the amplification was essential to maintain the aural perspectives resulting from the spatial arrangement of the musicians, and it was possible by means of careful speaker placement and level control to present a viable balance and perspective to the entire audience.

The amplification system design also needed to assist performers in hearing one another. Their spatial separation combined with the fact that sound did not carry well in many of the performance locations meant that performers had very little chance of hearing one another acoustically for much of the time. The change in location between each of the performances meant there was a tight schedule for system relocation, soundchecks and rehearsal, and limited crew and equipment resources made individual foldback for musicians impractical. Additionally, foldback speakers proximate to the musicians would potentially have had a detrimental effect on the spatial integrity of the reinforced sound. Headphone mixes were considered undesirable as they tend to isolate performers from the performance space, potentially compromising their engagement with the environment they were required to be responding to and interacting with. Speaker locations and orientations were therefore chosen with a view to presenting a workable balance to each musician as well as the audience. This is asking a lot in terms of system design for seven different system and ensemble configurations in seven different locations, and in some locations a degree of compromise was required. To provide the required flexibility, a mixing console configuration was utilized that allowed a discreet proportion of any musician to be fed to any speaker as required.

There was no desire in *Bar-do'i-thos-grol* to *animate* the sound spatially; rather the intent was to minimize the extent to which sound was disembodied by the amplification. A variable bus monitor-style console was chosen as a control surface because it allowed virtual sources to be positioned between any pair of speakers regardless of the bus they were being fed from. This is a versatile arrangement in that it allows flexibility in the positioning of virtual sources (dependent on listener position) and minimizes the effect of speaker directionality to some degree, which is of considerable assistance in presenting a spatially diverse audience with a viable balance of an even more spatially diverse ensemble.

The use of spatialized amplification proved essential in the rendering of *Bar-do'i-thos-grol* at the Midlands site. The ensemble could be re-scaled and re-shaped to integrate with a variety of different performance locations, largely because the spatial amplification could be designed to 'fit' the ensemble to the location. Beyond the success of the performances themselves, significant things were learned that have informed ELISION's subsequent sound spatialization practice.

1. Scaling to the location.

The establishment of a balance between the physical scale of the performance environment and the sonic scale of the production is critical to the effective rendering of a work in an environment of this nature.

2. Integration with the location.

Spatializing both performers and amplification in a way that is sensitive and responsive to the physical layout of the site is of considerable assistance in creating a plausible juxtaposition of art music and an industrial site.

3. Performance control.

The variable bus configuration employed was extremely flexible in the context of the *Bar-do'i-thos-grol* performances, but it was clear that the complexity inherent in the number of control changes required to move between spatial states for multiple inputs would limit its practicality in situations where spatial animation was required.

2.2.2 *Lament of Desire*

East Workshop, Fremantle Prison, February 1999

Lament of Desire was a collaboration between ELISION ensemble (directed by Timothy O'Dwyer) and Thai visual artist Araya Rasdjarmrearnsook. A site-specific installation work, *Lament of Desire* was commissioned for the 1999 Festival of Perth and took place in a large, at the time disused workshop building at Fremantle Prison. The visual art installation took the form of six video projections onto pools of water distributed around the floor of the venue, with audience free to move around the space and watch different projections during the performance. The images projected were of human corpses floating in shallow water, creating the impression they were floating in the pools themselves. *Lament of Desire* forms part of a series of Rasdjarmrearnsook's work centred on the transition from life to death.

http://www.elision.org.au/ELISION_Ensemble/ELISION_Articles__Hungry_Ghosts_files/lament-araya.jpg

Figure 1 – Araya Rasdjarmrearnsook reading to a corpse

The music in *Lament of Desire* was a structured improvisation between saxophones, soprano, spoken voice, electric guitar and electronics. All instrumental and vocal sources were, at times, subjected to computer controlled digital signal processing, up to three processes being available simultaneously and able to be fed by any combination of inputs, including returns from other processing hardware. Throughout the performance, fragments of the music were recorded ad libitum onto three stereo Mini Disc recorders and the fragments replayed in various improvised combinations during the final tutti improvisation section of the piece.

The East Workshop at Fremantle Prison is a clear span industrial building with concrete floor, stone walls and metal roofing. Musicians were elevated above the audience/installation area, being located on the roofs of office areas at either end of the space. The spoken voice (Rasdjarmrearnsook) moved freely around at floor level.

http://www.fremantleprison.com.au/Functions/venuehire/eastworkshops/Documents/East%20Workshops%20Layout.pdf

Figure 2 – Floor Plan of performance space for *Lament of Desire*

Eight speakers were positioned around the perimeter of the performance area, suspended at an elevation approximately equivalent to the elevation of the musicians. Musicians were amplified through speakers approximately coincident with their physical location, while up to three processed variations could be distributed dynamically throughout the space in response to the nature of the improvisation. In sections where a particular musician was performing solo, three alternate, or 'ghost' versions could be made to appear (or disappear) from different locations, their spatial animation improvised in response to the music. Aural focus on the soloist therefore became a performance variable, with possibilities ranging from static unprocessed amplification in situ, to a very active spatial scattering of three processed 'ghosts' darting about the space. During tutti sections, one 'ghost' of each performer was generated and could be moved around in the same manner. The playback of pre-recorded phrases during the final tutti added 'clones' of each performer into the mix resulting in increased spatial and textural density.

Spatialization control was by means of a standard eight bus analogue mixing console, and spatial location animated by switching signals between output busses. The use of switched busses for spatial manipulation was preferred over variable busses for *Lament of Desire* because the spatial plan for the work called for the rapid changing of spatial states rather than clear trajectories of motion or precise and flexible localization. The performance logistics were complex, requiring in the final tutti improvisation the active monitoring and rapid spatial reassignment of nine audio streams as well as real time processing control and mix balance. The limits of my audition, cognition and performance control capacity were soon reached, and it was this limitation that ultimately determined the complexity of spatial articulation of the work as well as the extent to which the spatialization could respond in a dynamic improvisational way to the instrumentalists' gestures.

At different times throughout the performance, visual artist Araya Rasdjarmrearnsook moved among the audience reading from a Thai text called the

Inao. Rasdjarmrearnsook's voice was amplified by means of a radio microphone, the signal from which was split across eight mixer channels, each channel being assigned to a single output bus. This configuration allowed fader control of amplified sound trajectories corresponding to the performer's movement through the space.

The 'ghosting' of performers was effective in populating the performance space with more voices than the limited size of the ensemble would otherwise have allowed. The final tutti improvisation was logistically complex in its execution, but manageable by a single spatialization performer and successful in both animating the space and occupying it with multiple voices. The illusion of unseen performers around and beyond the walls of the performance space was effective in its leveraging of acousmatic principles in ensemble performance, particularly due to the mixture of processed and unprocessed versions of the instrumentalists' output.

Lament of Desire was ELISION's first experience of complex improvised real-time spatial *animation* in the context of ensemble performance. The operational approach, while effective, was complex to execute and limited in scope. The limitations did not compromise the work, and the success of the spatialization whetted the apetite for being able to do more, and more easily.

2.2.3 *transmisi*

Tennyson Power Station, Brisbane, January 1999

transmisi was the first large scale spatialization of a Richard Barrett structured improvisation performed by ELISION, and took place in the boiler room of the disused (now demolished) Tennyson Power Station. *transmisi* was a collaboration between composer Barrett and Indonesian visual artist Heri Dono, whose video projections and installation work were spectacularly framed by the monumental scale of the performance space, some 80 metres deep, 40 metres wide and 20 metres high.

http://assets2.mirvacdevelopment.com/assets/mirvac-dev/tennyson-reach-photo-library/ulVslopRhZ6FC6p/tp48.jpg

Figure 3 – Tennyson Power Station exterior

Safety regulations prevented audience mobility for *transmisi*, the audience being contained to a narrow balcony created by a walkway approximately five metres above ground level along two sides of the performance area. Performers (saxophone, clarinets, electric guitar, live electronics and sound diffusion) were positioned at a variety of locations on the floor of the performance area, and those with portable instruments were able to move during the performance.

With the audience confined to the perimeter of the space, the sound spatialization was not designed as an enveloping surround sound experience, rather a means of sonifying the immense structure laid out before them. The scale of the room was of primary significance in the presentation of the work, particularly in light of the audience size, which was constrained by the limited audience area available.

The function of the sound design was firstly to facilitate the articulation of musical detail in the listening area. The extremely reverberant acoustic environment (reverb time in excess of six seconds) meant acoustic sound carried very readily, but struggled to maintain clarity. The significant distance between the audience and the acoustic sources meant the ratio of direct to reverberated sound was constantly weighted heavily in favour of the reverberation. While it is possible for improvising musicians to work in a manner appropriate for this type of acoustic environment, it is limiting in terms of the variety of musical gestures that can be employed effectively. Amplification can help in this regard. Microphones placed close to instruments can capture a level of detail that is lost even a few metres away in a reverberant environment, and magnify it to the point that it gains significant presence even from some distance. The inherent high frequency directionality of dynamic loudspeakers can also be exploited to focus this detail on the audience area with less excitation of room's reverberation than the relatively omnidirectional propagation characteristics of instruments.

Amplification also provided the ability to scale the ensemble sonically to the vastness of the performance space. The modest instrumental resources used for *transmisi* would, with the notable exception of the electric guitar, be incapable of dominating the room sonically if constrained to acoustic level. Simply amplifying to maximize sonic occupation of the space would not however have allowed exploitation of the extreme dimensions of the venue. Despite the audience being on the perimeter, it was possible to present an enormous, activated and, at times, animated three-dimensional sound stage capable of articulating considerable spatial detail, and to do so with the limited speaker resources available.

The sound system design was constrained by the lack of elevated rigging infrastucture and the installation complexities that resulted. Speaker elevation was essential to facilitate exploitation of the height of the space. At the rear of the performance area elevation could be relatively easily achieved by virtue of very high balcony walkways along the side walls. Speakers had to be carried up several flights of stairs, but did not need to be hung. Positioning high speakers at the front of the space was not aided by infrastructure in this way, so it was necessary to install flying points on the beams of the 30 metre high roof. Conventional elevation platforms could not be employed, as a sufficiently large machine to be capable of reaching the beams was not able to access the space. It was necessary therefore for riggers to scale the walls then climb across the beams to attach pulleys and drop ropes to which speakers could be attached and then hauled up from ground level.

The sound system design utilized eight speakers, loosely paired as follows –

Left/Right, High, Far

Left/Right, High, Near

Left/Right, Low, Far

Left/Right, Low, Near

This configuration was chosen to maximize the ability to sonically exploit the extreme dimensions of the space while keeping cost and installation complexity to a minimum. Despite the functional pairing of speakers, symmetry was decided against. Neither musicians nor the installation art was arranged symmetrically within the space, and given the infrastructure limitations it was prudent to continue this asymmetry in the sound system design, though care was take to position speakers so as to allow virtual source locations to be perceptible between any adjacent pair.

Spatialization control was a variation of the methodology employed for *Bar-do'i-thos-grol,* again implemented by means of a variable bus analogue mixing console of the type generally used for mixing musicians' monitoring. The significant characteristic of this type of console is the large number of variable mix busses, or auxiliary sends. Variable busses offer the ability to position a virtual source or generate a panning motion between any pair of speakers, which is not possible with fixed busses. It is essential for this application that all mix busses be available post fader, so balance adjustments can be made from channel faders rather than the individual send levels to the busses. It is a very flexible method, but suffers from the operational complexity imposed by the number of control changes required to reconfigure the spatial state or execute spatial motion. Even for the small ensemble performing *transmisi*, a move from one spatial state to another could require eight bus sends to be altered for each of ten inputs, resulting in up to eighty precise control changes for each change of spatial state. Control logistics therefore dictate that a complex change of state takes a considerable period of time to execute manually.

The use of mix busses to send signals to multiple outputs also enables the use of bus master faders to execute a traditional diffusion of prerecorded stereo material, and this technique was applied in *transmisi* for a ten minute section of the work that consisted only of prerecorded stereo electronics. With all instruments tacet, the left and right channels of the stereo tape were sent to all speaker pairs equally, and the console bus masters used to diffuse the sound throughout the space in the manner of a traditional acousmatic diffusion console.

The immense depth, height and width of the speaker array was extremely effective in scaling the work to the performance space, and the spatial control implementation, while complex, allowed significant animation of space where required.

transmisi represents a significant landmark in the development of ELISION's spatial practice in that the magnitude of the spatial scaling required to effectively sonically occupy the performance environment was far in excess of any venue previously encountered, which gave the sound spatialization a more significant role in realizing a work than had previously been the case. Valuable insight was gained into what might be possible in terms of spatial scaling for ensemble performance and the types of control structures that might be optimal for mounting work on such a scale.

2.2.4 *Inferno*

John Rodgers' *Inferno* is a musical depiction of Dante's poem, from which it takes its sectional structure and underlying narrative. The sectional structure is reflected in the orchestration of the work, and the functional relationships between performers, with different combinations of instruments coming in and out of focus at different times. The work is explicitly scored for amplification, with a part in the score dedicated to amplification control. Rodgers considered amplification to be an integral part of ELISION's performance practice and sought to exploit the capacity of amplification to enhance the articulation of orchestration as a compositional parameter. The work is scored for twelve performers playing a variety of instruments:

flute/bass flute/ice flute

clarinet /bass clarinet/live electronics

trumpet/bucket of water

trombone/bucket of water

alto saxophone

infernophone[7]/trash

percussion/water crotales/dog whistles/vegetables

electric guitar/demon duck/inferno guitar

[7] The infernophone is a metallic percussion 'kit' custom built for *Inferno*.

viola/quarter sized violin

violoncello 1

violoncello 2

sound designer/live electronics

The staging and spatialization strategy for Inferno was designed to reflect the concentric rings depicted in Figure 4, Porena's design of Dante's hell. The composer's staging plan called for an inner ring of performers at floor level surrounded by a ring of audience on low risers. Around the audience was a wider ring of performers on higher risers, then an elevated ring of speakers. The concentric layout and resulting spatial displacement of all amplified sound with respect to its source was an intentional performance strategy developed in consultation with the composer designed to disrupt the audience's sense of their spatial relationship to the ensemble. The principal structural role of the spatialization was to assist in the articulation of the sectional form of the work. As such, a number of spatial 'states' were required, as well as a means of quickly and smoothly changing between them. In order to facilitate these 'scene' changes, a larger console with voltage controlled amplifier (VCA) and mute-grouping facilities was specified. Inputs could then be split to two groups of channels, each of which could be activated or deactivated by means of mute group switching, and cross fades between spatial 'scenes' could be executed with VCA masters. The upcoming spatial state could be pre-configured while the ensemble was playing, and activated as required. Again, considerable operational complexity was unavoidable given that numerous spatial states were required, and the number of input channels was doubled to accommodate the splitting of signals across inputs, but the technique proved effective for executing otherwise impossible spatial scene changes prior to the widespread availability of digital mixing consoles.

http://oldblog.tilos.hu/malestripshow/DanteInferno.jpg

Figure 4 – Porena's design of Dante's hell

Adelaide, February 2000

The venue for the Adelaide performance of Inferno was an empty warehouse building on the dock at Port Adelaide. The floor area of the venue was approximately 50m x 20m, with a height of approximately 8m at the centre of the pitched roof, reducing to approximately 4m at the walls. The acoustic of the space was very reverberant due to a concrete floor, and both walls and roof made from galvanized iron sheet.

A central speaker cluster flown over the centre of the circle was included in the sound system design for this venue to add sonic 'weight' to the centre of the performance area. The central cluster could be flown much higher than the outer circle of speakers by virtue of the pitch of the roof, which expanded the vertical dimension of the sound field considerably. In order to better integrate the central cluster with the concentric circle design and provide more performance control over the vertical dimension, a further ring of speakers with approximately half the radius of the outer ring was suspended at 6m elevation, half way between the height of the outer ring and the centre cluster.

The result was a shallow hemispherical field of amplified sound above and around the performance area.

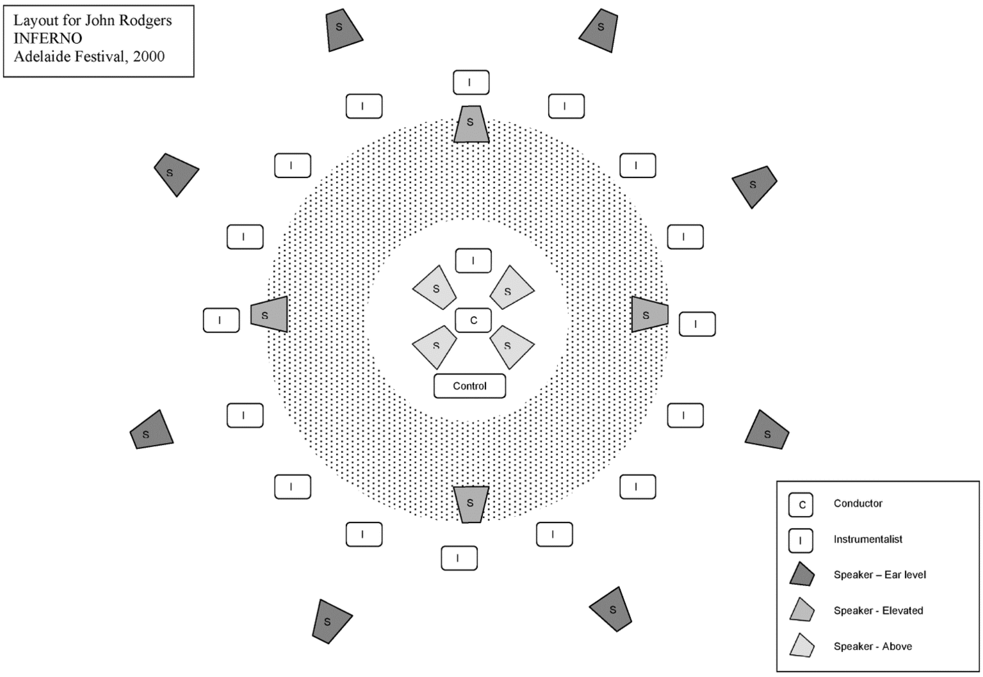

Figure 5 – Performer and speaker layout for Inferno, Adelaide 2000

The spatial control methodology was based around a MIDAS Heritage 3000 mixing console, which combines variable bus architecture with mute grouping facility and VCA grouping capability. With a 40 input console it was possible to split each source from the 11 instrumentalists to two inputs with different bus assignments for spatial location and cross fade between spatial states by means of VCA group masters. This allowed a spatial 'morphing' to be executed, effectively by the simultaneous execution of multiple panning motions between virtual locations.

This performance configuration (with no means for storage and recall of settings) meant the spatial states developed in rehearsal for each section of the work had to be accurately documented for recreation during performance. With the eleven-piece *Inferno* ensemble, the 40 input mixing console could accommodate two states, one of which would be active while the next required state was configured in preparation for the next change. From the spatialization performer's perspective this meant the initial settings for the upcoming state had to be implemented while simultaneously monitoring and adjusting the balance of the current state, following the score and executing the scored performance. This required extensive planning, score mark-up, aural cue learning, conducted cues and logistic coordination.

The implementation of the spatial performance strategy for the Adelaide premiere of Inferno was effective in enhancing the perception of the sectional structure of the work by means of spatially differentiated states being instantiated for each section.

The Adelaide performance of *Inferno* differed from *Bar-do'i-thos-grol, Lament of Desire* and *transmisi* in that the work is not site specific, and the explicit scoring of amplification directions means the spatialization design is generated from the score more so than from the performance environment, and is adaptable to different venues.

Brisbane, July 2002

The Powerhouse Theatre in Brisbane is a purpose built theatrical space in the renovated New Farm power station building. The venue features removable seating banks, so the venue can be configured as an empty box with arbitrary location of performers and audience, which was the configuration employed for the 2002 performance of *Inferno*. The dimensions of the space are 28m x 17m with an elevation of 11m. There is a gallery level at 4m along the centre of the side walls, and a balcony at 7m along three walls.

The Powerhouse Theatre presented a vastly different environment for the staging of Inferno from the Port Adelaide warehouse, principally because of the opportunities afforded by the available infrastructure. The availability of rigging infrastructure along with access to gallery and balcony levels allowed for the elevation of speakers and, more significantly, performers to levels of four and seven metres above floor level, so a variation on the initial spatialization strategy was devised. The original concentric circular arrangement was forfeited to take maximum advantage of the available elevation. Where in Adelaide each ‘ring’ had consisted of either performers or speakers, they were intermingled in the Brisbane performances for two reasons. Firstly, the positioning of musicians at seven-metre elevation in a work scored for amplification necessitated sources of amplified sound more or less coincident with the performers to facilitate localized reinforcement. Amplification of the elevated musicians also became important in balancing the ensemble due to their significantly greater distance from the audience compared to performers at ground level. Consequently, the two upper levels consisted of saxophone, trumpet, trombone and clarinet interspersed with speakers. These instruments were chosen for their ability to project acoustically over the extra distance, but the local amplification was still essential for passages of low dynamic level. The rectangular geometry of the venue meant the elevated performers and speakers were not able to form the rings specified in the original spatial design, so the strict circularity was abandoned in favour of maintaining a desirable lateral spread of elevated musicians.

The spatialization control implementation was the same as for the Port Adelaide performance, but the geometric variation in performer and speaker locations meant the spatial configuration of the individual sections of the work had to be redesigned. There was no requirement for a central elevated speaker cluster as the seven-metre elevation allowed the overhead space to be permeated relatively uniformly with sound. A central cluster in this instance would have been detrimental in that it would have undermined directional clues from more distant elevated sources. Overall symmetry was more or less maintained, but musicians and speakers shared elevation, and the concentricity of the original plan was lost, as lateral spread was consistent for the two upper levels.

The intermingling of acoustic and amplified sources at the various levels of elevation produced in some ways a more varied spatial field than had been achieved in the Adelaide performance, but the comfortable theatre environment and spatial dispersion of the ensemble resulted in a less confronting experience for the audience, not being surrounded by performers in a focused circular configuration and in closer proximity. The result was a more animated spatial experience, so in that sense arguably more successful, but perhaps lacking in terms of spatially reflecting a sonic journey through hell.

Inferno represents the first instance in ELISION's spatial performance history where a work specifically scored for amplified spatialized performance was remounted in significantly different venues. The process of adapting the spatialization of the work while maintaining the musical integrity of explicitly scored amplification directions proved instructive, and paved the way for further work involving scored spatialization.

2.3 Observations/Conclusions

It is significant that the milestones in the development of ELISION's spatial performance practice described in this chapter did not take place in the concert hall environment. In each case, the performed spatialization grew out of the ensemble's ongoing desire to seek out, exploit and where necessary manufacture synergies between the music and the performance environment, and generate a performance event unique to that time and place.

Chapter Three: The Spatial Ensemble

The Australian Research Council funded research project *The Spatial Ensemble: Scaling Instrumental Resonance and Morphology for Spatialised Performance* afforded the opportunity to investigate the implementation of the SIAL Sound Lab's software spatialization system as a performance tool for ELISION. To this end, a series of four performances of Richard Barrett's *codex IX* were mounted in Brisbane (2008), London and Bremen (2010) and Melbourne (2011).

The mounting of a series of performances of the same work facilitated the use of *codex IX* as a research and development platform for ensemble spatialization. This chapter charts that development process which laid the groundwork for the development of spatialization performance strategies leading to the premiere of *CONSTRUCTION*, a larger scale Barrett spatialized ensemble work that was premiered at the Huddersfield Contemporary Music Festival in November 2011.

3.1 *codex IX*

codex IX is a graphically scored structured improvisation, a significant organizational principle of which is that instruments form a variety of functional groupings over the duration of the piece (approximately 33 minutes). These functional groupings are not static throughout the work; rather they vary dynamically as a structural element articulating form. The structure of the work and the way instrument groupings are used to articulate it can be seen in the score below and the excerpt from the accompanying performance instructions.

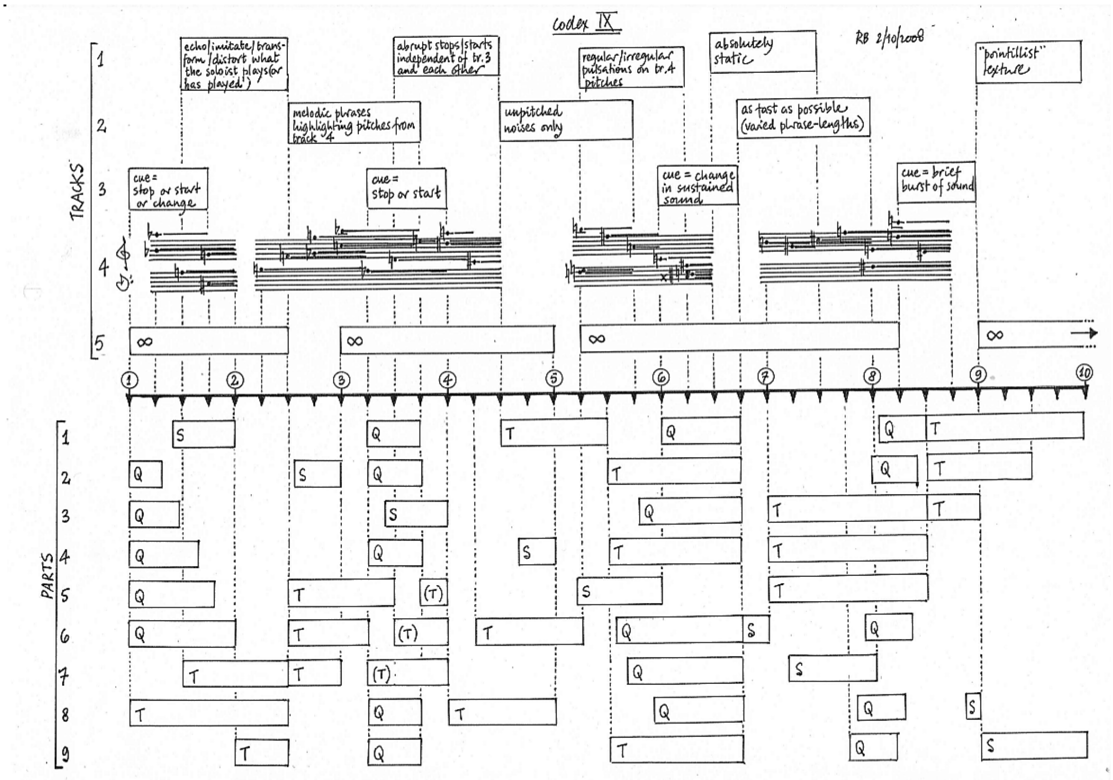

Figure 6 – *codex IX* score

From the composer’s performance instructions:

(1) The score consists of a single page divided horizontally into two. The upper half consists of five “**tracks**” and the lower of nine “**parts**”.

(2) The score is played through **three times**, with the “tempo” varying each time. In the first playthrough, the 36 markers at the centre of the score should be about 15 seconds apart, in the second 20 seconds and in the third 10 seconds. In practice the durations may vary quite widely around these “average” values. Each playthrough ends with three minutes of free improvisation for the entire ensemble (not necessarily all playing at once!). The time structure is thus:

(a) playthrough 1 (9 minutes)

(b) improvisation 1 (3 minutes)

(c) playthrough 2 (12 minutes)

(d) improvisation 2 (3 minutes)

(e) playthrough 3 (6 minutes)

(f) improvisation 3 (3 minutes)

(3) In each playthrough the nine performers are **differently allocated** to the nine parts so that the instrumentation is different at every point each time. Therefore the three playthroughs should end

up quite different from one another, sometimes perhaps almost unrecognisably so. The ninth part might be allocated to the same performer each time since this part has a directing role in the "coordinated events" (track 3 - see below) and may also indicate the passage of an entire playthrough by signalling the ten rehearsal numbers above the time-markers, and perhaps even some of the intervening markers as well.

(4) When a player's part indicates that he/she is to play (although it is **not** intended that he/she should necessarily play continuously through the indicated duration but just that the latter is a "frame" within which he/she should structure sounds and silences), it also indicates "**S**" (solo), "**T**" (trio) or "**Q**" (quintet). These do not indicate types of behaviour as such but rather types of interaction. A "solo" should not necessarily draw attention to itself except by being **distinct** from its musical surroundings. A "trio" or "quintet" involves paying particular attention to the other members of that group, for example making musical "sense" of a series of sequential entries and/or exits.

Allocation of players for version 2 (Kings Place, London, June 2010)

Performers: Richard Barrett (electronics), Daryl Buckley (electric guitar), Richard Haynes (clarinets), Graeme Jennings (violin), Genevieve Lacey (recorders), Benjamin Marks (trombone), Peter Neville (percussion), Paula Rae (flutes), Tristram Williams (trumpets)

part	*playthrough 1*	*playthrough 2*	*playthrough 3*
1	*Graeme*	*Peter N*	*Ben*
2	*Genevieve*	*Richard H*	*Peter N*
3	*Peter N*	*Daryl*	*Genevieve*
4	*Paula*	*Genevieve*	*Richard H*
5	*Tristram*	*Graeme*	*Paula*
6	*Richard H*	*Ben*	*Daryl*
7	*Daryl*	*Paula*	*Tristram*
8	*Ben*	*Tristram*	*Graeme*
9	*Richard B*	*Richard B*	*Richard B*

Figure 7 – *codex IX* performer map for 2010 London performance

The principle adopted for the spatial sound design for *codex IX* was to use the spatialization of the amplified sound to enhance the functional relationships *within* and the functional differences *between* instrument groups, and the way those relationships vary over the course of the piece. A quintet group might, in one instance, remain static at floor level, while a trio group is suspended in the air above the ensemble and a solo instrument made to weave a path in and around the other groups. Another section might have the solo instrument static and directly overhead, while the quintet becomes a slowly shifting cloud in the air around it while the trio instruments are darting rapidly throughout the performance space.

The composer provides no explicit spatialization directions in the *codex IX* performance notes. The approach outlined above is derived from the structure of the work, the explicit performance notes for instrumentalists regarding sub-ensemble groupings, the staging of the performance with instrumentalists and audience arranged in concentric circles and the capabilities of the SIAL software spatialization system.

3.2 The SIAL spatialization system

The SIAL software spatialization system is implemented in Max/MSP (Puckette and Zicarelli 1990-2010) and provides an input matrix that allow signals to be directed to spatialization algorithms, then via an output matrix to speakers. Matrix routings can be stored as presets and recalled to effect changes to the configuration in performance. In order to execute performance control by means of the SIAL software, two spatialization performers were employed for the series of *codex IX* performances. Jeffrey Hannam, one of the developers of the software system, operated the spatialization computer while I operated the mixing console. Sends from the mixing console to the spatialization computer were post-fade, either from direct, group or auxiliary outputs, which allowed ensemble balance to be controlled from the mixing console faders. Jeff controlled the spatial locations of instruments and/or their trajectories via the spatialization software.

Spatial positioning and motion was implemented by means of a three-dimensional vector based amplitude panning (vbap) algorithm (Pulkki 1997). The vbap algorithm requires co-ordinates for speaker locations to be entered to calibrate the algorithm for accurate geometry. The SIAL software system provides an interface for entering this data, derived from distance and angle measurements taken relative to a pre-determined point of origin. These measurements need to be taken in the venue *after* speakers have been positioned for accurate localization to be achieved.

3.3 Brisbane, September 2008

The premiere performance of *codex IX* took place in The Performance Space at the Judith Wright Centre of Contemporary Arts in Brisbane, Australia in September 2008. The venue is a flexible theatre space with a retractable seating bank and floor area 15 metres wide by 21 metres long with the seats retracted. Total elevation is 9 metres, with gantries at 6 metres determining the upper limit for speaker elevation.

The ensemble configuration for adopted for this series of *codex IX* performances consisted of performers seated in a circle, surrounded by the audience. The sound system design for the Brisbane performance of *codex IX* (developed in consultation with composer Richard Barrett) consisted of 16 speakers on discrete feeds arranged in an approximate hemisphere around and above the performers and audience. Around the audience, at ground level, was a circle of eight speakers fifteen metres in diameter. A further ring of four speakers was suspended at half room height with a smaller diameter approximating points on a hemisphere defined by the fifteen metre diameter of the lower speaker ring. Four more speakers were suspended in a tight ring just below the six metre gantry height, defining the upper portion of the hemisphere.

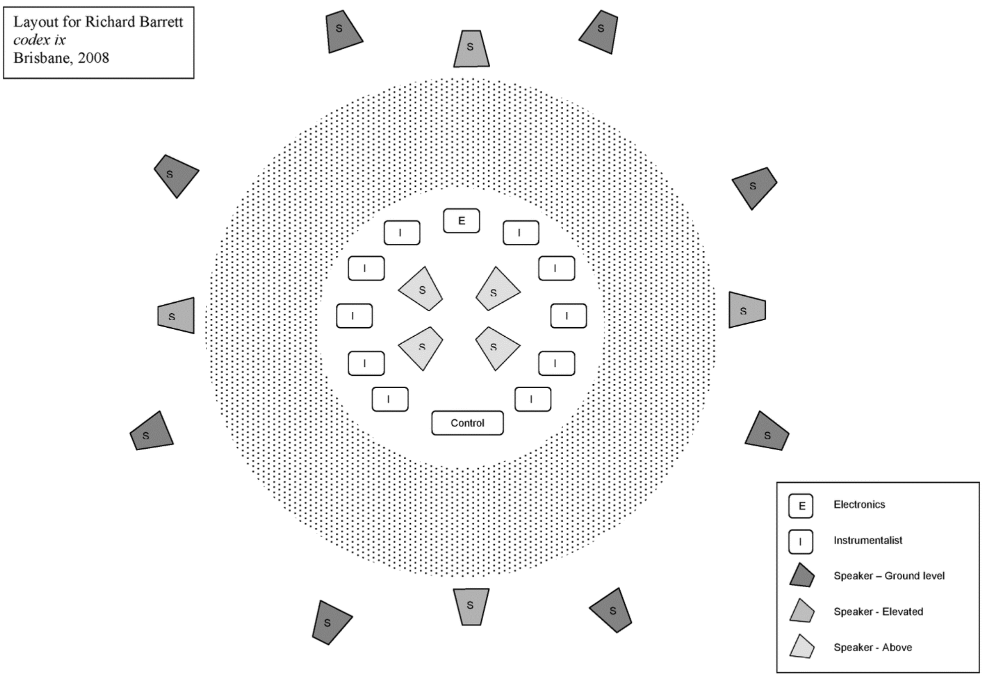

Figure 8 – Performer and speaker layout for *codex IX*, Brisbane 2008

Speaker locations were measured and coordinates entered into the spatialization software by system developers Lawrence Harvey and Jeffrey Hannam, and the software calibrated to allow the vbap algorithm to accurately position sounds at any location on the hemisphere. The spatialization computer's inputs were fed signals from post fade direct outputs from a Midas Venice 320 mixing console. The spatialization system's software matrix was then used to route each input either to a vbap algorithm or directly to a speaker as required. Real time performance control for the Brisbane performance was limited to eight MIDI faders, and automated control was only available by means of low frequency oscillator (LFO) modulation of azimuth and elevation parameters. In keeping with the strategy of using spatialization to assist in the differentiation between functional instrumental groupings, we decided in pre-production planning that quintet groups would remain statically spatialized at floor level, trio groups would be rotating slowly under automated control and solo instruments would be moved manually by means of direct MIDI fader control. LFO modulation was applied to the azimuth parameter of each of the vbap panners designated for the trio instruments. A MIDI fader was assigned to control the rate of each of the LFOs and the elevation parameter of each of the vbap panners. The trio instruments could thereby be made to rotate at a variable rate, with their elevation controlled with a fader. The remaining two MIDI control faders were assigned to the azimuth and elevation parameters of the vbap panner designated for the solo instrument, allowing manual control of its position or motion anywhere on the hemisphere.

Ensemble balance was controlled at the Midas console prior to analogue to digital conversion via two Metric Halo 2882 interfaces connected to the spatialization computer. While this approach fails to take full advantage of the full resolution of the Metric Halo converters, it has the benefit of providing fader control of ensemble balance, and access to input channel equalization in the analogue domain. To simplify the interface with the venue's sound system, the outputs from the spatialization computer were being routed to speakers via the Digidesign D-Show Profile console housed in the venue's control room. Because the spatialization software was untried in the context of ensemble performance, a contingency was put into place to guard against failure of the spatialization computer or software. In addition to feeding the spatialization computer from direct outputs, signals from the Midas console group and auxiliary outputs were sent directly to spare channels on the Digidesign console. These channels were routed via the Digidesign console to the ring of eight speakers at floor level. In the event of spatialization system failure, raising the appropriate output masters on the Midas console would send the ensemble inputs directly to speakers and allow amplified performance to continue while the spatialization system was brought back online.

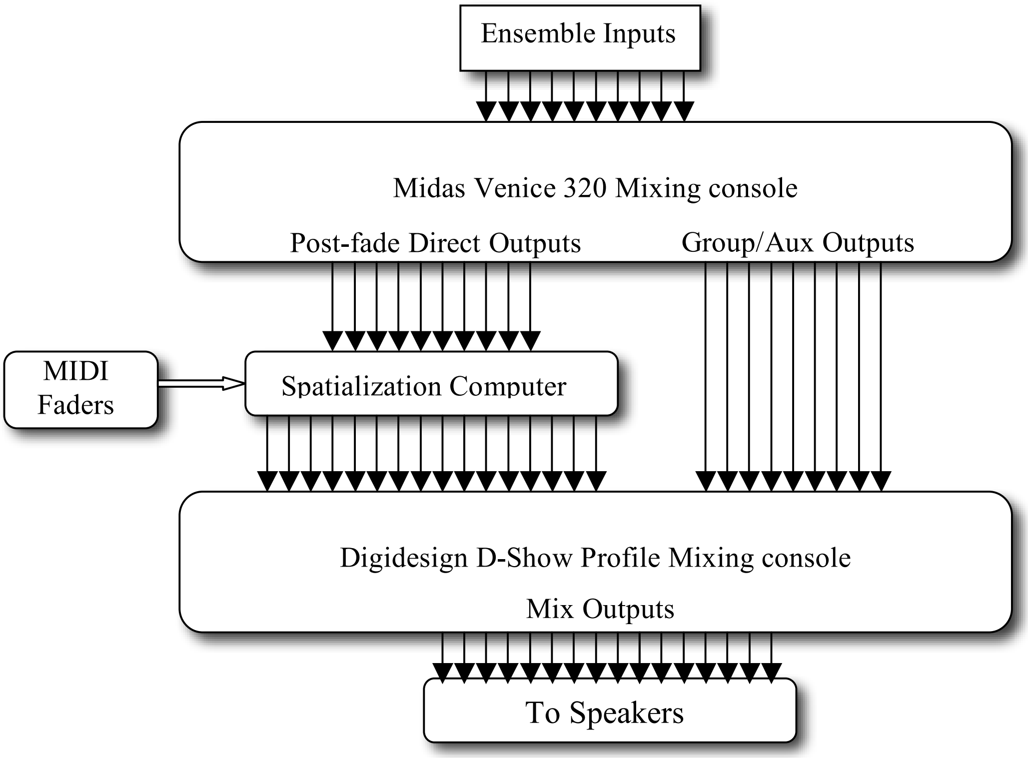

Figure 9 – Signal flow for *codex IX*, Brisbane 2008

The contingency patching proved useful, but not in the way it was conceived. When excessive signal latency inherent in the path through the spatialization computer became evident in rehearsal, the performance control strategy was modified such that the static quintet routing was handled directly by the Midas console. This made performance control more complex in that numerous group assignments and send levels had to be reset manually with each change in ensemble configuration, a task that was intended to be handled by recalling input matrix states on the spatialization computer. This reconfiguration eased the processing load on the spatialization computer, which allowed the audio buffer size to be reduced in Max/MSP, which reduced the latency but did not eliminate it entirely. Bypassing the spatialization computer for the quintet instruments meant they remained latency free. The failsafe remained in place with the trio and solo instruments simply needing to be routed to speakers from the Midas console in the event of spatialization system failure, which did not eventuate.

Figure 10 – Control position for *codex IX*, Brisbane 2008[8]

From a research perspective the process was instructive, but from the perspective of the quality of the concert presentation it fell considerably short of ELISION's established standard of technical production, due to the still audible latency in the spatialization system causing a constant delay that was clearly audible on transients. It was clear that the spatialization software had considerable potential for ensemble performance, but that substantial updating and reworking would be

[8] Photograph courtesy Lawrence Harvey

required for it to be usable in concert. The SIAL software system was subsequently updated by Stephen Adam in order that it be viable for continued research in a public concert environment.

3.3 London, June 2010

The second performance of *codex IX*, and the first with the revised spatialization software system took place at Hall Two, King's Place, London in June 2010. The revised software had been tested under load in the SIAL Sound Studios, and the latency problem appeared to have been solved. Other revisions to the software included the implementation of IRCAM's *Spat* spatialization engine (Jot, Jullien et al. 1995-2010), and enhancements to the user interface with the development of 'spatialization channels' that allow real-time user control via a choice of cartesian X, Y, Z or AED (azimuth, elevation, distance) parameters. OSC control (Wright 1997) was also implemented for all spatialization parameters to enable complex real time manual or automated control.

The performance system configuration for the London performance was an evolution from the Brisbane performance, with a Yamaha M7-48 digital mixing console used in place of the analogue console. Post fade direct outs were again used to feed the spatialization computer (again operated by Jeffrey Hannam), this time sent via analogue expansion cards installed in the M7. Significantly, the outputs from the spatialization computer were this time routed back to the M7 on another input layer and sent to speakers via the M7's sixteen mix busses. It would have been preferable to interface the spatialization computer to the console digitally and avoid two conversion stages[9], but the venue's console was pre-configured with analogue expansion cards, so in order to avoid the expense of hiring digital expansion cards the spatialization system was configured with A/D and D/A converters and the extra conversions tolerated. Since it is a simple matter to store and recall states on the M7, the contingency on this occasion was an alternate recallable mixer state that fed the instrument inputs directly to the mix busses. This loopback technique (routing the spatialization computer outputs back through the console) is effective as a failsafe when using a digital console, at the cost of doubling the number of mixer channels required.

[9] As well as the A to D and D to A conversions being redundant, conversion resolution was compromised by conversions taking place after attenuation for balance.

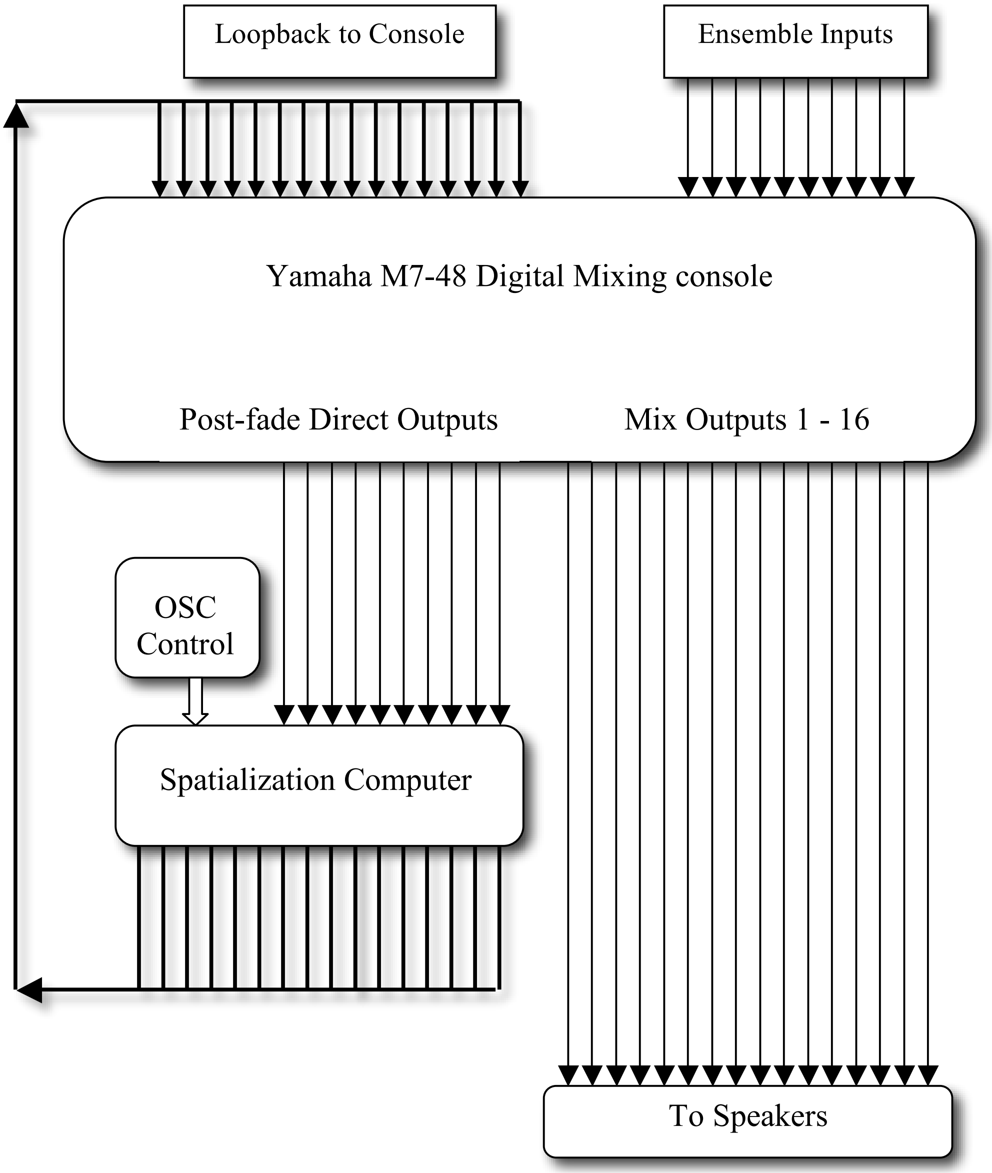

Figure 11 – *codex ix* revised signal flow incorporating loopback

One immediate benefit of the software revisions that had been implemented after the Brisbane performance was the inclusion of a graphic display of speaker locations. This allowed a pictorial representation of the system design to be sent to the King's Place technical personnel in advance, which considerably simplified the process of communicating the required configuration and expedited the venue's installation planning.

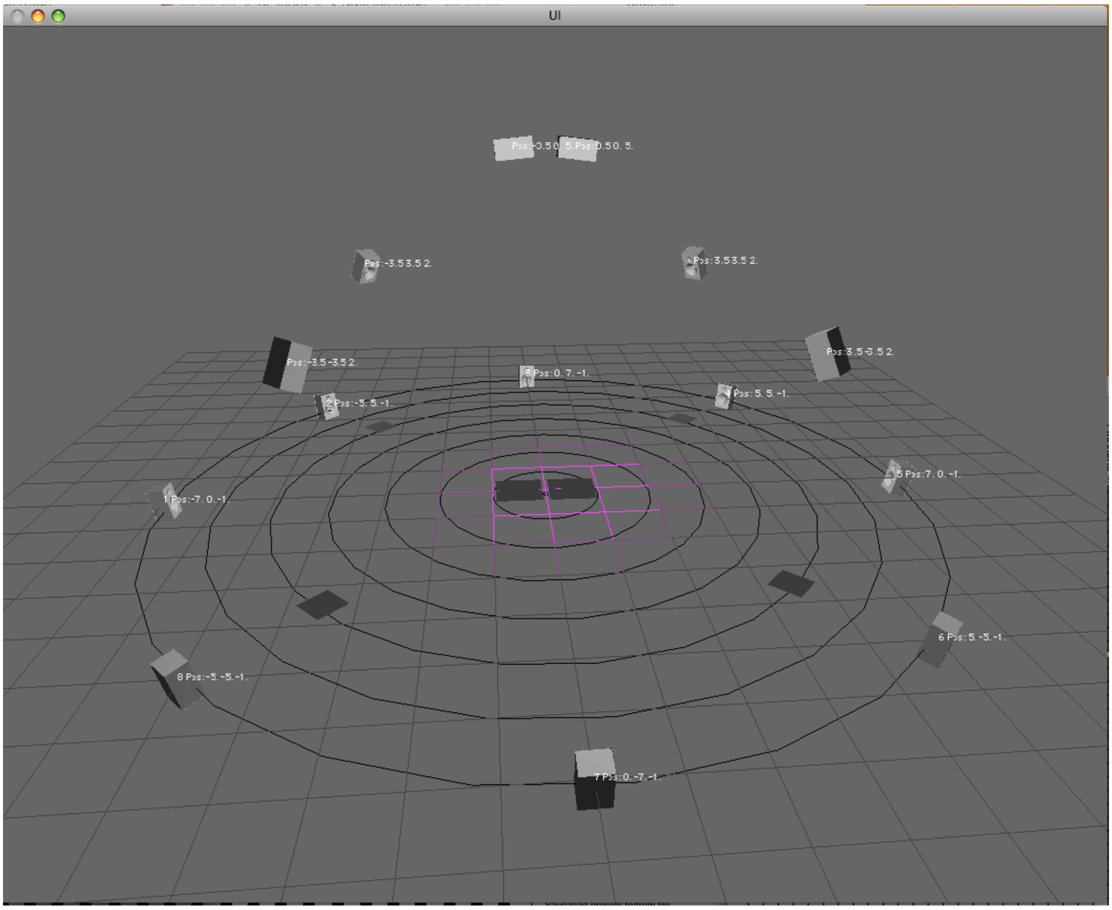

Figure 12 – SIAL Spatialization System speaker location display

The speaker configuration was slightly modified from the Brisbane performance in that only two overhead speakers were specified, and two speakers were added at floor level in the centre of the circle of performers. This was done to provide better spatial integration of electronic sounds with the acoustic output of the ensemble, without exceeding the sixteen-output limitation of the spatialization computer's routing matrix.

The system was installed in the venue and calibrated the day before the performance, and initial sound checking revealed uneven panning resolution in the vertical axis resulting from the centre ring of four speakers being positioned approximately 500mm below their required height. The accommodating venue crew made the adjustment, and vertical resolution was improved considerably. Further listening tests determined that clear spatial articulation was only possible with the aperture parameter of the IRCAM Spat spatialization engine set to its minimum value of ten degrees. I had hoped this parameter would be useable as a performance variable to define spatial fields rather than point sources, but this was unable to be achieved in context. With the aperture set to minimum, however, precise positioning and smooth motion were achieved in three-dimensional space.

The updated software performed well in the audio domain. Motion was smooth and clearly defined and there was no audible latency. The software control mechanism on the other hand exhibited an errant behavior that would impact performance control. As testing proceeded, the system became progressively less responsive to control input, eventually exhibiting latency of several seconds between user input and system response. A system reboot restored the control responsiveness to normal, but the progressive decline continued to occur. It was evident that even with a reboot immediately before the performance there would be significant deterioration over the duration of the piece, and this would limit the controllability of the system.

Rehearsal time with musicians was limited to a single three-hour call on the day of the performance. Further technical rehearsal was impossible due to scheduling constraints and the need to manage musicians' workload in the lead up to the concert. This only allowed time for microphone positioning, gain setting and input equalization, as well as overall system equalization. The musicians were able to rehearse while this was taking place, but there was insufficient time for spatialization strategies to be tested or rehearsed. A similar spatialization strategy to that employed in the Brisbane performance was implemented, although the enhancements to the real time control capabilities of the spatialization system and the resolution of the audio latency problem meant the quintet groups could be placed in motion rather than left static, and all inputs could be manually spatially controlled or placed in automated trajectories.

Twenty minutes before the start of the concert, a final line check revealed that four of the twelve inputs to the spatialization computer were no longer receiving signal. The inputs in question were all being sent to the computer by means of a standalone A/D converter connected to the lightpipe input of a Metric Halo 2882 audio interface. The eight analogue inputs to the interface continued to function, but rebooting the entire system and changing the lightpipe cable failed to rectify the problem with the optical inputs. *codex IX* was not scheduled until the second half of the concert programme, so further attempts to reinstate the missing channels were made at interval. After repeated unsuccessful attempts, the missing signals spontaneously reappeared, and the system again appeared to be functioning normally. Without a clear understanding of what had gone wrong or why it had righted itself, I decided to start the performance in 'safety mode', using a console preset that directly assigned inputs to outputs, then gradually transition to the spatialization system if it appeared stable.

The performance therefore began with static spatial amplification, with each musician localized to their actual position. As the spatialization system appeared to be functioning correctly, I transitioned instruments across to it channel-by-channel, commencing with the soloists, moving through the trio and finally the quintet. The result was the unintended addition of an extra layer of formal structure to the performance in the gradual progression from static to dynamic spatialization. Unfortunately this detracted from the effectiveness of the spatial articulation of the composed form of the work.

Figure 13 – *codex IX* rehearsal, King's Place, London, June 2010[10]

3.3 Bremen, July 2010

The next performance of *codex IX* took place in Radio Bremen's Sendesaal in Bremen, Germany. The nature of the venue meant an entirely different performance setup would need to be employed for both ensemble and technical configurations. The Bremen Sendesaal has a fixed stage and seating configuration that precluded a circle

[10] Photograph courtesy Jeffrey Hannam

of performers being surrounded by audience. The ensemble would be on an elevated stage at one end of the hall, with audience in a traditional fixed-seating arrangement. Additionally, the hall is equipped with no infrastructure for the hanging of overhead speakers, meaning the hemispherical speaker array that characterized the *codex IX* sound design could not be employed. Given these constraints, a two dimensional,

http://www.sendesaal-bremen.de/fileadmin/content/photos/Innen-_und_Aussenraeume/1515072984_3ffadad3b8_o.jpg

eight channel system design was substituted, consisting of stand-mounted speakers spaced evenly around the perimeter of the hall.

Figure 14 – Sendesaal, Bremen

The location of the ensemble on stage meant the spatialization control position could not be located at or near the centre of the sound field without sacrificing proximity to the instrumental performers with whom we were interacting. This complicated the rehearsal process somewhat, but once the behaviour of sound in the room was understood it proved possible to generate an even distribution of sound in spite of the compromised listening position. Spatial articulation in the hall was very clear, allowing spatially pointillistic sound fields to be generated with more articulate localization than had been possible in the previous performances.[11] We again experimented with widening the SPAT aperture in an attempt to generate unfocussed spatial 'fields', but the system became far too sensitive to feedback in the speakers nearer the stages, and there was insufficient time in the rehearsal schedule to stabilize the system sufficiently to make it viable. The technical difficulties with the optical inputs encountered at King's Place did not recur, but on this occasion the spatialization system produced audible glitching whenever rapid panning motions were implemented. There was no time to diagnose and rectify the problem, so it was necessary to limit the rate of motion for the concert performance.

The performance went smoothly, and while difficult to assess from my monitoring position, reports from audience were that the spatialization was effective. The asymmetrical ensemble/audience configuration varied significantly from the composer's suggested layout, and the spatial amplification was of compromised

[11] The location of the ensemble toward the periphery of the sound field enhanced the clarity of the spatial amplification due to the relative proximity of speakers for the bulk of the audience.

resolution and limited to two dimensions, but the simple and robust strategy of spatially differentiating ensemble groupings could nevertheless be articulated effectively.

3.4 Melbourne, March 2011

The fourth performance of codex IX took place at Iwaki Auditorium, Melbourne in March 2011. The Iwaki Auditorium is a recording and broadcast studio designed to also accommodate orchestral rehearsals. The floor area is 600 square metres, above which is a height-adjustable grid capable of bearing hanging speakers. This flexible infrastructure allowed a return to the preferred concentric circle arrangement for ensemble and audience, and meant a hemispherical speaker array could once again be utilized. A similar speaker arrangement to that employed in the London and Bremen concerts was used, with two central speakers at floor level and two speakers directly above them defining the top of the hemisphere. The interface between the mixing console and the spatialization computer was also configured similarly to the London and Bremen concerts, except in this instance the mixing console was SIAL's Yamaha 02R96 which is configured with sufficient digital inputs and outputs to allow all interfacing to take place in the digital domain. The spatialization software had undergone further revision since the European concerts, and the problem with control responsiveness has been resolved.

The Melbourne performance of *codex IX* was the first opportunity to trial in performance a multiple microphone signal capture technique that had been explored in workshops with ELISION instrumentalists, described in Chapter 4. This technique uses an array of microphones to capture the local spatial field in which a performer operates, with the microphone signals statically spatialized to allow the instrumentalist to control the spatiality of their performance by manipulating their local spatial field. The technique does not require the use of software to spatialize the signal, and was initially tested in rehearsal prior to the software system being configured. The initial results were very encouraging, but subsequent routing of these signals through the spatialization computer revealed an issue with the software system that had not previously been evident. Firstly, there appeared to be a significant drop in signal level in the path through the spatialization computer. Secondly, the sound system was much more prone to acoustic feedback when attempts were made to compensate for the level drop. Thirdly, sound localization was much less defined, and apparently not responding accurately to the positional information being input to the software. Speaker location data was re-entered in an attempt to resolve these issues, but a consistent response could not be achieved, and the desired amplification levels could not be restored without acoustic feedback. There was insufficient rehearsal time to diagnose and rectify the problem, so the performance took place with less than ideal amplification and the spatial articulation of the work was considerably compromised as a result.

The series of *codex IX* performances provided an ideal framework for initial experimentation with the use of software spatialization as a performance tool for ELISION and the development of the SIAL software system for ensemble performance. The software enhancements implemented over the course of these performances made a significant difference to the viability of the system as a performance tool, but more experimentation would be required to develop a better understanding of the system's behaviour before informed planning decisions could be made for the next stage of development.

3.5 *CONSTRUCTION* premiere

The culmination of the performance development research for *The Spatial Ensemble* project was the premiere of Richard Barrett's *CONSTRUCTION* (2003-11) for the 2011 Huddersfield Contemporary Music Festival.

CONSTRUCTION is a work of approximately two hours duration, for nineteen spatially amplified performers and spatialized prerecorded electronics. Originally commissioned for Liverpool European Capital of Culture 2008, the work was finally premiered on 19 November 2011 for the Huddersfield Contemporary Music Festival.

CONSTRUCTION consists of twenty sections of varying duration and instrumentation:

1	*strange lines and distances*	(2')	8ch fixed media
2	*Politeia*	(9')	ensemble
3	*Hekabe-α*	(4')	voice/ensemble
4	*wound I*	(2')	violin, oboe, cello
5	*Kassandra*	(4')	voice/ensemble
6	*heliocentric*	(15')	ensemble
7	*Omaggio a Chirico*	(6')	8ch fixed media, voices, strings
8	*Andromakhe*	(4')	voice/ensemble
9	*wound II*	(4')	violin/trio
10	*news from nowhere*	(7')	ensemble
11	*storming*	(3')	8ch fixed media, tutti
12	*Helene*	(4')	voice/trio
13	*wound III*	(5')	violin/ensemble
15	*Simorgh*	(11')	fixed media, voices, 3 recorders
16	*wound IV*	(3')	violin, voices, ensemble
17	*Hekabe-β*	(4')	voices, ensemble
18	*wound V*	(1')	violin, guitar, percussion
19	*Germania*	(3')	tutti
20	*ON*	(18')	tutti

Figure 15 – *CONSTRUCTION* sectional breakdown

The instrumentation, and performers for the Huddersfield premiere, is as follows:

conductor (Eugene Ughetti)

piccolo/bass flute/alto flute (Paula Rae)

tenor recorder/bass recorder/2 soprano recorders/2 sopranino recorders (Genevieve Lacey)

oboe/english horn (Peter Veale)

tenor saxophone/alto saxophone/contrabass clarinet/clarinet in A/bass clarinet (Carl Rosman)

baritone saxophone/contrabass clarinet/clarinets in Bb, A and Eb/bass clarinet (Richard Haynes)

bass saxophone/alto saxophone/bass clarinet (Timothy O'Dwyer)

bassoon (Dafne Vicente-Sandoval)

quartertone flugelhorn/piccolo trumpet (Tristram Williams)

alto trombone/tenor-bass trombone (Benjamin Marks)

percussion (Domenico Melchiorre)

electric guitar/electric lap steel guitar (Daryl Buckley)

baroque triple harp (Marshall McGuire)

violin (Graeme Jennings)

viola (Erkki Veltheim)

cello (Séverine Ballon)

contrabass (Joan Wright)

soprano (Deborah Kayser)

alto (Ute Wassermann)

baritone/countertenor (Carl Rosman)

live and prerecorded electronics, 16-channel sound projection (Steve Adam, Richard Barrett, Lawrence Harvey, Michael Hewes)

The venue for the performance was Huddersfield Town Hall, which is a typical nineteenth century rectangular hall of approximately 30m x 20m with 10m ceiling height.

http://www.digyorkshire.com/visuals/330x380/79/2879.jpg

Figure 16 – Huddersfield Town Hall exterior

Figure 17 – Huddersfield Town Hall interior[12]

[12] Photograph courtesy ELISION Ensemble

The hall has a fixed stage at 1.5m elevation across one end, and a balcony around the remaining three walls.

https://www.kirklees.gov.uk/townhalls/documents/HTHGroundplan.pdf

Figure 18 – Huddersfield Town Hall floor plan

As for *codex IX*, the composer's preferred staging plan for *CONSTRUCTION* is a circular arrangement of performers, surrounded by audience, with a hemispherical speaker array enveloping the entire performance area. The dimensions of the Huddersfield Town Hall meant this staging plan was not practical for mounting the work in this venue. The floor space required for a nineteen-piece ensemble would not allow for the concentric rings of ensemble, audience and speakers in a hall 20m wide.

To do so would limit audience capacity to an unacceptable degree, and necessitate positioning speakers too close to individual audience members.

Given the constraints of the venue it was decided to place the ensemble on the stage and the audience in a conventional seating arrangement at floor level. Balcony seats were not sold, as the spatialized amplification could not have been usefully conveyed to the balcony area. An alternate ensemble layout was devised by the composer for the Huddersfield performance, a plan of which is depicted in Figure 19.

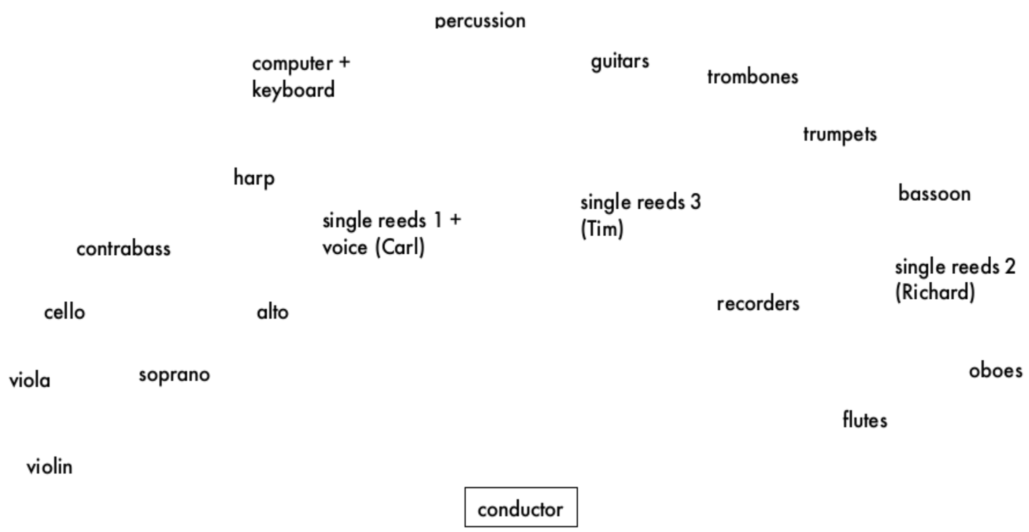

Figure 19 – Ensemble configuration for *CONSTRUCTION* premiere.

The control position for the spatial amplification remained in the centre of the hall to facilitate monitoring of spatial balance. In the original concentric staging plan the spatial control was intended to be co-located with the ensemble. Whilst ideal from a monitoring perspective, the separation from the ensemble created some complication with cueing and communication between spatialization performers and the conductor (and ensemble). This did not present a major problem in performance due to good sightlines and clear gestures from the conductor, although a degree of subtlety and refinement was inevitably lost due to the lack of proximity.

In addition to compromising the composer's intended spatial relationship between performers and audience, the hall also prevented the implementation of the dome- shaped array of loudspeakers specified in the *CONSTRUCTION* performance notes. The lack of infrastructure for overhead rigging of speakers in the centre of the hall meant the only possible locations for elevated speakers were speaker stands placed around the balcony and on the choir risers behind the stage. No elevated speaker positions would be possible above the audience area, meaning no sound could be made to emanate from directly overhead.

The compromise system design developed in consultation with the composer was sixteen speakers configured in two rings of eight, one ring on stands at floor level and another on stands at balcony level. The vertical spatial resolution of this limited arrangement would be rudimentary, but all that could be achieved in the circumstances. Horizontal spatial resolution would be less compromised, and the upper and lower rings were offset to maximize this resolution.

While this system design would aid with horizontal spatial resolution around the perimeter of the hall, the lack of overhead speaker positions meant the horizontal spatial resolution *across* or *through* rather than *around* the hall was the most compromised of all, particularly at or near floor level. The smaller path length differential might allow some degree of vague cross-hall imaging or discernable trajectory from the balcony level speakers, but only for the proportion of audience sufficiently central that the balcony itself did not mask any of the balcony-level speakers. At floor level, the path length differentials to which the bulk of the audience would be subjected meant there could be no useful cross-hall imaging for any but a few audience members in the very centre of the hall, effectively negating the usefulness of cross-hall trajectories.

With the ensemble located on the stage, any static reinforcement *in situ* would be weighted to the stage end of the hall. In designing the performance sound system I decided to make use of the in-house sound system for all in situ reinforcement. The in-house system would be fed a stereo mix directly from the mixing console, thereby simplifying the operation of the spatialization computer. Localized static reinforcement states would not need to be programmed into the software matrix, so fewer state changes would be required during the performance. An added benefit was that static and spatialized instruments would not be sharing the same speakers, so would more likely be perceived as functionally separate, which I hoped would enhance audience comprehension of their differing roles.

The sixteen input limitation of the SIAL spatialization system meant that the full *CONSTRUCTION* ensemble could not fit into the input matrix on discrete channels, even if percussion were sub-mixed to stereo. For most of *CONSTRUCTION* this would not be a concern due to the size of ensemble groups requiring spatialization, but for tutti sections requiring all inputs spatialized it would be necessary to generate sub-mixes at the mixing console to fit the ensemble to sixteen channels. Direct outputs from mixer input channels could therefore not be used to provide feeds to the spatialization computer, so a mixing console with at least sixteen mix buses would be required, and console presets would need to be programmed for each assignment change required by the spatialization computer. This meant the loopback technique devised for *codex IX* to mitigate against failure of the spatialization computer could not readily be employed. With the smaller *codex IX* ensemble, the feeds to the spatialization computer could be derived from channel direct outs as no sub-mixing was required to fit into the system's sixteen inputs. The *CONSTRUCTION* specification requires 40 inputs from stage and an additional eight for fixed media playback. Using the loopback method would have necessitated a mixing console with 64 input channels (48 from stage and playback plus 16 returns from the spatialization computer), feeding 32 mix buses (16 sends to the spatialization computer and 16 speaker feeds). Such consoles are expensive to hire and tend to be physically large, which is problematic in a venue where floor area is at a premium.

The two rings of eight speakers consisted of sixteen D&B Q7 speakers operating full-range, stand mounted at floor and balcony level respectively. The in-house system was a stereo configuration of Meyer CQ1 mid/high cabinets with Meyer PSW subwoofers at stage level, and Meyer UP junior cabinets flown at balcony level. The mixing console employed was a Yamaha PM5D-RH, providing 48 mono and 8 stereo inputs, feeding 24 variable mix busses with independent analogue outputs in addition to stereo mix outputs.

In addition to the nineteen-piece ensemble, *CONSTRUCTON* calls for 8 channels of pre-spatialized fixed media playback to be triggered at various times throughout the piece. For sections where ensemble spatialization is required simultaneously with playback, feeding the playback through the spatialization computer would leave only 8 channels of the input matrix available for the ensemble, which would necessitate a degree of sub-mixing that would compromise ensemble spatialization. To avoid this compromise, I devised a variation to the configuration of the spatialization computer hardware configuration that would allow the playback channels to be routed to the spatialization speakers from the mixing console without going via the spatialization computer. The Metric Halo 2882 audio interface was replaced with a MOTU traveler Mk3, which has the facility for 24 inputs. The 16 optical digital inputs were used for the feeds to the spatialization software, while the 8 analogue inputs were fed from the remaining 8 mix busses on the PM5D console. The MOTU interface's internal software mixer was then used to route the playback directly to speakers. It was immediately obvious when testing this configuration that there was a significant level difference between the signals direct from the mixer and those passing through the spatialization computer. Inspection of the MOTU interface's level meters confirmed this. The levels of ensemble and playback being sent from the mixing console were comparable, but the return levels from the spatialization computer were severely attenuated, even with maximum output gains set in the spatialization software. There was no time in the production schedule to further diagnose the cause of this attenuation, so comparable attenuation was applied to the playback channels in the MOTU software mixer to match playback and ensemble levels. Fortunately, the spatial audio system was sufficiently powerful that this attenuation did not compromise overall amplification levels.

The 40 mixer channels occupied by the *CONSTRUCTION* ensemble left eight channels available to further explore the multi-microphone technique developed in workshops and tested in the Melbourne performance of *codex IX*. With an enormous amount of music to be rehearsed in a limited time, it proved undesirable for instrumentalists to spend time rehearsing the spatialization of their own performance, so the idea was abandoned for the Huddersfield performance.

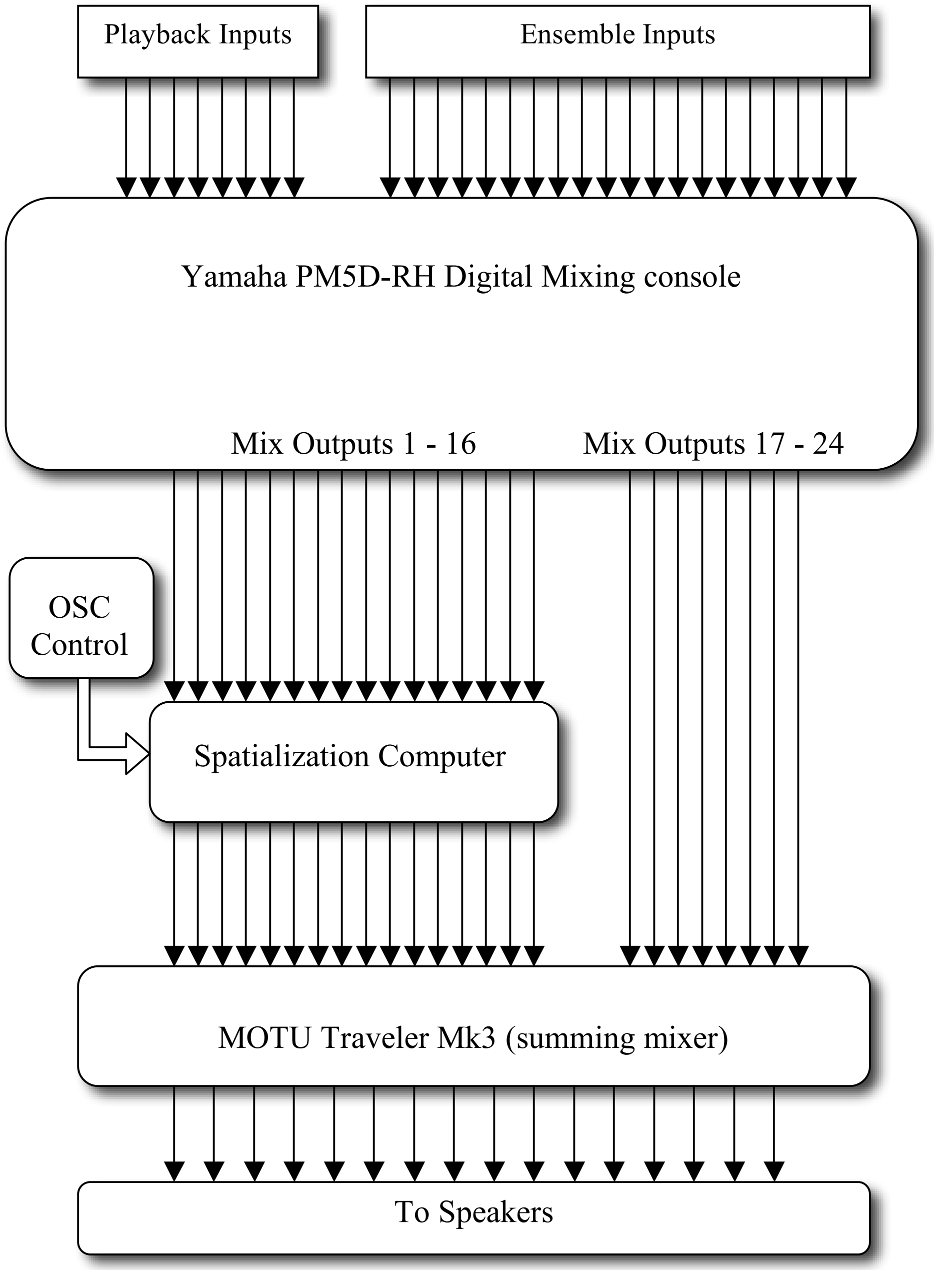

Figure 20 – *CONSTRUCTION* premiere signal flow

The performance notes in the *CONSTRUCTION* score include guidelines from the composer for sound spatialization for each of the twenty sections of the work (shown in Figure 20 on page 125). A mix of static spatialized reinforcement, automated motion trajectories and freely improvised spatialization is called for at different times. An enhancement of the software-controlled spatialization was implemented to take advantage of the OSC control capability of the spatialization software. SpatDIF files (Peters 2007, 2009, 2012) defining pre-programmed trajectories were generated by Lawrence Harvey using IRCAM's Open Music software (Agon Amado 1998). Playing the SpatDIF files from an SDIF player sends Cartesian coordinate data to selected channels in the spatialization software via OSC, and the pre-programmed trajectories are executed. For *CONSTRUCTION*, distance based amplitude panning (dbap) was employed instead of vbap to overcome the lack of positional articulation experienced in the Melbourne *codex IX* performance.

The spatialization of *CONSTRUCTION* for the Huddersfield premiere required three performers – myself operating the mixing console and fixed-media playback, Stephen Adam operating the spatialization software and Lawrence Harvey operating a second computer for SpatDIF playback. Following is a breakdown of the sectional structure of the work with instrumentation details, the composer's notes for spatialization, and notes on the spatialization design implementation.

Figure 21 - Rehearsal for *CONSTRUCTION*, Huddersfield 2011[13]

1 strange lines and distances

strange lines and distances is for pre-spatialized 8 channel fixed media, without ensemble. The direct routing of console busses through the MOTU interface to speakers meant the spatialization computer was not required for this section. Media playback was from a dedicated computer running AudioMulch (Bencina 1997-2011). AudioMulch allows the synchronized playback of multiple (or multi-channel) audio

[13] Photograph courtesy ELISION Ensemble

files and provides level control for up to 8 channels on a single fader. It also provides a facility for playback to be paused automatically at predetermined points on a timeline, which was required for a later section of the work.

Playback commences on a cue from the conductor, and is faded up at the console at a rate matching the natural fade in the recorded material. The dynamic range of the recorded material proved excessive for the venue, so lower-level passages were faded up to ensure audibility.

2 Politeia

Politeia is for two instrumental groups, an octet and a quintet, playing from separate scores. The octet is comprised of three saxophones (tenor, baritone and bass), bassoon, trombone, violin viola and cello. The quintet consists of recorder, flugelhorn, electric guitar and marimba.

At times the groups are synchronized, and at other times play independently of one another. The composer calls for static reinforcement for the octet, which for the Huddersfield staging layout could either have been localized to the stage, or spatially distributed. Since the thirteen instruments could be accommodated by the spatialization computer without sub-mixing, the octet was distributed spatially, but remained static. The composer calls for the quintet instruments to "wander slowly through the space independently of one another". This motion was implemented by means of automated trajectories controlled by pre-programmed SpatDIF files.

3 Hekabe-α

Hekabe-α is scored for alto voice and an ensemble of piccolo, sopranino recorder, two contrabass clarinets in Bb, baroque triple harp and contrabass. The composer calls for static reinforcement, which for the solo alto was oriented to the performer's location on stage directly from the mixing console to the in-house sound system. The harp and contrabass were localized in the same way, while the wind instruments were distributed around the room via the spatialization computer.

4 wound I

wound I casts the violin in a solo role, accompanied by oboe and cello. Static reinforcement is again specified by the composer, and in this case was entirely focused on the stage area so as not to draw audience focus away from the soloist.

5 *Kassandra*

Kassandra is scored for soprano voice with an ensemble of oboe, clarinet in Bb, alto saxophone, quartertone flugelhorn, baroque triple harp and viola. Also specified to be statically spatialized, the section was performed with the voice localized to the performer and the instruments distributed around the hall.

6 *heliocentric*

heliocentric is scored for an ensemble of 10 instruments, divided into three duos and a quartet as follows:

duo 1 - bass flute and bass recorder

duo 2 - 2 clarinets in A

duo 3 - quartertone flugelhorn and alto trombone

quartet - percussion (one player, at least 2 kalimbas or similar instruments), baroque triple harp, electric guitar, cello

The score specifies a complex spatialization design:

> "duos making concentric 'orbits' at different (slowish) speeds and at different vertical levels - duo members opposite one another as they rotate."

The relative spatial locations for the duo 'orbits' is also specified:

> "recorder/bass flute (lowest, closest to centre), 2 clarinets (intermediate), flugelhorn/trombone (highest, around the edge)"

The score is also explicit in regard to the spatialization of the quartet -

> "4 plucked instruments (kalimbas, harp, guitar, cello) make more isolated sounds, each sound from a different random position, with reverb (variable?)"

The adaptation of the ensemble layout and sound system geometry that was required for the Huddersfield performance meant the composer's spatialization instructions would also require adaptation. The duos' orbits could be realized by LFO modulation in the spatialization software, and the spatial opposition of duo members maintained by establishing opposing starting positions and matching modulation rates on the appropriate spatialization channels. The height differentiation of orbits was also easily defined by setting the elevation parameters for pairs of channels. The width of the orbits, however, could not be articulated clearly with the Huddersfield layout. I have already discussed the inability to localize sound in the centre of the hall, and this meant there was no clearly perceived sense of variation in the diameter of orbits.

The fragmented nature of the quartet material and the composer's desire to have each utterance heard from a different random location called for rapid changes to spatialization parameters, executed in the pauses between phrases. The simplest way to execute this was to prepare SpatDIF files that would generate the rapid changes, and stop and start playback of the file as required. With the rate of spatialization change not synchronized with the musical tempo, the result was effectively random, despite the SpatDIF file being pre-prepared.

7 Omaggio a Chirico

Omaggio a Chirico reintroduces 8 channel fixed media playback, with an ensemble of 3 vocalists, violin, viola, cello and contrabass. The fixed media is pre-spatialized, in addition to which the composer requests “each sound from each source from a different place, at a different distance (use reverb as well as spatial positioning).” To this end, the voices and instruments were statically assigned to virtual locations in the hall, and the distance parameter in the AED section of the spatialization channels set for varying perspectives.

8 Andromakhe

Andromakhe is scored for contralto voice, 3 bass clarinets, bassoon, baroque triple harp and cello. The composer’s specification is for static spatial reinforcement, so the contralto soloist was localized on the stage, along with the bassoon, while the clarinets and harp were statically distributed around the hall.

9 *wound II*

As for *wound I*, the violin features as soloist, this time accompanied by a trio of English horn, Eb clarinet and cello. In keeping with the composer's request for static reinforcement, and in order to link the *wound* pieces thematically, the solo violin was localized to the stage, and the ensemble statically distributed.

10 *news from nowhere*

The ensemble for *news from* nowhere consists of four wind players using multiple instruments, a percussionist using a single instrument able to produce at least four distinct timbres, and an unspecified number of (optional) drone instruments playing sustained sounds. The percussion and wind instruments are specified as being static. The percussion was localized to the stage, with the winds distributed around the hall to spatially animate the melodic material that shifts from instrument to instrument. The drones were, as specified, moved slowly around the space on trajectories pre-programmed in SpatDIF files.

11 *storming*

storming features eight-channel fixed media playback, and the entire ensemble except for the voices. The fixed media in this instance does not have a fixed time base, consisting instead of eight conducted cues. The playback media was not prepared as separate files for each cue, so the AudioMulch automation system was used to pause playback at the appropriate points in the file in preparation for each subsequent cue. The composer's spatialization directions are simply "free/chaotic", and rapid combinations of automated motions were generated by the spatialization software automation and SpatDIF playback.

storming was the first instance where, even with the fixed media directly routed, sub-mixes of ensemble inputs had to be generated at the mixing console in order to accommodate the sixteen-channel limitation of the spatialization software.

12 *Helene*

Helene is scored for soprano, recorder, marimba and baroque triple harp, and inherently static in nature, maintaining consistently low dynamic levels throughout. This point of stasis stands in stark contrast to the dense activity of *storming*, so *Helene* was simply reinforced statically localized to the stage.

13 *wound III*

wound III partners the solo violin with an ensemble of percussion, oboe, contrabass clarinet, electric lap steel guitar and cello. Much of the percussion part is material related to the violin part, so both were localized to the stage. The remainder of the ensemble was statically distributed around the hall.

14 Island

Island is scored for two improvising soloists (instrumentation not specified), and an octet of alto recorder, alto flute, flugelhorn, trombone, violin, viola, cello and contrabass. For the Huddersfield performance, the improvised solo parts were played by saxophone and electronics. The soloists are specified to be freely spatialized, which was improvised manually with the spatialization software, while the slow rotation requested for the octet instruments was automated.

15 Simorgh

Simorgh is for eight-channel fixed media only, with inbuilt spatialization, and was subjected to the static assignment routing direct from the mixing console. The only performance variable was level riding to manage dynamic range in the venue.

16 wound IV

The fourth piece in the *wound* cycle sets solo violin against three voices, and an ensemble of oboe, clarinet, percussion, electric lap steel guitar and cello. The composer requests “voices in motion with variable reverb, otherwise static”. This is the first time in the performance the voices were set in motion. With the exception of *Omaggio a Chirico*, where they were distributed statically in the hall, the voices have been localized to the stage to maintain focus on the singers when performing solo roles. The violin reinforcement was localized to the stage as for all the *wound* pieces, and the remainder of the ensemble distributed statically around the hall.

17 Hekabe-β

Hekabe-β is scored for solo alto voice, soprano and male alto chorus voices, piccolo/alto flute, bassoon, piccolo trumpet in Bb, trombone, baroque triple harp and violin. The composer calls for static spatialization. The solo alto and chorus voices were localized to the stage, along with the harp. The remaining instruments were statically distributed throughout the hall.

18 wound V

The final piece in the *wound* cycle sees solo violin accompanied by soprano, alto and baritone voices and an instrumental ensemble of percussion, electric lap steel guitar, alto flute, contrabass clarinet, English horn, flugelhorn in Bb, alto saxophone, contrabass and electronics. The solo violin and voices were localized to the stage, with the rest of the ensemble distributed through the hall.

19 Germania

Germania is a tutti section, with the following spatialization directions provided by the composer:

> "voices static, everything else slow independent rotations at different levels, gradually accelerating until just before sense of movement is lost"

With the entire *CONSTRUCTION* instrumental ensemble requiring spatialization, sub-mixing to the inputs of the spatialization computer was necessary. Mixing percussion, strings and reeds to stereo pairs allowed each group to maintain spatial spread, and allowed the ensemble to fit within the 16-channel limit. Rotation acceleration was executed by varying the playback rate of a suite of SpatDIF files.

20 ON

ON is a tutti improvisation based on material from the preceding nineteen sections of the work, with freely improvised spatialization and an amplification direction to highlight different groups at different times. Spatialization was a mixture of manual and automated control of software spatialization channels, using a combination of SpatDIF playback and automated preset interpolation within the software. The focus on different ensemble subgroups was achieved by means of fader control at the mixing console determining the relative levels of instruments sent to the spatialization computer. The performance of the spatialization reflected the structure of the section by revisiting spatialization states from the previous sections.

Summary

The *CONSTRUCTION* premiere provided the opportunity to explore the application of the SIAL spatialization software in a variety of operational contexts. The extensive and diverse nature of the work requires, at different times, pre-determined spatial states and trajectories that can be pre-programmed in software, and at other times the facility for improvised spatialization in response to indeterminate improvised activity from instrumentalists. The revised software implementation proved effective in realizing this diversity, and clearly has a role to play in rendering works of this nature.

Chapter Four: Scaling Instrumental Resonance and Morphology

4.1 Performer Engagement

The *codex IX* series of performances undertaken in the context of research for *The Spatial Ensemble* (outlined in Chapter 3) represented a significant shift in ELISION's spatial performance methodology with the introduction of computer-controlled trajectories. The computer's capacity to automate spatialization facilitated more complex spatial motion than had previously been possible, with the inevitable side effect of altering the relationship between my performance actions and the spatiality of the work. My role has always been one of mediation, shaping the way the ensemble interacts with the performance environment. The addition of the spatialization computer between my mixing console outputs and the performance environment resulted in my role becoming the shaping of the ensemble's interaction with the spatialization system, divorced from the specifics of the spatial activity.[14] Post-concert conversations with instrumentalists after the King's Place performance of *codex IX* revealed that in some cases they too felt disconnected from the spatiality

[14] The fact that Jeffrey Hannam was operating the spatialization system contributed to this sense of disengagement, but the fundamental difference between triggering automated events and shaping sonic events is of more significance.

of the performance in a way they had not previously experienced. Reflection on the first three *codex IX* performances (and the sense of disengagement or abstraction experienced) led to the initiation of a related thread of research, the motivation for which was reinforced by my experiencing a concert featuring instrumental spatialization as a member of the audience.

4.2 MANIFEST – an audience member's perspective

In September 2010, SIAL Sound Studios presented a concert entitled *MANIFEST* at the Meat Market Craft Centre in North Melbourne. I was not involved in the planning or production of the concert and experienced the performance as an audience member. Part of the concert was ELISION clarinetist Richard Haynes playing solo clarinet works by Richard Barrett, spatialized by Lawrence Harvey, Jeffrey Hannam and Stephen Adam using the SIAL Sound Spatialization System. The works were not conceived spatially, so the spatialization was interpretive rather than prescribed. From my perspective as an audience member, the spatialization drew focus away from the performer. Richard did not appear involved in the spatial life of the performance, more like a complex signal generator providing input to the spatialization mechanism.[15]

Emmerson refers to causal dislocation of this nature in his discussion of ‘Live’ versus ‘Real Time’ control in electroacoustic performance:

> The *fact* that a specific instrumental action or human gesture (at a control desk or computer, say) causes a musical event to occur is *not a sufficient nor even a necessary* condition for a musical 'cause/effect' connection to be made in the mind of any listener. (Emmerson 1994, p.97)

In the case of MANIFEST, the dislocation between performer and sound was partly due to staging. Richard was positioned at ground level and in a corner of the large performance space, so had no visual presence for much of the audience. Effectively this resulted in an acousmatic performance for that portion of the audience for whom the performer was not visible. Given the complex nature of the music and the extreme instrumental virtuosity required to perform it, I found this approach to the staging of the performance unsatisfying in that the physicality of the performance was

[15] In fact that was not the case as pitch tracking algorithms were causing the spatialization to respond directly to Richard’s performance, but this was not necessarily evident to the audience.

not apparent from where I was seated.[16] My impression was that while the sound occupied the entire performance space, the scale of the spatialization overwhelmed the detail of Richard's relationship with his clarinet.

Central to my practice in amplifying chamber music performance is the notion of allowing or assisting an audience to hear *into* the music. Stockhausen, as quoted in Chapter 1, described the role amplification can play in that it:

> can help with listening right into the timbres, and with bringing all the nuances closer. … I actually want everyone to hear the piano as the pianist hears it. (Stockhausen 1996, p.81)
>
> I would in every case bring out subtleties, project them with vivid transparency, bring them into physically perceptible proximity, and strive for the audibility of the musicians … I try by means of the sound-projection to render this as a chamber-music experience, in the original sense. (Stockhausen 1996, p.87)

When designing and performing sound reinforcement for ensemble, my aim is to convey to the audience the sort of intimate perspective experienced by a conductor (Harley 1999). This perspective is akin to that often sought in chamber music or

[16] It should be noted that this is not entirely an objective audience perspective, however, as I frequently work closely with both composer and performer and have well developed ideas about the presentation of the genre.

orchestral recording – more intimate and detailed than is generally experienced by the majority of audience at an acoustic performance. Close microphone positioning in both recording and performance utilizes microphones rather like sonic microscopes – magnifying detail and bringing it into focus. Sound engineers therefore spend much of their time listening *inside* instrumental sound, and the resulting recordings have over a number of decades acclimatized the listening audience to this intimate perspective. Solo instrumental recordings made with multiple close microphones frequently go a step further in that they go some way towards articulating the spatial dimension of the instrument(s) rather than treating each as a point source. This is particularly the case with piano and percussion recordings, but is also frequently evident with other instruments, notably solo guitar. Such recordings offer a perspective analogous to that experienced by the performers themselves.

This magnification of a performer's local spatial field is a phenomenon that I suspected might have some benefit in engaging performers more intimately with the spatialization of their performance as well as engaging the audience more intimately with the physicality of the instrumentalists' performance. To explore this notion, a series of workshops were conducted with ELISION instrumentalists.

4.3 Performer Workshops

The intention of the research workshops that were undertaken with ELISION instrumentalists was to investigate a possible methodology for engaging instrumentalists more directly in the spatialization of their performance. The workshops were designed to explore and extrapolate the musicians' local spatial field, and experiment with techniques and gestures that would allow them to actively engage in the spatialization process. The approach taken in the workshops was strictly exploratory. A more rigorous approach that quantified results with respect to the propagation characteristics of specific instruments is beyond the scope of this study.

The technical configuration for the workshops was adapted from a technique I had been using for several years in my work with Glass Percussion Project, adapted from the work of percussionist Peter Humble who employed a lavalier microphone[17] attached to his wrist to articulate timbral gestures in numerous performances throughout the 1990s. The motivation for adopting the technique for Glass Percussion Project was neither timbral nor spatial, rather a matter of logistics. In January and February 2008 in the atrium at Federation Square, Melbourne, Glass Percussion Project performed *Intermezzo*; a large scale performance for two percussionists using approximately 1500 glass instruments[18] arranged over an area approximately 50 metres wide and 9 metres high on several levels of elevation (Reid 2008). Amplifying

[17] A lavalier microphone is a sufficiently small microphone that can be attached to an instrument or performer with minimum impact on mobility or performance technique.

[18] The majority of instruments were hand made by glass artist Elaine Miles.

this array of instruments with fixed microphones would have required an impractical quantity of microphones and cabling. The solution was to attach lavalier radio microphones to the percussionists' wrists so the microphones would track the performers' hands and so pick up any instrument struck with either hand. A number of fixed microphones were also employed for instruments whose sustain would otherwise have been lost were the microphones moved away too quickly after the instrument was struck. While neither timbral nor spatial gesture was the motivation for adopting this technique, the performers soon began to employ the microphones for timbral manipulation and the inherent articulation of the performers' local spatial field proved a useful element in the spatialization design of the performance.

4.3.1 Ben Marks – trombone

The first workshop was with ELISION trombonist Ben Marks. Ben came into the workshop interested in the idea of developing a spatial gestural language or vocabulary for the trombone with a view to informing his own improvisational practise in a spatialized context and also defining, quantifying or parameterizing trombone-specific spatial gestures for the benefit of composers who may wish to write spatially articulated works either for himself or ELISION.

The workshop was conducted in a recording studio (Run Stop Sound in Abbotsford, Melbourne) where the control room (monitoring environment) is acoustically isolated from the recording room (performance environment). In this situation, Ben was not able to monitor sound spatialization while playing, and could only review the result by listening back to the recording. While not replicating a performance environment for Ben, this approach resulted in a working method that proved efficient and instructive for both Ben and myself.

For the trombone workshop, four microphones were employed as follows –

1. Large diaphragm condenser positioned in front of the bell
2. Headset microphone to focus on mouth sounds
3. Lavalier mic attached to left wrist
4. Lavalier mic attached to right wrist

The outputs from these microphones were recorded to separate tracks while Ben improvised freely. The outputs from the recorder were statically assigned to four channels of an ITU 5.1 surround monitoring system.[19]

Assignments used were as follows -

1. Left front
2. Right front

[19] The use of ITU 5.1 monitoring was governed by the studio's monitoring system, not a choice made specifically for this workshop. A symmetrical quadrophonic arrangement would have been more suitable, but studio reconfiguration was not practical.

3. Left rear

4. Right rear

Ben then came into the control room to listen to the spatialization of his improvisation. This objective review process immediately began to suggest to Ben ideas for trombone gestures and articulations that might usefully or interestingly exploit that particular spatial array, and he was able to step back into the studio and perform further improvisations incorporating his ideas.

A series of four improvisations were recorded, each of which was immediately evaluated. Ben quickly found that he could, for example, use embouchure to control the location of sound across the frontal plane. Front/rear location (and motion), and left/right positioning across the rear plane could be articulated by varying proximity of the wrist microphones to different parts of the trombone depending on the type of sound being produced. From the sound engineering perspective, it became evident that because the wrist-mounted microphones produce an extremely wide dynamic range due to their mobility, a static balance was unsatisfactory for maintaining stable and coherent spatial imaging. In performance it will be necessary to implement dynamic range control by means of audio compression and/or performed fader manipulation to maintain an effective balance for the wrist microphones. Another possibility might be to give Ben control of these levels via foot pedals so he can control microphone response as part of his performance gesture and also experiment with the pedals as expressive devices in themselves.

Audio 4.3.1a – Sustained texture spatially activated.

Audio 4.3.1b – Variation on 4.3.1a with explicitly performed gestural activity.

Audio 4.3.1c – Intimate mouth noise texture

Audio 4.3.1d – Spatially animated percussive texture

Audio 4.3.1e – Pointillistic spatial scattering using wrist mic positioning

By the end of the workshop it was clear that a solid basis for the building of a spatial gestural language for trombone had been established. The success of the workshop from a developmental point of view led to the decision to employ similar strategies and techniques in workshops with other ELISION instrumentalists.

4.3.2 Peter Neville – Percussion

The second workshop was conducted in the SIAL Sound Studios at RMIT with ELISION percussionist Peter Neville. Peter noted that the percussionist's performance environment is largely spatially defined. Instrument setups often occupy considerable area, up to several metres in any direction, and Peter expressed an interest in conveying the performer's sense of space to audiences. In contemporary chamber music, percussion instruments are frequently assembled in large numbers across a large spatial area, and arranged in zones to facilitate the logistics of performing complex repertoire. It was not possible to set up large instrument arrays for the workshop due to space restrictions in the studio, so experimentation was restricted to individual instruments and smaller combinations.

Peter brought to the workshop a range of instruments so that various configurations could be tested. The SIAL studio allows spatialization to be monitored by Peter during his performance, but the studio's size meant speakers were necessarily located close to microphones, which restricted monitoring levels to such a degree that the spatialized amplification often could not be clearly heard over the acoustic output of the instruments. As a result, the record/review process employed in the trombone workshop also proved useful for Peter in the development of performance techniques.

Steel Drum

Steel Drum was considered potentially fruitful for spatialization because the playing surface of the instrument itself occupies a three dimensional space, although the resonance of the instrument means the depth (vertical axis) is not readily captured with a simple microphone array. We focused on the two dimensional horizontal perspective, and set up a four microphone array using stand mounted cardioid condenser microphones evenly spaced around the instrument.[20]

Various playing techniques were tested and recorded, from conventional melodic playing to rolling a marble around the inside of the drum and rubbing the playing surface with a superball. On playback, the spatiality of many of Peter's performance gestures proved less clear and less dramatic than expected. While the excitation of areas of the instrument in the vicinity of the different microphones shifted the sound around in a quadrophonic playback field, the resonant nature of the instrument made the effect subtler than expected. This configuration is extremely useful from the sound design perspective in that it produces a rich and animated spatial field, but not as gesturally responsive as Peter had hoped.

Audio 4.3.2a – marble in steel drum

Cymbal, ceramic plate, tam tam

The steel drum was replaced with a various other circular instruments, and recordings were made with the same microphone array. As with the Steel Drum, the resonant nature of other metallic instruments resulted in a useful spatially articulated

[20] This was an extension of an approach to stereo field animation Peter and I had previously explored in our work with the dance/music ensemble *Nadoya*.

timbre, but made them relatively unresponsive to spatial articulation of performance gestures. Scraping metal around the edge of the cymbal produced a clear gesture, but there was not sufficient variation to develop a spatial gestural language of any depth. The ceramic plate responded similarly, providing clear articulation when scraped around its perimeter but otherwise limited in effectiveness.

Audio 4.3.2b – cymbal/tam tam and ceramic plate

Miniature Friction Drum

The same microphone array was used for a small friction drum, which is connected by a string to a wooden handle around which it spins. The small dimensions of the resonator (approximately 30mm) and the fact that the entire instrument was in motion resulted in a very clearly articulated spatial trajectory. An effective technique, but limited in the variety of gestures available.

Audio 4.3.2c – Miniature Friction Drum

Bullroarer

Stand mounted cardioid condenser microphones were arranged in a wide square above the performer's head height and a bullroarer was swung in a circle overhead. Playback revealed clearly articulated motion, although more than four microphones would be required to produce a smooth circular motion. Like the Miniature Friction Drum, the spatialization was clear and effective (and theatrically strong) but limited in gestural scope.

Audio 4.3.2d – Bullroarer

Thunder Sheet

For the Thunder Sheet, a combination of two stand-mounted microphones and two wrist microphones were employed. The stand-mounted microphones were positioned to the top and bottom of the sheet, as close as practicable, and assigned to the left front and right front. The wrist mics were assigned to left rear and right rear. The resultant spatial field was an even but mobile spread across the frontal plane, with the rear plane moving in and out of focus depending on microphone proximity to the sheet. The sound field was animated and enveloping, and in this case quite responsive to gesture in that the performer had individual control of the effective sensitivity of the rear-assigned microphones. Peter was able to move the focus of the field through and around the space by varying hand position and thus microphone focus. In addition to the spatial gesture, this arrangement allowed for timbral gesture by focusing the wrist microphones on areas of the sheet in which particular partials were dominant.[21]

Audio 4.3.2e – Thunder Sheet

'Kit'

A small percussion 'kit' was assembled from four timbrally distinct instruments, each with a closely positioned cardioid condenser microphone statically assigned to a quadrophonic field. Instruments selected were Swiss Cowbell, Wood Block, Tambourine and Chinese Gong. The close microphones gave sufficient separation between channels to produce a very clear expansion or magnification of the spatiality of the instrument array, but without an obvious sense of a spatial *field*. With the static spatial assignment, timbre and location were firmly linked, resulting the sense of being surrounded by four percussionists each playing a single instrument. Musically this could be quite startling in that the effect is of an ensemble dispersed throughout the space, but with a degree of interaction, integration and continuity that would be difficult to execute were it not being generated by a single performer.

Audio 4.3.2f – Percussion 'Kit'

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[21] This use of wrist-mounted microphones for capturing timbral gesture is specifically characteristic of Peter Humble's performance technique.

4.3.3 Genevieve Lacey – Recorders

Genevieve brought three recorders of varying sizes to the workshop – contrabass, tenor and sopranino. The microphone configuration employed was similar to that which had been successful in the trombone workshop, a stand-mounted microphone in front, a headset microphone to focus on mouth sound and a lavalier microphone on each wrist. The workshop was this time conducted in a larger room so that speakers could be positioned further away from microphones and the spatial amplification heard more clearly during performance. Again, a series of improvisations was recorded and the results reviewed.

Contrabass Recorder

The contrabass recorder produced an enveloping spatial field that could be manipulated to some degree by variation in articulation, particularly by varying the influence of the headset microphone with breath sound. The wrist microphones were also capable of spatially articulated gestures but these were limited in scope, with only percussive sounds from the instrument's keys being spatially articulated with clarity.

Audio 4.3.3a – Contrabass recorder

Tenor Recorder

The spatial field produced by the tenor recorder was less enveloping than the larger contrabass, but the mobility of the instrument enabled spatial gesture to be executed through proximity to the front microphone in a way that could not be achieved with the larger instrument. The headset microphone again rendered breathy sounds clearly, but the wrist microphones were limited in their gestural effectiveness due to the need to keep the instrument supported with the hands and resulting lack of mobility. Three stand-mounted microphones positioned to the front and either side would be more gesturally responsive in that the instrument itself is more mobile than the performer's hands, and should be the subject of future explorations for this instrument.

Audio 4.3.3b – Tenor recorder

Sopranino Recorder

The diminutive sopranino recorder produced a very limited sense of spatial field with the microphone array employed. The size of the instrument meant the wrist microphones were very close to one another and the headset microphone, which resulted in limited separation between their respective signals and a poorly articulated spatial field. Breath remained clearly articulated spatially, but an array of stand-mounted microphones would again be more responsive to spatial gesture due to the instrument’s mobility. A variation on the microphone positioning was tried with the lavalier microphones attached to the performer’s fingers rather than wrists, but this proved limited in effectiveness and cumbersome for the performer.

Audio 4.3.3c – Sopranino Recorder

4.3.4 Richard Haynes – Clarinets

The workshop with ELISION clarinetist Richard Haynes was conducted in the same environment as for the recorder, with a sufficiently wide speaker array to allow clearly audible spatial amplification during the improvisations. B flat and bass clarinets were tested, and the microphone array kept consistent with the previous wind instrument workshops.

B Flat Clarinet

The microphone array captured an animated spatial field around the B flat clarinet, and Richard was readily able to modulate the spatiality with variations in playing technique. Multiphonics proved particularly effective with different overtones being favoured by different microphones, resulting in a spatial expansion of timbre that would shift subtly as Richard varied his embouchure.

Audio 4.3.4a – B flat Clarinet

Bass clarinet

A more dramatic scaling of the spatial field was immediately evident with the larger bass clarinet. The response of the spatial field to performance variation was similar to the B flat, but more clearly articulated and more enveloping. The greater distance between the performer’s hands resulted in a considerably more pronounced spatial separation of percussive key click sounds.

Audio 4.3.4b – Bass Clarinet

4.3.5 Outcomes

The workshop series produced some useful insights into the local spatial fields of the performers and their instruments and provided a viable point of departure for further investigation of other instruments and different microphone arrays. The record/review process proved instructive for the instrumentalists in that it enabled objective analysis of the spatial field captured by the microphones without competition from the acoustic output of the instrument.

All instrumentalists found the multiple microphone capture activated their local spatial environment and, in various ways and to varying degrees, made the manipulation of their local space a controllable performance parameter. Each instrumentalist was able to devise instrument-specific techniques to shape the spatiality of their performance. Sonic outcomes ranged from the subtle spatial shifting of a spatially expanded timbre to clear trajectories of motion generated by manipulating the positions of wrist-mounted microphones.

Central to the responsiveness of the technique for the instrumentalists is the static spatial rendering of the microphone signals. The absence of dynamic intervention in the spatialization process from either an automated system or myself presented the instrumentalists with a predictable causal relationship between their actions and the spatiality of the result. This consistency of response allowed instrumentalists to begin to develop a spatial gestural language that, with more development, has clear potential for engaging instrumentalists directly in the spatiality of their performance. In the context of ELISION's developing spatial performance practice, the development of performer-driven spatial gestural language has considerable and immediate potential for music featuring improvisational elements. The discussion of spatialization strategies for Richard Barrett's *CONSTRUCTION* in Chapter 5 considers how the technique might be applied for existing repertoire.

The multiple microphone methodology has potential application beyond the engagement of performers in the spatialization process. The success of the technique in scaling the inherent spatiality of instruments has considerable potential to enhance audiences' perception of the intricacies of instrumental articulation that plays a significant role in contemporary works that employ extended and innovative instrumental technique. Also inherent in the technique is a spatial activation that is not reliant of dynamic control from an audio engineer or automated system, and as such generates a spatial field inextricably linked to the performance activity of the instrumentalists, even if they are not actively controlling spatiality. This characteristic of the technique is interesting in the context of my spatial sound design for ELISION in that it blurs the distinction between the *occupation* of space and the *manipulation* of space (see Chapter 1, p.19).

As a performance methodology, the multiple microphone technique is both conceptually and technically straightforward. It requires no specialized equipment, and no specialized expertise on the part of the sound engineer. It is, however, inefficient in terms of resources, which creates economic and logistical complexities that will be insurmountable in many current performance contexts. A large ensemble that would require 30-40 channels with conventional microphone technique could require 80-100 channels if all performers were to be captured with multiple microphones. This number of channels is considerably beyond the resources generally available for the majority of chamber music performance at present.

Chapter Five: CONSTRUCTION

5.1 Introduction

This chapter presents an example of a methodology for a spatial performance design for a contemporary chamber work based on the analysis and interpretation of a score. The work being considered is Richard Barrett's *CONSTRUCTION*. The spatial realization of the premiere performance of the work has been described in Chapter 3 as part of the performance series undertaken for *The Spatial Ensemble* research project. This chapter looks in more detail at ways in which spatialization design might be derived from the orchestration of the work and seek to facilitate the perception of compositional form and detail. To this end, sections of the work are analyzed specifically from the perspective of spatialization design, expanding on the existing spatial design practice summarized in Chapter 2, informed by the developmental work described in Chapter 3 and incorporating the multiple microphone methodology described in Chapter 4.

The composer describes the theme of *CONSTRUCTION* as "concerned with the relationship between utopian thinking and reality" (Barrett 2011) and that theme is reflected here. The premiere performance described in Chapter 3 is one version of the "reality" of rendering the work spatially, constrained as it was by the practicalities of a particular venue and production schedule. The spatialization design outlined in this chapter is my “utopian thinking”, guided by the composer’s notes on spatialization in the score, but unconstrained by the practicalities of performance.

5.2 The Work

The twenty individual pieces that constitute *CONSTRUCTION* are divided into four groups, or *cycles* as outlined in Figure 23.

	CYCLE 1 with electronics	CYCLE 2 vocal/instrumental	CYCLE 3 (*The Trojan Women*)	CYCLE 4 (violin solos)
1	*strange lines and distances* (2′)			
2		*Politeia* (9′)		
3			*Hekabe-a* (4′)	
4				*wound I* (2′)
5			*Kassandra* (4′)	
6		*heliocentric* (15′)		
7	*Omaggio a Chirico* (6′)			
8			*Andromakhe* (4′)	
9				*wound II* (4′)
10		*news from nowhere* (7′)		
11	*storming* (3′)			
12			*Helene* (4′)	
13				*wound III* (5′)
14		*island* (11′)		
15	*Simorgh* (11′)			
16				*wound IV* (3′)
17			*Hekabe-b* (4')	
18				*wound V* (1′)
19		*Germania* (2′)		
20	*ON* (20′)			

Figure 22 – The four cycles of *CONSTRUCTION*

The *CONSTRUCTION* score includes performance notes for spatialization that outline section-by-section the composer's intent for the spatial realization of the work, shown in Figure 23.

1 static (inbuilt spatialisation) but distributed vertically as a cube or dome

2 5 players (recorder, flugelhorn, trombone, electric guitar, marimba) wander slowly through the space independently of one another; the rest of the ensemble remains static

3-5 static

6 3 duos making concentric "orbits" at different (slow) speeds and at different vertical levels - duo members opposite one another as they rotate: recorder/bass flute (lowest, closest to centre) 2 clarinets (intermediate) flugelhorn/trombone (highest, around the edge) 4 plucked instruments (kalimbas, harp, guitar, cello) at centre, with/without reverb

7 in addition to inbuilt spatialisation of fixed media: each sound from each source from a different place, at a different distance (use reverb as well as spatial positioning)

8-9 static

10 4 solo wind instruments and percussion are static, the rest of the instruments play "drones" distributed through entire space, moving slowly & randomly

11 free/chaotic

12-13 static

14 octet positioned at 8 points around space, rotating very slowly; soloists freely spatialised

15 inbuilt spatialization

16 voices in slow motion with variable reverb, otherwise static

17-18 static

19 voices static, everything else slow independent rotations at different levels, gradually accelerating until just before sense of movement is lost

20 free improvisation (highlighting different groups at different times)

Figure 23 – The composer's spatialization notes for *CONSTRUCTION*.

The composer's spatialization guidelines reflect the differences between the four cycles, and indicate that spatialization might be used as a device to help articulate the formal structure.

The pieces in Cycle 1 (with electronics) contain all the fixed media material with inbuilt spatialization. For those pieces that also feature performers (*Omaggio a Chirico, storming* and *ON*) the composer suggests all sounds should be in constant motion, and the motion be (at different times) random, free and/or chaotic. Combined with a high degree of mobility in the pre-spatialized fixed media material, the Cycle 1 pieces are characterized as a group by constant motion.

The pieces that constitute Cycle 2 (vocal/instrumental) are also generally mobile, but in this case the motion is more controlled, with the composer calling for orbits and discernable trajectories. The rate of motion is generally slow (*Politeia, heliocentric, news from nowhere* and *Island*), or beginning slowly and accelerating (*Germania*). The Cycle 2 pieces also demonstrate the composer's desire to use spatialization and spatial motion to differentiate between functional groupings within the ensemble. *Politeia*, for example, features a group of five performers in motion while the remainder of the ensemble is static. *heliocentric* sets three duo groupings in orbital motion around a static ensemble, while *news from nowhere* places a static wind and percussion group against a background of slowly moving drones in the remainder of the ensemble. *Island* allows for free spatialization of the improvising soloists amongst a slowly rotating octet and in *Germania* a field of gradually accelerating orbiting instruments frames a static vocal group.

Cycle 3 (The Trojan Women) is a series of settings of excerpts of Euripides' *The Trojan Women* for solo voices with ensemble accompaniment and the composer's notes suggest static spatialization throughout the cycle.

Cycle 4 (violin solos) consists of a series of pieces (*wound I – V*) setting solo violin with varied instrumental and vocal accompaniment. As for Cycle 3, the composer suggests static spatialization with the exception of the voices moving slowly throughout *wound IV*.

The composer's performance notes indicate that the ideal staging for the work would be where:

> the ensemble is placed in the centre of the performing space surrounded by the audience, everyone in turn surrounded by a dome-shaped array of loudspeakers. (From *CONSTRUCTION* Performance Notes)

The spatial realization of *CONSTRUCTION* requires interpretation of the score informed by these performance notes. Following is an example of my approach to such an analysis, from the perspective of how the composer's spatialization notes might be articulated by a spatial sound design and other ways in which the presentation of the work might be enhanced by means of spatial articulation. The analysis focuses on the orchestration of the work, with a view to spatialization becoming a vehicle for clarifying the articulation of orchestration in performance.

5.3 *CONSTRUCTION* Analysis

The following sections look in detail at representative pieces and/or passages from each of *CONSTRUCTION*'s four cycles with a view to identifying aspects of orchestration that can inform or be clarified by spatialization design. Pieces are considered in the context of the cycle to which they belong, and are not presented here in they sequence in which they are performed. Pieces and/or passages that are not subject to extensive analysis are considered with respect to particular characteristics that are unique to them.

5.3.1 *CONSTRUCTION* Cycle 1 – with electronics

Strange lines and distances

Strange lines and distances is an eight-channel electronic work that takes its title from Francis Bacon's description of 'sound-houses' in his 1626 work The New Atlantis (Bacon 1626). The work is for fixed media, with the dynamic spatialization pre-rendered in multi-channel digital audio files. The performance notes specify a static assignment of channels, and vertical distribution “as a cube or dome”. The composer makes no prescription as to the preferred locations or directions to which channels should be assigned, or spatial relationships between channels.

Auditioning of the audio files leads to some observations about the relationships between the eight channels that can assist in devising the most spatially articulate assignments. The eight channels are rendered as four pairs of two, with inbuilt panning trajectories between the files in each pair. This arrangement provides a greater degree of spatial design flexibility than pre-rendered trajectories across all eight channels. Were trajectories rendered across all channels, the choice of spatial assignments for channels would potentially be limited by the need to preserve the rate of motion and possibly the directionality of trajectories. Rendering to pairs is less limiting in that whilst the velocity and direction of trajectories will vary depending on the distance between speakers, the velocity will not vary *during* a trajectory, which has the potential to distort the spatial articulation of the rhythm of the work.

Omaggio a Chirico

The second piece in Cycle 1 of *CONSTRUCTION*, *Omaggio a Chirico*, also features 8 channels of fixed media, this time in conjunction with an ensemble of voices and strings. The fixed media has spatialization pre-rendered in the audio files and therefore calls for a static assignment to speakers in the same way as *Strange lines and distances*. The ensemble improvises from a text-based score; meaning for the first time in *CONSTRUCTION* the material to be spatialized is non-determinable. Also, the voices are not cast in soloistic roles that require particular focus, allowing the possibility of dynamic spatialization.

The composer's notes call for each utterance from each ensemble member to come from a different direction and a different distance, and suggest use of varying artificial reverberation to simulate distance and vary the depth of the sonic image. Software control of source location is a useful tool in this instance, with independent rate-variable pre-programmed or random automated trajectories available for each performer able to be triggered as and when appropriate in an improvisational manner. Variable reverberation can also be implemented as an integral parameter in the spatialization software. Alternatively, real-time spatialization controls for each musician could be implemented and employed improvisationally.

storming

The eight-channel fixed media component of *storming* differs from the other fixed media pieces in that the media playback consists of eight discrete sound events triggered on conducted cues. The playback cues alternate with cues for tutti ensemble, playing structured improvisational responses to the electronic sound events.

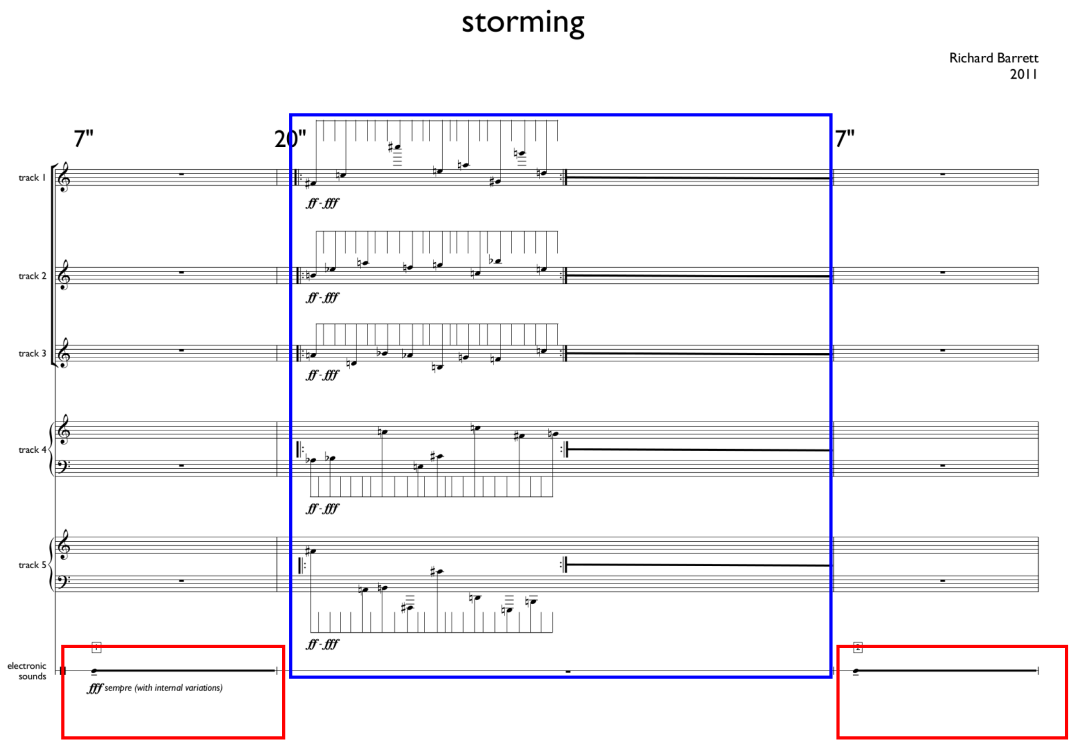

Figure 24 – Opening of *storming* showing alternating cues

The composer suggests the textural density of the ensemble cues should be generally high, and the spatialization should be free and/or chaotic. Rapid automated trajectories and/or fast random positional fluctuation would serve the composer's ends in this instance, and could be applied consistently to all instruments for the duration of the piece. In practice, however, the apparently free and chaotic nature of the notated parts results in an ensemble texture that sounds free and chaotic with the ensemble statically spatially displaced, and automated trajectories are not essential. Performer-controlled spatialization via the multiple microphone technique (discussed in Chapter

4) could be implemented in this instance as a means of engaging performers in the spatial activity of the movement.

Audio 5.3.1 – *storming*

Simorgh

Simorgh is for eight channels of fixed media with spatialization pre-rendered in the audio files and requires static spatial assignment only.

ON

ON is a twenty-minute tutti improvisation that invites the performers to devise for themselves the culmination of *CONSTRUCTION*. While the composer gives license for totally free improvisation, a temporal framework is mapped out by cues from the conductor. The framework is a temporal diminution of the overall form of *CONSTRUCTION*, approximately to scale, and performers are given the option of referencing their improvisation to musical materials from earlier sections as the improvisation unfolds.

section	start time	duration	material source
1	0'00"	20"	*strange lines and distances*
2	0'20"	1'30"	*Politeia*
3	1'50"	40"	*Hekabe-alpha*
4	2'30"	20"	*wound I*
5	2'50"	40"	*Kassandra*
6	3'30"	2'30"	*heliocentric*
7	6'00"	1'00"	*Omaggio a Chirico*
8	7'00"	40"	*Andromakhe*
9	7'40"	40"	*wound 2*
10	8'20"	1'10"	*news from nowhere*
11	9'30"	30"	*storming*
12	10'00"	40"	*Helene*
13	10'40"	50"	*wound 3*
14	11'30"	1'50"	*Island*
15	13'20"	1'50"	*Simorgh*
16	15'10"	30"	*wound 4*
17	15'40"	40"	*Hekabe-beta*
18	16'20"	10"	*wound 5*
19	16'30"	30"	*Germania*
20	17'00"	3'00"	.....
end	20'00"		

Figure 25 – *ON*, conducted cues

Given the indeterminate nature of the piece, two spatialization strategies suggest themselves, and could be employed either singly or in combination. Firstly, given an appropriate real-time control structure, spatialization could be freely improvised. Alternatively, the spatial states for the preceding nineteen sections could be stepped through with the conducted cues. In addition to helping articulate the formal structure of *ON*, this approach will inherently satisfy the composer's desire that different sections of the ensemble be “highlighted at different times”. Various combinations of performers have been spatialized in different ways in each preceding section, sometimes focused, sometimes diffuse and sometimes mobilized. While the formal reflection on the preceding sections provides a beneficial framework, the indeterminate character of *ON* invites a strategy that includes the capacity to intervene with real time control of any combination of performers as might be desirable as the improvisation unfolds. A suitable software-based spatialization system (such as the SIAL system) can be configured to allow for spatialization states to be recalled while maintaining the ability to selectively apply real time control to arbitrary combinations of channels, so would facilitate a structured yet flexible approach to the spatialization of *ON*.

5.3.2 *CONSTRUCTION* Cycle 2 – vocal/instrumental

Politeia

Politeia is composed for two separate instrumental groups – an octet consisting of tenor, baritone and bass saxophones, bassoon, trombone violin, viola and cello, and a quintet of recorder, flugelhorn, percussion, electric guitar and harp. The composer’s suggestion for spatialization is that the octet should remain static, while the quintet "wander slowly through the space independently of one another."

While the motion of the quintet could be achieved by means of real-time control, the desired "wandering" characteristic would be more simply achieved by implementing pre-programmed or random automated trajectories. The precise implementation of the static reinforcement of the octet can be determined from analysis of the score.

The opening bars of *Politeia* feature the octet only, and the orchestration divides the octet into three functional groups, clearly indicated by three distinct layers of rhythmic activity. Figure 23 depicts the rhythmic layers, with each group outlined in a different colour.

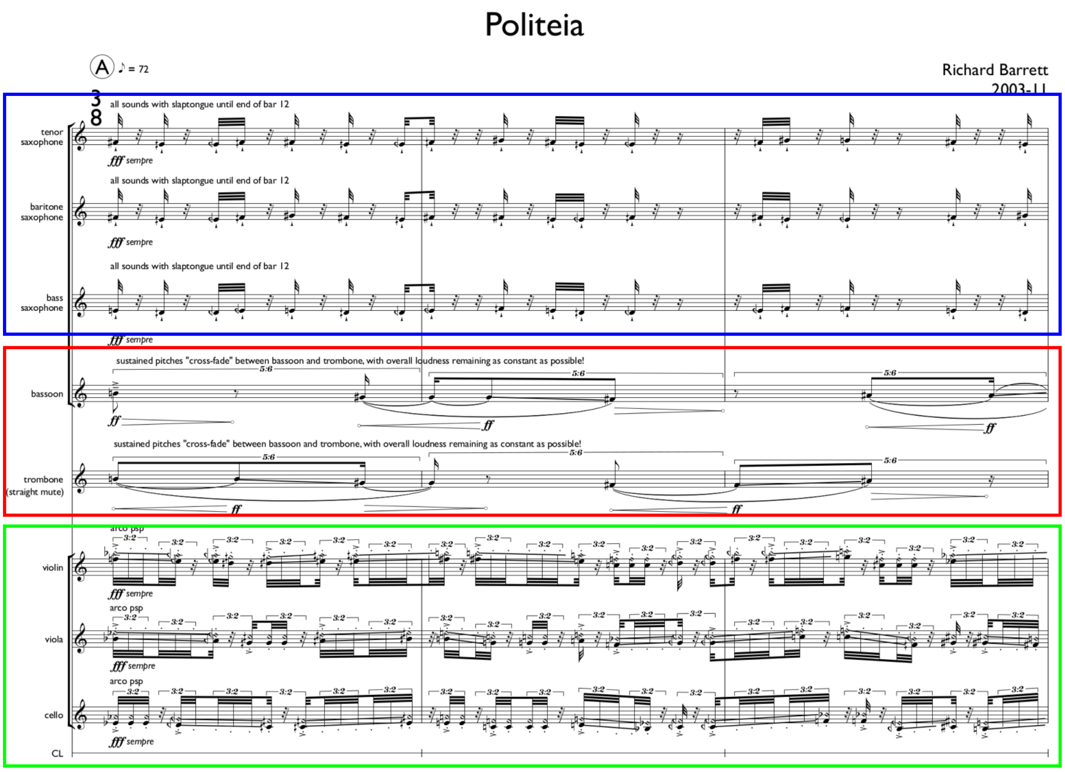

Figure 26 – *Politeia* bars 1 - 3 showing octet entry

The three saxophones (tenor, baritone and bass) play staccato (slaptounge) chords in rhythmic unison. Two possibilities arise as to how the relationship between the saxophones might be articulated spatially. Spatial co-location would lend a sense of unification to the trio, a single polyphonic timbral hybrid of the three instruments perceived as a point source. A static spatial displacement of the trio would, conversely, enhance the perception of the timbral differences between the instruments and result in them being perceived as an ensemble rather than a single source. In the event of an extremely precise performance of the rhythmic unison, spatial displacement might result in perception of a single spatially expanded hybrid, but in practice it is likely that variation in attack time between the three performers would be discernable if they were spatially separated. In the broader context of the octet, the saxophone trio forms a distinct textural layer, but does not warrant more focus than will naturally be drawn to it by virtue of it's percussive character and *fff* dynamic level. Consequently, I would elect to separate the trio spatially to some degree, as co-location would give the already strident musical material a spatial focus. The degree of separation should be such that the trio remains a cohesive entity rather than becoming diffused or individual members isolated.

The string trio (violin, viola and cello) also enters *fff* and staccato, and largely in rhythmic unison, but the texture is more complex, with each instrument having an independent phrase structure or pattern of rhythmic fragments. Rests separate the individual fragments, and each new fragment begins with an accent. Each instrument drops out of the texture monetarily at the end of each fragment, and then rejoins the texture with the accented commencement of a new rhythmic fragment (see Figure 20). The resultant texture is active and animated, and the animation could be articulated in performance by spatially displacing the strings such that each accented entry has a different location from the last, perceptually 'scattering' the rhythmic fragments. Significantly, aggregation of the accented attacks in the string texture yields a similar (but not synchronous) rate of attacks to the saxophone parts, creating a rhythmic counterpoint between the two groups that, correctly balanced and with each trio given a distinct spatial identity, could facilitate a perceptual connection between the two textural layers.

The remaining octet element, a duo of bassoon and muted trombone, behave quite differently from the remainder of the octet, playing alternating but overlapping phrases at a slower rate relative to the other parts. The overlaps between the phrases occur with the overlapping instruments playing the same pitch, with crescendo/decrescendo markings indicating that each phrase cross-fades or morphs into the next. The composer's performance notes call for the combined dynamic level to remain "as constant as possible" during these cross-fades, indicating that the desired result is a single line that modulates in timbre as it progresses. The combined line exhibits an undulating contour, broadening in pitch range as it unfolds and creating a sense of goal-directed motion. The regular cyclic nature of the pitch undulation and timbral cross-fading mitigates any sense of melodic contour within the line itself, but it is clearly heading towards something, which becomes clear at bar 13 when the wind duo ceases and is replaced by the entry of the quintet, with the wind duo line effectively being taken up by the tenor recorder which is soon joined by the remainder of the quintet. From the perspective of spatialization, the question becomes whether to statically co-locate the bassoon and trombone as a point of contrast with the spatially active elements in the octet and to provide a static 'launch pad' for the spatially animated quintet entry, or whether to employ a spatial cross-fade to expand on and reinforce the 'to and fro' character of the duo's combined line. Spatial separation of the wind duo in diametric opposition would help clarify the passing back and forth of the line, yet retain a sense of stasis by virtue of repetition, thereby providing a stable point of departure for the slowly wandering quintet.

The opening of the *Politeia* octet can, without compromising the composer's desire that the reinforcement be static, have the articulation of its orchestration design significantly enhanced by considered and appropriate spatial amplification of instruments with respect to their functional relationships both within and between instrument sub-groups. Any resultant spatial motion or gesture is a natural consequence of the orchestration itself and representative of a scaling of the space *between* instruments, as distinct from the moving of an instrument through space. The spatialization effectively becomes part of the orchestration and is driven by the composed relationships between instruments, rather than an a separate or independent activity.

The quintet, which is scored independently of the octet, enters at bar 13, with the entry marked on the octet score as shown in Figure 24.

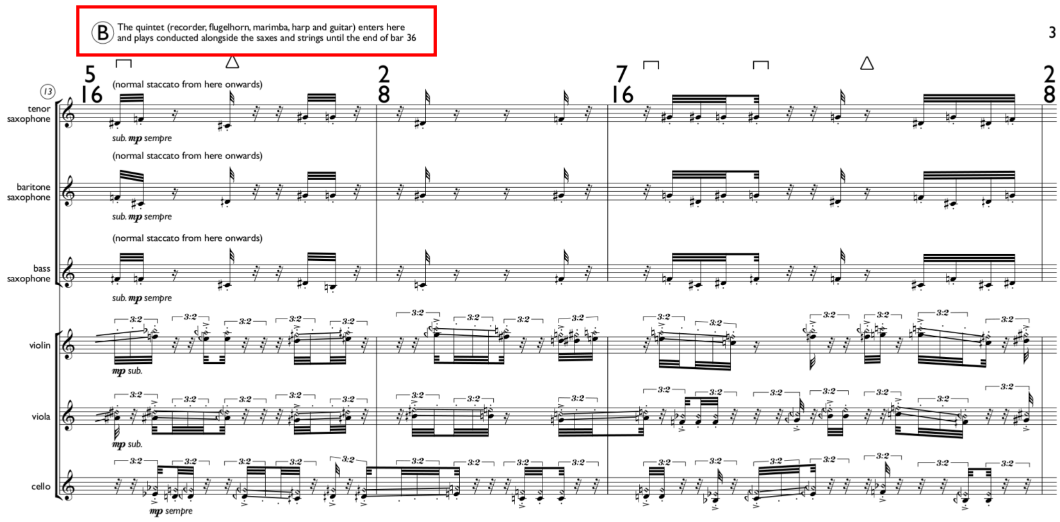

Figure 27 – *Politeia* bars 13 - 15, octet score, showing quintet entry

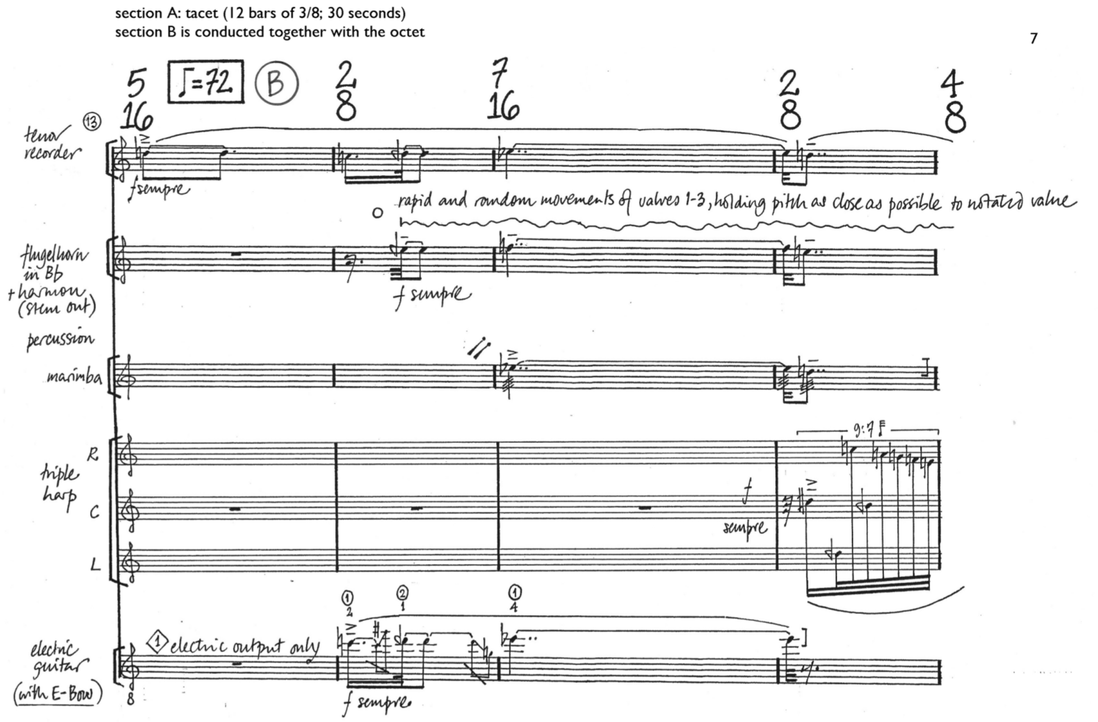

Figure 28 – *Politeia* bars 13 - 15, beginning of quintet score

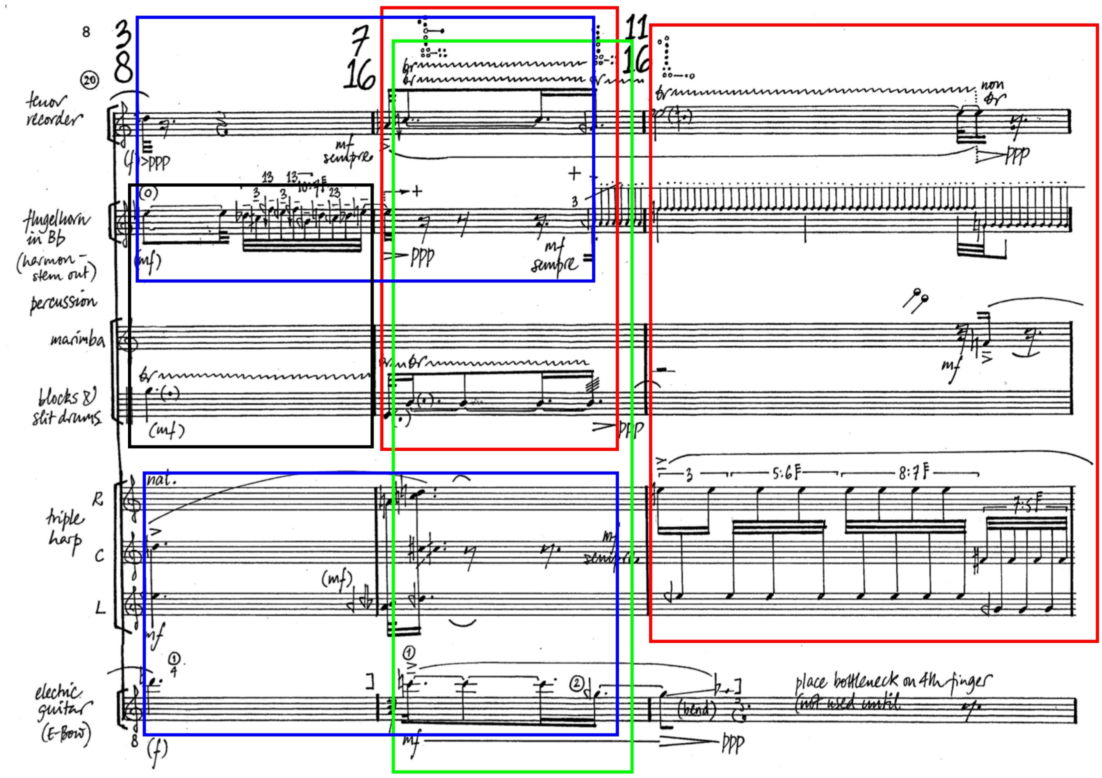

Figure 29 – ***Politeia*** **bars 20 - 22, quintet, orchestrational relationships.**

While the composer calls for the quintet to wander randomly through space independent of one another, the orchestration is such that spatial gestures between instruments could occur. The trill passing from flugelhorn to tenor recorder in bars 21-22, for example, could result in a spatial as well as timbral gesture if the instruments are spatially separated at that moment. Similarly, the combined texture articulated in tenor recorder, flugelhorn and triple harp in bar 22 would be variably spatially expanded depending on the respective locations of instruments.

Audio 5.3.2 – *Politeia* opening

heliocentric

heliocentric is separately scored for 3 duos (recorder and bass flute, 2 clarinets and flugelhorn and trombone) and a quartet of plucked instruments. The composer's spatialization notes request

> "…duos making concentric "orbits" at different (slowish) speeds and at different vertical levels - duo members opposite one another as they rotate.
>
> recorder/bass flute (lowest, closest to centre)
>
> 2 clarinets (intermediate)
>
> flugelhorn/trombone (highest, around the edge)
>
> 4 plucked instruments (kalimbas, harp, guitar, cello) make more isolated sounds, each sound from a different random position, with reverb (variable?)"

The opening bars of the *heliocentric* quartet score indicate the first two duo entries and clearly depict the plucked quartet fragments to be individually and randomly spatialized.

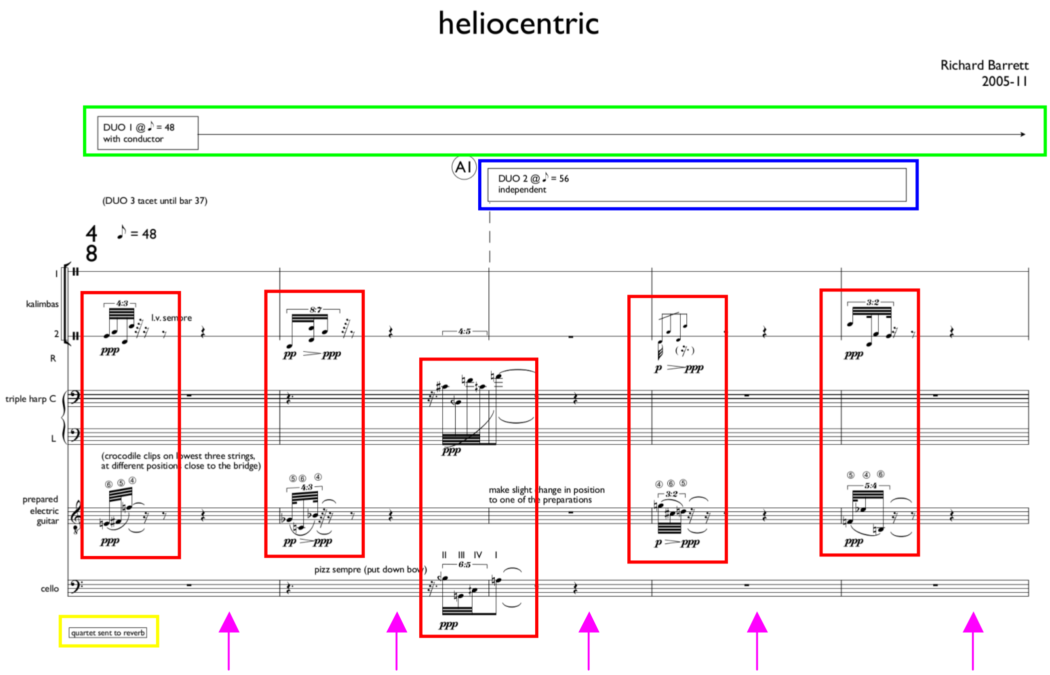

Figure 30 – *heliocentric*, opening bars

The rate of positional change required for quartet parts is such that 126 changes are called for over the 15-minute duration of the movement. This process cannot be automated to a fixed time base. The rate of change varies, and the conducted tempo may vary between performances and between different conductors. Manually executed random positional changes are necessary, and can be achieved with a computer-controlled spatialization system or a succession of scene changes programmed into a suitable digital mixing console.

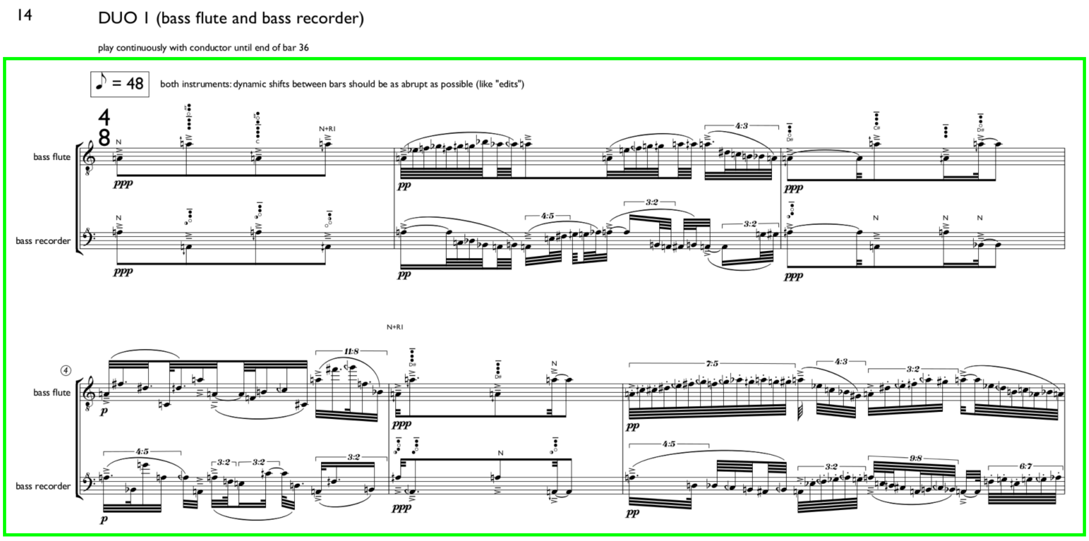

Figure 31 – *heliocentric*, opening bars, DUO 1

The opening bars of the *heliocentric* duo 1 score indicate two closely related parts to be spatially opposed but synchronous in rotation. Computer-controlled automation of orbital trajectories readily facilitates such motions, and careful control of initial location and rate of rotation could maintain the spatial opposition. Alternatively a constraint could be applied in the spatialization software to ensure separation is maintained.

At times the duo groups play phrases of similar duration to the quartet fragments, so in order to maintain perceptible differentiation between the quartet and the duos it is necessary to ensure a sufficiently slow orbital rotation for the duos that their paths can be perceived as continuing between phrases, distinct from the random scattering of the quartet fragments.

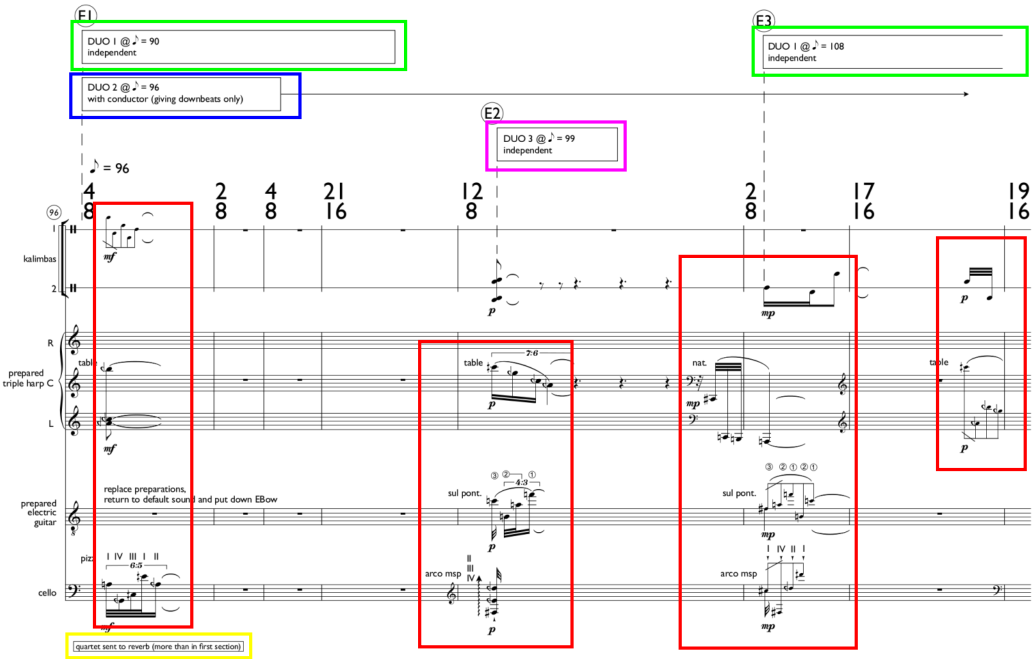

Figure 32 – *heliocentric*, bars 96 - 102, short duo phrases

Audio 5.3.3 – *heliocentric* opening

news from nowhere

The ensemble for *news from nowhere* consist of four wind soloists playing an unspecified variety of instruments, a percussionist playing a single unspecified instrument capable of four distinct timbres and an unspecified ensemble of drone instruments. The composer suggests the winds and percussion remain static, while the drones are spatially distributed and possibly moving slowly. Where applicable to particular instruments, multiple microphones for the drone performers could again be employed in this instance, providing a natural spatial spread of each drone while allowing performers to spatially animate the drones by means of performance gesture.

Static spatialization of solo winds could enhance the perception of the notated melody being passed between them, so long as their spatial distribution was such that the continuity of the melody was maintained. The passing of the melody between wind instruments is indicated but the red outlines in Figure 30.

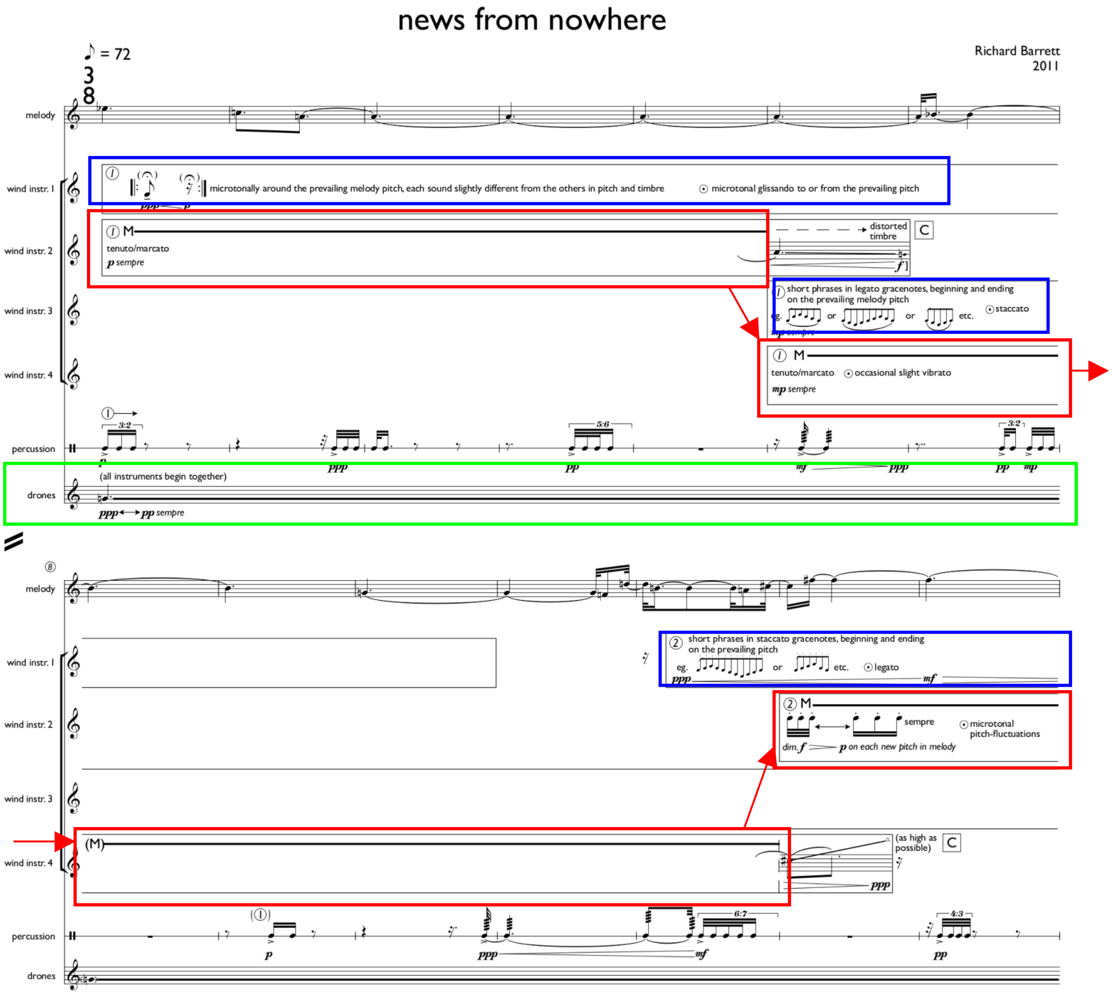

Figure 33 – Opening of *news from nowhere*

Audio 5.3.4 – *news from nowhere* opening

Island

Island is scored for two unspecified soloists with an accompanying octet. The composer suggests the soloists be spatialized freely and manual control offers an advantage over automation as it allows the spatialization to be performed in direct response to the performers' improvisation. For the octet, the suggestion is discrete spatial locations for each performer, slowly rotating. Automated orbital trajectories are ideal for this purpose, and easily varied over the course of the piece in response to its sectional structure.

Island is in eight sections; with the octet part sometimes fully notated and sometimes playing directed improvisations. In some sections the octet divides into sub-groups, and variation of their rotational trajectories would serve to clarify this. In section D, for example, the octet divides in two with strings aligning with one soloist and winds with the other. Opposing rotational direction for the two groups would enhance the perception of this division. In section H the octet divides into four independently operating pairs. A unique spatial identity could be established for each pair by varying rotational direction and rate, along with orbital elevation, as a means of articulating this grouping.

Germania

Germania sees all three voices come together to form a vocal trio, the only section of *CONSTRUCTION* where the voices function this way throughout. Strict rhythmic unison and identical text phrasing ensures the three voices remain bound together, and the composer's suggestion they remain static further clarifies this intent.

Around this block of voices, the composer's performance notes suggest the remainder of the (tutti) ensemble move in "slow independent rotations at different levels, gradually accelerating until just before sense of movement is lost". Study of the score reveals that some constraints placed on the independence of the rotations might yield benefits in comprehension of the orchestration.

The piece begins with the instruments clearly divided into two sub-ensembles. One group (bassoon, trombone, lap steel guitar, violin, viola and cello) plays continuous asynchronous glissandi, punctuated periodically by short synchronous chords from the remaining instruments.

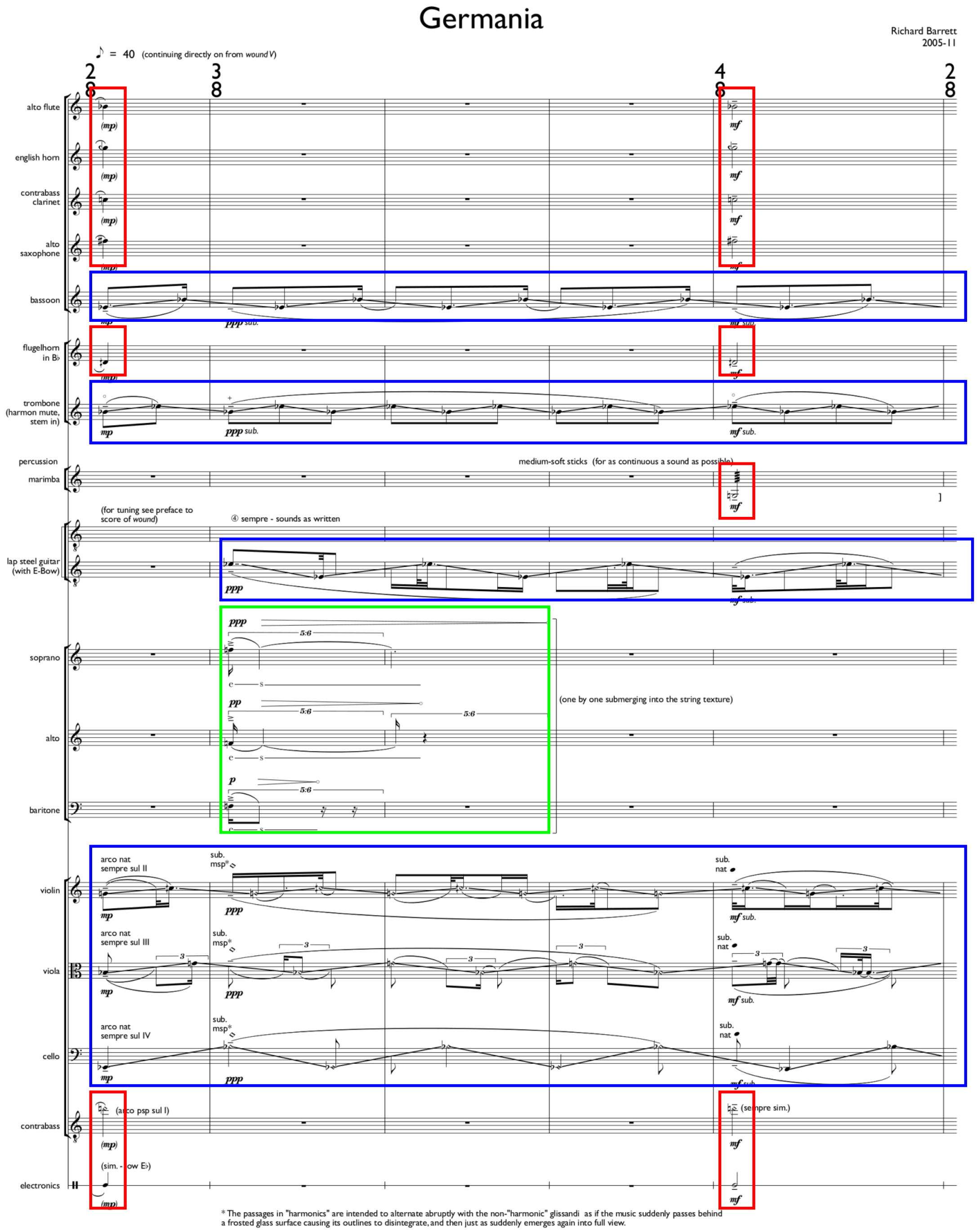

Figure 34 – *Germania*, bars 1 - 5

This scheme continues until bar 13, where the entire ensemble coagulates into a tutti crescendo to *fff* before evaporating into a bar of tutti rest.

Figure 35 – *Germania*, bars 12 - 14

The ensemble remains a single, coherent entity from this point, alternating synchronous phrases with synchronous silences, before a final vocal utterance triggers the sustained crescendo that launches the ensemble into *ON*, the final section of *CONSTRUCTION*.

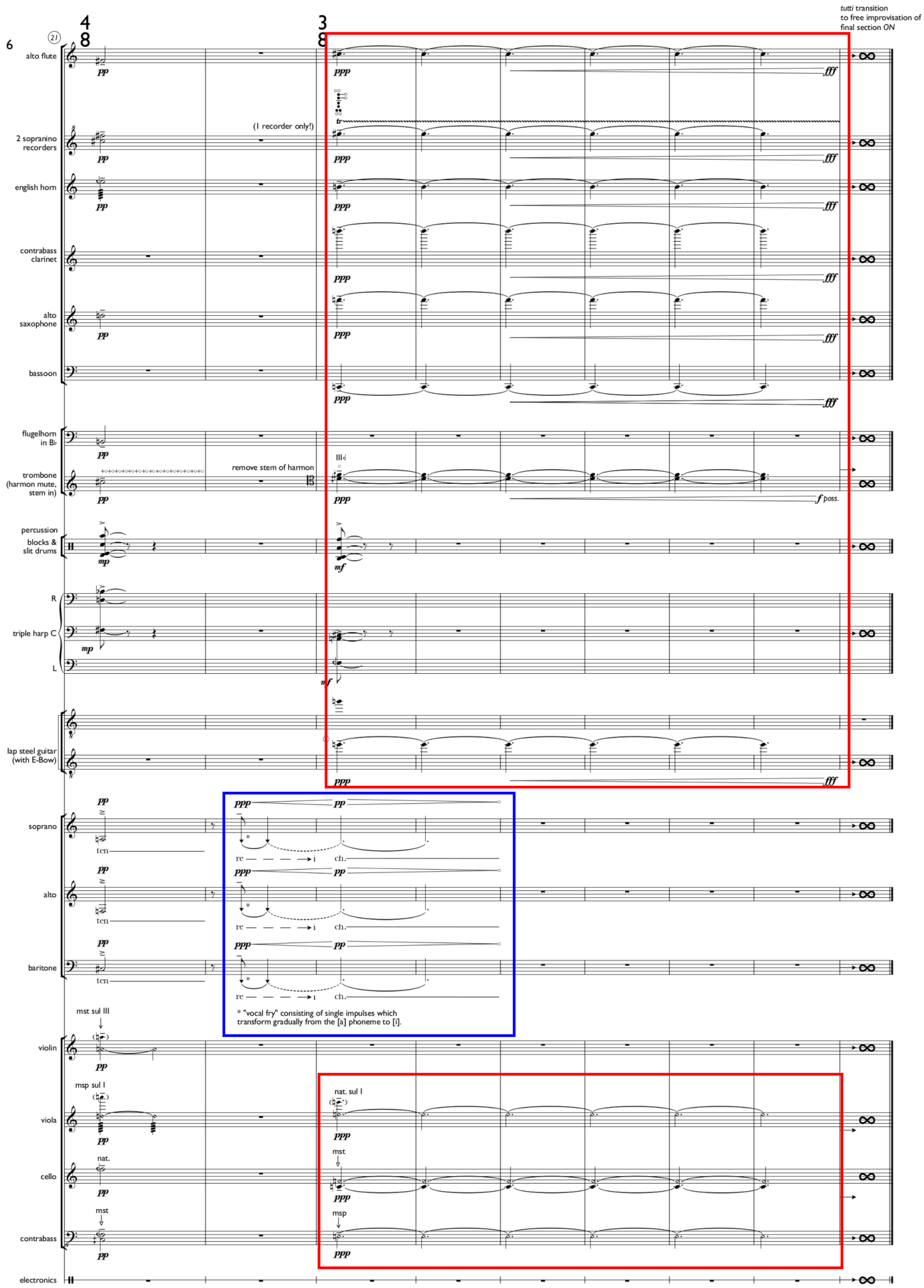

Figure 36 – *Germania*, bars 21-29

5.3.3 *CONSTRUCTION* Cycle 3 – The Trojan Women

Hekabe-α

Hekabe-α is the first of a series of vocal pieces that constitute the third of the interwoven thematic threads that run through *CONSTRUCTION.* The composer's spatialization notes suggest static reinforcement, and the opening of *Hekabe-α* clearly suggests stillness.

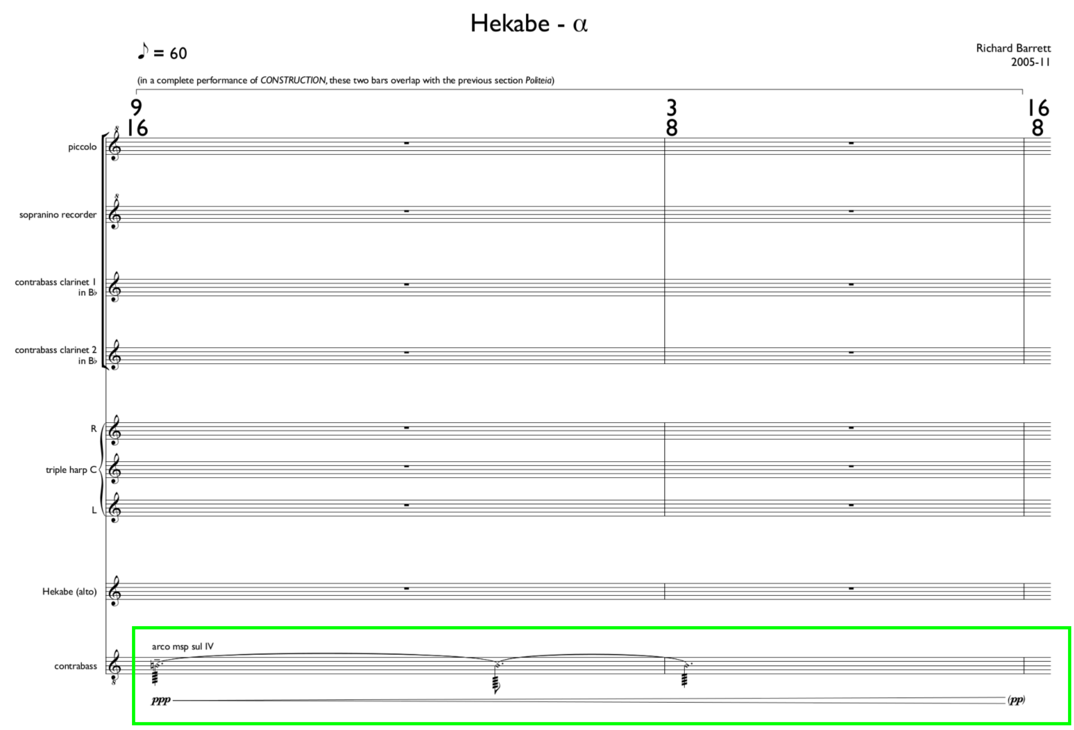

Figure 37 – *Hekabe-α* bars 1 - 2

The *ppp* contrabass entry overlaps final two bars of *Politeia*. The octet has been gradually dissipating over the preceding bars, leaving the soloistic harp clearly in focus. The spatialized quintet finishes suddenly with a simultaneous *fortissimo* leaving the harp one final bar, a decrescendo to *ppp* before damping the instrument suddenly to leave exposed the pianissimo tremolo in the contrabass that begins *Hekabe-α*.

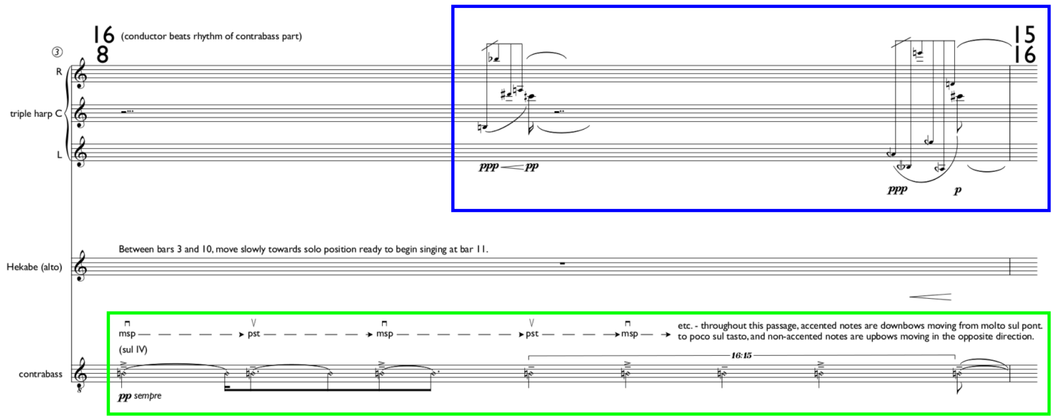

Figure 38 – *Hekabe-α* bar 3

This moment of stasis is the first time during *CONSTRUCTION* that there is no spatial motion, and as such represents a point of arrival, or *spatial cadence* to *Politeia*.

The harp punctuates the gradual contrabass crescendo with fragmented utterances echoing its preceding soloistic passage, and they are joined in bar 4 by piccolo, recorder and clarinets playing sustained pianissimo microtonal undulations.

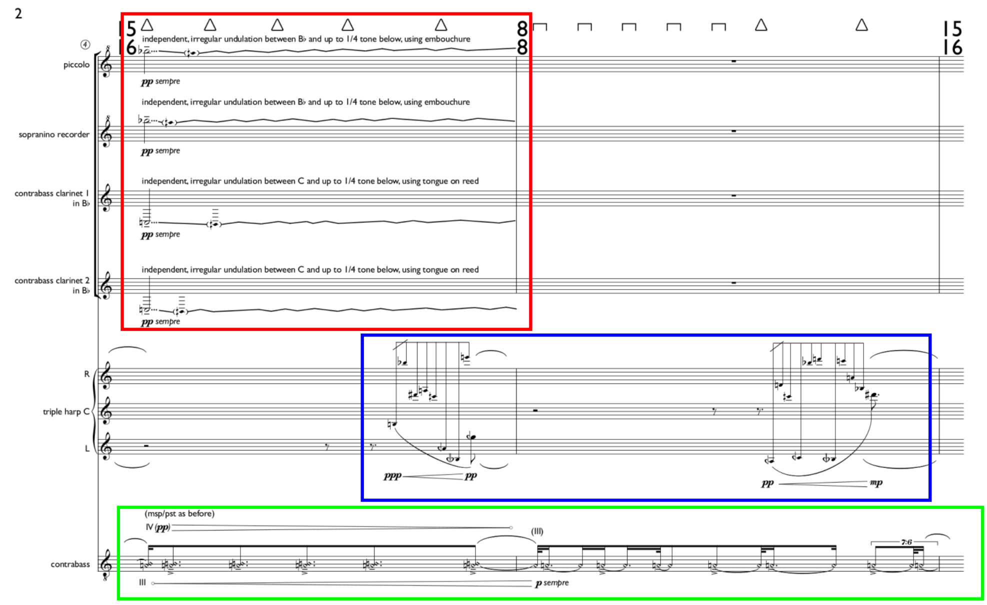

Figure 39 – *Hekabe-α* bars 4 - 5

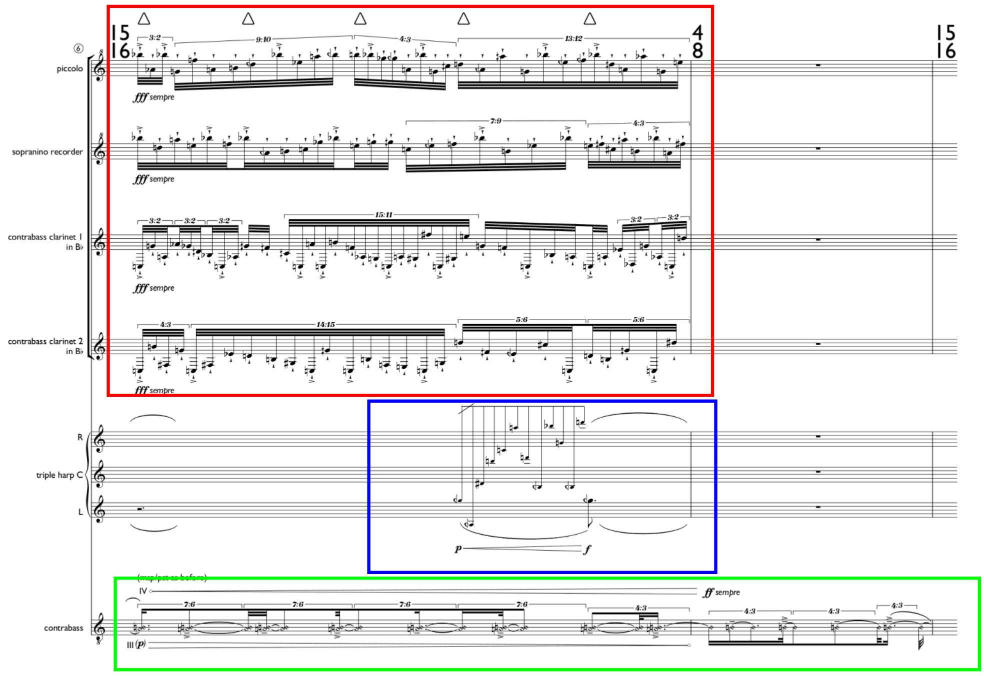

Figure 40 – *Hekabe-α* bars 6 - 7

The second entry of the wind quartet sees the microtonal pitch fluctuation expand into melodic fluctuation, coinciding with increased complexity in contrabass rhythm.

Figure 41 – *Hekabe-α*, bars 8 - 9

Winds settle on alternating pitches and complex but steady rhythm closer in character to contrabass rhythm.

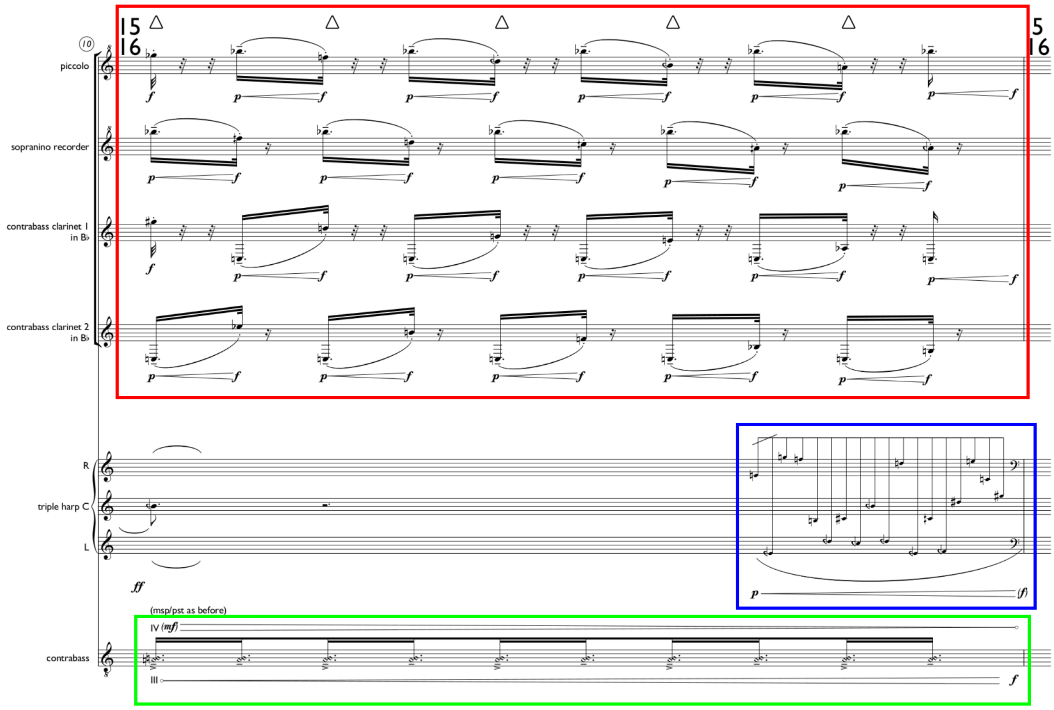

Figure 42 – *Hekabe-α*, bar 10, Winds and contrabass establish functional relationship

When the alto enters in bar 11, we hear voice for the first time, and the performer has moved to a dedicated 'solo' position on stage, creating a moment of theatrical significance. The orchestration clearly indicates the significance of this entry, with winds and contrabass falling silent as the voice enters and the harp providing simple accompaniment in rhythmic unison. This textural reduction framing the entry would be enhanced by the accompanying spatial reduction that would result from the winds being spatialized and the alto entry providing a strong directional focus as the spatialized parts suddenly cease. This spatial focusing would be most clearly articulated if the amplification of the alto voice were co-located with the performer as much as possible, and completely static.

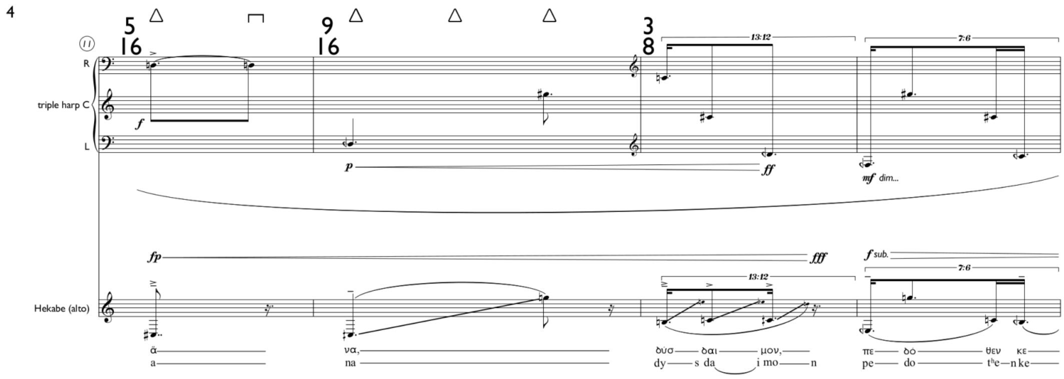

Figure 43 – *Hekabe-α*, bar 11- Alto entry

Throughout *Hekabe-α*, the division of the ensemble into functional sub-groups is clearly indicated in the orchestration. Broadly speaking, the alto and triple harp function as a one group and the winds function as a separate group, with contrabass shifting between the two.

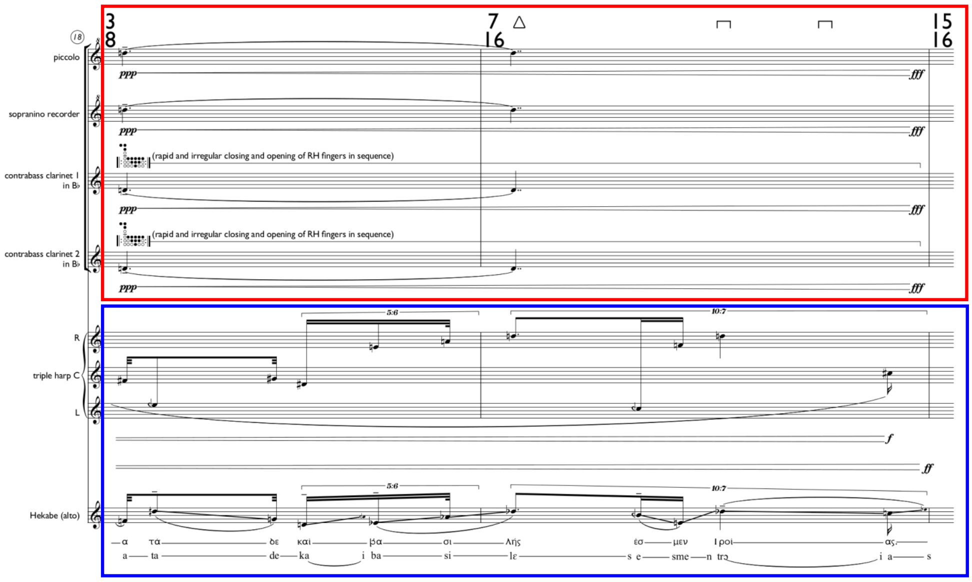

Figure 44 – *Hekabe-α*, bars 18 - 19, depicting functional relationships

Figure 45 – *Hekabe-α*, bars 40 - 41, contrabass shifting between functional groups

This otherwise consistent orchestration scheme is disrupted briefly from bar 20, when the alto falls silent and the melodic focus shifts to sopranino recorder, with the contrabass joining the two contrabass clarinets in accompaniment.

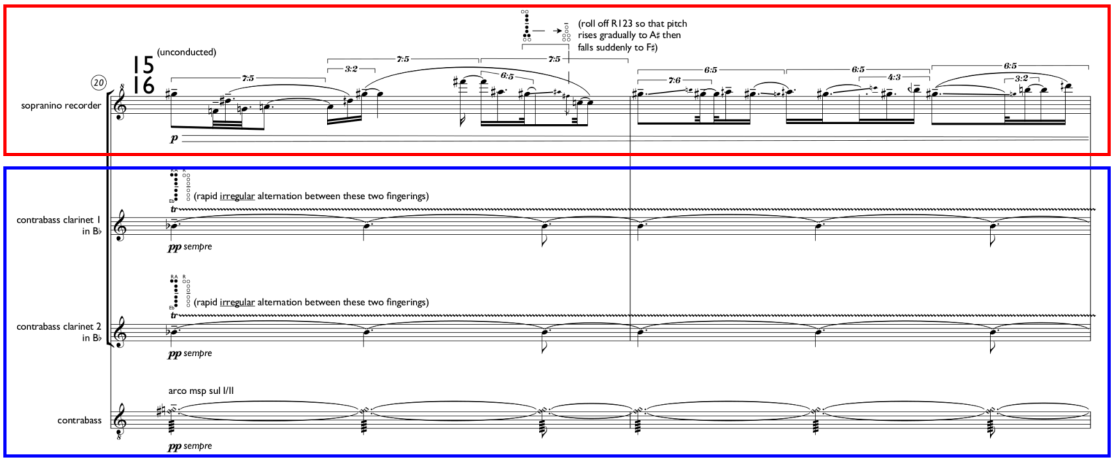

Figure 46 – *Hekabe-α*, bars 20 - 21

A momentary grouping marks the re-entry of the alto in bar 23 with the piccolo and recorder rejoining the contrabass clarinets in an accompaniment role, before the triple harp rejoins the alto in bar 24.

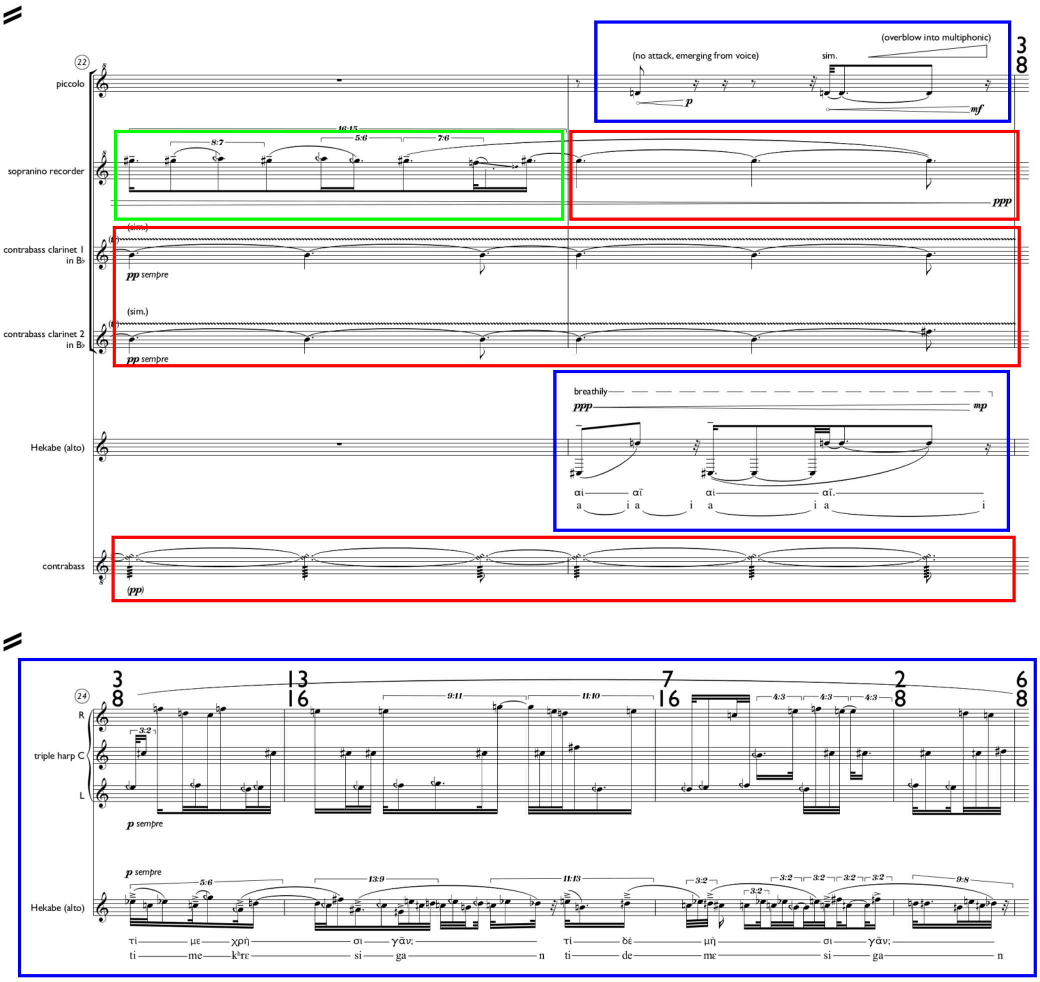

Figure 47 – *Hekabe-α*, bars 22 - 24

Keeping the alto and harp static, and localized as much as possible to their physical location, would assist in emphasizing the uniqueness of their role. Contrabass would also benefit from localized amplification in situ, initially to draw focus at the beginning of the piece and also to maintain spatial coherence when in functional relation to the alto and harp.

The winds, on the other hand, could be spatialized such that their accompaniment forms a spatially articulated ‘aura’ surrounding the alto/harp duo. Static displacement of the winds would not detract from the overall stillness of the piece, and provide a clear differentiation from the wandering trajectories of the quintet in *Politeia*. Provision could also be made for enabling focus on the sopranino recorder during its melodic passage and spatially reflecting the momentary relationship between piccolo and alto in bar 23.

The spatialization of the winds could be achieved by employing a multi microphone technique (described in Chapter 4) for each player in the wind group, not for gestural manipulation of the spatial field but to leverage the amorphous nature of the spatial magnification facilitated by the decorrelated capture of the local spatial field inherent in the technique.

Audio 5.3.5 – *Hekabe-α* opening

Kassandra

The second vocal piece in *CONSTRUCTION* also calls for static reinforcement of the voice to maintain a clear focus on its soloistic role. In the opening of *Kassandra*, the vocal melody is accompanied by discrete phrases, or cells, distributed around the ensemble with no clear connection between them, and none with particular relationship to the voice.

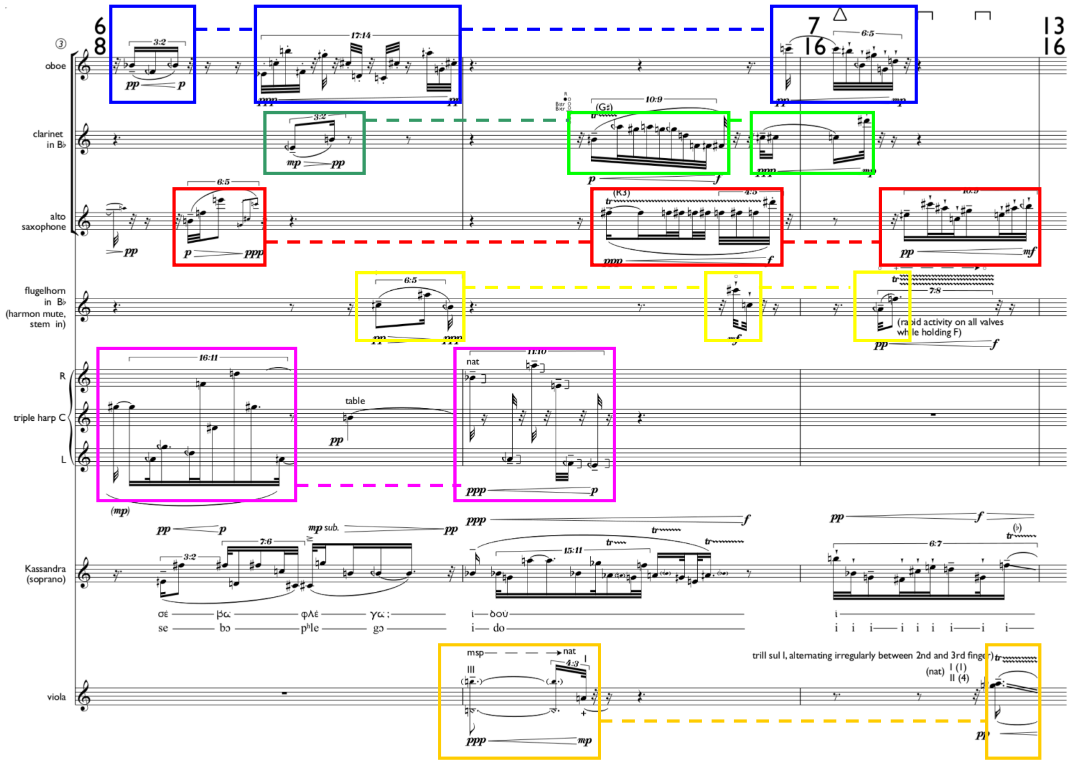

Figure 48 – *Kassandra,* bars 3 - 5

At times cells are contained to a single instrument, at other times instruments combine, even tutti playing a cell on occasion.

Figure 49 – *Kassandra,* bars 73 - 75, accompaniment tutti cells

Periodically there are fleeting connections between an accompaniment cell and the vocal line, for example viola in bars 5 and 6, the oboe trill in bar 6 and alto saxophone in bar 7. The relationship between voice and accompaniment is not static; rather it is in motion around the ensemble.

Figure 50 – *Kassandra,* bars 6 - 7

At times individual cells of combine to form ‘lines’ that are passed around the ensemble. Flugelhorn, clarinet and oboe share a line in bars 9 and 10, and in bars 26-31 an accompaniment line is passed around the whole ensemble.

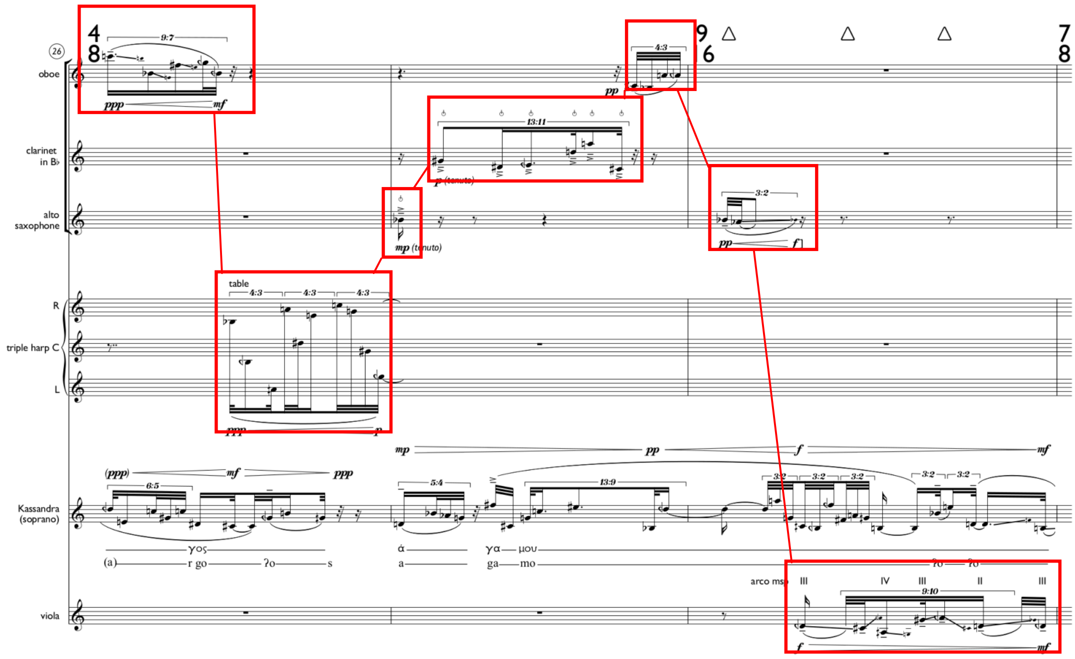

Figure 51 – *Kassandra,* bars 26 - 28

Spatial articulation of this 'episodic' accompaniment around a static and more flowing vocal line could create a sense of accompaniment 'flowing around' the voice, further emphasizing the moments of 'coagulation' in accompaniment, such as when voice rests in bar 44.

Andromakhe

Andromakhe is scored for contralto voice and ensemble and is suggested by the composer to be spatially static, continuing the theme of stasis common to Cycle 3. The piece opens with two distinct functional groupings – the bassoon accompanies the voice, and 3 clarinets form an independent group. Each group plays in rhythmic unison (Figure 52).

Figure 52 – *Andromakhe*, bars 1 - 5

The voice and bassoon should be localized in situ to enhance focus on the contralto soloist. The clarinets, on the other hand, could be spatialized in the same way as the winds in *Hekabe-a* (using a multiple microphone technique) to generate a diffuse field of accompaniment.

In bar 17 the harp enters independently of either group, playing short fragmented cells (Figure 53). The harp should be statically reinforced in situ. The uniqueness of the part and natural attack characteristic of the instrument set it apart clearly from the ensemble texture, and any extreme spatial displacement (or spatial motion) would draw focus away from the soloist.

Figure 53 – *Andromakhe*, bars 17 - 20

At bar 40, the rhythmic unison in the clarinet trio begins to dissolves. Voice and bassoon fall silent, and the cello enters forming a group with the harp (Figure 54).

Figure 54 – *Andromakhe*, bars 40 - 41

The distinction between the material played by the respective groups becomes progressively less defined until bar 46, where cello is clearly more aligned to clarinets than harp. The voice and bassoon re-enter in bar 47, forming a trio with cello while the harp resumes independence.

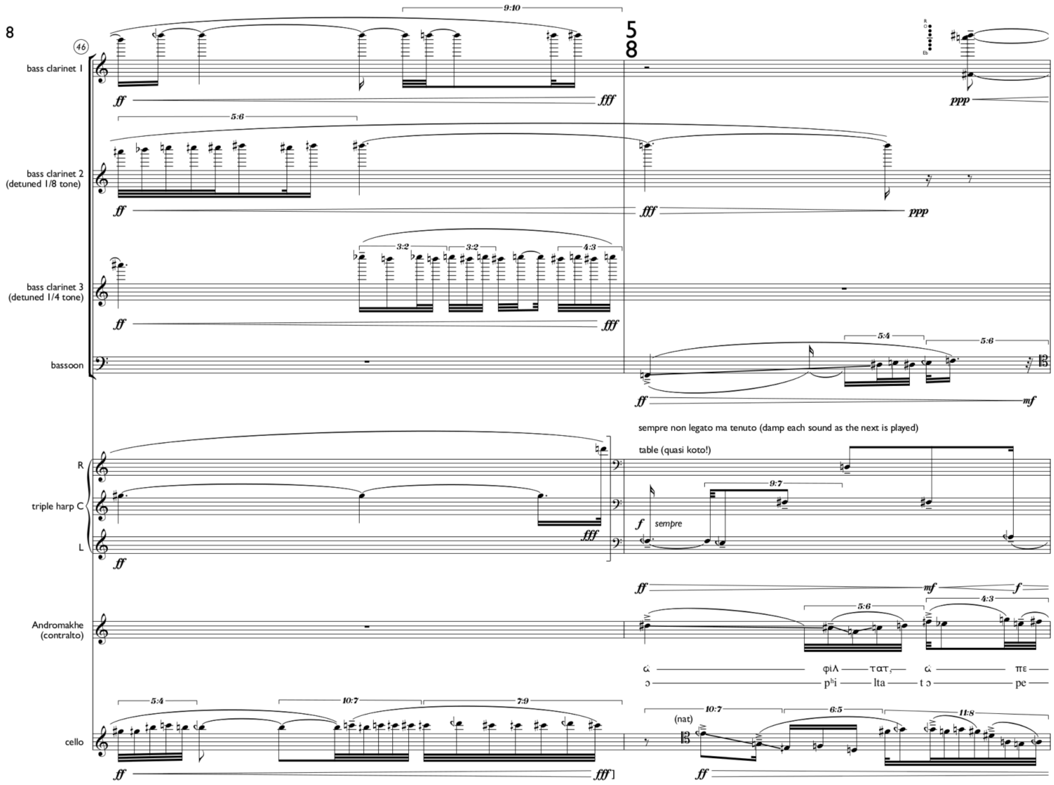

Figure 55 – *Andromakhe*, bars 46 - 47

The spatial plan for *Andromakhe* remains consistent throughout, a diffusely spatialized cloud of clarinets framing static co-located reinforcement of the voice and other instruments. This scheme allows focus to be maintained on the soloist when present while providing some spatial life through the spatial activation of the clarinet trio.

Helene

Helene is scored for soprano voice accompanied by a trio of tenor recorder, marimba and triple harp. The composer's suggestion for spatialization calls for static reinforcement, and the performance notes clarify this perspective. Instructions for sound reinforcement indicate "Amplification should be used to ensure an equal balance between the four performers and a consistent barely-changing dynamic level." Further to this end, all performers' parts are marked *p* throughout and the score is devoid of expression markings. The stillness the composer is seeking is emphasized by the direction in the score that the piece should be performed "...almost without nuance or "expression"..."

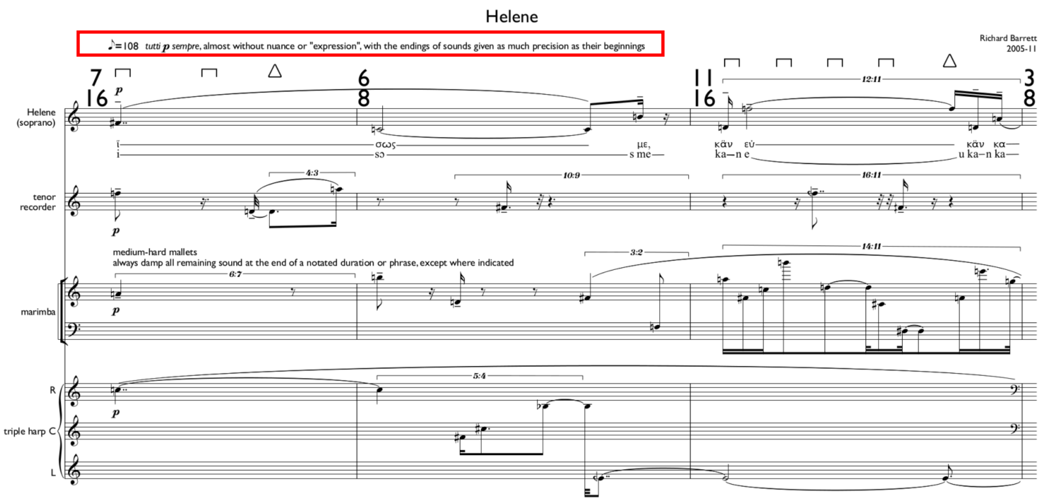

Figure 56 – *Helene,* bars 1 - 3

In light of this unambiguous intent of the composer, *Helene* calls for static amplification, with all sounds localized to their source as much as possible. The resultant stillness represents a dramatic contrast to the spatially, rhythmically and texturally chaotic nature of *storming*, which precedes it.

Audio 5.3.6 – *Helene* opening

Hekabe-β

Hekabe-β links back in its orchestration to *Hekabe-α*, with solo alto voice accompanied by triple harp, a quartet of winds and a single string instrument. The instrumentation is varied in that the *Hekabe-β* wind quartet consists of piccolo doubling alto flute, bassoon, piccolo trumpet and trombone. The double bass from *Hekabe-α* is replaced by violin, and vocal chorus parts are added for soprano and male alto.

The piece begins with a series of one bar phrases alternated with one bar rests. Each phrase consists of a single short accented utterance from the solo alto launching bar-long rhythmic unison figures in the harp and winds. The first of these phrases features only bassoon and trumpet from the wind quartet, expanding to the whole quartet for the second and expanding in registral range. The registral expansion continues through the third and fourth phrases, paralleled by progressive increases in the rate of rhythmic activity and overall dynamic level.

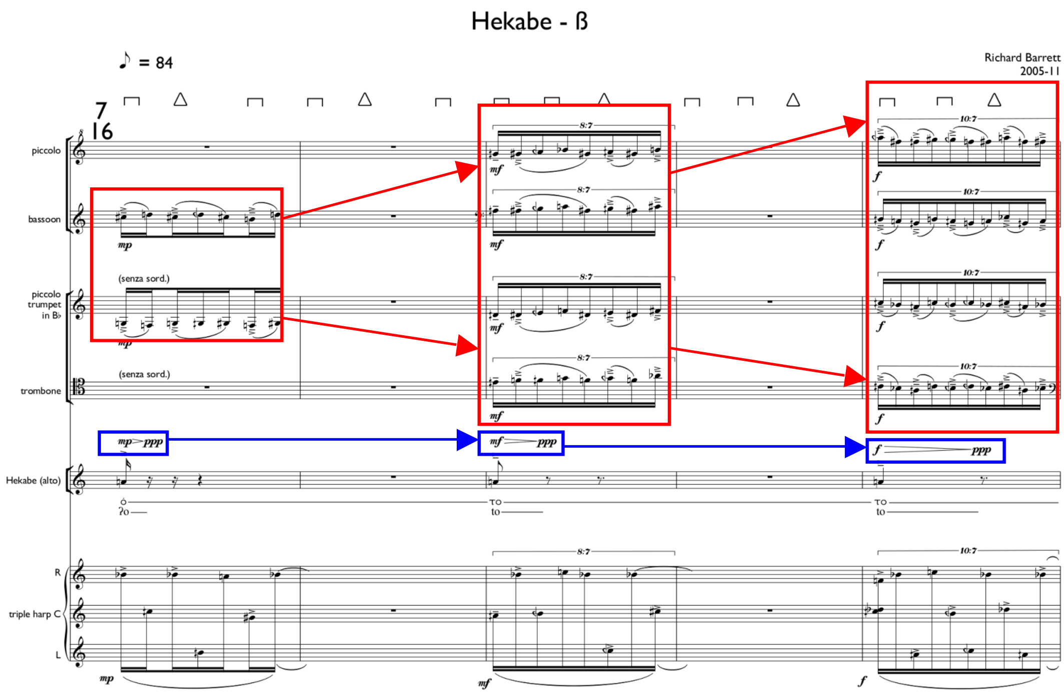

Figure 57 – *Hekabe-β*, bars 1 - 5

This build up reaches its peak in a simultaneous accented fortissimo in bar 9 that launches the solo alto into its first melodic phrase, accompanied by harp and violin, which entered at bar 7 and sustains a pianissimo harmonic across the transition into vocal melody.

Figure 58 – *Hekabe-β*, bars 6 - 10

Given the structural parallels in both orchestration and phrasing between *Hekabe-α* and *Hekabe-β*, a similar spatialization strategy would reinforce the relationship between the two pieces, especially in light of their separation in time and the diverse nature of the music between them. The winds, then, could be spatialized in a static diffuse field, framing the solo alto, harp and violin.

The chorus voices enter in bar 18, echoing the text of the solo alto, but quickly aligning themselves with the phrase structure of the accompanying winds.

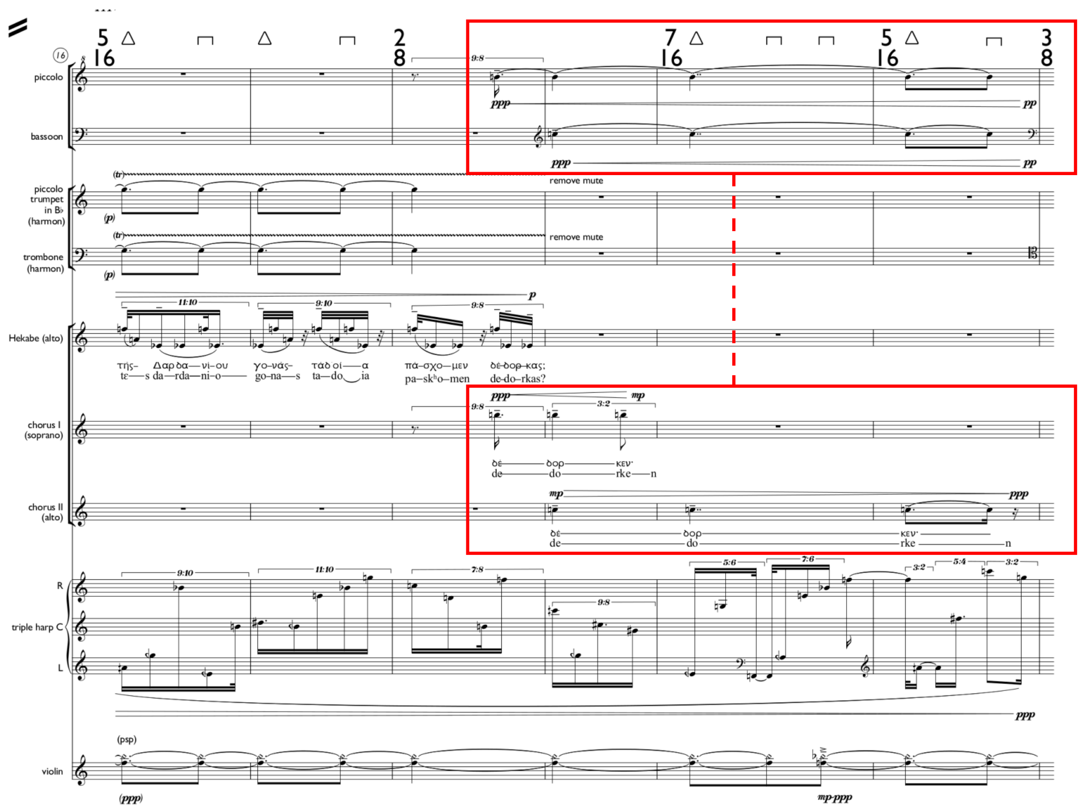

Figure 59 – *Hekabe-β*, bars 16 - 21

The chorus voices, in spite of their functional relationship with the wind quartet, should be statically co-located with the solo. The setting of text in the chorus voices immediately connects them with the solo alto, and coupling that with phrasing shared with the wind quartet establishes the chorus as having a unique role in the texture, bridging the two groups. This is evidenced in bar 22, when in the absence of the solo alto the harp is drawn by the chorus voices into a direct functional relationship with themselves and the winds.

Figure 60 – *Hekabe-β*, bars 22 - 25

The harp has re-established its connection with the solo alto by bar 27, at which point the rhythmic unison in the winds dissolves into a single line being passed around the quartet. The composite line maintains rhythmic unison with the chorus voices, and the spatial animation of the line resulting from the spatialization of the winds provides further justification for localizing the chorus voices with the solo alto. If the chorus voices were spatialized with the wind quartet, the spatial flow of the winds' composite line may be less clearly articulated, and the tight rhythmic unison harmony of the chorus parts would be undesirably diffused.

Figure 61 – *Hekabe-β*, bars 26 - 29

Co-location of the chorus voices with alto solo would also serve to enhance the focused stillness that closes the piece, with all voices in rhythmic unison accompanied by a single violin.

5.3.4 *CONSTRUCTION* Cycle 4 – Violin Solos

wound I

wound I is the first piece in a five part suite for solo violin and ensemble. The five wound pieces are conceived to be performed singly, as a suite, or as part of *CONSTRUCTION*. In the context of performance within *CONSTRUCTION*, the five pieces are not performed sequentially, but interspersed throughout the work providing the fourth interwoven thematic thread that runs through the work. The ensemble instrumentation varies for each of the *wound* pieces, consisting of only oboe and cello in *wound I*.

The violin soloist is directed (if possible) to move from their normal (seated) ensemble playing position to a dedicated solo position, demonstrating the composer's desire to draw focus to the soloist. It is therefore desirable to co-locate the focus of the amplified sound with the performer so as to avoid blurring the spatial focus or drawing attention away from the soloist.

The piece opens with a series of repeated accented *fff* triple stops in the violin, accompanied by *ff* multiphonics in the oboe and *mf* accented harmonics in the muted cello. All parts maintain rhythmic regularity throughout the opening bar, but each instrument divides the bar differently. The result is three parallel streams that are clearly related but not synchronized.

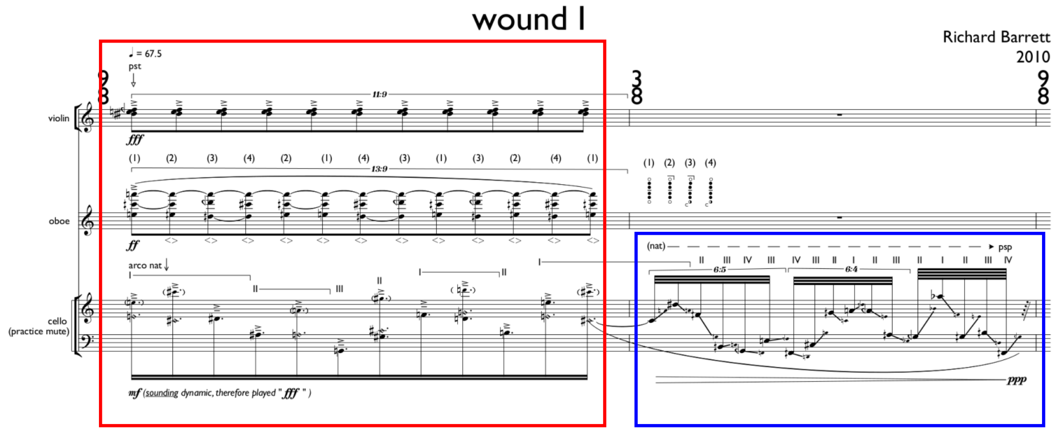

Figure 62 – Opening bars of *wound I*

The complexity of the combined rhythm of the first bar is such that the individual lines and relationship between the parts would be more clearly expressed by spatially locating the accompaniment instruments away from the violin. A static state (as suggested by the composer) is preferable as spatial motion within parts could detract from comprehension of the rhythmic relationships.

The polyphony of the opening bar gives way in bar 2 to a brief decrescendo cello solo. Bar 3 returns to a rhythmically complex trio texture followed again by solo cello in bar 4. This formal scheme of alternate bars of trio then solo continues for the duration of the piece, but in bar 8 the oboe plays the solo bar and bar 10 is silent. Cello takes the solo bars again from bar 12 and the pattern continues until the final bar, when a violin solo bar ends the piece.

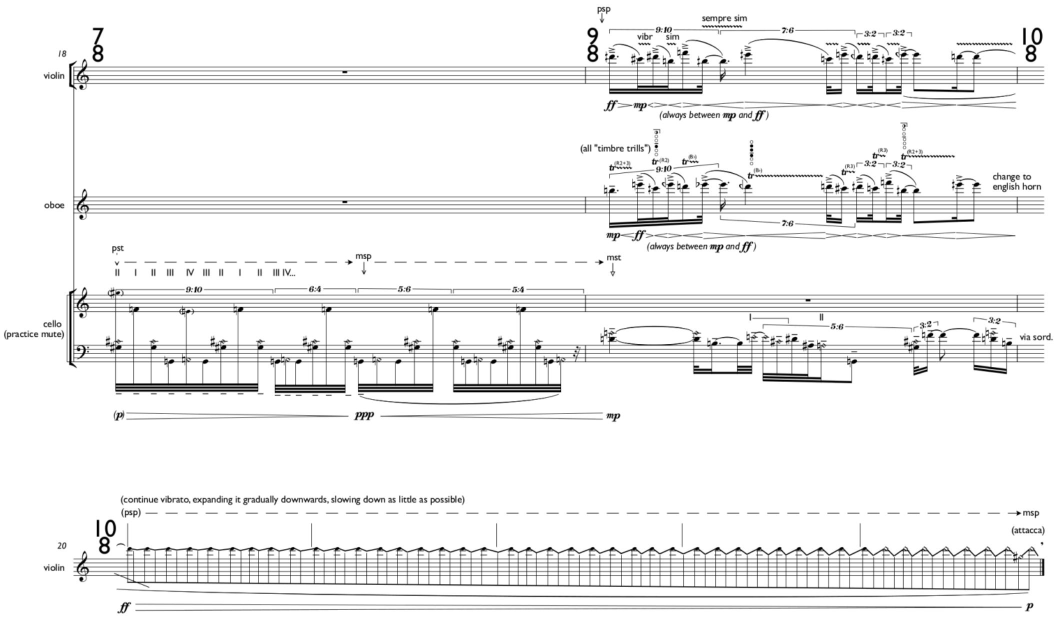

Figure 63 – Final bars of *wound I*

wound II

The second of the *wound* cycle sees the solo violin accompanied by a trio of English horn, clarinet in E flat and cello. The composer again suggests static reinforcement, and the virtuosic solo violin part clearly warrants the focus. The piece consists of a series of virtuosic phrases, the beginning of each marked by the entry of one or another of the trio instruments. The trio accompaniment consists of sustained pitches and tremolos, sometimes equal in duration and sometimes bridging two or three phrases, resulting in a timbrally shifting bed that emphasizes the phrase rhythm of the violin part. A multiple microphone technique (described in Chapter 4) would be ideal for the accompaniment in this instance, providing a timbrally modulating cloud to frame the soloist.

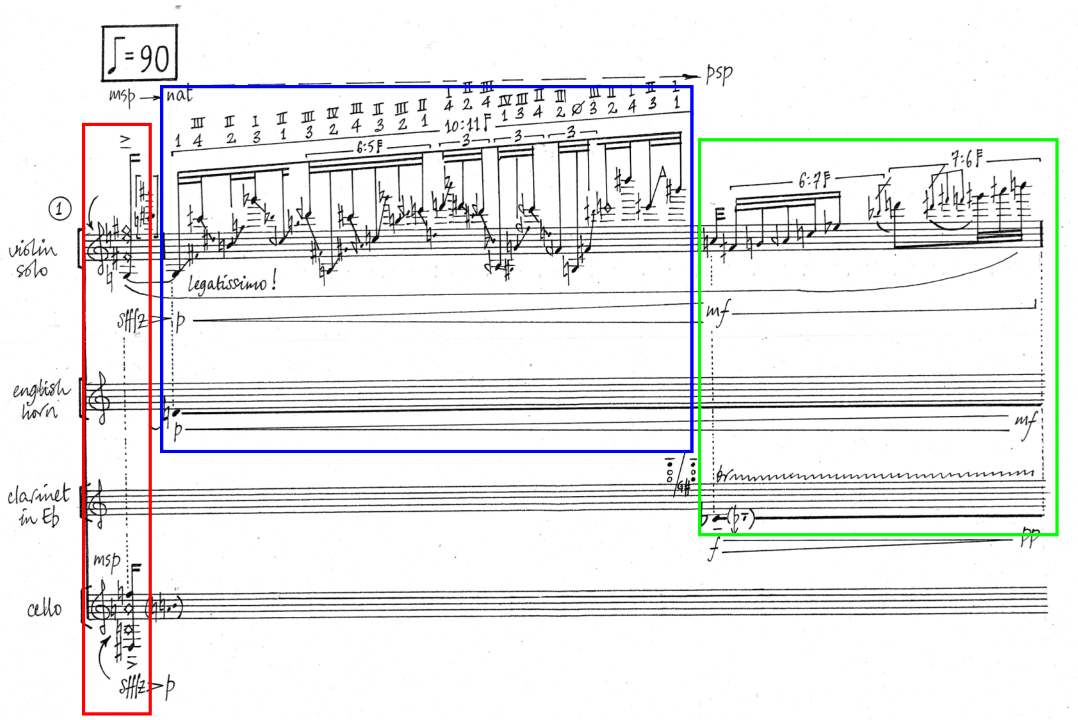

Figure 64 – Opening of *wound II*

wound III

wound III opens with an emphatically stated rhythmic unison relationship between the solo violin and percussion playing udu drums, accompanied by an independent line on lap steel guitar. Static localized amplification of violin and would emphasize the solo violin as a point of focus and the accompaniment role of the udu drum, while the lap steel guitar could be diffused throughout the space.

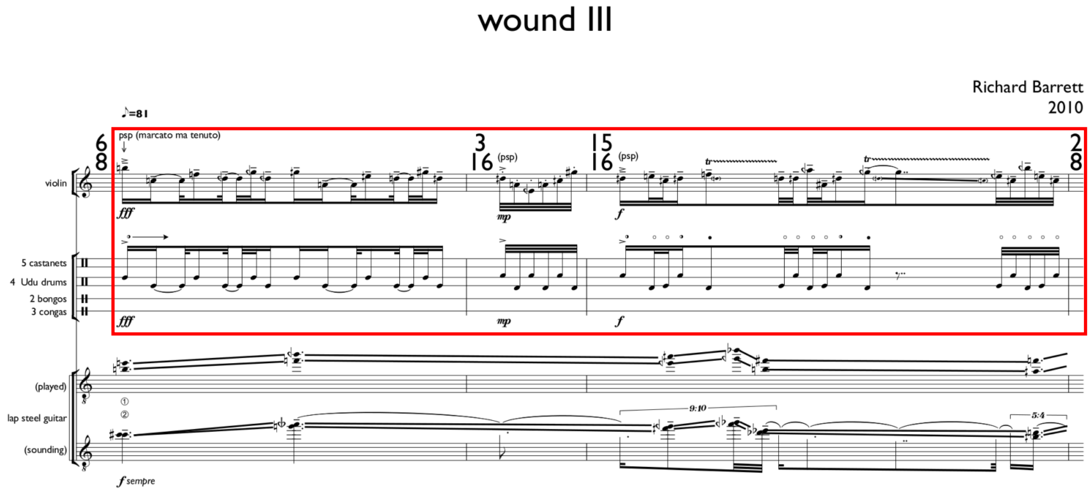

Figure 65 – *wound III*, bars 1 - 3

Violin and percussion remain in precise rhythmic unison with precisely matched dynamic levels until bar 10 when they briefly diverge before re-synchronizing at bar 14.

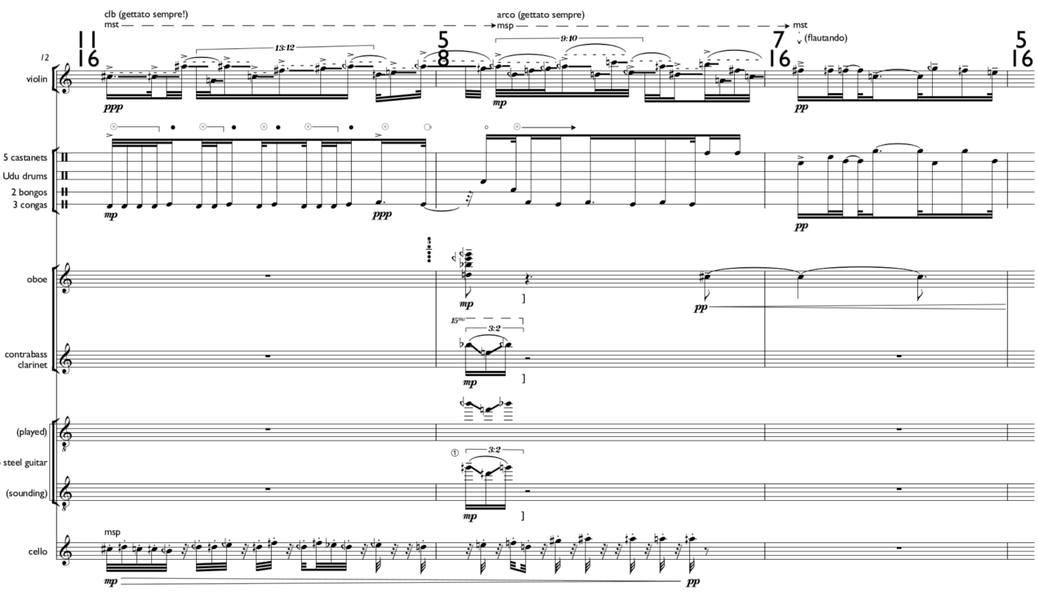

Figure 66 – *wound III*, bars 12 - 14

Oboe, contrabass clarinet and cello could be statically spatialized such that they become part of the diffuse field established for the guitar. Rhythmic unison gestures such as in bar 13 would be enhanced by the spatial articulation of timbre and the solo violin would maintain focus, supported by percussion.

wound IV

The fourth piece in the *wound* cycle sets the violin solo with accompaniment from voices as well as instrumental ensemble, and the composer suggests the voices be subjected to spatial motion (with variable reverberation modulating relative spatial depth) while the instruments remain static. The ensemble is divided into two clear groups, with oboe and cello grouped with the voices, and the clarinet, lap steel guitar and percussion (castanets and udu drums) forming the second group. The two groups alternate in accompanying the solo violin, and the spatial activation of the voices will result in an alternation between static and mobile states. Mobilization of oboe and cello could further enhance the spatial contrast between groups, but the effect should be clear even if they remain static.

Audio 5.3.7 – *wound IV*

wound V

wound V is primarily scored for solo violin, percussion and lap steel guitar. When performed outside the context of *CONSTRUCTION* this is the full instrumentation. When performed as part of *CONSTRUCTION*, alto flute, contrabass clarinet, English horn, alto saxophone, flugelhorn, contrabass and electronics augment this trio. The solo violin, percussion and guitar play a series of short phrases that combine, alternate and intertwine in a variety of ways over the duration of the piece. The percussion (congas and bongos) and guitar provide an augmentation or elaboration of the violin part more than accompaniment, and as such should remain static and spatially focused with the violin. Giving these parts their own spatial identity could result in them drawing equivalent focus to the solo violin and cause their parts to be heard as part of a trio texture rather than augmenting the solo violin.

Figure 67 – *wound V*, bars 11 - 12

The remainder of the ensemble functions quite differently, mostly playing sustained mezzo piano chords, gradually expanding their timbral range over the duration of the piece. Static diffuse spatialization of these parts would result in a shifting, spatially expanding cloud floating around the principal instruments.

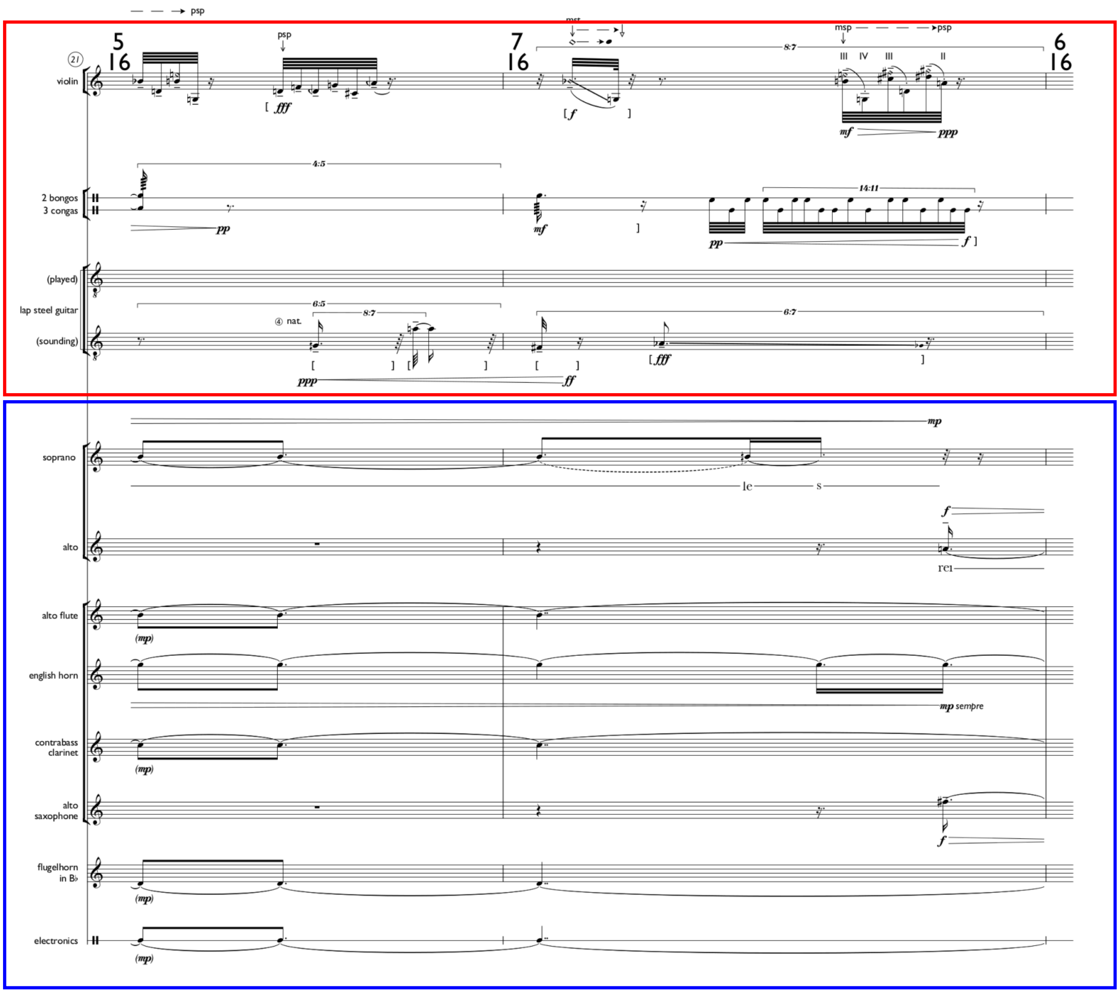

Figure 68 – *wound V*, bars 21 - 22

The gradually increasing density of the spatialized chords would also provide an effective lead-in to the animated spatial field of *Germania*, which follows attacca.

5.3.5 *CONSTRUCTION* summary

The spatial design for *CONSTRUCTION* presented above represents a typical (if idealized) example of my approach to spatial performance design for ELISION, informed and enhanced by discoveries and observations made in the course of research undertaken for *The Spatial Ensemble* project. The governing design principle is to create an experience for the audience (Buckley n.d.) that reflects as closely as possible the composer's intent (Barrett 2011).

The broad outline of the composer's intent is drawn from performance notes and personal communication, with the detail of the design implementation derived from detailed study and interpretation of the score. The approach to interpretation is the result of the evolutionary developmental process outlined in Chapter 2 and is based on a functional analysis of orchestration.

The performance series undertaken in the context of *The Spatial Ensemble* research project has informed the spatial design presented in a number of ways. Firstly, the employment of a software-controlled spatialization system (as outlined in Chapter 3) allows spatial trajectory automation that facilitates motion that would be impractical to execute by other means, and such motion would assist the realization of the composer's intent for several sections of *CONSTRUCTION*. Secondly, the potential problem of performers feeling and appearing disengaged from the spatialization process is addressed by (where appropriate) allowing for performer-driven spatialization control based on the multiple microphone technique developed during this research and outlined in Chapter 4. Thirdly, the spatial design is careful to preserve points of focus in the music. Where the analysis or performance notes identify that a performer warrants focus at a particular time, they are not subjected to the spatial displacement or motion of their sound and the sense of disembodiment that results. As a result motion and displacement, and conversely stasis, take on a functional role in articulating the orchestration and formal structure of the work.

Summary and Conclusions

The spatial sound design practice I have developed with ELISION Ensemble has grown out of a long history of performing in non-traditional environments and seeking through sound system design to integrate the performance of contemporary chamber music effectively with a variety of performance spaces. Parallel to this, working closely with composers interested in spatialization such as John Rodgers and Richard Barrett has led to works being composed for the ensemble that have exploited our spatial performance experience and extended our practice beyond venue-specific sound design. In combination, these two factors have evolved into a performance practice whereby spatial design is derived as much from the analysis of scores as the physical characteristics of the performance environment.

The essence of this practice is spatial design that is based on musical interpretation, filtered through and informed by accumulated aural spatial intelligence, rendered by technological means for a particular performance environment. The underlying design principle is that the aural spatial intelligence of audiences can be leveraged to facilitate the comprehension of ELISION's complex repertoire by means of the appropriate spatial mapping of ensemble orchestration. The fundamentals of this approach to design have remained unchanged in an evolving technological environment. The design methodology has evolved alongside technological developments but is neither dependent on nor a product of any particular technology other than amplification.

Technological developments will continue to refine the tools available for spatialized music performance. Computer-controlled automation of sound spatialization enables complex spatial motion that could not otherwise be executed practically, and this has influenced the design process by increasing the palette of available options. Richard Barrett's performance notes for the spatialization of *CONSTRUCTION* exemplify this. The rotational motion called for in various sections of the work is a spatial design decision guided by the typical behavioural characteristics of contemporary automated spatialization systems. Software control theoretically allows sound to be placed in any location or prescribe any trajectory through three dimensions, and a variety of control structures are available to execute this. In practice, however, the reliance on virtual imaging between loudspeakers for positioning and trajectory rendering is a significant limiting factor in the ability to convey precise spatial detail to every audience member regardless of their position. Effective spatial resolution at and beyond speaker distance is largely possible, but often compromised by the size and geometry of the performance environment as was the case for the *CONSTRUCTION* premiere described in Chapter 3. More proximate localization 'inside' the speaker array remains problematic, especially in the context of varied listening perspectives resulting from audiences' spatial distribution.

ELISION’s initial exploration of automated spatialization control has raised questions for instrumentalists and myself with regard to the role of performers in the spatiality of performance. Automation will continue to have a role to play, but performer-driven spatialization methodologies warrant further investigation. More exploration of the multiple microphone technique described in Chapter 4 is required before it can be considered a viable performance methodology in an ensemble context, but some conclusions can be drawn from the initial work undertaken in this study:

1. The local spatial environment of instrumentalists is rich with spatial information.

2. Performers' local spatial fields can be re-scaled with amplification to leverage the information contained therein.

3. The spatial field of the ensemble as a whole is an aggregation of individual spatial fields, any of which can be re-scaled in varying ways.

4. Performers can manipulate the spatiality of their own performance if given the means to control or interact with the amplified rendering of their local spatial field.

5. Useful spatial information is yielded even if performers do not actively manipulate the capture of their local spatial field.

The analysis-based approach to spatial performance design that characterizes my spatial performance practice with ELISION demonstrates that, as shown in the analysis of Richard Barrett's *CONSTRUCTION*, spatial design for contemporary chamber music performance can be substantially derived from ensemble orchestration. Formal design, phrase structure and orchestrational relationships can inform spatialization design and their perception can be enhanced as a result. Implicit in this approach is that spatialization design is functional and purposeful, not incidental or implemented for effect or as a technological exercise. The derivation of spatial design from score analysis ensures the music remains the primary focus, and the technological implementation remains a vehicle for communicating it to the audience. Spatial amplification based on considered and informed score analysis can contribute to the performance of contemporary chamber music more profoundly than making the sound louder and clearer; it can actively contribute to the interpretation of the music and substantially influence the audience's perception and comprehension of compositional form and detail.

As ELISION's spatial performance practice continues to evolve, composers, instrumentalists and myself as sound designer all have a role to play in ensuring that the spatiality of our performances continues to be an interpretive activity rather than a technical function.

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APPENDIX 1

Notes on Audio Examples

The accompanying Audio CD contains 30 tracks consisting of binaural renderings of audio examples from the instrumental workshops described in Chapter 3 and *CONSTRUCTION* excerpts based on the analysis presented in Chapter 5. The source material for the *CONSTRUCTION* excerpts is a multi-track recording of the premiere performance. Stereo versions of the *CONSTRUCTION* excerpts are provided for comparison with the spatialized renderings.

All audio examples are *binaural*, designed to be listened to with headphones. Binaural rendering is not capable of accurate spatial field reproduction, with limited capability for precise localization to the rear and vertically. Binaural rendering does, however, have the advantage of requiring no specialized equipment for monitoring. The examples presented here convey the spatial design effectively enough to demonstrate the design principles outlined in this exegesis, but should not be taken as an accurate representation of live spatial performance.

Reproduction of these examples on stereo speaker systems will *not* provide an adequate representation of the spatialization.

APPENDIX 2

Audio Example Files

Audio 4.3.1a – sustained texture spatially activated

Audio 4.3.1b – Variation on 4.3.1a with explicitly performed gestural activity

Audio 4.3.1c – Intimate mouth noise texture

Audio 4.3.1d – Spatially animated percussive texture

Audio 4.3.1e – Pointillistic spatial scattering using wrist mic positioning

Audio 4.3.2a – marble in steel drum

Audio 4.3.2b – cymbal/tam tam and ceramic plate

Audio 4.3.2c – Miniature Friction Drum

Audio 4.3.2d – Bullroarer

Audio 4.3.2e – Thunder Sheet

Audio 4.3.2f – Percussion 'Kit'

Audio 4.3.3a – Contrabass recorder

Audio 4.3.3b – Tenor recorder

Audio 4.3.3c – Sopranino Recorder

Audio 4.3.4a – B flat Clarinet

Audio 4.3.4b – Bass Clarinet

Audio 5.3.1 – *storming*

Audio 5.3.1a – Stereo version of *storming*

Audio 5.3.2 – *Politeia* opening

Audio 5.3.2a – Stereo version of *Politeia* opening

Audio 5.3.3 – *heliocentric* opening

Audio 5.3.3a – Stereo version of *heliocentric* opening

Audio 5.3.4 – *news from nowhere* opening

Audio 5.3.4a – Stereo version of *news from nowhere* opening

Audio 5.3.5 – *Hekabe-a* opening

Audio 5.3.5a – Stereo version of *Hekabe-a* opening

Audio 5.3.6 – *Helene* opening

Audio 5.3.6a – Stereo version of *Helene* opening

Audio 5.3.7 – *wound IV*

Audio 5.3.7a – Stereo version of *wound IV*