Spatiality of sound and stream segregation in twentieth century instrumental music

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1. INTRODUCTION. BACH IN SPACE

Let us imagine a situation: a listener seated in a concert hall witnesses a performance by a trumpet player (standing on the stage) of a sequence of four quarter-notes, with the pitches of B♭3–A3–C4–B3.[1] The listener chooses to ignore the immediate physical surroundings and hears one of the following: (i) four trumpet sounds equally spaced in time, (ii) a sequence of intervals – minor second, minor third, minor second, (iii) an instance of set 4-1, (iv) a motive referring to the name of BACH. The 'web of interpretants' (term from Nattiez 1987/1990) surrounding a simple musical fact is already quite dense, even though we have only considered its aspects relating to pitch, pitch class and pitch notation (representation by letters). What if the performer's gestures, the facial expressions, the direction of the bell of the instrument became important? Might one say, then, that the music has become theatre?

Let us consider a different situation. Four trumpet players stand in the corners of a rectangular hall, each playing one note of the motive in succession. The listener is now surrounded by the 'B–A–C–H'. When the notes slightly overlap in time, one might say that the sound rotates, or meanders through space (depending on the order of entries). The motive has become 'spatialised'. A different effect arises when the four musicians play each note of the motive together. The identity of pitch, the timbral and temporal coherence lead to a transformation of the sound image heard by the listener in the centre, equidistant from the four musicians. The sounds appear to extend in space, covering the whole area in-between; Henry Brant calls this phenomenon 'spill' (Brant 1967). Again, the spatialisation of music has occurred. Is it negligible from the analytic standpoint? What if the musicians walk around while playing repeatedly the same motive, each presenting the same pitches in a different rhythmic pattern and a different order? The listener may focus on any of the four trajectories of sound movement, she or he may notice evolving timbres, changing distances and directions. Is the music reducible to the simple 'B–A–C–H'? Is it theatre? Would it be music or theatre if all the participants of the musical situation wandered through the entire hall, foyer, backstage, in a sort of a 'hide-and-seek' game? Would it make a difference if the composer just gave one page of vague instructions or if the entire spatiotemporal design was specified in detail in the score?

Imagine a situation of quadraphonic sound projection created by four loudspeakers surrounding the listener.[2] The recorded trumpet motive swirls around at a breathtaking speed in the virtual space. Imagine that while rotating it simultaneously approaches the listener and accelerates to an overwhelming, dizzying climax. Could this form of 'spatialisation' be ignored as inessential to the music's true identity? What if sound processing resulted in the motive's drifting in and out of the threshold of audibility, so that the old 'B–A–C–H' would be barely recognisable, like an apparition from a distant past? What if, to change the sound image completely, a huge brass chorus 'blared away' from all directions at once, crushing the listener with the immensity of a quasi-Brucknerian apotheosis? And, to outline just one more option, would anything in the music change if a musician, the trumpet player from the beginning of this 'what-if'

[1] I discuss this example in chapter four, 'Spatialization and the Musical Work', of my doctoral dissertation, *Space and Spatialization in Contemporary Music: History and Analysis, Ideas and Implementations* (Harley 1994a). An earlier version of this paper was presented at the study session, 'Auditory Scene Analysis: Future Directions for Musicological Research', at the 16th International Congress of the International Musicological Society, London, August 1997. I thank Albert Bregman, David Huron, Bo Alphonse and Susan McClary for comments that helped me improve this text.

[2] This example is completely fictional and does not refer to any particular technology. The field of spatial sound reproduction has seen an explosive growth; it is, for instance, the focus of the 16th International Conference of the Audio Engineering Society (⟨http://acoustics.hut.fi/aes16⟩, scheduled for April 1999, Finland; with keynote addresses by Brian Moore, Durand Begault, David Griesinger, Soren Bech and Jean-Marc Jot). Some recent publications: Soren Bech: 'Spatial aspects of reproduced sound in small rooms' (*Journal of the Acoustical Society of America* **103**, January 1998, pp. 434–45); Durand Begault: 'Multichannel spatial auditory display for speech communications' (*Journal of the Audio Engineering Society* **42**, October 1994, pp. 819–26); C. Kyriakakis: 'Fundamental and technological limitations of immersive audio systems' (*Proceedings of the IEEE*, **86**(5): 941–51).

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game, appeared in the middle of the virtual space, and if the motive performed by the live musician was surrounded, overwhelmed and silenced by a barrage of distorted, artificial sounds (with the same sequence of pitches, though, as the perennial 'B–A–C–H')?

In addition to the obsessive reliance on one, short sequence of pitch classes, all the situations outlined above have one element in common. All imply the presence of the listener. The location, orientation, attention and, sometimes, movement of this person are crucial for the 'spatialisation' to occur. The listener orients him/herself toward the music, the music is directed toward the listener. Their reciprocal relationship is essential.[3] The appraisal of the musical situation changes when the attention shifts to the spatial perspective of the performer. A solo musician deals merely with the space of the instrument, or, if walking around, of the performance setting (Merleau-Ponty 1945/1962: 146). Two or more performers may interact with each other. Louis Andriessen asks: 'What is the difference between two people playing a melody and one person playing the same melody? And what about two people playing one note turn and turn around?' (Andriessen 1977). Andriessen's answer is musical – *Hoketus* for two groups of musicians (discussed below). This composition is a musical game which challenges the performers to compete with each other. The 'artefacts' of the sound images, though interesting as such, are merely by-products of the musical actions.

This example notwithstanding, most concert music subordinates the aural perspective of the performers to that of the listeners, to whom the music appeals for an aesthetic judgement. Iannis Xenakis expresses this stance lucidly:

> 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. (Xenakis 1992: 11)

The emphasis on the aural perspective of the listener brings in a paradigmatic shift in the understanding of music and musical works. The traditional account draws from 'the notion of a pure or disembodied sound' (Ihde 1976: 78) which deprives music of its physical spatiality.[4] Often, musical substance is thought to consist only of structures in pitch and time which unequivocally determine the identity of a composition (Goodman 1976). The notion of 'spatialisation' requires a change of perspective which, however, does not necessarily contradict and invalidate the tradition. Musical spatiality, though always present, is not always crucial for the understanding of this art in which spatial relationships may be (and have been) expendable. Heelan's horizontal epistemology posits the existence of 'many-to-one and one-to-many mappings of perceptual objects contextually defined within mutually incompatible but complementary contexts' (Heelan 1983: 270). The 'spatial' perspective is just one such mapping, reformulating perceptual objects of music in a new context.[5]

When the role of spatial projection, sound location and direction become important elements of musical structure, we speak of the music's 'spatialisation'. Many composers of the twentieth century have created spatialised works; some of them have unwittingly followed the principles of auditory scene analysis. Examples from the outputs of Louis Andriessen, Bela Bartok, Henryk Mikołaj Gorecki, Marta Ptaszynska, and Kazimierz Serocki will demonstrate how spatiality of sound works with or against stream segregation. Before examining the music, I will briefly summarise Albert Bregman's review of the role of spatial cues in audition (Bregman 1990).

2. BREGMAN ON SPATIAL CUES

According to Bregman's *Auditory Scene Analysis*, spatial cues play an important role in the process of segregation and integration of incoming signals into auditory streams. Bregman refutes a theory that only frequency and time are 'indispensable attributes' in audition (cf. Kubovy 1981) and writes that:

> . . . two simultaneous frequency components differing only in place of origin can be heard as parts of two separate sounds at different spatial locations rather than uniting to form a sound heard between those locations. In addition, when a spatial difference is added to some

[3] Here, I have considered the 'spatialisation' of music as perceived by a lone auditor. The presence of a larger audience complicates the situation, because each listener hears a slightly different sound image from a different spatial position.

[4] Since the 1980s musicologists began considering spatial features of sound, though some still encountered problems caused by their rejection of the physical dimensionality of sound and music, e.g. Thomas Clifton in *Music as Heard: A Study in Applied Phenomenology* (New Haven, CN: Yale University Press, 1983). In contrast, more recent works, such as Robin Maconie's *The Concept of Music* (Oxford: Clarendon Press, 1990) take into account the complications arising from considering musical spatiality as a vital element of this art.

[5] Since the emphasis of this text rests on perceptual and compositional matters, I will not consider sociological accounts of the construction of space, such as the groundbreaking work by Henri Lefebvre, *Le production de l'espace* (Paris: Editions Anthropos, 1974). Lefebvre approaches his subject from a Marxist perspective.

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> other difference (say in frequency or in a match to a prior event in one ear), it greatly increases the amount of segregation. (Bregman 1990: 293–4)

While this statement is true only in limited circumstances, and does not apply to the basic idea of stereophony (i.e. when identical components heard from two distant loudspeakers create one unified sound heard in-between),[6] Bregman's emphasis on the importance of spatial cues in stream segregation provides an interesting point of departure for a review of experiments by twentieth-century composers. According to Bregman, the tendency to segregate 'sounds that come from different spatial locations' (Bregman 1990: 299) belongs among the primitive, i.e. innate, principles of auditory analysis (in opposition to schema-based principles created through the mediacy of culture and learning). Bregman speculates that the spatial separation of a multiplicity of sounds prevents 'the auditory system from computing certain dissonances between them' (Bregman 1990: 300). He also points out the importance of conscious focus of attention, apparent in the so-called 'cocktail party effect'.[7] Listeners immersed in complex soundfields (e.g. a noisy crowd at a cocktail party) are able to pick out sounds reaching them from one direction as more worthy of attention (e.g. words of their partner), and exclude other simultaneous sounds, e.g. other conversations. This effect depends on pitch; it is strongest for the frequency range around 1 kHz; below 400 Hz it noticeably worsens.

However, Bregman's praise for the usefulness of spatial cues in audition is not unqualified. He notices that reverberant environments, the presence of strong echoes, and the bending of sounds around obstacles cause a decrease in the precision of localisation. He also warns about conflicting cues: if two sound events occur at the same point in space, their integration may depend on other cues (i.e. spectrum, envelope, common fate) and, as a result, 'when the cues all agree, the outcome is a clear perceptual organization, but when they do not we can have a number of outcomes' (Bregman 1990: 302). Moreover, spatial cues are weaker than visual ones. In the so-called 'ventriloquism effect', sounds originating as far as 30 deg away from their apparent, visible source will be integrated with this source (Bregman 1990: 307). This occurrence is due to the importance of 'world structure cues' in perception (Bregman 1990: 312): the coherence of visual and auditory stimuli, as well as the assumption of the spatial permanency of sounds. We tend to expect sounds of similar spectral characteristic and close in time to be related.[8] A summary of this account is included in the table.

Table. Spatial cues and stream segregation.

No.	Name	Description
1	Difference and separation	Different sounds from different locations belong to separate sound complexes.
2	Confluence of cues	Spatial difference increases the amount of segregation arising from other cues (spectral, durational, onset/offset).
3	Innate quality	The tendency to segregate sounds from different spatial locations belongs with primitive (innate) principles of auditory analysis.
4	The role of attention	'Cocktail party effect' (selectively focusing on sounds from one direction) suggests the importance of the conscious focus of attention; the effect is strongest around 1 kHz, worsening below 400 Hz.
5	Reasons for imprecise localisation	Sound localisation is imprecise in reverberant environments, in the presence of strong echoes, and because of the bending of sounds around obstacles.
6	Conflict of cues	If two sound events occur at the same point in space, their integration may depend on other cues (i.e. spectrum, envelope, common fate).
7	Spatial and visual cues	Spatial cues are weaker than visual ones. In the 'ventriloquism effect', sounds originating as far as 30 deg away from their apparent, visible source will be integrated with this source.
8	World-structure cues	There is a tendency in audition to expect sounds of similar spectral characteristics and close in time to be related.

3. SPATIAL DISTANCE AND STREAM SEGREGATION: BRANT AND CAGE

The notions that spatial separation clarifies musical textures and helps decrease the level of dissonance between distinct layers of sound appear in the writings of several composers who discuss the usage of spatial features of sound in their music. Henry Brant

[6] Examples of recent research in spatial sound reproduction: O. Kirkeby, P. Nelson and H. Hamada: 'The 'stereo dipole' – a virtual source imaging system using two closely spaced loudspeakers' (*Journal of the Audio Engineering Society* **46**(5): 385–95); D. G. Malham and A. Myatt: '3-D sound spatialization using ambisonic techniques' (*Computer Music Journal* **19**(4), 1996, pp. 58–70); F. Pachet and O. Delerue: 'A mixed 2D/3D interface for music spatialization' (*Virtual Worlds*, *First International Conference*. *Proceedings*, pp. 298–307. Berlin: Springer Verlag, 1998).

[7] A recent contribution to the 'cocktail party problem' is by Gerald Kidd, Jr, Christine R. Mason and Tanya L. Rohtla: 'Release from masking due to spatial separation of sources in the identification of nonspeech auditory patterns' (*The Journal of the Acoustical Society of America* **104**(1), July 1998, pp. 422–31). The authors interpreted the results of their study as 'evidence for an important role of binaural hearing in reducing sound source or message uncertainty'.

[8] This tendency extends to hearing virtual, continuous sound motion by mentally integrating discontinuous sounds from two loudspeakers, cf. K. Mizushima, S. Nakanishi and S. Morimoto: 'Continuity of a moving sound image caused by successive signals from two discretely located loudspeakers' (*Journal of the Acoustical Society of Japan* **15**(3), May 1994, pp. 179–87).

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has written about spatial music since 1955; his observations, based on 'ad hoc' subjective tests, may be summarised in the following points:[9]

(1) Spatial separation clarifies the texture; this is particularly important if the music consists of several different layers located in the same pitch register.
(2) Spatial separation is equivalent to the separation of textures in pitch space; one can hear separately layers of music that are located in different registers, and layers that originate from distant points in performance space.
(3) Spatial separation permits a greater complexity in the music; which may, therefore, include more unrelated elements perceived simultaneously.
(4) Spatial separation makes exact rhythmic coordination impossible; distant groups should avoid simultaneous, identical rhythmic patterns.
(5) There are no optimum positions of the listeners or the performers in the hall; each situation is different.

To these general rules Brant added a number of detailed hypotheses, claiming for instance that sounds of higher pitch appear to be emanating from a higher vertical location. He also discussed specific spatial effects exploring spatial separation in conjunction with timbral similarities and differences. In particular, *a wall of sound* might be created by the strings placed vertically by the wall of the hall and arranged from the lowest to the highest, *a spill* might occur when the similarity of timbre and musical material causes a fusion of sounds which are performed by widely spaced musicians but seem to extend and cover the whole area in-between, and an effect of *filling up* might take place when stationary performers placed around the walls of the hall begin to play one after another. The most important factor in Brant's spatial music is the conjunction of spatial cues with other cues for stream segregation. During an interview I conducted with him in 1992, Brant declared that:

> . . . one of the essential realities of space music, as I have come to understand it, is that direction and tone quality should work together to identify certain kinds of music, and if this cannot be done, or if it is not done, then the space does not do anything at all, except create confusion. (Brant 1992: 12)

In his works Brant uses spatial distance in conjunction with dissonance, differences in tempo and metre, melodic patterns and instrumentation, in order to separate the music into simultaneous layers. The effect of juxtaposing several different types of music played simultaneously was used before Brant, by, for instance, Berlioz, Mahler and Ives.[10] Brant's writings and pieces contain many examples of his usage of spatial cues working in conjunction with other cues to create stream segregation. It is important to note that this composer was not particularly interested in the unity and coherence of the musical form. He shares this characteristic with another American composer, John Cage, whose Darmstadt lecture entitled 'Indeterminacy' (1958) contains the following statement:

> Where the performance involves several players (two or more) it is advisable for several reasons to separate the performers one from the other, as much as is convenient and in accord with the action and the architectural situation . . . This separation allows the sounds to issue from their own centers and to interpenetrate in a way which is not obstructed by the conventions of European harmony and theory about relationships and interferences of sounds. (Cage 1961: 39)

Cage believes that throughout the history of Western art music, a fusion of sound was essential. Therefore, the players in an ensemble were brought as close to each other as possible: together, they produced a coherent work of music, 'an object in time' (Cage 1961: 39). Cage's ideal of new music leaves that notion behind. He seeks to juxtapose non-related events; spatial separation of musicians is very useful for this purpose as it facilitates 'the independent action of each performer'. The exact temporal coordination of these actions is not necessary; new music does not need a common metre because it is based on *the copresence of dissimilarities*. This notion resembles Brant's idea of multilayered spatial music in the emphasis on the conjunction of spatial and nonspatial cues: musical material that differs in respect to timbre, pitch, rhythm, etc., is also dispersed in space. Here, again, spatial cues are supposed to clarify the complex texture.

I will exemplify the Cagean–Brantian type of musical spatiality which amplifies pre-existing musical contrasts in stream segregation with a fragment of Brant's composition, *Meteor Farm. A Spatial Concert of Ceremonies* (1982) commissioned for the 150th anniversary of the Wesleyan University. Perhaps appropriately for such a festive occasion, the work employed almost all of the University's music students and faculty. The performing forces include:

- symphony orchestra (with the principal conductor, double winds and strings),

[9] In 'The uses of antiphonal distribution and polyphony of tempi in composing' (published in the *American Composer's Alliance Bulletin* **4**(3), 1955, pp. 13–5) and in 'Space as an essential aspect of musical composition' (published in *Contemporary Composers on Contemporary Music*, pp. 221–42. Elliott Schwartz and Barney Childs (eds.). New York: Holt, Rinehart and Winston, 1967). I discuss Brant's spatial music in 'An American in space: Henry Brant's 'Spatial Music'' (*American Music* **15**(1), 1997, pp. 70–92).

[10] In his articles Brant discusses the polychorality of Gabrieli, Berlioz's *Requiem*, and Ives's *The Unanswered Question* as the main influences on the development of his type of 'spatial music'.

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- wall brass (of trumpets and trombones positioned in a single file along a side wall of the hall),
- two groups of percussion (staffed by four percussionists each), including both unpitched and pitched instruments, as well as pianos,
- jazz orchestra (trumpets, trombones, saxophones, tuba, drum set),
- two choruses, each with a separate conductor and with accompanying instruments (three saxophones in Chorus I, and three piccolos in Chorus II),
- Javanese gamelan orchestra,
- West African drumming ensemble,
- South Indian Trio (singer and two instruments), and
- two soprano soloists.

All the ensembles are placed as far as possible in the various areas of the hall. Here, the idea of juxtaposing layers of music of distinct timbre and style is taken to its extremes. Spatial separation and stream segregation (by timbre and melo-rhythmic coherence) work together to amplify this effect of total disparity. The plurality of musical styles has a programmatic justification: 'the work unfolds as an image of a culture in which the most diverse elements remain unassimilated'.[11] These extreme stylistic contrasts resemble the disparities envisioned by Charles Seeger (see Nicholls 1990) in 'total heterophony' in which a non-Western ensemble would play alongside a symphony orchestra.[12] This lack of unity results from the fact that the non-Western strands of the music are not composed but quoted from the repertories of the non-Western musicians.[13] The score gives only general indications about the order of entries and the duration of the sections in which individual groups perform (see figure 1). While juxtaposing different strata in the music, the composer attempts to balance the textures and dynamics of the disparate elements, so as, for example, not to overpower the delicate sonorities of the Indian music. Nevertheless, he is not concerned with the 'unity' or 'coherence' of the work as a whole:

> I try to avoid relationships between the elements. I not only have them contrasted in tone colour and position, but I try to avoid any musical relationship as much as I can. I think that this is what kills all music: there are so many things that are related that people are not listening to anything past the first minute because it all sounds the same and there are so many repetitions that it is not possible to keep track of it. I try to counter that in every way possible. (Brant 1992: 9)

4. SPATIAL MOVEMENT AND STREAMING EFFECTS: STOCKHAUSEN, XENAKIS AND SEROCKI

The construction of 'spatial music' by means of complete segregation of its distinct, simultaneous layers (contrasting in spatial location, timbre, pitch, rhythm, register, etc.) is not the only way of drawing from perceptual principles to create novel musical effects. Many composers have tried to articulate various patterns of virtual sound movement by dispersing stationary musicians in the performance space. Here, unlike Brant's *total antiphony* and Cage's *copresence of dissimilarities*, the composer's goal is to create a perception of a unified, continuous motion. Spatial sound movement may be *discrete*, that is, it may proceed stepwise – if a musical phrase is presented successively in one ensemble of performers after another. This technique has been known since the Venetian school of polychorality in the late renaissance; I will return to some twentieth-century examples later.

Sound movement in space may also assume a *continuous* form. An interesting method of creating continuity of motion introduced in instrumental music of the post-war avant-garde, involves ensemble dispersion, dynamic shading and temporal overlapping of sounds. Stationary instrumental groups are placed around the audience and successively play sounds of the same pitch and timbre with similar dynamic envelopes (crescendo–decrescendo). The sound seems to rotate in space, gradually shifting from one instrumental ensemble to another. This effect was first used in Karlheinz Stockhausen's *Gruppen fur Drei Orchester* (1955–7); it also appears in Stockhausen's *Carre* for four orchestras and choirs (1959–60), Kazimierz Serocki's *Continuum* for six percussionists (1965–6), as well as in several compositions by Xenakis including *Terretektorh* for eighty-eight musicians scattered among the audience (1965–6) and *Persephassa* for 6 percussionists encircling the audience (1969).[14]

[11] From the programme notes for the premiere of *Meteor Farm* by the Wesleyan University Orchestra and Chorus, cited by Gilbert Mott in a review of the concert (Mott 1982: 36).

[12] I discussed this issue with David Nicholls, who suggested that 'total heterophony' may be an appropriate label for Brant's polystylistic and multicultural collages (private communication; letter of 27 April 1994).

[13] The *Notes on Performance* in the score of *Meteor Farm* include the following statement: 'It is central to the conception of the piece that these non-Western ensembles perform in their own styles and traditions, and no attempt should be made to dilute or Westernize their music.' (Brant 1982: C) During the interview, Brant, asked about borrowing musical material, responded: 'I seldom quote anything. I make examples of my own in that genre, I prefer to do that. Except when I have the participation of groups from other cultures, such as the gamelan group or a group of Indian soloists. In that case I listen to their music alone, I pick up what I want and decide where it should go. They use actual examples from their repertory which I never change.' (Brant 1992: 9)

[14] I discuss *Gruppen* in 'From point to sphere: spatial organization of sound in contemporary music (after 1950)' (*Canadian University Music Review* **13**, 1993, pp. 123–44); for an overview of Xenakis's approach to spatialisation, see my article 'Spatial sound movement in the instrumental music of Iannis Xenakis' (*Interface. Journal of New Music Research* **23**(3), August 1994, pp. 291–314).

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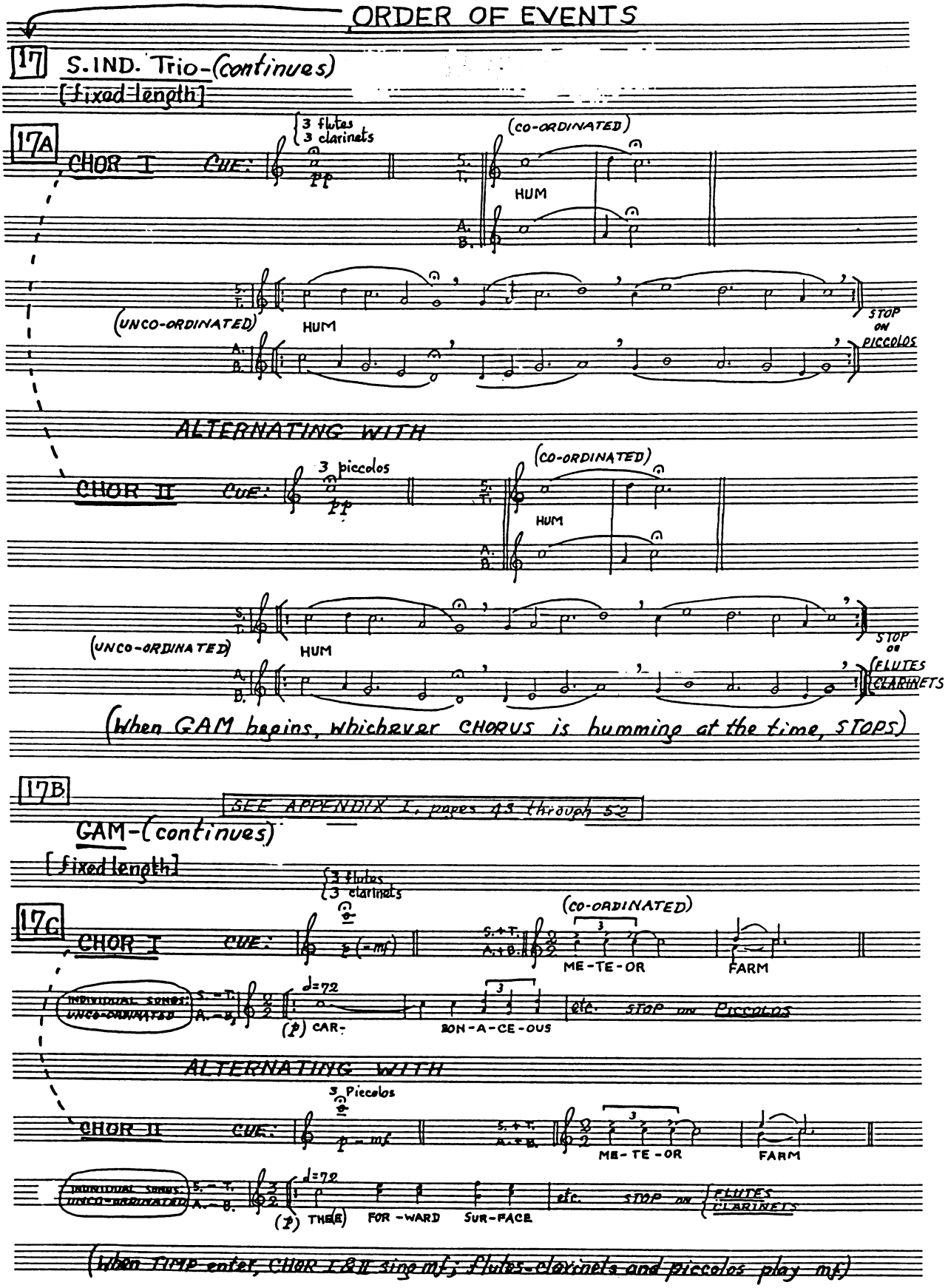

Figure 1. Order of events in Brant's *Meteor Farm*.© 1988 by Carl Fisher Inc.

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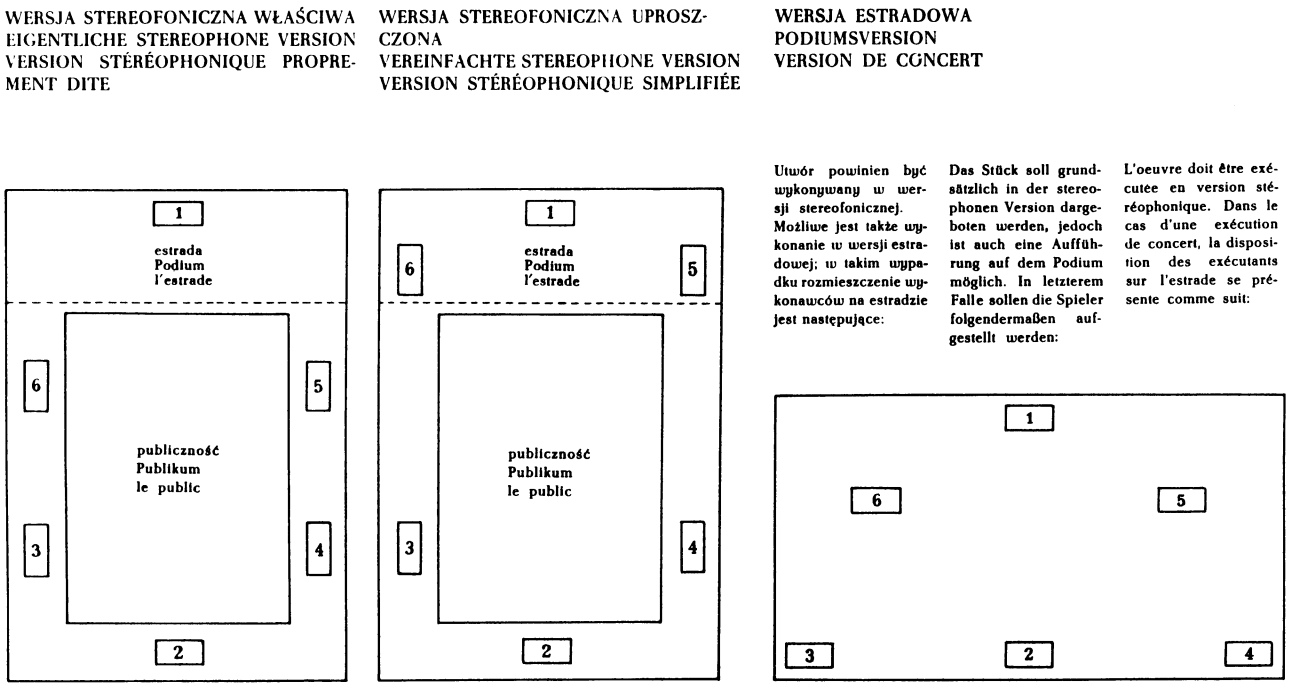

Figure 2. Location of performers in Serocki's *Continuum*. (permissions at the end of the article)

The score of Kazimierz Serocki's *Continuum*, sextet for percussion instruments (1965–6), includes three diagrams of the location of performers in the concert hall (see figure 2).[15] In the first diagram, entitled 'Stereophonic Proper Version', the percussion groups are spaced equidistantly around the audience, with one group in the front, one in the back and two on each side. (This arrangement provided inspiration for Xenakis's *Persephassa*, also written for Les Percussions de Strasbourg.) The 'Simplified Stereophonic Version' and the 'Concert Stage Version' are provided as less preferable solutions for performances in smaller spaces. The composer draws from principles of stream segregation (and, in this case, also stream emergence) to create an illusion of a continuous movement of sound between groups 2, 5 and 6 (following a triangular trajectory, see figure 3). The performers play tremolos on three identical drums with changing dynamic envelopes, crescendo–decrescendo. Since the peaks in each dynamic envelope do not occur simultaneously, the sound appears to shift from one spatial location to the next. Against this mobile background, soft strokes on the deeply resonating tam-tams in group 1 to groups 3 and 4 create a rich, spatially extended continuous sonority. Its gradual emergence owes its perceptual distinctness to the similarity of timbres of the three metallophones; while the same concept of timbral identity (amplified by identical articulation and similar dynamic levels) underlies the virtual movement of drum sonorities. Figure 4 presents another excerpt from Serocki's *Continuum* (reh. no. 34). Here, the marimba in group 1 and xylophones in groups 3 and 4 perform the same dense, chromatic cluster (B5–F5) with the predominant dynamic markings of '*pp–crescendo–fff*'. The trajectory of the sound movement from group to group is marked in the score. Despite the timbral differences between the xylophone and marimba, the similarity of pitch material (the cluster) and articulation (tremolo) supports the impression of a cohering, unified stream of sound moving from one location to the next. The perception of this type of virtual movement requires the establishment of the identity of a moving object and the existence of a time–space that this object travels through. Obviously, changes in the pitch domain are unwarranted – they would destroy the identity of the rotating musical object.

The idea of using superimposed dynamic envelopes and temporal shifts to cause continuous changes in the apparent position of instrumental sounds was modelled on an electroacoustic technique, that is, on stereo sound projection. In stereophony, differences of intensity between identical signals from two separate channels (loudspeakers) are used to suggest changes in the location of virtual sound sources. Iannis Xenakis concludes his description of this phenomenon with the following words:

> In reality, sound movements are usually more complex and depend on the architecture of the performance

[15] The output of Serocki has been discussed in one book, Tadeusz Zielinski's *O tworczosci Kazimierza Serockiego* (About the Creative Output of K.S.) (Krakow: PWM Editions, 1985).

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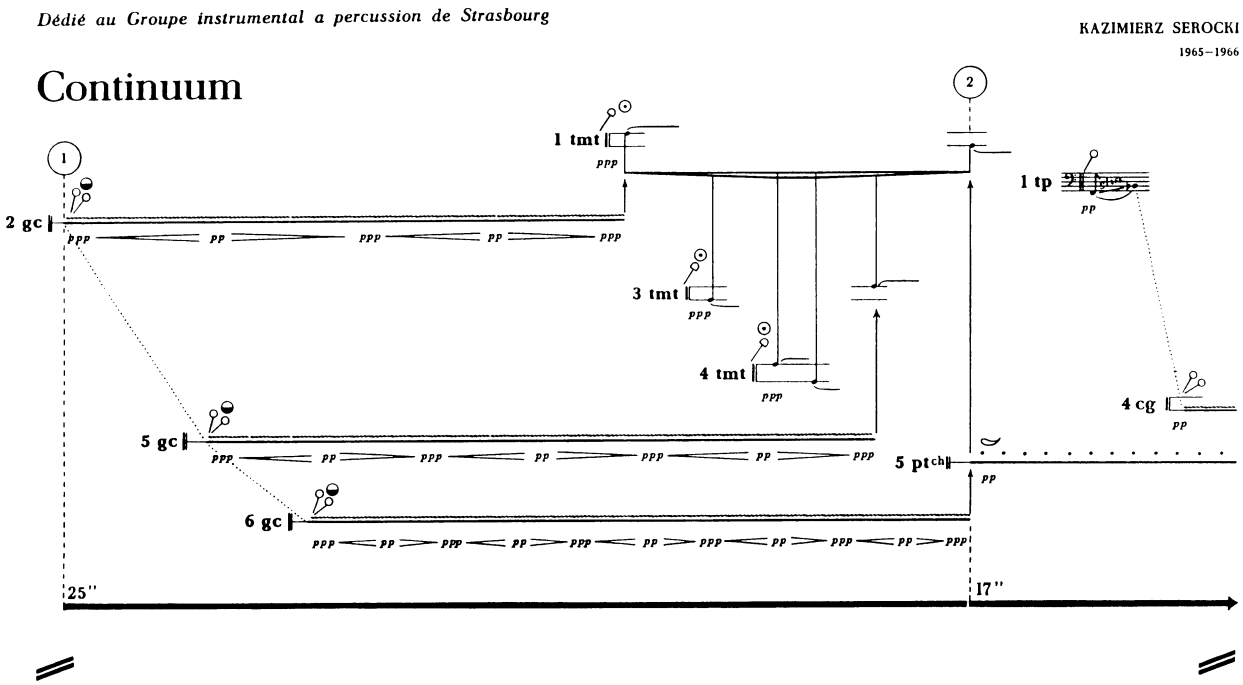

Figure 3. First score example from Serocki's *Continuum*. (permissions at the end of the article)

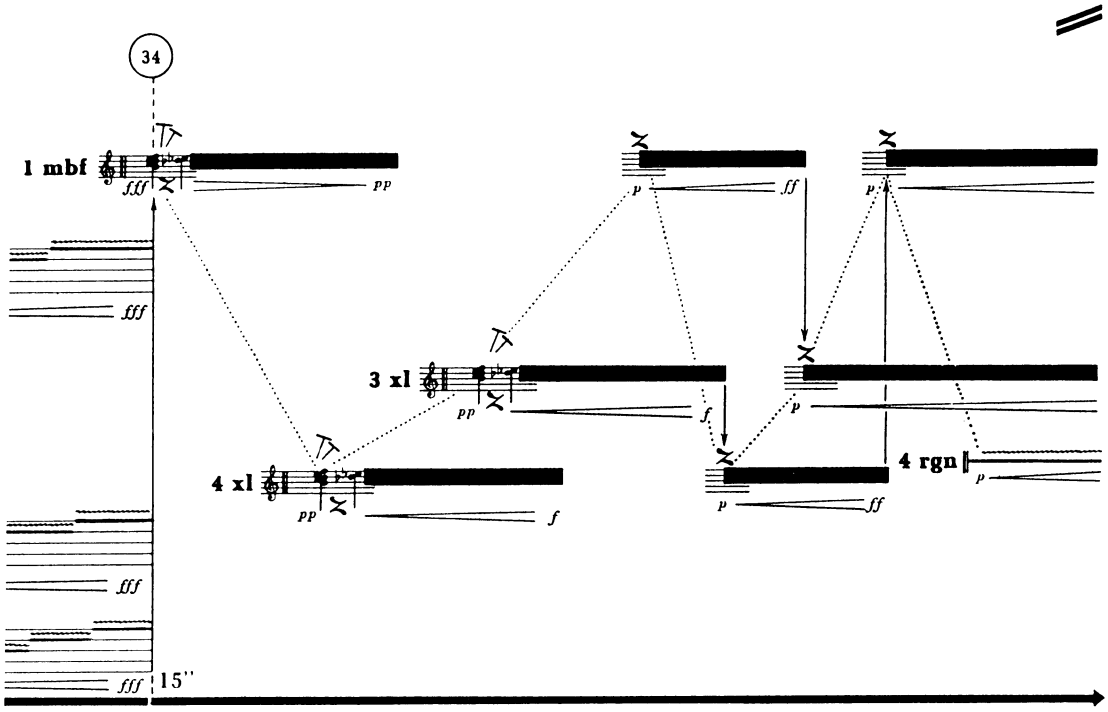

Figure 4. Second score example from Serocki's *Continuum*. (permissions at the end of the article)

space, the position of the speakers and many other things. When you want to reproduce such a complicated phenomenon with live musicians playing one after another with amplitude changing in the same way that you change the levels in a stereo sound projection, sometimes it will work and sometimes it will not. It depends on the speed of the sound as well as on the angle of two loudspeakers or musicians, that is on the relative position of the listener. These two considerations are equally important. (Xenakis 1992: 6–7)

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5. AVANT-GARDE MISTAKE 1: THE SERIALISATION OF DIRECTION

The predominance of abstract designs over audibility of their sonorous results is the basic problem in postwar modernist music. The speculative writings of European postwar avant-garde composers are filled with disregard for musical tradition, including the tradition arising from the primitive principles of auditory scene analysis, that is the nature of hearing. One instance of such an overreaching theory is the idea of serialisation of direction proposed by Karlheinz Stockhausen in an influential article, 'Music in space', written after the premiere of *Gruppen* in 1958 as a lecture for the summer courses in Darmstadt (Stockhausen 1959/1961). Stockhausen links the necessity of spatialisation with a need to clarify the constantly varying surface of serialised music, which could evolve so rapidly that it gave the impression of not changing at all. The 'standstill' of the music results from the equalisation of all the parameters of sound: if one sound characteristic predominated, it would act to articulate the music but, simultaneously, would destroy the work's balanced structure. Therefore, in order to preserve the 'neutralisation' of the parameters and to make the music more interesting for the listeners, various long time-phases of homogeneous sound structures may be distributed in space, among different groups of loudspeakers or instruments. Thus, for Stockhausen, spatialisation heals the dissolution of polyphony into monody (a characteristic of serialised music) and it is 'possible to articulate longer pointillistic structures by having them wander in space, by moving them from one place to another' (Stockhausen 1959/1961: 70).

This statement resembles Brant's main argument in favour of the use of space in music: spatial separation clarifies musical texture, especially if this texture consists of many layers confined to the same register. Nonetheless, Stockhausen has something entirely different in mind: he postulates the adoption of spatial direction, easily serialised, as the new parameter in music. He claims that by establishing exact proportions, analogous to durational ratios, between various positions on the circle, it is possible to create 'the scale of localities corresponding to the scales of pitch, duration, timbre and loudness' (Stockhausen 1959/1961: 82; see figure 5). Stockhausen's image of a circle, evenly subdivided into equal segments, represents a scale of directions which is theoretically possible, but not viable in performance practice.

The acuity of the perception of sound direction differs depending on the orientation of the listener; human beings distinguish sounds from the front, side and back with different degrees of exactness (Blauert 1983: 37–50). While this notion of 'preferred direction' may not be relevant in all real-life situations, Stockhausen's structuring of the performance space as a circular scale of directions imposes a rigid order on an infinitely variable phenomenon and disregards the changeability of spatial positions of his listeners (enhanced by the subjective focus of attentive listening). Therefore, Stockhausen's metric scale of directions measured as intervals on the circle or as angles is a theoretical construct with a very limited potential for compositional practice. However, this idea is inherent in total-serialist thinking: all aspects or parameters of sound should be treated equally and all should be readily available for manipulation. The problem is, though, that not all might be heard in the same way. Later on, Stockhausen reconsidered this stance and came to believe that distance, as well as direction, may become an element in the composer's workshop (1971 lecture on electroacoustic music, Maconie 1989). This idea occurred much earlier to Stockhausen's colleague, the French leader of the postwar avant-garde, Pierre Boulez.

6. SPATIALITY ON THE STAGE: BOULEZ, ANDRIESSEN AND BARTOK

In his 1963 article, Boulez distinguished two types of distribution of musical structures: *static distribution* and *mobile distribution*, also called *static relief* and *dynamic relief* (Boulez 1963/1971: 68). He proposed that mobile distribution should be realised by *conjunct and disjunct movements*, which are not dependent on distance, but on the temporal overlapping of sounds with common features in the domain of pitch, timbre, dynamics and duration (figure 6). I have already discussed examples of conjunct spatial intervals in Serocki's *Continuum* (without using Boulez's label, of course). *A disjunct interval* occurs when a pause separates the two chords; this pause should be sufficiently short to allow for the impression of the displacement – if the pause is too long the perception will be of two distinct events (see figure 6). By using the two types of spatial intervals, it is possible to create 'continuous displacements of lines or discontinuous leaps between points' at various levels of structure (Boulez 1963/1971: 69). Nonetheless, Boulez is rather derisive of the excessive 'space glissandi' and prefers a *fixed spatial layout* in which the conjunct and disjunct intervals are fixed and observe the 'elementary laws of regular or irregular symmetry, of asymmetry, and of the combination of these two forms'. He takes into consideration all possible combinations of groups of instruments in space:

> . . . two groups will be symmetrical if they are situated at an equal distance from an axis of some kind; if they possess homogeneous or non-homogeneous timbres, identical in quality and density, they can be considered as *regularly symmetrical*; they are *irregularly*

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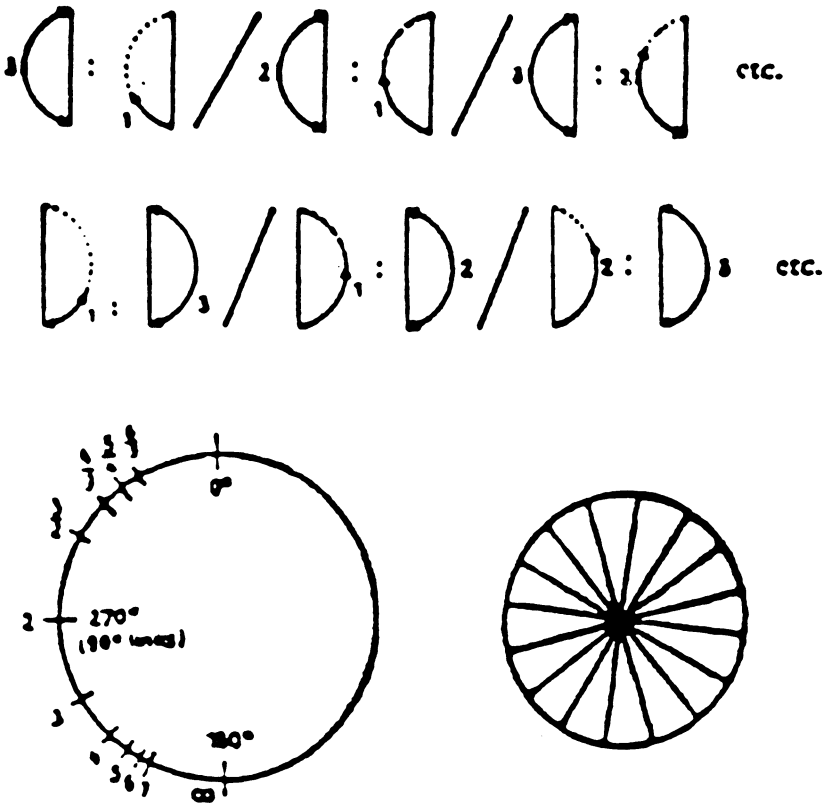

Figure 5. Spatial intervals and scale of directions on the circle in Stockhausen's *Musik in Space* (Stockhausen 1959/1961: 82).

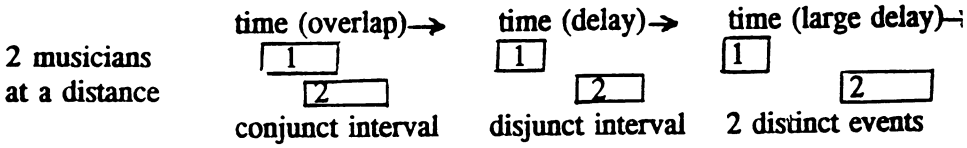

Figure 6. Disjunct and conjunct intervals described by Boulez.

> *symmetrical* if their homogeneity is not of the same nature (a group of brass against a group of strings, for example) or if their non-homogeneity differs in quality and density; they will otherwise be *asymmetrical*. (Boulez 1963/1971: 70)

We should notice that the typology of spatial relationships between instrumental groups includes timbre as an important criterion for symmetry. Again, the conjunction of various types of perceptual cues serves to differentiate the various elements of the musical texture.

Let me turn to musical examples now, and first discuss a case of Boulez's regular symmetry (two groups equidistant from an axis and analogous timbres), fixed layout and disjunct spatiotemporal intervals in Louis Andriessen's *Hoketus* (1975–7). In this work, two ensembles of five instrumentalists (both with pan-flutes, electric pianos, pianos, bass guitars and set of congas) placed on the far ends of the stage produce sounds of exactly the same sound and volume. The groups should be as wide apart as possible, facing each other. The musicians 'alternate in playing chords that are practically identical. They are free to repeat a bar or group of bars as often as they wish.' (Andriessen 1977; see figure 7) The composer cherishes the intensity of the live performance and claims that 'only in this way . . . you can hear *what music is about*, not only through the notes but through the musicians as well' (Andriessen 1977). The work's effectiveness rests on several competing scene-analysis principles:

(1) What is spatially separated belongs to different streams regardless of other cues.
(2) Auditory cues are weaker than visual ones (the piece is much more effective in live performance than on recording).

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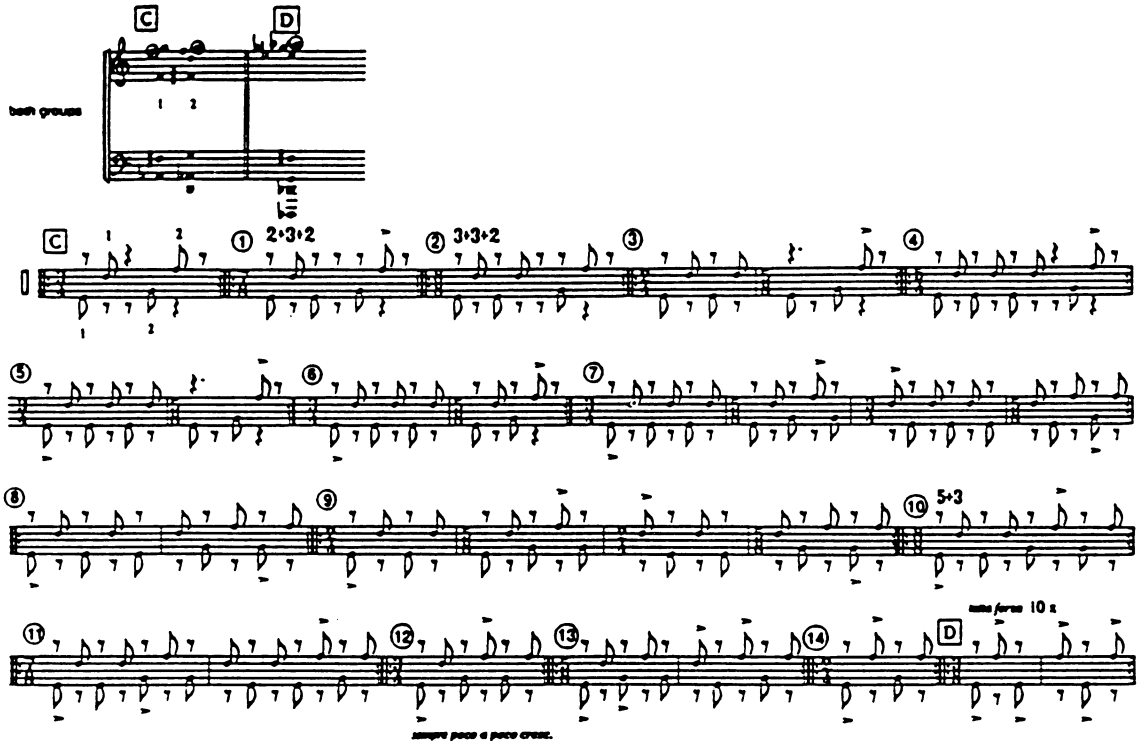

Figure 7. Excerpt from Louis Andriessen's *Hoketus* for two groups of five instrumentalists (1975–7), p. 5. © 1994 by Boosey & Hawkes Music Publishers Ltd. Reprinted by permission.

(3) An emergent new quality arises from juxtaposition of two incomplete layers.
(4) The auditory system is sluggish in response to sudden changes in stream allocation.

If not for spatial segregation, the music would consist of just one sequence of repetitive patterns. Indeed, listening to the work's recording is a rather tedious task, entirely lacking the excitement that the composer was so proud about. A look at the waveform diagram of the work's overall temporal shape shows the reason – a complete monotony, predictability, repetitiveness. However, a closeup of the waveform graphs shows the interaction of musicians placed on the left and right of the stage. Their fast interchange in a true 'hoketing' manner is the essence of the music. The excitement for the listeners arises from the ambiguity between the perception of one stream (series of chords) and two distant groups of identical timbres that create this stream. Because of the presence of high pitches in each of the groups and sudden attacks (reset value), it is possible to focus on each group separately, paying attention to the music heard from the left or right. But a listener might also choose to ignore the spatial interplay and listen solely to the overall, centred result. What is heard will, in each case, be different.

The next example of competition and cooperation of various cues in the creation of distinct perceptual streams comes from the composition in which the first detailed plan of performer placement was used, Bela Bartok's *Music for Strings, Percussion and Celeste* (1936–7). Again, all the performers are located on the stage in a symmetrical design with percussions and keyboards framed by the two groups of the strings (see figure 8). In the fourth movement of this work, Bartok explores a variety of spatial interactions between the instrumental groups, for instance:

(1) The whole ensemble performs simultaneously (homophonic texture; m.m. = 136–140) or with individual instruments entering successively (polyphonic texture; m.m. = 220–230).
(2) All the strings in unison alternate with piano and harp (heard as whole space or outer fringes vs centre; m.m. = 114–120; see figure 9(a)).

Bela Bartók: *Music for Strings, Percussion and Celesta*, IV

DISPOSITION APPROXIMATIVE DE L'ORCHESTRE

	Cb. I	Cb. II	
Vc. I	Timp.	Gr. cassa	Vc. II
Viola I	Tamb. picc.	Piatti	Viola II
Viol. II	Celesta	Xyl.	Viol. IV
Viol. I	Pianoforte	Arpa	Viol. III

Figure 8. Performer placement in Bartok's *Music for Strings, Percussion and Celesta*. © 1937 by Universal Edition (see full caption for figure 9, the same terms apply).

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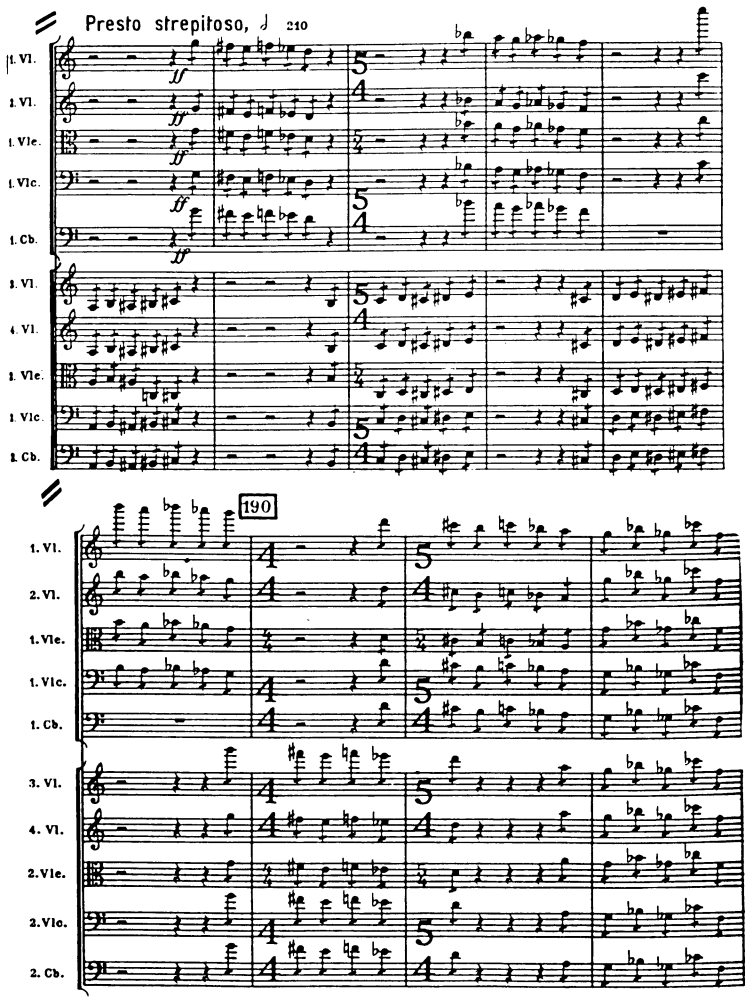
(a)



(b)

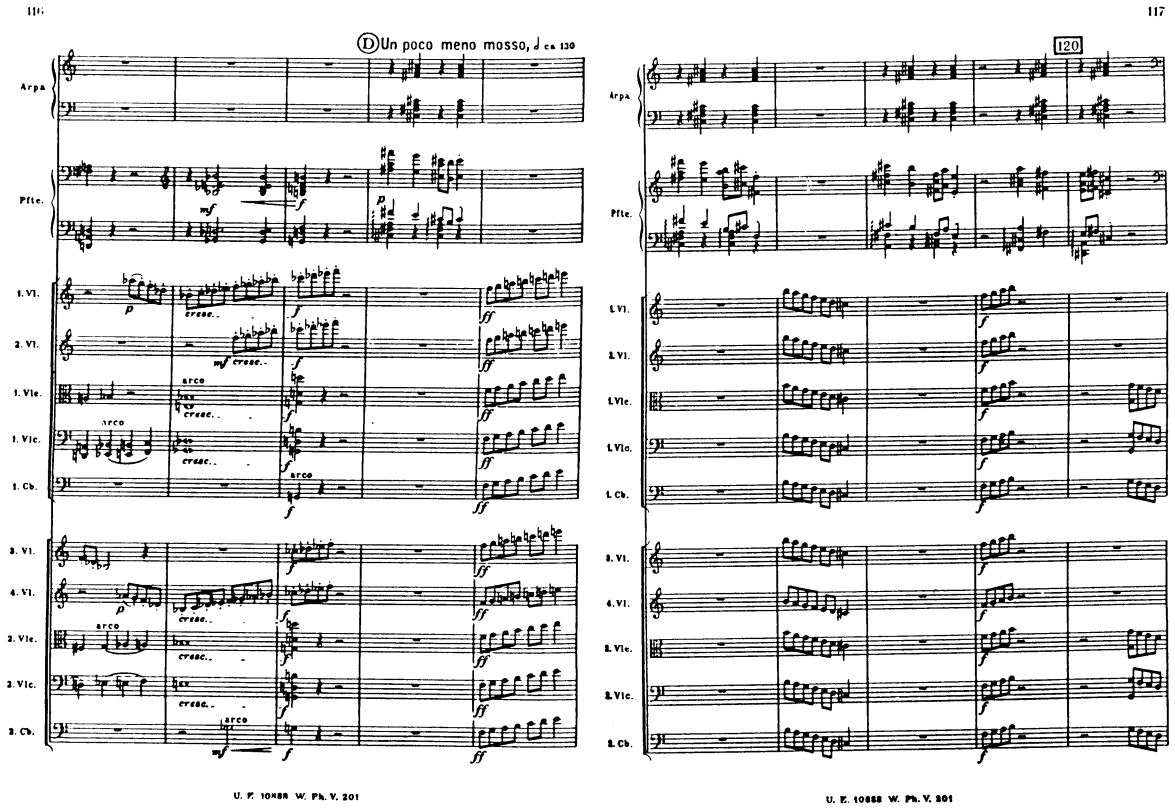


Figure 9. Score examples from Bartok's *Music for Strings, Percussion and Celesta*. © 1937 by Universal Edition A.G., Vienna. © renewed. All rights owned by Universal Edition A.G., Vienna throughout the world excluding the U.S. Used by permission of European American Music Distributors Corporation, sole U.S. and Canadian agent for Universal Edition A.G., Vienna. For the territory of the United States of America (C) 1937 Boosey & Hawkes Inc. Copyright Renewed.

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(3) The two groups of the strings alternatively play music with identical rhythm, articulation and dynamics, but with melodic motion in different directions (Group II – up, Group I – down); (m.m. = 184–203).

In the last of these examples we have a case of textural transformation: the spatial and registral differences gradually disappear on the way to a full identity of musical material (see figure 9(b); m.m. = 184–193). This identity is made possible by the use of the same instrumental timbres and arises when all the strings play in unison at the same time. In the previous example (figure 9(a)), the unison strings, if well performed, could give rise to the effect called by Brant 'spill' – that is the integration of all the textural elements heard simultaneously from the opposite ends of the stage into one spatially extended sound. The sonority covering the whole stage is contrasted with a sound of a lesser spatial extension, performed by the centrally positioned piano and harp. In separating this musical fragment into two streams in dialogue, all the cues work together: spatial location, timbre, pitch and rhythm, and motivic material. *Music for Strings, Percussion and Celesta* connects symmetries in pitch space and in timbral domain with symmetries in performance space. It is also important to note that its layout, while suggesting the relative position of all the instruments with respect to each other, does not specify distances, or geometric shapes outlined by the music.

7. AVANT-GARDE MISTAKE 2: GEOMETRIC SOUND SHAPES

The musical ideas of postwar avant-garde music referred to spatiality in three main ways: (i) in a geometric sense, because music was conceived of as consisting of points, blocks and shapes presented in a space of two or three dimensions based in pitch and time (e.g. Webern's music interpreted by Ligeti and Eimert); (ii) in a general, mathematical sense, because features of sound were separated into 'musical parameters' and manipulated by spatial means (e.g. the use of vector space by Xenakis); (iii) in a physical sense through the use of spatialisation in performance space. Music composed of spatial sound matter which is characterised by a solidity of physical objects or a staticity of geometric figures is not designed to be expressive; instead, what it tries to express are different geometric shapes. How can one hear a triangle, or an oval? How can one distinguish a rectangular sound shape from a polygon? How can such complex spatial shapes be projected in sound? It is possible for the rare individual endowed with the phenomenon of synaesthetic hearing: I recall reading a comment by Zenon Feszczak on the 'music aesthetics discussion list' about hearing the music of Miles Davis as coloured polygons in movement . . . But, for the more ordinary and less talented listeners this task seems next to impossible. Yet, many composers in the 1950s and 1960s attempted to create fixed spatial shapes out of fluid spatiotemporal sounds.

In Henryk Mikołaj Gorecki's *Genesis* cycle (1962–3) an elaborate seating plan precedes every movement (figure 10).[16] However, in listening to these three works, the triangular, polygonal or rectangular layout of sound sources seems not as important as the introduction of symmetries between elements placed on the left and right, or organised along the line connecting the centre–back–front. In listening to *Genesis II. Canti strumentali*, the most striking feature of the music is its incessant dissonance, coupled with the lack of themes and the absence of regular patterns, leading to formal chaos. However, the waveform diagram of the overall shape of this movement reveals what is also noticeable in aural perception: the music's temporal-dynamic outline is made up of strongly contrasted block-like sections. An attempt to clarify the form by segmenting it and by introducing spatial symmetries helps to introduce order into this work. *Genesis*, a prime example of sonoristic composition (known also as sound mass, or bruitistic, music), reduces the sound domain to its raw elements, to clusters and scattered brief snatches of sound matter. Spatial symmetries introduce a degree of formal organisation. However, the attempt to transform the auditory space into precisely drawn geometric figures (indicated by the location of the performers) is doomed to failure.

In contrast to Gorecki's work, Marta Ptaszynska's *Space Model* for solo percussion and tape (1971–5) uses the spatial layout for a practical purpose (figure 11). All the instruments are drawn on the diagram of locations, because the exact position of each percussion instrument is important for the kinetic character of the performance itself. The musician has to shift between three distinct positions; the distances between them have to be sufficiently large to allow for aural differentiation between live and prerecorded layers of sound (projected from the loudspeakers in the front). During the course of this work what has been played in the first spatial location on the left side of the stage and recorded is then played back as a 'virtual music' from the loudspeakers, while the percussionist moves to the second location (walking with maracas) to the right side of the stage. After recording the performance of the earlier taped performance and the new 'live' layer, the second tape is played while the percussionist adds a third layer, centred on the stage.

[16] The cycle consists of *Genesis I: Elementi per tre archi*, Op. 19 No. 1, *Genesis II: Canti strumentali per 15 esecutori*, Op. 19 No. 2, and *Genesis III: Monodramma*, Op. 19 No. 3 (1963).

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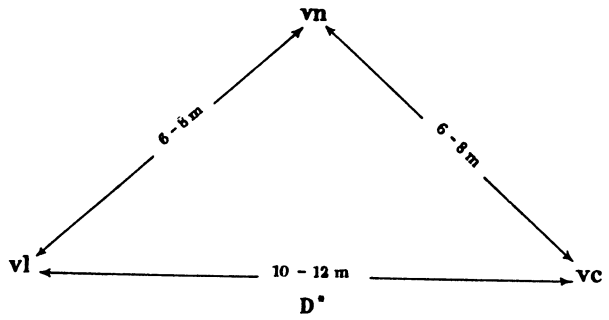
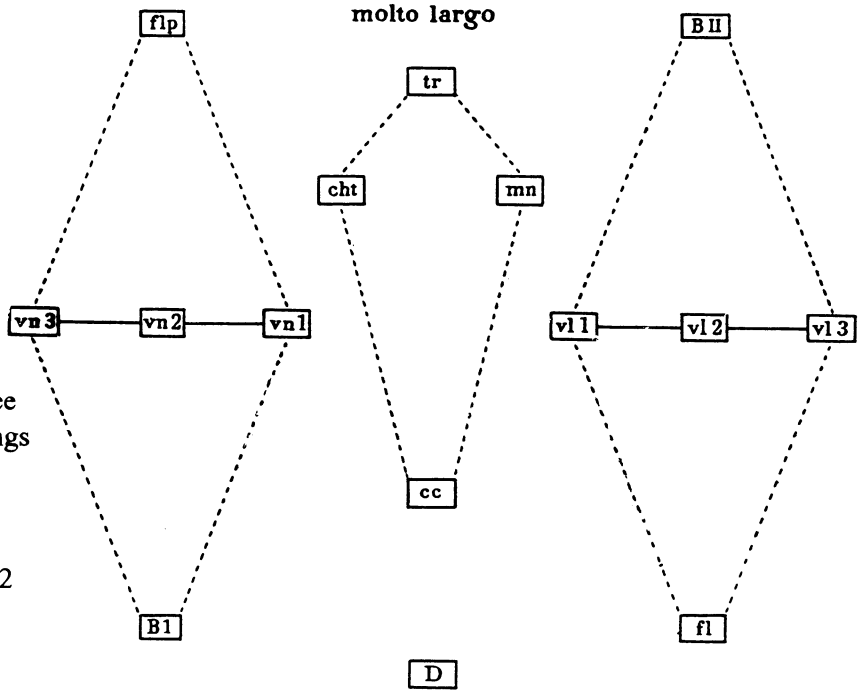
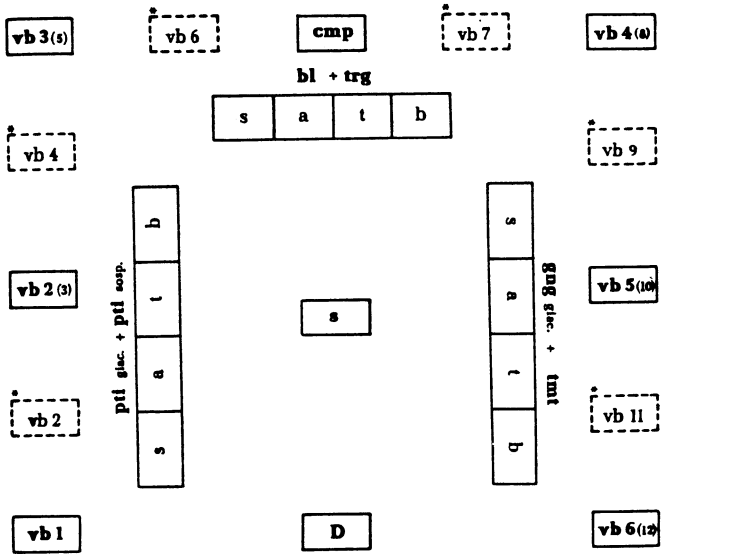


1. Triangular layout in *Genesis I: Elementi per tre archi* Op. 19 No. 1 (1962)



2. Symmetrical layout of three polygones in *Genesis II* (strings as axes, winds in a mirror LF-RB arrangement) *Genesis II: Canti strumentali per 15 esecutori* Op. 19 No. 2 (1962)



3. Symmetrical layout with rectangular shapes in Genesis III (All instruments in a mirror L-R arrangement) *Genesis III: Monodramma per soprano, metalli di percussione e sei violbassi* Op. 19 No. 3 (1963)

Figure 10. Seating plans for Gorecki's *Genesis* cycle. (permissions at the end of the article)

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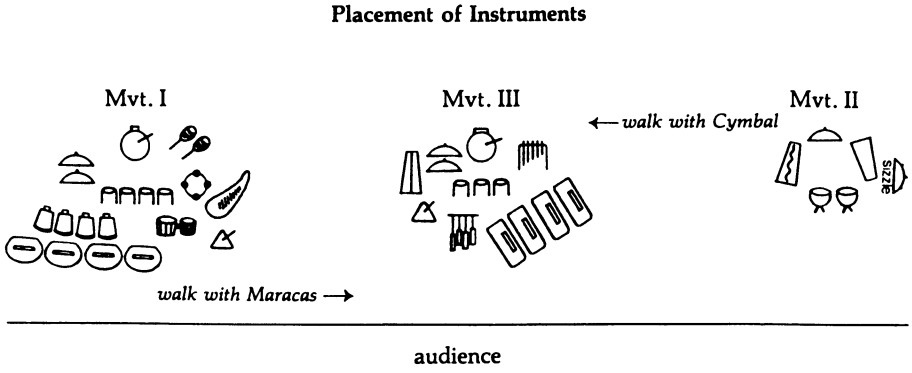

Figure 11. Spatial layout of instruments for Ptaszynska's *Space Model*. (permissions at the end of the article)

In *Space Model*, the idea of the canon is transformed into the complementarity of the strata of different musical material. Unlike the layers in the music of Henry Brant – which display an internal tonal and musical coherence – Ptaszynska's complementary elements of the overall texture are not written to be self-standing when heard in isolation. The first part, filled with pauses and lacunae, leaves room for additions and may puzzle with the unexpected shifts in the direction of musical development. Only the final, third part, presents the music as a whole. This process of addition and complementation, especially at points where the performer plays instruments of a similar timbre as those recorded on tape, recalls somewhat the streaming effects used intuitively in African music, where the juxtaposition of two patterns creates a new, emergent quality. The second page of excerpts from Ptaszynska's work shows a 'drumming' section, with overlap and coexistence of related timbral qualities. In the recording it is difficult to distinguish which sounds belong to which layer, but in a live performance, with less-than-perfect loudspeakers, there would be no problem. (figure 12: Ptąszynska – drumming). In most cases, however, Ptaszynska seeks to keep the layers perceptually clear by using timbral differentiation along with spatial distances.

The juxtaposition of dissimilar, clearly separated elements in the opening of the piece presented in the first example from Ptaszynska's composition reveals one of the main perceptual difficulties arising in 'sonoristic' music. In the opening sequence, eight different instrumental timbres are heard in short motifs which are laid out into two phrases (the fermata and crescendo mark the endings of each phrase). It is hard to place all these sounds in one auditory stream or one layer of the texture, because of timbral and temporal discontinuities, changes of timbre, register, etc. While all the sounds originate from roughly the same point in space (the left side of the podium), there are enough timbral and temporal differences between them to create an ambiguity of belonging. Only when the recording appears with new live material does the prerecorded portion start to fuse into, i.e. be understood as, one spatial-musical layer. This impression is reinforced by the third appearance of the music, with a new 'counterpoint' from the live instruments commenting upon and complementing the musical discourse. It is easy to read this arrangement in the score; its audibility is further augmented by the visual setting. As the reproduced plan indicates, the movement of the performer adds visual cues to the perception of the layering of the music. The awareness of the location of each of the sound layers depends somewhat on the ventriloquism effect: the visual appearance captures the location and stabilises it.

8. SPATIALISATION, SOUND MASSES AND FUSION: GORECKI'S *COPERNICAN SYMPHONY*

In the final series of examples I will point out how the simultaneous usage of spatial and other cues, including harmonicity, dissonance and timbre, is used in Gorecki's Symphony no. 2, *Copernican* (1973–5). With the programme outlining the creation of the universe from chaos, the work spans the trajectory from dissonance and spatial incoherence of sound images to their fusion in the final, consonant A♭ major chord.[17] The opening of this work is quite dramatic: a series of fortissimo chordal motives, each articulated with a sudden stroke of several kettledrums, each interrupted by silence (figure 13, excerpt from the score). The orchestra's whole-tone cluster spanning 6 octaves from E1 to e iv, resolves by stepwise motion to a pentatonic-based chord F to d♯. The basic melodic motion e–d♯/E–F is coloured by the underlying dissonances, in a manner not dissimilar to organ mixtures, but the ingredients are not harmonically related. Therefore, the surface of the music splits into a vibrating mass of sound, all the more voluminous that this symphony calls for huge performing forces: quadruple winds, six percussionists, twelve strings per section ... The irregularity of the drum patterns adds to the chaotic order of the music and introduces a powerful 'reset' effect after each of

[17] A somewhat different account of the symphony's programme, emphasising the human 'nothingness' and awe felt when contemplating the universe, is presented by Adrian Thomas in *Gorecki* (Thomas 1997: 74–81).

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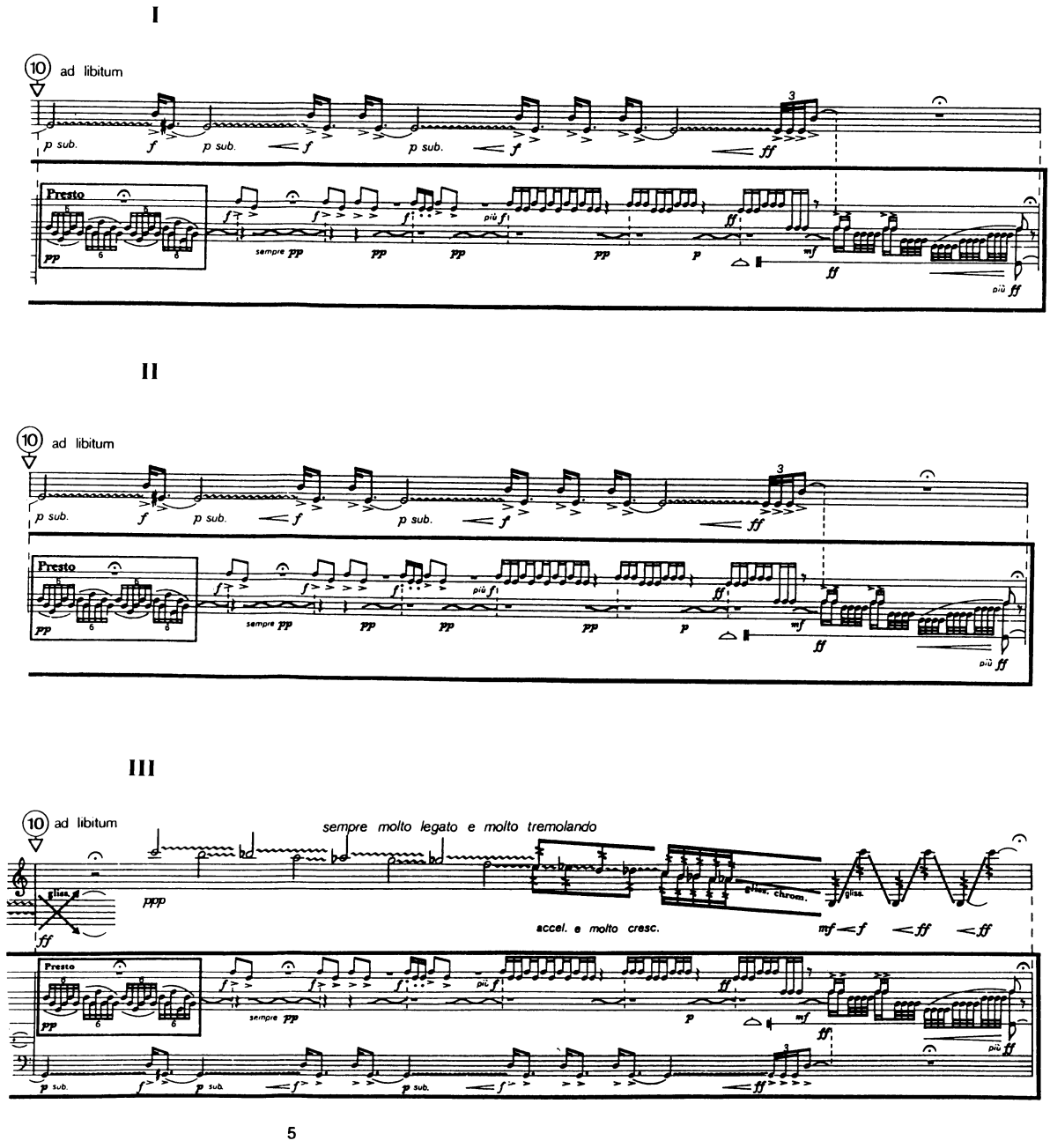

Figure 12. Score excerpts from Ptaszynska's *Space Model* – 'drumming' section. (permissions at the end of the article)

the unexpected pauses; general pauses of several seconds also break up the music into irregularly proportioned sound masses. Here, we find ourselves at the beginning of time, at the edge of creation. The waveform diagram displays the contrast between spatially extended, sustained dissonant chords and sharply articulated, strongly localised (on the left) dynamic peaks of the percussion. The exact localisation is less important than the contrast between spatially extended sound masses and clearly outlined percussion strokes. The music's obvious state of disarray arises from the disordered state of its vast, dissonant sound masses, formed into being by sudden percussive interventions.

I will omit the description of the followng chaos and emergent order, to focus on the final minutes of the second movement of the *Copernican Symphony*. Here we find one of the largest continuous chords in classical music: a pentatonic-based sonority spanning five octaves from its lowest pitch of D♭, and resolving into a higher, narrower, A♭ major triad in the first inversion (the resolution follows the rules of voice-leading). In the score, the D♭ pentatonic chord builds up gradually, with the addition of successive groups of violins, then brass and woodwinds, with the dynamic arch arranged symmetrically from *pp* to *p mf f ff ffff ffff ff f mf mp p*. At this moment in the score, the composer's annotation calls for irregular, not simultaneous taking of

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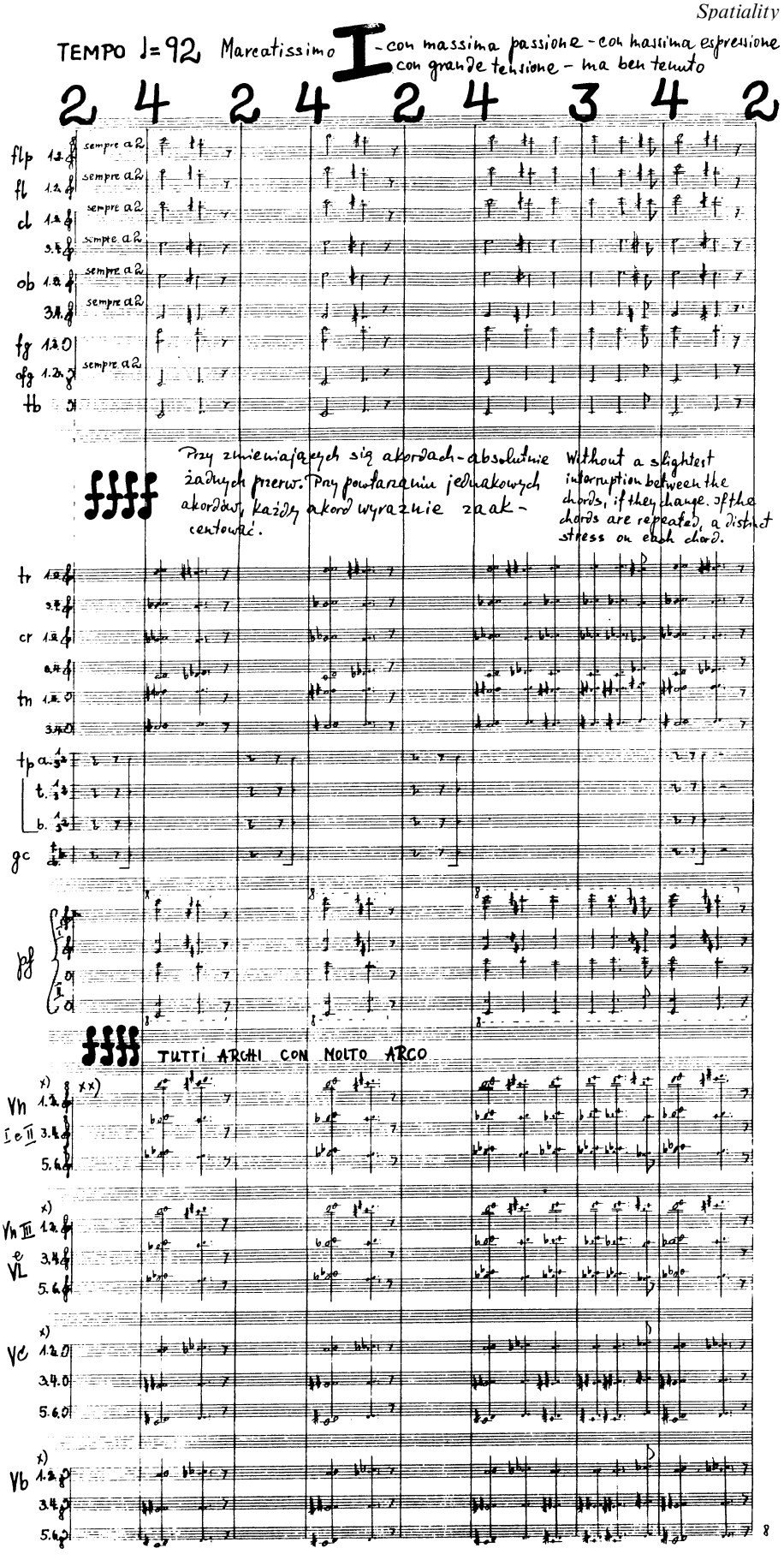

Figure 13. First score example from Gorecki's *Copernican Symphony*. (permissions at the end of the article)

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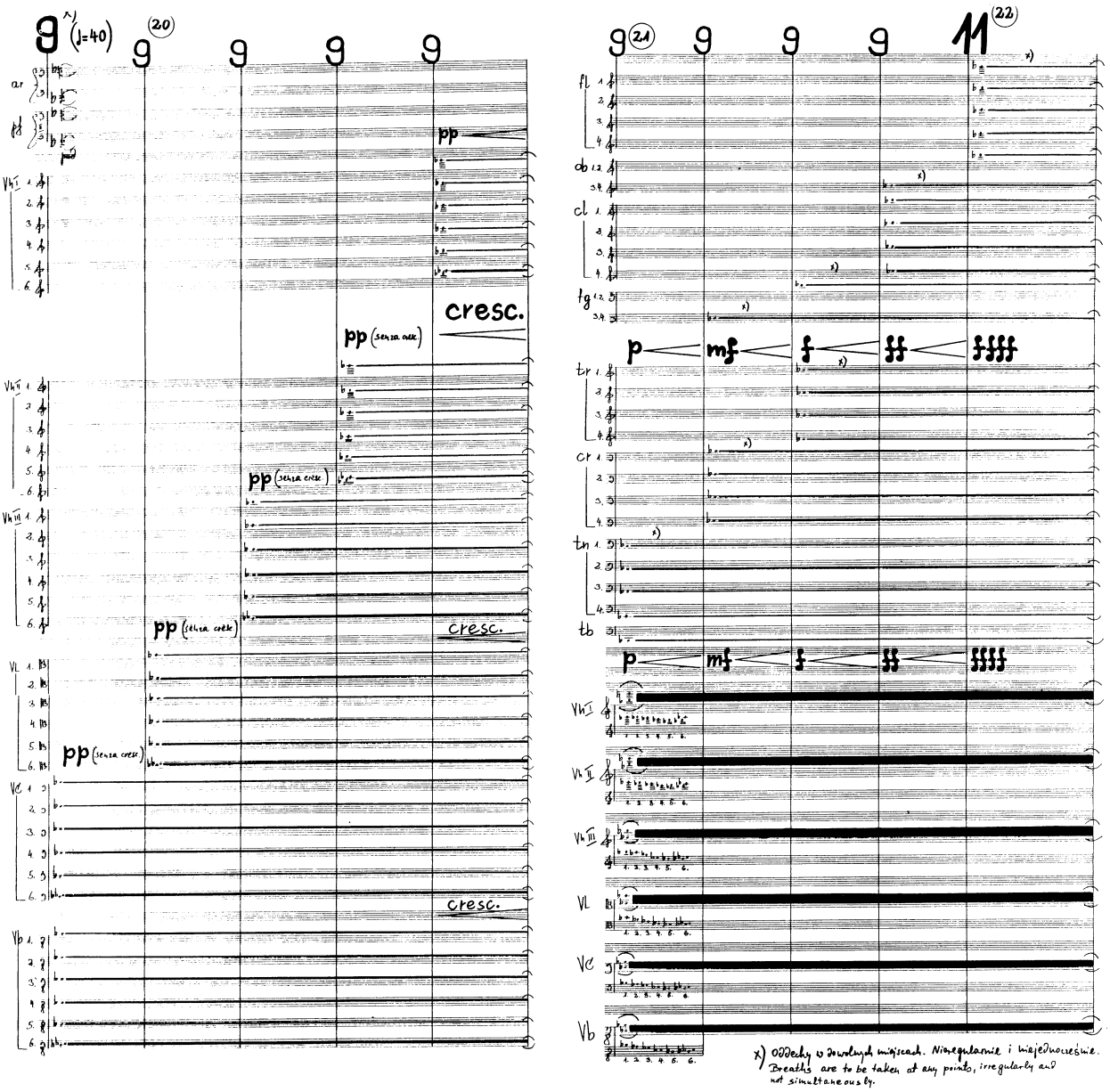

Figure 14. Second score example from Gorecki's *Copernican Symphony*. (permissions at the end of the article)

breath by the winds – no doubt in order to not disturb the smooth surface of the music (see figure 14). However, when performed, these sustained pitches (D♭, E♭, G♭, A♭ and B♭) begin to misbehave and to transform the static chord into a fluctuating mass of sounds. This might be seen in the overall waveform diagram, filled with sudden and very large peaks: their appearance must be audible. In addition, the A♭ and B♭ pitches at the top of the violin parts (especially in the descending portion of the dynamic arch) begin to be heard in alternation, as a slow tremolo. Finally, the beats appearing between the two lowest pitches of D♭ and E♭ in the double basses might be the reason for the following disturbance, just before the shift into the harmonically stable A♭ major chord (figure 15, waveform diagram of the whole). In the closeup of the waveform diagram the difference between the sounds originating from the left and the right side of the stage begins to be visible: the low-pitched sustained strings display irregularities which add to the liveliness of this dissonant chord. At the end, however, all the dissonance disappears, and the sounds fuse into a unified, quiet conclusion. Thus, spatial articulation of texture, divisions into distinct successive and simultaneous layers, and timbral differences all disappear in the beauty and harmony of God's order. The music's fusion has occurred, Cage's 'coexistence of dissimilars' has ceased to exist. The music has returned to its tonal roots.

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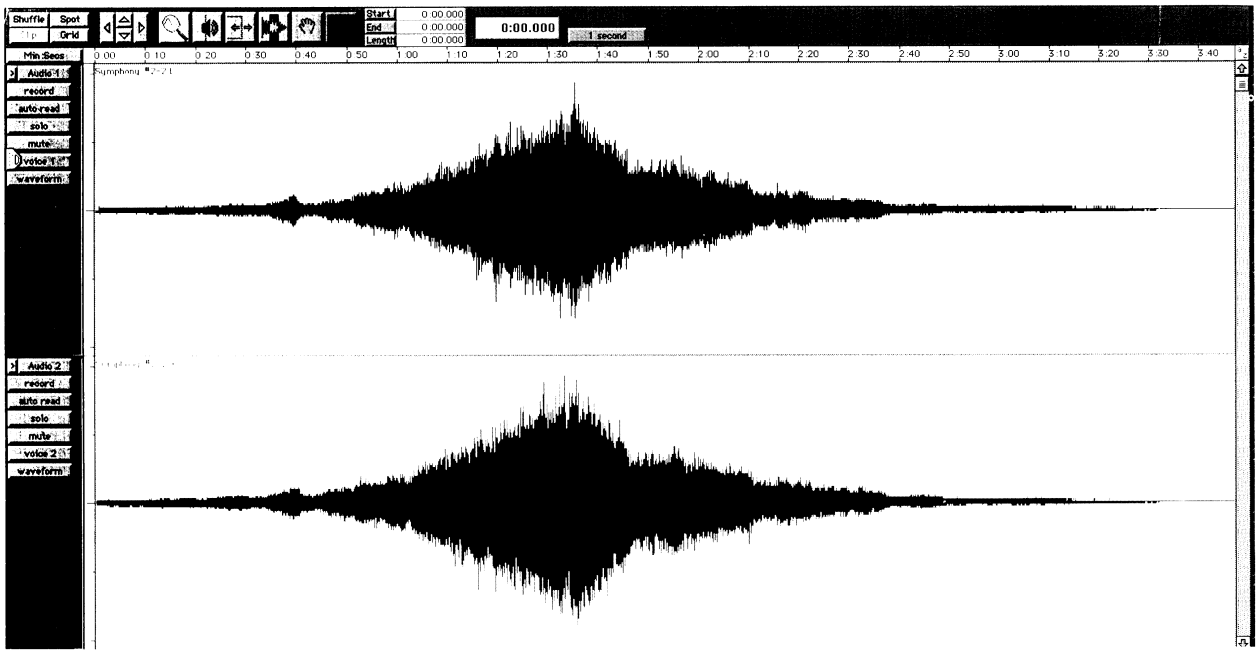

Figure 15. Waveform diagram from Górecki's *Copernican Symphony*.

9. CONCLUSION

This final example suggests how much work can be done in the domain of spatial analysis of compositions written for traditional orchestral forces by drawing, even generally, from principles outlined in Albert Bregman's theory of auditory scene analysis. Many composers, from Bartok to Brant and Boulez, from Stockhausen to Ptaszynska and Gorecki, have intuitively stumbled upon the primitive or innate principles of scene analysis regarding sound spatiality. There seems to be a consensus that the spatial segregation helps to clarify complex textures; and that it works best in conjunction with other cues for stream segregation, especially pitch and timbre. In these examples, I have attempted to point out the conjunctions of and the competitions between the auditory principles in the music composed for spatially dispersed performing forces. That is virtually all music, of course. I have also tried to point out that when composers depart from these principles, as in the short-lived ideas of the serialisation of direction, and the sonorisation of geometric shapes, the musical effects are not very convincing. These effects are like well-behaved children: they are seen, not heard.

I should emphasise the fact that, even if only seen, the geometric designs may play an important role in the musical compositions to which they belong. As signs and symbols, geometric floor plans and performer placement diagrams are integral, though inaudible, elements of the musical structure – as integral and inaudible as some abstract orderings in the domains of pitch and rhythm. Finally, to close this long catalogue of possibilities and effects, the examples of composing virtual sound movement demonstrate how the streaming effects can be forced by the conjunction of pitch–timbre–dynamics–timing. The often-mentioned problems with the practical realisation of such effects leaves no doubt that this 'forcing' of the stream creation, i.e. inducing the perception of sound rotation with stationary sources, is very fragile. Nonetheless, this and many other interesting new musical patterns may emerge from the interplay of various principles of auditory analysis, from the paradoxes of audition. Their investigation is still a matter for the future.

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