Towards a Philology of Electroacoustic Music
- Xenakis's Tape Music as Paradigm.

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Word count: 56,893

Declaration of Authorship

I, Reinhold Friedl, hereby declare that this thesis and the work presented in it is entirely of my own. Where I have consulted the work of others, this is always clearly stated.

Signed:

April 27, 2019

Abstract

This research focuses on the electroacoustic tape music of the French-Greek composer Iannis Xenakis as a case study for a philology of electroacoustic music. It is shown that most commercially released versions of his three most well-known pieces contain major faults. *Persepolis* (1971) and *La Légende d'Eer* (1979) have been released with incorrect sample rates.

In light of these facts, the work of Xenakis serves as a good subject for the discussion of a philology of electroacoustic music. A systematic philological research method for electroacoustic music is developed. Thus, philology of electroacoustic music is an ideal field to apply newer tendencies in philology; *critique génétique* widens the focus on the development of the compositional process, and *material philology* broadens the view of the text and its support. In the case of electroacoustic music, it encompasses not only paper, but also magnetic tape, digital media, etc. It will be shown that a philological research approach allows a new holistic view of Xenakis's work and ideas. Philological research in the field of electroacoustic music is urgent, as a vast number of possible sources will soon disintegrate. It will enable us to critically discuss the sources of electroacoustic music in the light of the changed technology.

In the practical part of the thesis Xenakis's textural approach is extended: I developed the computer programme TTM (Texture Transformation Machine) that facilitates the construction of non-symmetrical, probability-controlled transitions between given musical textures. The software and the realisation of two compositions, *String Quartet No. 3* and *KRAFFT* for orchestra, are discussed in detail.

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1. Overview

1.1. Philology of electroacoustic music

The first part of the theses focuses on the electroacoustic tape music of the French-Greek composer Iannis Xenakis (1922–2001) as a case study for a herein developed philology of electroacoustic music.

What do we hear when we listen to Xenakis's electroacoustic music? There are archives full of different tape formats and much of it has been released on vinyl and CD, but none of it in terms of a critical edition. This would have required comparing different existing versions of the compositions and studying additional sources in order to find the "original" or at least the most authoritative version.

In my examination I will show that almost all commercially released versions of the three most well-known pieces contain major faults. I will demonstrate that *Persepolis* (1971) and *La Légende d'Eer* (1979) have been released with incorrect sample rates. Moreover, *Bohor* (1962) – said to be the piece that caused the biggest scandal in the history of electroacoustic music[1] – was released on CD with extensive parts of the original 8-track version missing.

In light of these facts, respective works of Xenakis appear as interesting subjects to discuss and with which to develop a philology of electroacoustic music, starting with such questions as: Which version of a composition is 'the right' one?, leading to such practical questions as: Must so-called master-tapes be performed as such, or are there other instructions, as is the case for *La Légende d'Eer*? Furthermore, how shall we handle the heterogeneous nature of the archive materials such as tapes, drafts, notes, scores, files, etc.?

[1] Chion, M. (1972) Vingt années de musique électroacoustique, in: Musique en Jeu 8, Seuil, Paris. « Le seul scandale de taille qu'ait connu la musique électroacoustique (pour ne point parler d'Orphée 53 et de Déserts, qui mettaient en jeu des interprètes vivant s) fut peut - être la diffusion de *Bohor* de Xenakis, dans la plaisante salle à l'italienne du Théâtre de la musique, lors des SMIP 1968. C'est que l'auteur avait poussé le niveau sonore à une puissance assez effrayante pour que deux amplificateurs y aient succombé, cependant que le public réagissait par une hystérie, une panique qu'on n'a point exagérée. Justifiable ou non, un tel procédé avait au moins la conséquence d'aller jusqu'au bout d'un parti pris d'agression souvent affiché mais rarement défendu fermement. »

Understanding contemporary technology as well as the examination of Xenakis's theoretical writings will be an important prerequisite for further investigation.

An important aim of this thesis is the development of a systematic philological research method for electroacoustic music. Many standard techniques of classical philology, as outlined, for example, in Georg Feder's *Music Philology* (1987), can be transferred to electroacoustic music: collation[2] (comparing of versions) and resulting stemmatic graphs[3] (genealogy table) are of great assistance and allow us to better understand the provenance of the different versions. For electroacoustic music, stemmatic graphs can even be extended to the compositional process: a considerable number of electroacoustic pieces are composed from recorded sounds on tapes that are than treated, cut, and edited for the final montage.

Thus, philology of electroacoustic music is an ideal field in which to apply newer tendencies in philology, such as *critique génétique*[4], which widens the focus on the development of the compositional process, and material philology[5], which broadens the view of the text and its support; in the case of electroacoustic music, it encompasses not only paper, but also magnetic tape, digital media, etc.

On the basis of Iannis Xenakis's electroacoustic music and the corresponding resources – extensive archive materials, including heretofore unknown scores, sketches, material tapes, notes etc. – it will be shown that a philological research approach allows a new holistic view on Xenakis's work and ideas. There are many open questions and the method can be easily adapted to all kinds of electroacoustic music, based on the question of sources and what we can learn from them. This allows a focus on electroacoustic composition as procedure – or even performance – and extricates us from the idea of an electroacoustic work as a static oeuvre, fixed for eternity on whatever media. In this sense the philology of electroacoustic music is clearly *philologie génétique*.

And time is of the essence: we have a situation in which many sound storage media are disintegrating without being saved for future research. It could

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[2] Definition and description see: Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 33.
[3] Ibid, 35.
[4] Zattra, L. (2006) The critical editing of computer music, EMS: Electroacoustic Music Studies Network, Beijing, http://www.ems-network.org/spip.php?article236, last visit March 1, 2017, 1.
[5] Ibid.

well become the case that music connected with the hope of eternal existence on a fixed medium is the first to be almost forgotten. An array of questions with political impact emerges: how can we save the heritage of electroacoustic music, including the media, the machines, operational knowledge, etc.?

Further on, the philology of electroacoustic music can lead to very practical results: historically informed versions of Xenakis's *Bohor* and *La Légende d'Eer* could be performed, and the latter, along with *Persepolis*, could finally be rereleased.

1.2. Compositional Software Tools

As a practical part of this thesis, I developed a software application for musical composition: a Texture Transformation Machine (TTM). With the aid of this machine, a musical texture can be gradually transformed into another. Figuratively speaking: the genealogy of a texture is rotated through 90°, and successive changes of the texture become audible. This is realised by sculpting random functions closely related to Xenakis's stochastic techniques.

My research will allow extension of some of Xenakis's approaches that will be explored within the scope of my theoretical research. A central technique in Xenakis's electroacoustic music was spatialisation. As early as 1958, his ideas of moving sound emerged in *Concret PH*; in *Bohor* (1962) he placed eight speakers in a circle around the audience; for *La Légende d'Eer* he developed a sophisticated computer driven spatialisation, just to mention a few examples.

1.2.1. Spatialisation: modular stochastic spatialisation programme

My modular stochastic spatialisation programme (programming: Sukandar Kartadinata with pure data, later versions in Max) starts with an 8×8 matrix: eight channels are spatialised to eight speakers, and not, as is usual, to a virtual position in the room. Continuous and non-continuous movements between the speakers can be realised: rotations and jittering (jumping randomly inside a given angle). The third primary module is the width of the sound protection. All parameters can be changed, including velocity and direction of the rotations.

Moreover, the form of jittering can be sculpted by using different random functions for changing the probabilities of hitting different positions inside the angle. All these functions can be combined. The individual parameters such as rotation speed, spread factor, jitter, loudness, and width can be controlled directly via the software or with a fader board. With these functions and their potential combinations, it becomes possible to create spatial textures for the whole audience, not only for the 'best seat in the hall'[6]. Even auditors sitting much closer to some speakers than others will have almost the same perception of the textural spatialisation.

The software has also been used to transfer Xenakis's automated spatialisation of *La Légende d'Eer* inside his multimedia project *Diatope* (based on the research of the musicologist and architect Elisavet Kiourtsoglou[7]) to a new situation with 8-channel-surround sonification. I presented the result in the sound dome at the Wundergrund Festival in Copenhagen in 2015, and it is available as an 8-track file[8].

1.2.2. Composition Tool: Texture Transformation Machine (TTM)

Xenakis believed in the idea of developing a composing machine[9]; however, he did not reach the point where he would have accepted all different outputs of his computers as equally valid as a final composition. For his compositions *S.709* and *Gendy 3*, he simply chose the 'best' results. His idea of calculating on different levels reaches from sound synthesis to structured composing of sound materials as in *Diamorphoses* (discussed in detail in the related chapters).

I will transfer these ideas to my composition of an orchestral score, developing a computer programme that allows constructing non-symmetrical transitions from a given sound material pool to another. For example, each

[6] A term coined by Nicholas Cook in: Cook, N. (2013), Beyond the Score, Oxford University Press, Oxford, 374.
[7] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.
[8] 8-track-files and Software included in "Related Materials".
[9] Compare: Xenakis, I. (1991) Formalized Music, Pendragon Press, Hillsdale, 134.

instrument has three low sounds in *pianissimo*, and plays them in a *tutti* situation, changing them in a non-isometric way. New sounds can now be introduced slowly – for example longer notes in the higher register – and brought in one by one, also in a non-isometric way, in order to avoid repetition of patterns. Because of the complexity of this idea – that can result in a huge superstructure, – it makes sense to use a computer for these sound world transitions. For such a purpose, an overall development of a whole orchestra can be realised by sculpting random functions: each sound s_i of a texture appears with a probability p_{si} at a given moment t_0.

This new compositional tool can not only aid the generation of scores, but can also be used in the future to work directly on sound samples. As realised already with 8 oscillators[10], the modular spatialisation tool and the compositional tool can now be combined in order to create multi-track electroacoustic compositions or installations.

The mathematical part of the project, based on ideas Xenakis implemented for his electroacoustic compositions, was critically discussed with the expert advisor Prof Dr. Ehrhard Behrend of the department of mathematics at the Freie Universität Berlin.

A first composition was realised with a preliminary version of TTM.

- *string quartet no 3*, premiered and recorded for CD-Release in December 2016 by Quatuor Diotima.[11]

and led to the orchestral piece

- *KRAFFT*, for eighteen musicians, premiered and recorded in Paris and Marseille in May 2017 by ensembles *zeitkratzer* and *2e2m*, Paris.

The output of the preliminary version of TTM were columns of numbers to denote instrumental events. These numbers had to be transferred into the final scores. The software (Max/MSP programming: Sukandar Kartadinata) is now, in

[10] Friedl, R. (2013) Eight Equidistant pure wave oscillators, while slipping very slowly to a unison, texturally spatialised on eight speakers, concret, 60 minutes, released on the Australian label Room 40, Sydney. http://emporium.room40.org/products/508069-reinhold-friedl-eight-equidistant-pure-wave-oscillators-while-slipping-very-slowly-to-a-unison-textually-spatialised-on-eight-speakers-concret-60-minutes, last access February 25, 2019.

[11] Released on the label of La muse en circuit 2018: Reinhold Friedl: String Quartets – performed by Quatuor Diotima, corelease on vinyl (LP) by BOCIAN Records Warsaw, same title.

the newest version, capable of producing MIDI-Files that can be transferred directly to computer notation software (For KRAFFT: Sibelius 2018.7).

1.3. Related materials

(see Annex 1, list of additional digital materials, including this pdf-document with figures in colour)

- Reinhold Friedl: *Eight Equidistant pure wave oscillators, while slipping very slowly to a unison, texturally spatialised on eight speakers, concret, 60 minutes,* released on the Australian label *Room 40*, Sydney.
    - Max-Patch
    - Score
    - Recording
- Reinhold Friedl: *Xenakis's Legend*, spatialized version of Xenakis's *La Légende d'Eer.*
    - Max-Patch
    - 8-channel Recording
- Reinhold Friedl: *string quartet no 3*, premiered and recorded for CD-Release in December 2016 by Quatuor Diotima.
    - Score
    - Recording
- Reinhold Friedl: *KRAFFT*, for eighteen musicians, premiered and recorded in Paris and Marseille by ensemble *zeitkratzer* and *2e2m*, Paris.
    - Score
    - Recording
- TTM-Software, giving out Midi-files.
    - Max/MSP patch

1.4. Publications, Releases and Concerts

Lectures and Publications

- Opening lecture of *Auditorium of Rotten Sounds*: Die Suche nach dem Original: vom Verfall elektroakustischer Musik, mdw, Musikuniversität Wien, March 28, 2019.
- Reinhold Friedl, *Performance in Xenakis's electroacoustic music*, in Alfia Nakipbekova (ed): *Exploring Xenakis: Performance, Practice, Philosophy, Vernon Press*, March 2019.
- Radio Feature: Reinhold Friedl - *techné [78]: Baschet-Instrumente* for WDR3, Studio elektronische Musik, Cologne, Germany. Sept 29, 2018.
- Lecture *Performance in Xenakis's electroacoustic music,* Leeds University, Congress "Exploring Xenakis: Performance, Practice, Philosophy. Leeds, September 9, 2017. Support by Goldsmiths University.
- Friedl, R. (2015), *Archive elektroakustischer Musik I-IV*, radio script for Westdeutscher Rundfunk Köln, Germany (Archivnummer: 5189 959 – 5189 963, Broadcast: March & April 2015).
- Friedl, R. (2015) *Towards a Critical Edition of Electroacoustic Music: Xenakis – La Légende d'Eer*, in: Solomos, M. (ed) (2015): Iannis Xenakis, La Musique électroacoustique, Paris, 99-108.

Releases

- Reinhold Friedl: *KRAFFT* for 18 musicians, 2e2m Paris and zeitkratzer, conducted by Pierre Roulliet; CD on zeitkratzer records, Berlin. Oct 2019.
- Quatuor Diotima - Reinhold Friedl *String Quartets*; re-release on Bocian Records, Warsaw, Poland, LP 12"vinyl (BC RFQ), July 2018.
- LP Release *Persepolis*, Perihel Series curated by Reinhold Friedl, Karlrecords – KR044, March 2018.
- CD Quatuor Diotima – Reinhold Friedl *String Quartets*, released on La Muse in Circuit (ALM008), Paris, March 2017.
- LP Release *La Legende d'Eer,* Perihel Series curated by Reinhold Friedl, Karlrecords – KR024, July 2016

Concerts and Scholarships

- Performance of historically informed *Bohor* 8-track version, Ultima Festival Oslo, Norway. Oct 2018.

- *Arbeitsstipendium* (Composition Scholarship) of the City of Berlin, Germany, 2016/2017 for further developing the texture transformation software (including orchestral application).
- Commission of the Copenhagen contemporary Music Festival G((o))ing for Diotima Quartet: string quartet no 3, using the first prototype of the texture transformation software. Premiere: October 29, 2016, Academy of the Arts, Copenhagen.
- Commission of the French State for KRAFFT: composition for ensemble 2e2m Paris and zeitkratzer Berlin, using a first draft of the texture transformation software. Premiered in Paris, Festival “Extensions”, (La Muse en circuit) and Festival “Les Musiques”, GMEM Marseille, May 2016.
- Performance of spatialised version of *La Légende d’Eer* “Xenakis’s Legend” Copenhagen, Sound Dome, Festival Wonderground, Denmark, October 12, 2015

2. Philology of electroacoustic music

2.1. Introduction

The starting point for this research is a questioning of Xenakis's compositional approach, especially to his electroacoustic music. Did Xenakis think of electroacoustic music as fixed media or did he have a more flexible and open concept? Are his electroacoustic compositions fixed on media, or are they of a flexible nature, demanding interpretation and live performance?

My approach to this question is a philological one: to compare all available versions of Xenakis's electroacoustic compositions in order to better understand the differences between them. Did Xenakis consider, on a conceptual level, that there can be different versions of the same composition? Comparing the different commercial releases of *Persepolis*[12], it is apparent that one CD release has been transferred from the master tape at the wrong sample rate,[13] while another[14] (see chapter on *Persepolis*), omits approximately three minutes in the middle of the piece.[15] So my first assumption that the existence of different versions gives evidence for an open, or at least flexible, concept of work was incorrect: a different version can either be the result of an interpretation or of a technical fault.

The work that I had started deals with the subject of philology:[16] This finding leads to a discussion of the difference between a philology of electroacoustic music and that of a classical music or text work. Electroacoustic music, especially tape music, is bound to sound storage media in every production stage. It is possible to reconstruct the genesis of some of Xenakis's pieces from the initial sound recordings, through many different manipulations and levels of montage, up to the final composition. This reveals more than processes: it elucidates composition techniques and finds contradictions between the techniques used and the composer's statements. Aside from showing that we have listened to false versions of some major works of electroacoustic music for

[12] Xenakis, I. (1971) *Persepolis*, 8-track-tape, Salabert - réf. 4965; LP (1972), Philips « Prospectives 21e Siècle », Paris; Audio-CD (2000), Fractal Records, Paris.
[13] Xenakis, I. (2002) *Persepolis*, Audio-CD, Asphodel, San Francisco.
[14] Xenakis, I. (2003) *Persepolis*, Audio-CD, Edition RZ, Berlin.
[15] Friedl, R. (2009) Polyphone Monophonie, in: Musiktexte 122, Köln, 12-17.
[16] Due to the discussions with Eric Denut, responsible for Iannis Xenakis at Salabert 2007-2012.

several decades, new aspects of Xenakis's oeuvre impose themselves for further critical studies.

The philology of Western art music usually focuses on musical scores as the text. In many cases, different editions and versions of scores exist – as an example, Carl Czerny's edition of Johann Sebastian Bach's *Well-Tempered Clavier*[17]. The critical editing of musical texts gives rise to such questions as: Which version is the correct one? What is the original text? What is the correct text? Has the composer produced different versions? In what way has the score been changed by later editors? These questions have been and still are widely discussed, and have great bearing on performance practice.

Traditional philology has posed the same questions to classical texts. The philological method that was developed in the 16th century could also be used for music, as Georg Feder stated in the first comprehensive book on music philology, his *Musikphilologie*[18] of 1987. Feder systematises the methods and techniques of critical editing of music in detail. James Grier, who refers to Feder, published the first English book about the critical editing of music in 1996, and showed that "editing is an act of criticism" [19].

2.1.1. Text versus Notation

Feder's methodology and techniques cannot be applied to electroacoustic music one-to-one: sources of electroacoustic music are not paper based but multimedia. Text can be inscribed on different media. The text does not need to be of a symbolic nature but can be an electromagnetic field of an analogue tape, or a sequence of numbers (in the case of a digital representation). Further, an algorithm causing a musical composition or a programme controlling live-electronic music can also be considered as text.

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[17] Butt, J. (ed) (2003) The Cambridge Companion to Bach, Cambridge, 207.
[18] Feder, G. (1987) Musikphilologie: Eine Einführung in die musikalische Textkritik, Hermenutik und Editionstechnik, Darmstadt. English translation: Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale.
[19] Grier, J. (1996) The critical editing of music. History, method, and practice, Cambridge University Press, Cambridge, XIII.

The notion of text is directly connected to the notion of work, as Feder underlines: “For the methods of philology it only matters that the work exists in written form! (If there is no written form, as in improvised music, the music is not a “work” in the philological sense.)”[20]

Reading this carefully shows, that Feder does not particularly speak of a ’text‘, but of a “written form”. Actually, music philology treats musical scores as texts, even so, they do not have the same properties. The most accepted linguistic criteria, such as coherence and cohesion, meaning the semantic and formal internal connections between the elements of a text[21], do clearly not fit musical scores. Consequently, Feder ignores this grammatical-semantical aspect: his music philological definition of “written form” reduces the notion of text to strings, rows of signs, inscribed on paper or other media.

Another definition categorises text as a performative act[22]. As music is a performative act, this holds true for probably all music scores. Georg Feder divides ‘prescriptive’ and ‘descriptive’ musical notation: “In Western music […] music notation exists at the outset (although it came after the composer’s creative fantasy); the text is ‘prescriptive’. Descriptive notation, then, is a report of how a particular musical piece is supposed to be audibly performed.”[23]

In his explanations, Feder mixes ‘music notation’ and ‘text’ together,[24] but a music notation does not need to be a text in the linguistic sense. Musical notation is not coherent in the same sense as a written text. That is why Feder focusses on the aspect of performance instruction and broadens the notion of a text towards a communicative performance. In this sense musical notation is a text.

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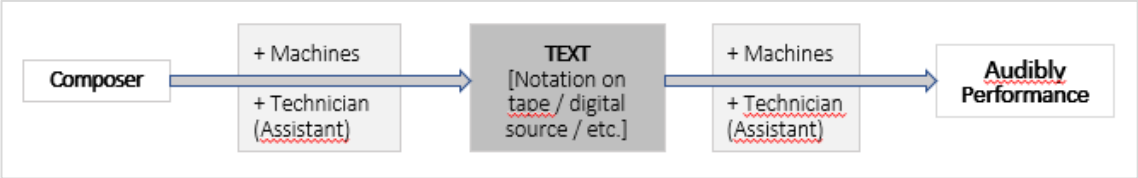
[20] Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 13.
[21] Coherence is defined in the Cambridge dictionary as „when the parts of something fit together in a natural or reasonable way”, Cohesion is the grammatical and lexical linking within a text or sentence that holds a text together and gives it meaning. It is related to the broader concept of coherence.
[22] The music ethnologist Jeff Todd Titon gives an overview of the text definitions in: Titon JT (1995) Text, in: The Journal of American Folklore, Vol. 108, No. 430, (Autumn, 1995), 432-448.
[23] Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 14.
[24] Compare the chapter ‘work and text’ in: Grier J. (1996) The critical editing of music. History, method, and practice, Cambridge University Press, Cambridge.

Consequently, the question of whether music inscribed on magnetic tape is, in this sense, a text, needs to be resolved. As it fits perfectly Feder's definition of descriptive notation as "a report of how a particular musical piece is supposed to be audibly performed", the answer is in the affirmative.

One difference remains, however: the text of electroacoustic music – manifest on magnetic analogue tape or as digitised file – requires a machine to be read and to be transferred into music.



Scheme 1

Analogue tapes are not readable for a human being, but they can be used to register and to reproduce sound. On the other hand, a digitisation is theoretically a symbolic inscription, and the numbers could be read (but not interpreted like a musical score). Both the information on an analogue tape and in a digital sound file, though, are "a report of how a musical piece is supposed to be audibly performed." We can consider them as text and apply philological methods.

Moreover, the need of a machine to transfer a text into an audible performance is not as distinctive to instrumental music as it seems at first glimpse: a piano piece also needs a machine – a piano – to be acoustically realised, and what about punch tapes used for player pianos?

Hence, an inscription of sound on any media can be treated as "philological text". However, we need the ability to read and to decode the inscriptions, and the knowledge and technical facilities to do so. For example, confronting an analogue tape, one must first clarify in which direction and at which velocity it is to be played, or what kind of noise reduction has been used, or – in the case of a digital medium – which sample rate the sound file has.

2.1.2. Archiving

In order to systematise the techniques to archive tapes, and especially to assure correct transfers of analogue tapes to digital files, the International Association of Sound and Audiovisual Archives (IASA) published *Cataloguing Rules*.[25] They define precisely how sound sources should be archived and catalogued. The publication also discusses historical sound recording formats and how they should be denominated when being archived in physical or digital form. This archiving technique was exemplarily executed by Gregorio García Karman, who catalogued the tape collection of the Spanish composer Roberto Gerhard.[26] Most archives do not follow such extended rules. To give an example: the Bibliothèque nationale de France (BnF) does not archive photographs of the original tape boxes together with the sound files. This would allow doublechecking of notes and information on the boxes, properties of the tape, etc.

The archiving strategies of digital and digitised media do widely differ: large institutions usually archive their material professionally and take care with respect to regular data migration, whereas internet archive platforms – used by many artists to archive their own work – do not usually adhere to this standard. For instance, the Archive of Digital Art (ADA) neither defines archiving formats nor guarantees future data migration[27] to updated platforms.[28]

2.1.3. Authenticity

Georg Feder quotes the philologist Friedrich Ast, that “all critical questions can be reduced to one: the question of authenticity, namely that of authorship,

[25] Miliano, M. (ed) (1999) Cataloguing Rules (IASA 1999), International Association of Sound and Audiovisual Archives IASA Editorial Group. www.iasa-web.org/cataloguing-rules, last access March 3, 2017.
[26] Karman, G.C. (2014) Annotated Catalogue of the Roberto Gerhard Tape Collection, Huddersfield. http://info.ggkarman.de/sites/default/files/pdf/catalogue_export_PhD_20052014_09.pdf, last access March 2, 2017.
[27] Data migration is not a problem limited to sound archives. Techniques and problems are largely studied in computer science.
[28] Archive of Digital Art (ADA), http://www.virtualart.at/nc/home.html, last access March 1, 2017.

date and actual text."[29] Authenticity in the case of digital music has been discussed by the musicologist Maria Guercio,[30] who asked how the authenticity of a digital source could be controlled and proved. Guercio (ibid.) mentions the UNESCO *Preserving digital heritage data for future generations standards*, developed in the framework of the EU-sponsored, large-scale *Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval project* (CASPAR)[31].

2.1.4. Critical Discussion

So far, there has only been little critical discussion of electroacoustic sources. One has been led by the laboratorio MIRAGE,[32] directed by Angelo Orcalli in Udine, Italy. Almost all publications of the research group are published in Italian only, but Orcalli presents a good overview of their work in his article *Traces sonores du XXe siècle – Pour une critique des sources audiovisuelles*[33]. He exposes some preconditions of critical source discussions and agrees with Georg Feder that source critique is necessarily a hermeneutic technique. Orcalli calls it "principle of feedback: critique of the critique",[34] what is exactly the definition of the hermeneutic circle. Orcalli gives prominent examples of audio reconstructions, including Luigi Nono's *La fabbrica illuminata*[35]. The methods Ocalli used are therefore mainly computer-based. They range from the comparison of digital sound files with the aid of graphic representations (sonograms) to flexible noise reduction algorithms. Some practical problems of restoring analogue tape are also mentioned. Finally, Orcalli discusses different

[29] Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 41.
[30] Guercio, M. (2013) La notion d'authenticité en conservation numérique, in : Teruggi, D. (ed) (2013) Musique et technologie, Institut National de l'Audiovisuel, Paris, 75-92.
[31] UNESCO, *Preserving digital heritage data for future generations: CASPAR project,* http://www.unesco.org/new/en/natural-sciences/science-technology/space-activities/space-for-heritage/activities/open-initiative-projects/caspar-project/ last visit March 2, 2017; ironically offline March 2019.
[32] Laboratorio MIRAGE, http://mirage.uniud.it/, last access March 01, 2017.
[33] Orcalli, A. (2013), Traces sonores du XXe siècle – Pour une critique des sources audiovisuelles in : Teruggi, D. (ed) (2013) Musique et technologie, Institut National de l'Audiovisuel, Paris, 33-74.
[34] Ibid., 38.
[35] Ibid., 60-63.

approaches to audio reconstruction: the “conservative approach”, conserving the totality of information, and the “aesthetic approach”, exploring the potential of the new media as thoroughly as possible.[36]

Italian Musicologist Laura Zattra has also published several articles on the topic. She repeatedly emphasises that the source material of electroacoustic music is necessarily multi media.[37] Zattra describes the application of classical philological methods in her article *The Assembling of "Stria" by John Chowning: A Philological Investigation*.[38] She emphasises the necessity of comparative listening to the acoustic sources without further explanation, but also – and similar to Orcalli, uses computer-aided analysis of sound sources to compare different versions of Chowning’s *Stria*. Together with computer scientist Nicola Orio she developed software for comparing similar sound files[39]. This software is supposed to visualise similarities and differences between two sound files. As the authors of the software stated already in 2007, the results are not completely consistent[40], and the computer programme has not been enhanced since.

A special philological case is Xenakis’s algorithmic computer music. Musicologist and computer scientist Peter Hoffmann showed that it is determinate by re-programming Xenakis’s algorithm.[41] He succeeded in recreating the composition *Gendy 3* (1991) – if not as an exact clone, at least as an almost indistinguishable ‘perfect twin’[42] of the original. In this case, the algorithm is the ‘text’ of the composition, if not the composition itself.

These are just a few examples of the fact that the philology of electroacoustic music clearly differs from music philology of instrumental Western

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[36] Ibid., 73. « Les approches conservative et esthétique constituent deux pôles opposés : la première s’emploie à conserver la totalité des informations […] ; la seconde exploite le plus largement possible le potentiel du nouveau medium. «

[37] Zattra, L. (2006) The Identity of the Work: agents and processes of electroacoustic music, in: Organised sound, Vol 11, 113-118, Cambridge.

[38] Zattra, L. (2007) The Assembling of "Stria" by John Chowning: A Philological Investigation, in: Computer Music Journal, Vol. 31, No. 3, 38-64.

[39] Zattra, L. Orio, N. (2007) Audio Matching for the Philological Analysis of Electroacoustic Music, ICMC 2007.

[40] Ibid.

[41] Hoffmann, P. (2009) Music out of nothing? A rigorous approach to algorithmic composition by Iannis Xenakis, Berlin, Technische Universität, Dissertation, published only online: https://www.deutsche-digitale-bibliothek.de/binary/LAF3UGXKQSY7J4KLAZ6Z2YMSA5LLFO66/full/1.pdf, last visit February 27, 2017.

[42] Ibid., 11-12.

art music discussed by Georg Feder. However, it is striking that some classical strategies discussed by Feder have not yet been subsequently applied to electroacoustic music. The so-called 'filiation method' is especially efficient: a genealogy graph is constructed with the help of 'significative errors', and 'lower' and 'higher criticism'[43].

'Significative errors' can be found by comparing different versions of a text or another kind of source. If two sources show the same error, a so-called 'conjunctive error', one must stem from the other, or they both stem from a third source containing the same error. 'Separative error' means that two sources do not contain the same error, thus the one without error is most probably not a copy of the one with error.

'Higher criticism'[44] includes historical and contextual knowledge. This kind of high criticism can be applied to Xenakis's *Diamophoses*, for example: a score of Xenakis's first tape composition from 1957 can be found in the Xenakis family archives, but it is no 'original score' in the traditional sense. Instead, it is a transcript, written for the music publishing society SACEM, in order to prove that this music was real art music. They would not accept tape.[45] The score turns out to be a transcription by the composer of his own work!

The 'stemma codicum', a filiation graph of the existing sources is of great assistance and classifies different existing versions and their relationships. In the case of electroacoustic music, it can be enlarged: electroacoustic music – and especially that of Iannis Xenakis – often makes use of pre-recorded sound material. In the process of composing, this material is treated, varied, cut, and combined in numerous variations, before the final montage happens. This allows the stemmatic scheme to be extended towards a genealogical table (see chapters on *Bohor* and *La Légende d'Eer*): in some cases, as in *La Légende d'Eer*, significant parts of the compositional process can be made visible in this way.

More philological research techniques, systematically listed by Feder, can be applied to electroacoustic music. Feder's *Source Description* includes a description of the physical paper and especially the watermarks that sometimes

[43] Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 63.
[44] Ibid., 42.
[45] Interview with Francois Bayle with the author, Paris, 2013.

allow precise dating of sources.[46] As we will see in the chapter on *La Légende d'Eer*, the same result can be found by describing the tape that for several decades became the main carrier medium of electroacoustic music. The digitisation fault made in the commercial edition of the piece (a section has been digitised at the wrong sample rate – see the chapter on *La Légende d'Eer*) could be proved using this method.

Furthermore, applying critical editing methods to electroacoustic music enables the discovery of so far unknown composition methods: during my examination and with the aid of this method, I detected techniques that contradict Xenakis's statements, or found 'hidden' material, for example several minutes of a previously unknown double bass solo in *La Légende d'Eer*, (see 3.4.5) or the also previously unknown use of the Baschet instruments in *Bohor* (see 3.4.2).

These kinds of results may show new aspects of Xenakis's notion of a work, and his approach to interpretation. They can sharpen some practical questions, such as which version(s) should be played today and in what way. To underline the importance of such questions: the performance version of *La Légende d'Eer,* sent to a German concert promoter, turned out to have been digitised backwards:[47] the correct tape has been digitised, but played in the wrong direction, from tail to top. This most probably happened because the tape had not been rewound.

One main difference between traditional music editing and electroacoustic music editing is that in electroacoustic music, the final version - on tape or other media - is not primarily made for the performer, but for the listener (for example, in the case of a commercial stereo release). This allows us to further explore if and how electroacoustic tape music needs to be performed or interpreted in a concert situation.

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[46] Feder, G. (2011) Music Philology – an Introduction to Musical Textual Criticism, Hermeneutics, and Editorial Technique, Hillsdale, 47.

[47] E-Mail to the author from Kilian Schwoon, Director of Studio für elektroakustische Musik, Hochschule der Künste, Bremen, who received this copy as official performance material via Ricordi Milano; E-mail from November 30, 2010.

2.2. Methodology

In classical philology the main aim was to find the “real and purest text version”.[48] This editorial purpose was increasingly replaced by the idea of obtaining insight into the artist’s workshop, and to learn more about the genesis of a work. During the last decades, the philological discussion was expanded by the ‘New Philology’, the ‘Material Philology’, and the ‘*critique génétique*’.[49] The last two, especially, are of great interest for a philology of electroacoustic music: the Material Philology puts a new focus on the writing material. For example, the use of paper was limited:

> Until the nineteenth century, this expensive, handmade commodity was employed sparingly, mainly to preserve finished compositions. We know now, that from the fifteenth century through to the eighteenth century, reusable surfaces of various kinds (wood covered with layer of wax, slate, plaster, varnished parchment, etc.) were employed to work out their ideas before consigning them to paper.[50]

This can explain missing links between sketches and versions of a composition. Exactly the same happened with the expensive magnetic tape in early electronic music: often, tapes used in the production process of an electroacoustic composition were erased and reused.

The *critique génétique*[51], developed in the 1970s in France, started to also research preparatory material to the final text, such as drafts, drawings, lists, etc. The process of writing or composing became a topic of research. A famous example in the music philology are the sketchbooks of Beethoven. The focus shifts from the idea of finding a definite version of a composition to the internal dynamic between the different sources. This approach can be applied especially to the studio work of electroacoustic composers: in a studio it is almost impossible

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[48] Martens, G. (1971) Textdynamik und Edition, in: Martens, G., Zeller, H. (eds) (1971) Texte und Varianten, München, 165.
[49] Urbanek, N. (2013) Was ist eine musikphilologische Frage? In: Calella, M., Urbanek, N. (eds), Historische Musikwissenschaften – Grundlagen und Perspektiven, 147-184.
[50] Sallis, F. (2015) Music Sketches, Cambridge, 56.
[51] Grésillon, A. (1994) Eléments de critique génétique. Lire les manuscrits modernes, Paris.

to work without drafts, mixing schemes, recording notes, etc. In the case of Xenakis, there is a rich fund of notes and drafts in different archives that allow further knowledge of the genesis of his compositions and even the role of different versions. It opens the composer's 'secret' workshop and his performance of composing.

Even simple philological methods can be very fruitful. For example, collation: with the help of standard sound editing programmes, digitised versions of compositions can be compared and related to each other. Stretching effects, as caused by a digitisation with an incorrect sample rate, for example, are then clearly visible.

As the text of electroacoustic music can only be written and read by machines – computers, tape recorders, etc. – the philology of electroacoustic music needs to include knowledge about the history of technology. This would be included in what Feder called "higher criticism". All acoustic sources need to be related to the respective machines. The eight tracks of Xenakis's *Bohor* for example could not be synchronised, because there was no machine to do this. Some tapes had been produced with contemporary noise reduction techniques and risk being read without the reverse reading mechanism. History of technology also becomes crucial in order to date and to evaluate the sources.

Moreover, text sources can be of great assistance: composers' notes or statements by other witnesses as technicians, assistants, publishing houses, or commissioners can support the categorisation of sources. We will see that Xenakis recorded the so-called Baschet-instruments for his composition *Bohor*, probably simply because they were available in the studios of the *Groupe de Recherches Musicales* in Paris. As these instruments are almost forgotten today, it was crucial to study the historical context in the studio: who was working there, and on what kind of music in the same period as discussed in detail in the chapter *Bohor*.

In summary it can be said that a philology of electroacoustic music is a prototype of modern philology. When one considers recorded sound as text, the collation methods can be applied and put together with methods of *critique génétique* and the material philology. Contextualising the results and findings with

the contemporary history of technology and the production conditions in the respective studios promise strong results.

It is astonishing that music philology has rarely been applied to electroacoustic music until today. The German standard compendium *Musikphilologie*[52] from 2017 does not even mention electroacoustic music, nor do the English standard references by Feder or Grier.

On the other hand, almost no writing on electroacoustic music questions the role of the author, as has been widely questioned in literature. The role of the composer is not scrutinised; even composers' statements are rarely questioned. However, even the author is not a stable entity, as we often tend to assume. A composer may prefer one version of his composition today, another tomorrow, or simply forget that there have been better versions. Xenakis obviously forgot the mastering of *Bohor* with Robert Ludwig (see chapter on *Bohor*). When Karlheinz Stockhausen published his *Konkrete Etüde*[53] for the first time in 2001 – almost 50 years after its production – he had completely forgotten that the largest part of the released version was not his original composition, but an improvisation, with the original material by Herbert Eimert.[54] Stockhausen was at least not the only author of this very music.

Closely connected to those questions is the "authorised version". Many confuse an – anyhow often questionable – "authorised version" with "the original". Often, if not commonly, there are no single originals. Especially in music, different occasions give rise to different versions. Different instrumentations of the same composition – for instance, for string quartet *or* chamber orchestra – are absolutely common in music history. In electroacoustic music many different versions may coexist: spatialised 8-channel-versions, stereo mixes for commercial releases, 5.1-mixes for DVD, etc.

Finally, philological examination of electroacoustic music is based on sound material and comparative listening. A fundamental problem is the fact that sound files can often only be listened to in public libraries due to legal reasons. This fortifies the role of a special comparative listening.

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[52] Appel, B., Emans, R. (eds) (2017) Musikphilologie, Laaber-Verlag, Laaber.
[53] Stockhausen – Elektronische Musik 1952-1960, CD, Stockhausen-Verlag, Kürten 2001.
[54] Friedl, R. (2016) Was ist ein Fehler? Radio Feature, Deutschlandfunk, Berlin.

Comparative listening includes several aspects:

- Collative listening: In which other sources can I find the same sounds?
- Genetic listening: From where do the sounds stem? (Exactly the opposite to Pierre Schaeffer's "*écoute réduite*", which tries to avoid the connection of the sound with its source.) Where else can I find the same or similar sounds, for instance, transpositions or other manipulations?
- Forensic listening: How have sounds been technically produced? What kind of electroacoustic manipulations have been applied? Are there audible technical faults?

The fact that musical notation of electroacoustic music seldom occurs strengthens the necessity to comparatively listen to the objects of research. As "visual representation is fundamental to the common Western conceptualization of music"[55], this unusual challenge might be the most compelling point of a new philology of electroacoustic music: listening to the sources!

2.3. Scheme

The following scheme is designed as a practical guide for a philological research of electroacoustic music.

The philological question

Philological research normally begins with a philological question. Usually, a philological question asks for a fault in, or an evaluation of, a version of a composition. The philological question can, however, also aim at studying the genealogy of a compositional process. Even though questions do change, and new questions appear in the research process, they should all be listed in the beginning of a philological study.

The apparatus

[55] Nettl, B. (2015) The Study of Ethnomusicology, Illinois, 73.

An interesting philological research needs conflicting sources and enough sources to study the provenance of these conflicting sources. All sources are traditionally listed in the apparatus. In classical philology, the critical apparatus is the listing of the manuscript variants. It is a starting point of every philological research and can be done in footnotes. If the critical apparatus is large, it is useful to follow the advice of James Grier, to present all primary sources in the annex:

> I expressed a preference […] on several grounds. It preserves a clean page, minimizes page-turns, and allows the edition to function as the base text for other editions. This presentation also allows the editor more room to present a fuller selection of variants without having to worry about the apparatus swelling up to dominate the visual impact of the page if it were printed in the bottom margin of the principal text.[56]

The presentation should be neatly arranged to ensure the reader can find the sources quickly. The naming of the sources in the apparatus is important and should contain as much information as possible.

2.3.1. Sources

The first part of philological research should be a complete list of all available sources with the following details (if known):

2.3.1.1. Acoustic sources

- Name (informative and clear identifier)
- Provenance (library, archive, signature)
- Original Name
- Media (tape, file, CD, DVD, etc.)
- Material details (measurement of tape-box etc.)
- Technical Details (length, sample-rate, velocity, etc.)

[56] Grier, J. (1996) *The critical editing of music: History, method, and practice*, Cambridge University Press, Cambridge,172.

- Date and place of production (radio studio, private studio, etc.)
- Indications and notes (name on boxes, all written hints, connected material, etc.)
- Connected further media (photograph of tape-box, CD-booklet, etc.)

Listening protocols are often indispensable and can be integrated. Many archives are not permitted to hand out digitisations of analogue tapes or sound files, not least due to legal limitations. Thus, acoustic sources can often be visited only in situ. A sound editing programme that would allow visualisations is normally not applied; the sources are played via a media player on a computer screen. Copying or recording is not allowed. This makes protocolling inevitable. These listening protocols should concentrate on comparative listening, as introduced at the end of the preceding chapter: collative listening, genetic listening, forensic listening.

The naming of sources should not be underrated, and should be done after some research has already occurred, and some details are known. For instance, this allows for fewer main sources. The given name should be as clear and substantial as possible. Providing too much information in a lengthy name can impair the clarity. Conversely, a short very clear name cannot carry much content. A compromise is necessary, and usually only emerges during the ongoing research.

2.3.1.2. Catalogues and Data Bases

Existing catalogues and electronic databases can be of great assistance: they often contain additional information, sometimes directly from the analogue tapes that cannot be examined directly. Quoted notes on magnetic tape boxes etc. can sometimes be of interest. Those entries may be integrated in spreadsheets listing the sources (see apparatus for *Bohor*, GRM sources).

Catalogues of great interest are the classical databases of electroacoustic music:

- RIME, the *Repertoire International des Musiques Expérimentales,*[57] which lists information indicated by prominent electronic studios in 1961 about compositions, equipment, etc. This catalogue became the prototype for several other catalogues of electroacoustic music, such as:
- The International Electronic Music Discography[58]
- Hugh Davies' *International Electronic Music Catalogue*[59]*,* or the
- *International Documentation of Electroacoustic Music* of Elektronisches Studio der Technischen Universität Berlin.[60], online as:
- *International Documentation of Electroacoustic Music*[61]

Catalogues of special studios can also be of interest, for instance:

- *GRM Répertoire Acousmatique (1949 – 1980)*[62]
- *Schwingende Elektronen*, including a list of productions at Studio für elektronische Musik WDR Cologne[63]
- *The Studio di Fonologia*[64]

2.3.1.3. Visual sources (photos, drafts, scores, mixing scheme, etc.)

Visual sources should be listed and reproduced in the annex as they can take much space. Often showing relevant details of visual sources in the main text allows an easier understanding. The secondary information should include:

- Provenance (self-made, institution, internet source, etc.)
- Names (objects, persons in the photograph)
- Details (place, date, references to audio sources, etc.)
- Material, measures, etc.

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[57] The full text can be found at: https://archive.org/stream/InternationalElectronicMusicCatalog/EMR2_3_djvu.txt, last access March 01, 2017.
[58] Kondracki, Stankiewicz, Weiland (1979) International Electronic Music Discography, Schott, Mainz.
[59] Davies, H. (1968) International Electronic Music Catalog, Paris.
[60] Hein, F. (1996) International documentation of electroacoustic music, Saarbrücken.
[61] https://www.emdoku.de/en, last visit March 20, 2019.
[62] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris.
[63] List of WDR productions in: Morawska-Büngeler, M. (1988) Schwingende Elektronen, Köln.
[64] Novati, M.M., Dack, J. (2009) The Studio di Fonologia, Milano.

2.3.1.4. Text Sources

Text sources, such as newspaper critiques, letters, etc. that exceed a certain length, should be put in the annex. Handwritten notes and drafts are also visual sources. The secondary information should be the same as for visual sources:

- Original name
- Provenance (library, archive, signature)
- Media (paper, book, score, file, pdf, etc.)
- Material details (length and height, number of pages, etc.)
- Indications (date, place, name on book, drafts, references to audio sources, etc.)
- Category (score, draft, transcription, notebook, etc)

2.3.1.5. Oral sources

As electroacoustic music is very young, there are still contemporary witnesses. Many details can only be cleared with their help. Because the role of an assistant or a technician became so important in electroacoustic music, it is advisable to interview them first. If such interviews are recorded and not published elsewhere, they could be transcribed in the annex. Some more information should be given:

- Provenance (library, archive, internet, self-made, etc.)
- Names (interviewer, interview partner, institution)
- Role of interview partner (composer, editor, technical assistant, etc.)
- Details (place, date of the interview)
- Recording details (length, media format)
- Transcription (by whom, translation, etc.)

Even the collecting and listing of sources is not static and can be finished in a first step; often further research brings up new sources. One source can comprise hints to other sources.

2.3.2. Collation and Critical discussion

2.3.2.1. Secondary literature

As a first step, the existing secondary literature should be studied – if available. Secondary literature often refers to unclear sources or mentions differences between several sources. This often helps to formulate the philological questions, even though it involves the risk of believing false assumptions (see the chapter on *Bohor*). False naming of sources in secondary literature can mislead.

2.3.2.2. Historical Background

The history of the composition should be outlined:

- Title and its meaning
- Commissioner
- Place and date of production
- Concepts and ideas
- Contents
- Place and date of the premiere
- Etc.

2.3.2.3. Collation

Systematic collation is the main part of the source criticism. It should start with a clearly formulated philological question. The “hermeneutic circle” also holds here: studying the sources gives rise to new questions and specifies others. Initially, all commercial releases and/or final versions are compared. A careful listing of the differences allows research on where, why, and when they appeared, and from where they originate. This can be done by collation with the production tapes: if those sources are available, it might be possible to reconstruct a genealogy of the production process.

If this does not work by comparative listening, one should not forget the classical techniques of finding separative errors: a longer version can hardly originate from a shorter one. A multitrack cannot originate from a single mono tape, etc. A simple timeline also often helps.

2.3.2.4. Sound Material / Mixes / etc.

It cannot be said often enough: comparative listening is as important as notation and transcription in ethnomusicology. It is the “fundamental skill”[65], as Bruno Nettl calls it. It is, however, not only the ear that allows recognition of sonic relationships between sources. Often cryptic inscriptions can be found on the tape boxes or elsewhere that can be decoded, once the ear has shown the path. The other way around, it is usually easy to hear that a certain sound is missing in a mix. Distinctive listening is often simpler than recognising common sounds in different sources.

An important point is also to identify primary sound sources: What has been recorded? Where and with whom have the recordings be made? This is often an underestimated aspect, as composers of electroacoustic music sometimes hide their sound sources (see the chapter on *Bohor*). Notes, drafts, etc. can provide hints of what one might seek in the audio sources.

2.3.2.5. Technical Context

We should always consider technical history. An 8-track composition cannot have been made without an 8-track machine. A mono composition can hardly be changed into a stereo one, etc.

- Media format collation: check contemporary technical possibilities.
- Matching with other technical facilities: e.g. noise reduction, effects, synthesizers, special constructions, such as the phonogène at GRM studio Paris, etc.
- Lists of technical studio equipment at the time of the production.

[65] Nettl, B. (2015) The Study of Ethnomusicology, Illinois, 72.

2.3.2.6. Institutional Context

The institutional context of a musical production is crucial for the critical research on electroacoustic music, as this music could for decades only be produced inside larger institutions:

- Assistant of production, commission letters, etc. (e.g. sounds named after the assistants as in *La Légende d'Eer*)
- Contextualisation with institutional history (e.g. necessity of a score in order to be payed)
- Function of audio sources (master tapes, obligatory archive copy, etc.)

2.3.3. Stemmatic Graph / Genealogy

The previous steps will now allow entry into the main hermeneutic process of textual criticism; the multifarious materials can be related to each other step by step, and contradictions made visible. The classical philological techniques can be applied to detect separative errors, contradictions, relations, etc. This will ideally allow the drawing of a genealogy of the compositional process and subsequent versions.

2.3.4. Critical Discourse

Results of philological research can have concrete consequences. They can show that commercial releases are corrupted, and raise the question of whether they should be withdrawn. This can lead to a critical discourse with concerned parties, publishing houses, mixing technicians, etc. A re-examination of the sources can become necessary, as was the case, for example, with *La Légende d'Eer* (see chapter of *La Légende d'Eer*).

2.3.5. Conclusion

The results will most often be already presented in context with the genealogy. However, the results may have further implications: if all final versions are corrupted, a new critical edition may be necessary. The result can show

common faults of analyses of the examined composition that might be avoided in the future, if certain rules are respected.

Unexpected side-results often appear and raise interesting questions for further research. Furthermore, questions such as the following should be considered:

- What do the results mean for the concept of oeuvre?
- Are there versions to prefer in the future?
- Do the results have consequences in the form of performance instructions?
- Are there analytic results concerning form, sound, etc.?

In the next chapter, this method will be exemplified on the basis of Xenakis's electroacoustic tape music.

3. Xenakis's Electroacoustic Compositions

Xenakis's electroacoustic works are ideal subjects for this new method of philological research, as a wealth of rich material exists in different places and conditions. Rich material means that there are not only music and acoustic sources, but also texts by the composer, different notes, drafts, calculations, graphic mixing schemes, etc., and secondary literature.

Xenakis's electroacoustic music can be roughly divided into three periods (James Harley provides a good overview, and presents four divisions[66]):

- 1957 – 1962

The early years. Xenakis is a member of the Groupe de Recherches Musicales (GRM) in Paris. Three electroacoustic compositions originate: *Dimorphoses* (1957), *Concrète PH* (1958), *Orient-Occident* (1960) and *Bohor* (1962).

- 1967 – 1988

The second period comprises his Polytopes: multimedia compositions, including light or laser shows, architecture, dance, etc. The titles of the first *Polytopes* suggest that Xenakis thought of these compositions as variations of one single piece. Later, he began to name them differently. The *Polytopes* include: *Polytope de Montréal* (1967), *Persepolis* (1971), *Polytope de Cluny* (1972), *Le Diatope* (*La Légende d'Eer*) (1978), *Polytope de Mycènes* (1978)

- 1989 - 1994

The third period brought about the last three electroacoustic pieces of purely electronic computer music, realised at his *Centre d'Études de Mathématique et Automatique Musicales (CeMaMu)* in Paris, from 1985 called *Les Ateliers UPIC*. This period may actually have started earlier with *Taurhiphanie* (1988), composed exclusively with digital sounds, as later *Voyage absolu des Unari vers Andromède* (1989) and *Gendy 3* (1991)

Several compositions do not really fit into this system: *Concret PH* (1958) is treated as a GRM piece by the GRM, even though Xenakis did not realise it at

[66] Harley, J. (2002) The Electroacoustic Music of Iannis Xenakis, in: Computer Music Journal, Vol 26, No 1, MIT Press, Cambridge, 33-57.

the GRM studio, but in the DMS Studio in Paris, owned by Philips.[67] *Pour la Paix* (1981) and *Kraanerg* (1969) are what is called in French *musique mixte,* "mixed music": tape and choir, and tape and instruments respectively. These pieces do not fit directly in the given grouping either.

This research focusses mainly on the three compositions *Bohor* (1962), *Persepolis* (1971) and *La Légende d'Eer* (1978) as paradigms for a philology of electroacoustic music. The multi-media aspect of Xenakis's work will not be discussed.

3.1. Sources and Archives

3.1.1. Acoustic sources:

- **Commercial releases on Vinyl, CD, DVD**

To compare commercial releases of the pieces is a solid starting point. Releases are the last link in a chain and often promise the consumer that the release is the definitive version of a composition. With Xenakis's music, this is not often the case, as most of his pieces are not conceived as mono or stereo; they are multi track, and the commercial releases are not definitive versions, but stereo reductions. Independent of this fact, though, there often are several releases of different stereo versions. This begs the question where these differences originate, leading directly to the archives.

- **Archives Xenakis, Bibliothèque nationale de France (BnF), Paris**

The Archives Iannis Xenakis at the Bibliothèque national de France (BnF) comprises 1,082 sound storage media, most of them not fully classified. 390 seem to be related to electroacoustic music.

The Archives are a deposit to the Bibliothèque national de France, which means they are still owned by the Xenakis family. The analogue tapes are stocked in air-conditioned rooms outside of Paris, with no access for visitors. Access to the digitised tapes is possible; they can be listened to in small cabins

[67] Le Corbusier did not allow him to realise the music in the more sophisticated Philips studio in Eindhoven, see: Tazelaar, K. (2013) On the Threshold of Beauty, Colophon, Rotterdam, 153.

on a computer with a very simple media player, but without amplitude images or other visual display. As part of this research, some files were played back in different listening sessions, and found to be at different speeds, meaning – presupposing they were the same files – that they have been played back with a false sample rate.

The boxes and tapes cannot be examined or even seen, and have not been visually documented in the system. No photographs are included. However, there is a database documenting notes and titles (see annex).

- **Archives of the Groupe de Recherches Musicales (GRM) at Radio France**

Xenakis's early compositions, including *Diamorphoses* and *Bohor* have been realised at the studios of GRM. The archives are not yet completely digitised either, so it is difficult to access the complete material. Furthermore, the GRM had a policy of only stocking the "Master-tape" of each composition. The GRM did not archive material or production tapes as montages, etc. If composers wanted to archive this kind of material, they had to do it privately. This is the reason why most of Xenakis's material and production tapes can only be found at the Bibliothèque Nationale de France.

- **Archives of Westdeutscher Rundfunk Köln (WDR), Germany**

In the case of *La Légende d'Eer*, many production tapes, montages, recordings, a group of multitrack-versions, stereo reductions, etc. can be found in the archives of Westdeutscher Rundfunk Cologne, as the composition was commissioned by and produced at the WDR. Volker Müller, the responsible technician, archived privately all material left over from the production, which would normally have been thrown away.

Within the framework of this dissertation, approximately fifty tapes (mono-, stereo-, 4-track, and 8-track tapes) within the WDR archive were digitised. This allowed for far-reaching reconstruction of *La Légende d'Eer*'s genealogy and further discoveries.

- **Archives of Edition Durand/Salabert/Eschig**

The publishing house holding the publishing rights of almost all Xenakis's electroacoustic music, allows access to the digitised performance material they provide for public performance. Within the framework of this dissertation, and with great support from the publishing house, I was able to borrow some of the original analogue tapes and digitise them with the help of Volker Müller in the studios of Westdeutscher Rundfunk Köln (WDR).

3.1.2. Catalogues and databases of acoustic sources

- **Groupe de Recherches Musicales (GRM): "Registre des Originaux"**

The register is the handwritten original of GRM's *Acousmathèque*, the collection of all master tapes produced in the studios of the GRM. Their commission contracts included articles stating that the composer must leave the original master tape at the GRM, once the composition was finished. In the days of analogue production, many composers left a copy of the master tape.

The inventorisation of this collection was done by Geneviève Bayle-Mâche,[68] who acted as "*phonothécaire*" from 1962 until 1992. She began the *Registre des Originaux*, the so-called "Bible", around 1970,[69] listing 1,429 tapes.

This register was used to realise the:

- **GRM Répertoire Acousmatique (1949 – 1980)**[70]

During the transfer process information included in Bayle-Mâche's register needed to be transposed, corrected, and unified; some comments have been added, including notes and comments written on tape boxes for example. The Répertoire Acousmatique is a printed book, but lists only a selection of important works and a part of the archived tapes.

[68] Geneviève Bayle-Mâche is the wife of François Bayle, who was the GRM's director from 1966–1997.
[69] Email from Geneviève Bayle-Mâche to the author from April 11, 2016.
[70] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris.

As early as 1962, The GRM released the so-called RIME, the *Repertoire International des Musiques Expérimentales,*[71] which lists information indicated by prominent electronic studios in 1961 about compositions, equipment, etc. This catalogue became the prototype for several other catalogues of electroacoustic music, such as Hugh Davies' *International Electronic Music Catalogue*[72] or the *International Documentation of Electroacoustic Music* of Elektronisches Studio der Technischen Universität Berlin.[73]

- **GRM – Excel File (2012)**

The GRM has not digitised their archive, and has never developed a formal database. However, some works are registered in an Excel file.[74] The file includes some new comments and additional information: the information on the tape boxes has been checked and completed, and, where possible, the tapes chronologically classified. This work has been done by students.

- **Bibliothèque Nationale de France, Paris**

The Bibliothèque Nationale has catalogued the tapes in the Xenakis Archives including information on titles and handwritten notes on the tape boxes, information on the kind of tape, duration (if known), etc. Most tapes are digitised and available for listening in situ.

- **Other archives**

The Archive of the Centre Iannis Xenakis at Rouen University[75] in France and the Médiathèque Musicale Mahler[76] in Paris (founded in 1986 by Maurice Fleuret, former *Directeur de la Musique* of the French government and a friend of Xenakis) own some interesting documents including reviews and letters, but no original acoustic sources aside from commercial releases. Some interesting

[71] The full text can be found at: https://archive.org/stream/InternationalElectronicMusicCatalog/EMR2_3_djvu.txt, last access March 01, 2019.
[72] Davies, H. (1968) International Electronic Music Catalog, Paris.
[73] Hein, F. (1996) International documentation of electroacoustic music, Saarbrücken.
[74] Access by courtesy of Daniel Teruggi (director GRM), Yann Geslin (responsible for the archives at GRM) and Evelyne Gayou (responsible for research at GRM).
[75] http://www.centre-iannis-xenakis.org/, last visit April 15, 2019.
[76] http://www.mediathequemahler.org/, last visit April 15, 2019.

listings can be found there, for example, the list of film appearances ("filmographies") of Xenakis on the homepage of Centre Iannis Xenakis[77], and many concert programmes and concert critiques.

3.1.3. Scores, drafts, and other written sources

Xenakis used to plan his compositions and, for most compositions, did extended preparatory work, often in the form of a score using millimeter graph paper. These types of sources and different kinds of drafts can be found in the following collections:

- **Archives of the Xenakis family**

As the Xenakis Archive at the Bibliothèque Nationale de France was not a donation, Xenakis's daughter, Mâkhi Xenakis, took back the paper part in 2014 (only the tape archive is still at Bibliothèque Nationale de France). Rejecting the restrictive policy of Bibliothèque National, she now makes it available for research.[78] The archive contains many different documents, especially note books, scores and drafts, and montage plans, but also letters, contracts, etc. Much of this material is published for the first time in this study.

- **GRM Archives**

The GRM archive holds a few written sources, such as scores or performance instructions of compositions that Xenakis realised at the GRM, including some montage plans.

- **Other archives with secondary sources**

There are several Archives containing secondary sources that can help to reconstruct performance dates and other background information, for example, the Internationales Institut für Neue Musik, Darmstadt. It holds a collection of

[77] http://www.centre-iannis-xenakis.org/filmographie-xx-siecle, last visit April 14, 2019.
[78] I thank her for her generous support and the permission to publish many different documents for the first time here.

reviews proving the date of the simultaneous performances of two different versions of *La Légende d'Eer* in Paris and Darmstadt.

3.1.4. Oral sources

In the course of producing 50 radio features about the French electroacoustic music scene (mostly for the German radio station Westdeutscher Rundfunk WDR3), I interviewed many living protagonists, among them Radu Stan (Xenakis's assistant at Edition Salabert), François Bayle (Director of the GRM from 1966–1997), Daniel Teruggi (Director of the GRM since 1997 and Xenakis's technical assistant for some compositions).[79] These interviews are important sources for exploring historical contexts, technical conditions, and many other important issues.

3.1.5. Historical and technical context

It is important to understand specific media formats used for particular compositions in relation to the contemporary technical possibilities of the time in which they were produced. For example, the GRM only acquired their first 8-track machine in 1978. Therefore, it seems unlikely that there would have been any 8-track-tapes before that year, produced in this institution. The reverse is also true: Iannis Xenakis was known to be very open to and interested in the newest technical possibilities[80]. He normally used the most sophisticated machines available, e.g. the first 3-track machine for *Concret PH*. Xenakis realised the first 8-track composition at the GRM (*Bohor*), and used the new 12-track-machine without hesitation when he was invited to the Japanese radio studio at NHK[81] to compose *Hibiki-Hana-Ma*.

Xenakis did not speak about all aspects of his work. Having released his first article "La crise de la musique sérielle", published in 1955 in Hermann

[79] Furthermore: Guy Reibel, Michel Chion, Yann Geslin, Denis Dufour, Evelyne Gayou, François-Bernard Mâche, François Delalande, Mâhki Xenakis, Makis Solomos.
[80] Stan, R. (2008) Interview with the author in Paris, June 11, 2008: "he took the most powerful technique he could get".
[81] Nippon Hōsō Kyōkai, Japanese Broadcast Station.

Scherchen's *Gravesaner Blätter*[82], he found himself in a difficult situation, for some serialists (very prominently, Pierre Boulez, who held a powerful position in Paris) completely ignored his musical work for several years. In this article Xenakis had argued that serial music is just an example of stochastic music. Despite Xenakis's international success and reputation, his music was not performed at Boulez' concert series *Domaine musicale* for a long time. It might be seen in this context that, as late as 1985, Xenakis compared the early serialists with fascists.[83] In the context of serialism, Xenakis almost avoided mentioning the informal aspects of this work. He was instead focusing on the mathematical aspects of his work that became a kind of trademark for his music.[84] He did not significantly discuss the issue of non-synchronised stereo tapes in *Bohor* (1962)[85], except in an interview in 1981 (which was first published in 1997).[86] In addition, the extended double bass solo, included almost without any editing in *La Légende d'Eer*, was never publicly mentioned by Xenakis. It seems possible that he did not want people to know that his electroacoustic compositions could include improvisations by acoustic instruments. Presumably, this might have called into question the mathematical and scientific approach to music for which he was known.

Especially in electroacoustic music, it is of crucial importance to refer to all information in light of the contemporary technical history. A stereo version of a piece could not be produced before stereo techniques were implemented in the production studio. This is the case with *Concret PH*: in the GRM archive the piece is only listed as a stereo file, but stereo did not exist at the GRM studios in Paris at the time.

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[82] Xenakis, I. (1955) La crise de la musique sérielle, in: Gravesaner Blätter 1 (1955), Gravesano, 2-4.
[83] Xenakis, I. (1991) Television interview with Heinz-Otto and Volker Banfield at Kunsthalle Bremen, ARD, Germany.
[84] Friedl, R. (1994) Musik und Mathematik, in: Lettre international, Heft 24, Berlin.
[85] Karlheinz Stockhauen also never discussed the asynchronicity of the three tape machines (2 Stereo, 1 Mono) in *Gesang der Jünglinge*, foiling the serialist approach of the piece. Compare: Stockhausen, K. (1964) Texte zu eigenen Werken und zur Kunst Anderer, Vol.2, Dumont, Köln, 46.
[86] Xenakis, I., Delalande, F. (1997) Il faut être constamment un immigré. Entretiens avec Xenakis, Buchet/Chastel, Paris, 41.

The technological history of GRM, as described by Daniel Teruggi[87] and Evelyne Gayou[88] must be considered. For example, the question of the sound sources of *Bohor* cannot be resolved without relating it to the instrument making in Paris at the time (see below “Research chapter” on *Bohor,* especially 3.5.1. 22-34).

3.1.6. Presentation of the Critical Apparatus

As the critical apparatus, especially for *Bohor* and *La Légende d’Eer* is large, I follow the advice of James Grier, to present all primary sources in the annex.[89]

The annex also includes the spreadsheets of the primary acoustic sources with my comments and listening protocols. To guarantee a good readability I decided to include further sources directly in the text, and to give the references to secondary literature in the footnotes. Some visual sources are also shown in the main text in the interests of enhanced clarity.

[87] Terrugi, D. (2007) Technology and musique concrète: the technical developments of the Groupe de Recherches Musicales and their implication in musical composition, in: Organised Sound 12(3): Cambridge, 213–231.
[88] Gayou, E. (2007), Le GRM, Groupe de Recherches Musicales: Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris.
[89] See above (29, footnote 56).

3.2. Paradigm 1: *Persepolis* (1971)

3.2.1. The Sources

Xenakis's tape composition *Persepolis* is the acoustic part of his *Polytope*, realised in Persopolis, Iran in 1971. A short overview over his multimedia projects, called *Polytopes* is given in 3.4.3. *Persepolis* was a commissioned work for the Shah of Iran and was produced in the private studio Acousti in Paris on eight tracks. Studio Acousti no longer exists, and it is unknown where, or even if, any materials and/or documents are archived. Thus, the apparatus of analogue tapes for *Persepolis* is relatively small and therefore a good example with which to enter into the practical discussion. There are 27 tapes in the Xenakis Archives at the BnF, the performance versions of the 8-track tape by the Publishing house Durand/Salabert/Eschig, and six different commercial releases. Insightful visual materials, such as rudimentary 'scores' and mixing plans can be found in the Archives of the Xenakis Family (AFX). All acoustic and visual sources are listed in detail in the annex.

Persepolis has not yet been analysed in detail. Maria Anna Harley[90] gives a good overview of the *Polytopes* and their historical background but does not discuss the musical composition in detail. Daniel Teige's *Dead or alive. Aspects concerning the Performance and interpretation of Xenakis' Polytopes today* [91] focuses on the performance of Xenakis's *Polytopes* and discusses some sources but is not very precise (see below, 43f).

3.2.2. The philological questions

A limited number of sources has produced six commercial releases of *Persepolis*. Those versions must have been realised with the archived material.

The releases PER-01-Ph-F (1972) and PER-02-PH-JP (1974) are identical. The latter is the subsequently licensed version of the first release for

[90] Harley, M.A. (1998) Music of Sound and Light: Xenakis's Polytopes, in: Leonardo, Vol. 31, No. 1 (1998), MIT Press, 55-65.
[91] Teige, D. (2012) Dead or alive. Aspects concerning the Performance and Interpretation of Xenakis' Polytopes today, in: Kanach, S. (ed) (2012) Xenakis matters, The Iannis Xenakis series No. 4, Pendragon Press, Hillsdale.

the Japanese market. PER-06-KR has been released on the *Perihel series*, curated by me for the label Karlrecords as a result of this research. The remaining four versions differ significantly in length:

Name	Label	Signature	Media	Date	Tracks	Length
PER-01-Ph-F (= PER-02-Ph-JP)	Philips France	6521-045	LP	1972	stereo	22:50+23:50 = 46:40
PER-03-Fract	Fractal Records, Belgium	FractalOX	CD	2000	stereo	55:06
PER-04-RZ	Edition RZ, Germany	Ed. RZ 1015-16	2CD	2003	stereo	50:49
PER-05-Asph	Asphodel, USA	ASP2005	2CD	2005	stereo	60:40
PER-06-KR	Karlrecords, Germany	KR044	LP	2018	stereo	31:28+24:36 = 55:06

The philological question discussed is:

- From where does the difference in length of these versions come?

3.2.3. Technical Background

Persepolis was composed in 1971. 8-track tapes were limited to approximately 30 minutes at that time. Xenakis had to use two 8-track tapes: The end of the second tape (Figure 1) is annotated with 'FIN 2^{e} bob' meaning 'End of second tape bobbin'.

Figure 1: Detail from PER-VS-AFX-04

Xenakis had to use two 8-track tape recorders for the production and for the composition's performance. After approximately 30 minutes, the two tapes

were superposed to guarantee an inaudible transition. The lengths of the digitised single 8-track tapes which can be found at the Publishing house (PER-AS-EH-01) are:

- Tape 1: 31:29
- Tape 2: 24:38

The sum of the length of those two tapes is:

- 31:29 + 24:38 = 56:07

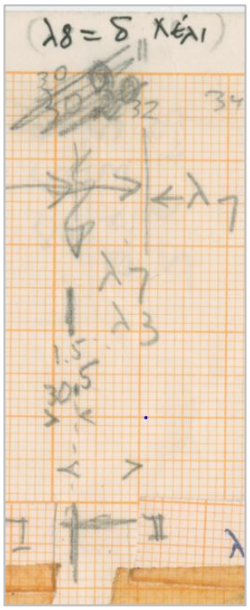

Figure 2: Detail of PER-VS-AFX-01.

Figure 2 shows a detail of the ‘score’; the Roman numerals ‘I’ and ‘II’ most probably denote Tape I and Tape II. The timecode is indicated above;

The dash between ‘I’ and ‘II’ in the lower part of the given detail probably indicates the overlapping period of the two tapes. If the number ’30.5’ means ‘30:30’ as the metric structure suggests (1 minute = 5 mm) and denotes the starting point of the second tape, the overlapping would be less than 0:59 (from 30:30 to the end of the tape at 31:29. This would result in an overall length of the composition of almost 55 minutes. (length of the tapes 56:07 – 0:59 = 55:08) This coincides with the length indicated in PER-VS-AFX-01 (Figure 3).

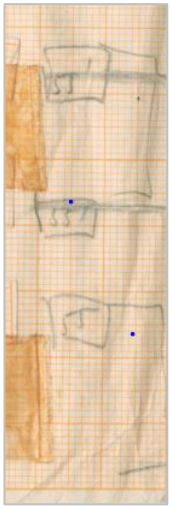

Figure 3: Detail from PER-VS-AXF-01.

3.2.4. Collation of the Commercial Versions

Persepolis was released on vinyl shortly after the premiere in 1972 (PER-01-Ph-F). The length of both sides (A: 22:50, B: 23:50) is 46:40. Compared to the 8-track tape PER-AS-EH-01, PER-01-Ph-F is 8:20 minutes – or 15 % – shorter (55:00 – 46:40 = 8:20)

This fact has not been mentioned in any literature on *Persepolis* so far. There is a possible reason for the shortening of *Persopolis*: in 1972, 12'-vinyl record sides could not be longer than 25 minutes without significant loss of sound quality; As the most dense part of the composition would have been at the end of side A, the loss of sound quality would have been even multiplied, as the reading velocity is there about four times lower. It looks like Xenakis was limited by the media conditions and simply shortened his piece.

Xenakis had worked out the details of the mixing on two different 'scores' for each 8-track tape individually on separate pages. These pages can be found in the Xenakis Family Archives: PER-VS-AFX-03 and PER-VS-AFX-04.

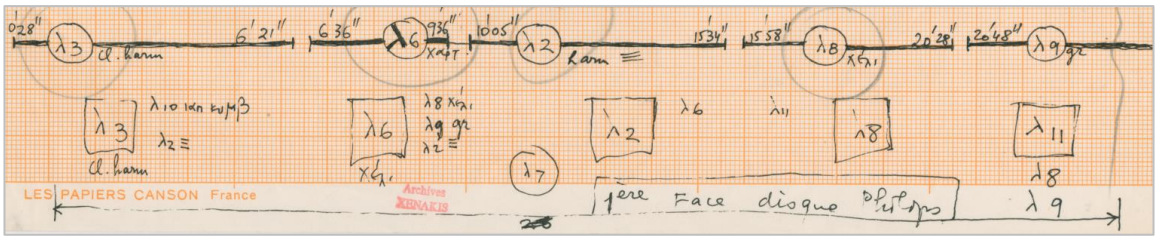

Figure 4: Detail from PER-VS-AFX-03.

A double arrow from ca. 1:10 to ca. 24:00 is located below the systems for the eight tracks (Figure 4) and labelled ‘1ère Face disque Philips’. The length is

- 24:00 – 1:10 = 22:50 = length of Side A of PER-01-Ph-F.

The same holds for the arrow from ca. 00:45” to 24:30 which can be found below the score for the second part of the composition (Figure 5).

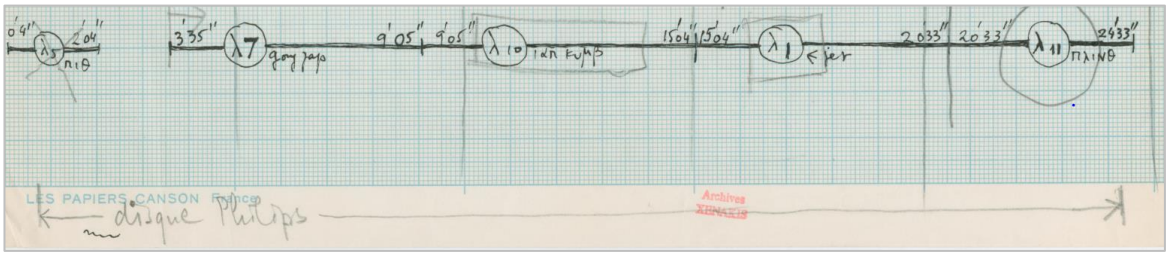

Figure 5: Detail from PER-VS-AFX-04.

The length is

- 24:20 – 0:40 = 23:40 = almost the length of Side B of PER-01-Ph-F.

In the vinyl release PER-01-Ph-F the following segments are missing:
~ 1:10 from the beginning,
~ 0:18 from the ending,
~ ca. 6 minutes from the middle part (compared to the overlapping 55 minute version).

The first CD with Xenakis’s *Persepolis* was released in 2000 on Fractal Records (PER-03-Fract). In the booklet is written: “Continuous version, without interruption between part I and part II, realized in June 1999 and mixed to stereo in April 2000 at the ‘Studio für Elektronische Musik des Instituts für Neue Musik der Staatlichen Hochschule für Musik Freiburg im Breisgau’, Germany.”

The length of 55 minutes is correct, however there is no indication of which tape was used reducing it to stereo. The mix is credited to Joao Rafael, who studied electronic music in Freiburg[92] and was not a sound engineer. The sound of the release lacks a professional quality.

Another CD was released in 2003 by Edition RZ (PER-04-RZ). The booklet offers: *Persepolis* (Version "Avec Mouvement", meaning 'with spatialisation'). In reference to the sources, this must be an error, as no spatialised version has ever been produced. Movements in the stereo panorama are not audible on the CD. The mix was realised by Daniel Teige, the length is 50:49, so more than four minutes are missing. As Teige stated in an interview, he cut them out in the middle by overlapping the two parts[93] – a fact he did not mention in his article on the performance of the *Polytopes* (Teige 2012). Here, Teige gives a scheme of the overlapping tapes with a resulting length of approximately 54 minutes. This contradicts the given sources as well as the version realised by Teige himself. On the other hand, his version was superior in terms of sound quality.

The most recent (double) CD (PER-05-Asph) was released by the label Asphodel (USA), including several remixes of the composition. The *Persepolis* version on CD 1 is 60:40 long, thus more than 5 minutes too long. Comparative listening reveals that the music is almost one whole tone too deep. This occurs, when a 48 kHz digital tape is read at 44,1 kHz.

The mix for this CD was produced by Daniel Teruggi at the Groupe de Recherches Musicales GRM in Paris. There, they standardly used 48 kHz for master tapes in order to achieve a better sound quality. As the Asphodel version is the only version that is longer, and has shifted in pitch, it is obvious that this kind of error occurred. In philological terms, the Asphodel version is corrupted.

[92]http://www.mic.pt/dispatcher?where=0&what=2&show=0&compositor_id=58&pessoa_id=134&lang=EN&site=ic, last visit March 28, 2019.
[93] Friedl, R. (2009) Polyphone Monophonie, in: Musiktexte 122 (2009), Köln, 12-17.

3.2.5. Genealogy

As Xenakis produced *Persepolis* in 1971 in the Acousti Studios in Paris, he noted the available tape machines (Figure 6).

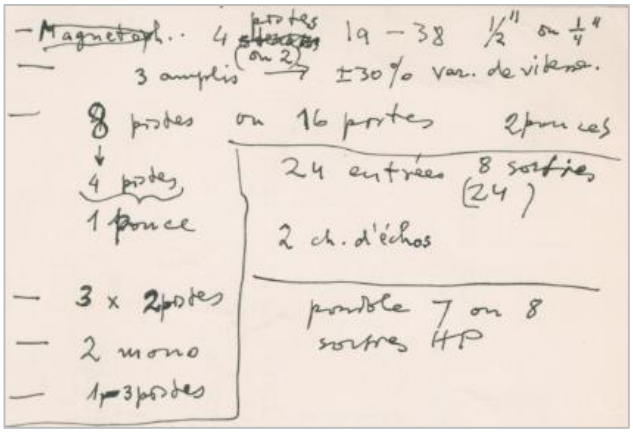

Figure 6: Details of PER-VS-AFX-06.

There was only one 8-track (16-track) tape machine available (‘8 pistes ou 16 pistes, 2 pouces’ means ‘8 or 16 tracks, 2 inches’). The same can be seen in PER-VS-AFX-05 (‘Enregistreur Ampex 16 pistes 8-4-3-2-1’, ‘Ampex’ is the brand of the tape machine). Xenakis’s production had to be done in three steps (Figure 7):

a) Preparation of the audio material (copies from older material, new recordings): The fixed elements can be found on PER-AS-BnF 23 to -26.

b) The audio material was – according to the ‘scores’ – transferred to 16 mono tapes, as listed in the genealogy and the annex.

c) The 16 mono tapes then had to be synchronised: the eight mono tracks of part I to the first 8-track tape, and the eight mono tracks of part II to the second 8-track tape. Clearly Xenakis could never have heard the complete 8-track-composition in the studio, as there was only one 8-track machine. But for the performance in *Persepolis* in Iran, Xenakis had two 8-track tape machines which allowed him to overlap the two

tapes in the middle of the piece, in order to not interrupt the musical flow.

All commercial releases had to be mixed down from the two separated 8-track tapes, that have also been digitised into separate files by the publishing house Durand/Salabert/Eschig (Figure 7).

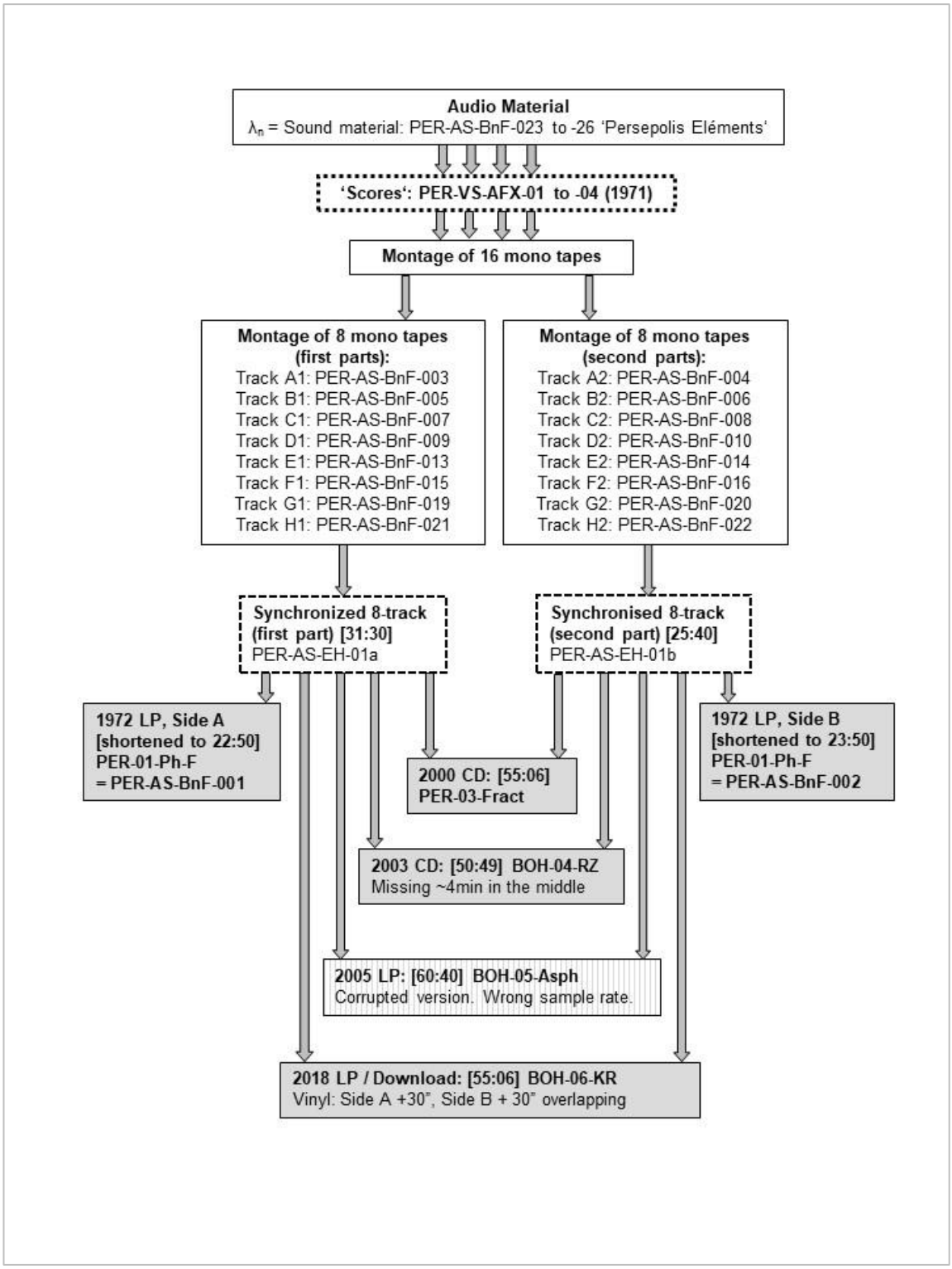

Figure 7: Genealogy of *Persepolis*

3.2.6. Conclusion

Philology of electroacoustic music can lead to significant results: for almost five decades no-one had mentioned that the famous *Persepolis*-record was more than eight minutes too short. Furthermore, we listened to the corrupted Asphodel version (over 140 critiques have been written on the release) without realising the corruption, and nobody mentioned the missing three minutes of the Edition-RZ version. These results are a motivation for the next two detailed chapters. Further philological consequences (implications for ‘the original’, ‘authorised version’, etc.) will be discussed in the conclusion of the thesis (5.).

3.3. Paradigm 2: *Bohor* (1962)

3.3.1. The Sources

Xenakis's tape composition *Bohor* fulfils the conditions for interesting philological research: there are four commercial releases, which differ significantly in length and sound quality. The rich fund of analogue tapes – more than 35, some digitised, some not – in the archives of the BnF and the GRM promises explanations of the origins of the different versions and answers to the connected questions: Which one is the "right one"? Are there different authentic versions? Etc.

There are also considerable visual materials, such as drafts, mixing notes, an apparent score, etc. Some of those materials have been digitised for this research, and are published here for the first time.

Several catalogues including notes on the different versions and mixes of the composition are also extant.

As discussed in 3.8., primary sources are listed and shown in the annex.

3.3.2. The philological questions

Bohor is the subject of at least six articles, discussed in detail below. All articles mention a piano or a prepared piano as one of several recorded sound sources of the composition. Listening to *Bohor* with my background as a pianist specialised in extended contemporary techniques, I cannot hear that the corresponding sounds have been produced with a piano. This and the differences between the commercial recordings lead to two main questions:

1) Can the alleged piano sound and other recorded sounds, used in *Bohor*, be found in the production tapes of the composition, or have other sound sources been recorded and used? And not least: What is the sound that has been erroneously identified as piano sound?
2) What are the reasons for the differences between the commercial releases of *Bohor*?

3.3.3. Historical Background I

Bohor was premiered in Salle des Conservatoires, Paris, on December 15, 1962.[94] At least six texts and analyses of *Bohor* have been published, but all – except Brody (1970) and Xenakis's own text (1968) – came more than forty years after the premiere:

- Xenakis (1968): *Témoignage d'un créateur*[95]
- Brody (1970): Liner notes on the LP *Iannis Xenakis Electroacoustic Music*[96]
- Harley (2004): *Xenakis – His Life in Music*[97]
- Kim, Borissov (2006): *Iannis Xenakis's Bohor* (1962)[98]
- Couprie (2006): *Une Analyse détaillé de Bohor* (1962)[99]
- Hünermann (2009): *Iannis Xenakis: Bohor*[100]
- Gibson (2015): *À propos de Bohor (1962) de Iannis Xenakis*[101]
- Turner (2015): *Why Bohor?*[102]

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[94] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 67.
[95] Xenakis, I. (1968) Témoignage d'un créateur, Pensée et création, Paris, 78-83.
[96] Nonesuch H-71246, USA 1970. LP. The release is often dated 1972 (e.g. on www.discogs.com), but as Alfred Frankenstein released his critique in 1970 (December 1970, High Fidelity Magazine number 25), quoting the liner notes, it seems to be evident, that the LP was already released in 1970. Even so, Bob Ludwig, who mastered the LP, wrote: I got to work personally with Maestro Xenakis in 1972 when I cut the (US) Nonesuch (H-71246) disk "Iannis Xenakis, Electro-Acoustic Music". http://www.mombu.com/music/music/t-xenakis-*Bohor*-the-last-time-5106581.html, last visit April 17, 2019.
[97] Harley, J. (2004) Xenakis: His life in music, Routledge, New York.
[98] www.music.columbia.edu/masterpieces/notes/xenakis/index.html, must have been published before 2005, as it is quoted in a lecture given by Pierre Couprie in 2005, later published as an article: Une analyse détaillée de *Bohor* (2006), last visit April 17, 2016. The same article by Kim, Rebecca is also quoted on www.iannis-xenakis.org as "KIM Rebecca, BORISSOV Liubo, Iannis Xenakis's *Bohor*", http://www.music.columbia.edu/~liubo/*Bohor*/present/ (consulté en mars 2011), last visit April 17, 2019.
[99] Couprie, P. (2006) Une analyse détaillée de *Bohor*, in: Solomos, M. (ed) (2005): Definitive Proceedings of the International Symposium Iannis Xenakis, www.iannis-xenakis.org, last visit September 17, 2019.
[100] Hünermann, T. (2006) Iannis Xenakis: *Bohor*, in: Paland, R. (ed) (2009) Iannis Xenakis - das elektroakustische Werk: Internationales Symposion Musikwissenschaftliches Institut der Universität zu Köln 11. bis 14. Oktober 2006, Vol. 14, Der Apfel, Wien.
[101] Gibson, B. (2015) À propos de *Bohor* (1962) de Iannis Xenakis, in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 83-96.
[102] Turner, C. (2015) Why *Bohor*? in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 97-108.

Moreover, James Mansback Brody's 1970 liner notes on the LP *Iannis Xenakis Electroacoustic Music*, released in 1970[103] by Nonesuch[104] might be an important source: at that time Brody was Xenakis's composition student at Bloomington University, where Xenakis held a position from 1967 to 1972. They were in personal contact and probably discussed the liner notes before releasing them.

The title *Bohor* was explained by the composer in 1968:[105] *Bohor* refers to Bors, who was a member of King Arthur's round table. In a programme note from 1986, Xenakis explains in more detail: "*Bohor* or *Bohor*t l'Essillié (*Bohor* the exiled), cousin of Lancelot of the Lake"[106]. The father of *Bohor*, who had the same name, was also a member of the Round Table, but he had lost his land. His son *Bohor* reconquered it together with King Arthur and became one of the most noble knights. In other sagas, *Bohor* takes the Holy Grail to the mythical island Sarras together with Lanzelot, Galahad and Parzival.

The autobiographic relation to the composer seems obvious. Hünermann points out that *Bohor* was known for his huge facial scar. Iannis Xenakis, too, had huge scars from combat during or shortly after the Greek Civil war[107], where he was seriously wounded in the face and lost his left eye. Hünermann even refers to the metallic sounds of the piece (jewelery, etc.) as a reference to fighting knights. Xenakis himself never explicitly referred to such a direct autobiographic dimension, but James Brody (1970) clearly referred to *Bohor* as "the name of a brave Knight of the Round Table*"*.[108]

On the other hand, Charles Turner's speculation that *Bohor* could have been intended as a reference to the famous physician Niels Bohr[109] seems rather

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[103] The release is often dated 1972 (e.g. on www.discogs.com), but as Alfred Frankenstein released his critique already in 1970 (December 1970, High Fidelity Magazine number 25), quoting the liner notes, it seems to be evident that the LP was released already in 1970. Even so Bob Ludwig, who mastered the LP, wrote: I got to work personally with Maestro Xenakis in 1972 when I cut the (US) Nonesuch (H-71246) disk "Iannis Xenakis, Electro-Acoustic Music". http://www.mombu.com/music/music/t-xenakis-*Bohor*-the-last-time-5106581.html, last visit April 17, 2019.

[104] Nonesuch H-71246, LP, USA 1970.

[105] Xenakis, I. (1968) Témoignage d'un créateur, Pensée et création, Paris, 78-83.

[106] Archives Xenakis, OM 33-11, supl.02, *Bohor* 001, translation by the author.

[107] Matossian, G. (2005) Xenakis, Moufflon Publications, Lefkosia, 36f.

[108] Brody, J.M. (1970) Iannis Xenakis Electroacoustic Music, LP, Liner notes on: Erato STU 70530 France. Nonesuch H-71246 États-Unis, backside of the cover, New York NY.

[109] Turner, C. (2015) Why *Bohor*? in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris,101.

daring. Turner argues that Bohr died on November 18, 1962, only a few weeks before the premiere of *Bohor*. All the preparatory tapes, however, are labeled *Bohor*[110], and the production had already begun in 1958.[111]

It is interesting that no source before 1968 explains the title. There is not even a secondary text source about *Bohor* older than 1968. This means that there was so far no known contemporary text source about the premiere or even the piece's performance in December 1962. The only known source was the quoted *Répertoire acousmatique* (BOH-CAT-GRM-03)[112]. Benoît Gibson underlines that even Maurice Fleuret, who was an important supporter of Xenakis's work, did not mention the concert in an article from December 27, 1962.[113] Astonishingly, he mentions *ST 10*, a chamber music composition by Xenakis, as part of "the last concert of the GRM". As *ST 10* was performed on December 19, 1962 (*Bohor*-TS-GRM-01), there have even been even doubts as to whether *Bohor* was in fact premiered in the GRM concert four days earlier.

The *Répertoire acousmatique* BOH-CAT-GRM-03 lists the following pieces as being performed in the same concert:

- Bernard Parmegiani: *Phonosophobe* 10 min 45 sec[114]
- Eduardo Canton: *Animal Animal* 10 min[115]
- Claude Ballif: *Point - Mouvements* 10 min 08 sec[116]

Including *Bohor,* the concert lasted no longer than 53 minutes.

Iannis Xenakis had left the GRM on June 1, 1962[117] because his concept for the *Concert collectif* had been rejected by his composing colleagues at GRM. Xenakis wanted to impose a structure on all music composed by the other musicians – a kind of meta-composition (Figure 8). The other composers did not accept.

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[110] For example BOH-AS-BnF-003, see annex.
[111] Gayou, E. (2007), Le GRM, Groupe de Recherches Musicales: Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris, 373. « Iannis Xenakis est le premier, en 1958, à enregistrer ses sons en stéréophonie, pour composer *Bohor* ».
[112] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris.
[113] Fleuret, M. (1962) Vingt-cinq ans après sa mort. Faut-il prendre congé de Ravel?, in: France Observateur, December 27, 1962, 17-18, cited from: Gibson, B. (2015) À propos de *Bohor* (1962) de Iannis Xenakis, in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 84.
[114] INA-GRM (ed), (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 66-67.
[115] Ibid., 72-73.
[116] Ibid., 68-69.
[117] Tournet-Lammer, J. (2006) Sur les traces de Pierre Schaeffer, Paris, 143.

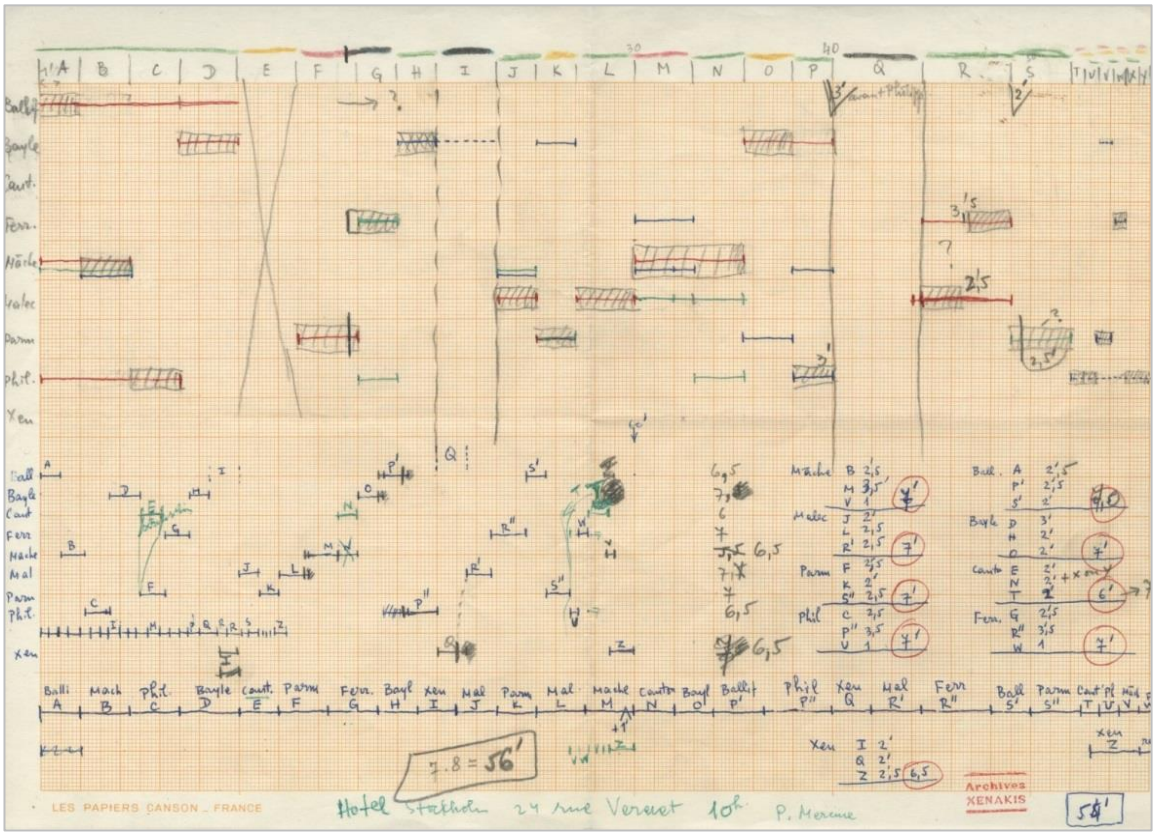

Figure 8: Iannis Xenakis, Plan de concert collectif, 1962, Archives Xenakis, OM-14-5, 65. Unpublished.

In the draft the abbreviations for Claude Ballif, François Bayle, Edgardo Canton, Beatriz Ferreyra, François-Bernard Mâche, Ivo Malec, Bernard Parmegiani, Michel Philippot, and the superpositions on the score of their musical material can be tracked.

Bohor's premiere happened half a year later, and was almost ignored. It seems as though nobody noticed the world premiere of *Bohor*. With the programme of this concert, published here for the first time (Bohor-TS-GRM-01), I found the proof that the premiere did indeed happen.

But the even more astonishing fact is that *Bohor*'s performance six years later in 1968 came to be thought of as the "biggest scandal"[118] in the history of electroacoustic music.

[118] Chion, M. (1972) Vingt années de musique électroacoustique, in Musique en Jeu 8, Seuil, Paris.

The occasion was the festival *Journées de Musique Contemporaine* de Paris, dedicated to the oeuvre of Edgar Varèse, Iannis Xenakis, Luciano Berio, and Pierre Henry.[119] Michel Chion reports: "The only big scandal in electroacoustic music was probably the performance of *Bohor* in 1968. Xenakis pushed the volume to such a level, that he blew two amplifiers, the audience reacting with a hysteria and panic, impossible to increase."[120]

Pierre Schaeffer wrote about this concert: "*Bohor*, […] his was no longer tiny embers, each with its own allure [tilt], this was an enormous burst of explosions [une enorme pétarade], an offensive accumulation of lancet jabs to the ear at maximum volume level."[121]

Xenakis argues that the high volume in the concert situation is not intended to provoke, but is necessary: "Especially concerning *Bohor*: it should penetrate the ears with sound. That's why it needs a high volume: that makes it possible to perceive all those minimal sonic details. I got the feeling that it needs more volume, simply to get into it."[122]

Pierre Schaeffer, founder of the GRM, did not like *Bohor* at all, even though Xenakis had dedicated the piece to him. Possibly the dedication was a conscious provocation, as the dissent with the GRM and Pierre Schaeffer had become evident in 1962, before *Bohor* was finished. But it is not clear whether Xenakis's dedication dates from 1962, or was only declared at the 1968 performance of the

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[119] La Revue Musicale N° 265-266 (1969), Les Journées de musique contemporaine de Paris, 25-31 octobre 1968: Varèse, Xenakis, Berio, Henry: oeuvres, études, perspectives, Paris 1969.
[120] Chion, M. (1972) « Vingt années de musique électroacoustique », in: Musique en Jeu 8, Seuil, Paris. « Le seul scandale de taille qu'ait connu la musique électroacoustique […] fut peut - être la diffusion de *Bohor* de Xenakis, dans la plaisante salle à l'italienne du Théâtre de la musique, lors des SMIP 1968. C'est que l'auteur avait poussé le niveau sonore à une puissance assez effrayante pour que deux amplificateurs y aient succombé, cependant que le public réagissait par une hystérie, une panique qu'on n'a point exagérée. »
[121] Schaeffer, P. (1981) in: Gerhards, H. (ed) (1981) Regards sur Iannis Xenakis, Editions Stock, Paris, 86; cited from: Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 18.
[122] Xenakis, I., Delalande, F. (1997) Il faut être constamment un immigré: Entretiens avec Xenakis, Bibliothèque de recherche musicale, Buchet/Chastel, Paris, Bry-sur-Marne, 138. « Et là, pour *Bohor* en particulier, c'est parce que cela demande une pénétration de l'oreille dans le son. Et il faut donc du volume. Pour entendre tous ces minimes détails des sonorités, j'avais la sensation qu'il fallait plus de volume. Pour entrer dedans, tout simplement. »

piece. Pierre Schaeffer must have understood this dedication as an elegant provocation, as he stated in 1969:

> I detest *Bohor*, even though Xenakis had the friendliness to dedicate it to me. I could even tell him that fair in the face, as he is one of the rare persons where that is possible. And he was not very surprised, as he knows pretty well what I like and that I persist in preferring the music he makes instinctively, rather than the one he wants to compose systematically.[123]

3.3.4. Technical Context I

Bohor is listed in the GRM catalogue[124] (BOH-CAT-GRM-03) as the first 8-track composition at the GRM.[125] 8-track did not mean, however, that the final composition was realised on an 8-track-tape. The first 8-track-machine arrived at GRM only in 1977[126]. In fact, Xenakis used 4 Stereo-tape-machines for *Bohor* (4 x 2 = 8 tracks).

An automated synchronisation of 4 stereo tape machines was technically not possible at that time. The machines had to be started simultaneously, but there was no way to avoid the tapes drifting out of synchronisation.[127] As *Bohor* is almost twenty-two minutes long, the variation of the tapes' lengths became evident during a performance. Xenakis never mentioned this problem until 1981,

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[123] Pierret, M. (1969) Entretiens avec Pierre Schaeffer, Paris, 23. « Je deteste *Bohor*, que Xenakis avait eu pourtant la gentillesse de me dédier. J'ai même pu lui dire ça en face, parce qu'il est un des rares avec qui ça soit possible. Et ça ne l'a pas tellement surpris, parce qu'il sait bien que je préfère, que je persiste à préférer la musique qu'il sait faire instinctivement à celle qu'il veut faire systématiquement. »

[124] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 67.

[125] There have been already 8-track compositions (8 x mono) in the context of John Cage „Project for Magnetic Tape" from 1952 (John Cage: „Williams Mix", Morton Feldman: „intersection"…).

[126] INA-GRM (ed), (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 285. It is unclear if 1977 is meant or 1978; Compare: Gayou, E. (2007), Le GRM, Groupe de Recherches Musicales, 373: Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris: "Puis arrive le magnétophone multipiste qui s'impose dans le studio de musique électroacoustique, comme dans tous les studios, à partir de 1961 : d'abord avec un 4 pistes Schlumberger 1 pouce, puis un Studer 8 pistes 2 pouces (1978)".

[127] Compare Straebel, V. (2008) Das Altern der elektroakustischen Musik, in: Forum Musikbibliothek (2008/4), Kromsdorf/ Weimar, 329: In John Cages „Williams Mix", the difference between the single tapes over a length of 4:15 is already 2 seconds.

when he discussed it in an interview with François Delalande, which appeared in print only in 1997: “Yes, *Bohor* is thought in a way, that this postponement that can be a few seconds, perhaps 10 or 20 seconds, is not crucial. No, No, … it’s intended.”[128]

3.3.5. The Sound Material

How did Xenakis realise the composition? Initially he recorded sound materials, and then manipulated and recombined those recorded sounds. The final piece consists of four stereo tracks played simultaneously. These four stereo tracks are called “piano”, “orgue”, “irak”, and “byzance”. The same naming can be found in all his drafts, concerning mixing as well as spatialisation.

Most articles[129] discussing this sound material conclude that “piano” stands for “prepared piano” because of some strange, piano-like sounds, and moreover that “orgue” stands for a transposed recording of a mouth organ from Laos. “Irak” is interpreted as the sound of jewellery and/or small percussion instruments from Irak. “Byzance” has also been associated with the sound of jewellery and bracelets.

In the drafts and notes at the Xenakis Archives[130] only the following names (and no others) are used for the final eight tracks:

	track		Abbreviation
Tape I	1	Piano	Pi
	2	Piano	pi
Tape II	3	Orgue	org
	4	Orgue	org
Tape III	5	Byzance	By
	6	Byzance	By
Tape IV	7	Irak	ir

[128] Xenakis, I., Delalande, F. (1997) Il faut être constamment un immigré: Entretiens avec Xenakis, Bibliothèque de recherche musicale, Buchet/Chastel, Paris, Bry-sur-Marne, 41.
« Oui, mais c'était conçu de manière à ce que le décalage qui aurait pu être de quelques secondes, peut-être de quelques dizaines de secondes, n'était pas crucial. Non, non ... c'était pensé comme cela. »
[129] See the mentioned analyses by Pierre Couprie, Charles Turner, Rebecca Kim and Benoît Gibson.
[130] Archives Xenakis, OM 33-11, annex.

	track		Abbreviation
	8	Irak	ir

Figure 9: Names of tracks in BOH-VS-AFX-01, BOH-VS-AFX-02 and BOH-VS-03.

Xenakis used the same names in his mixing schemes and drafts:

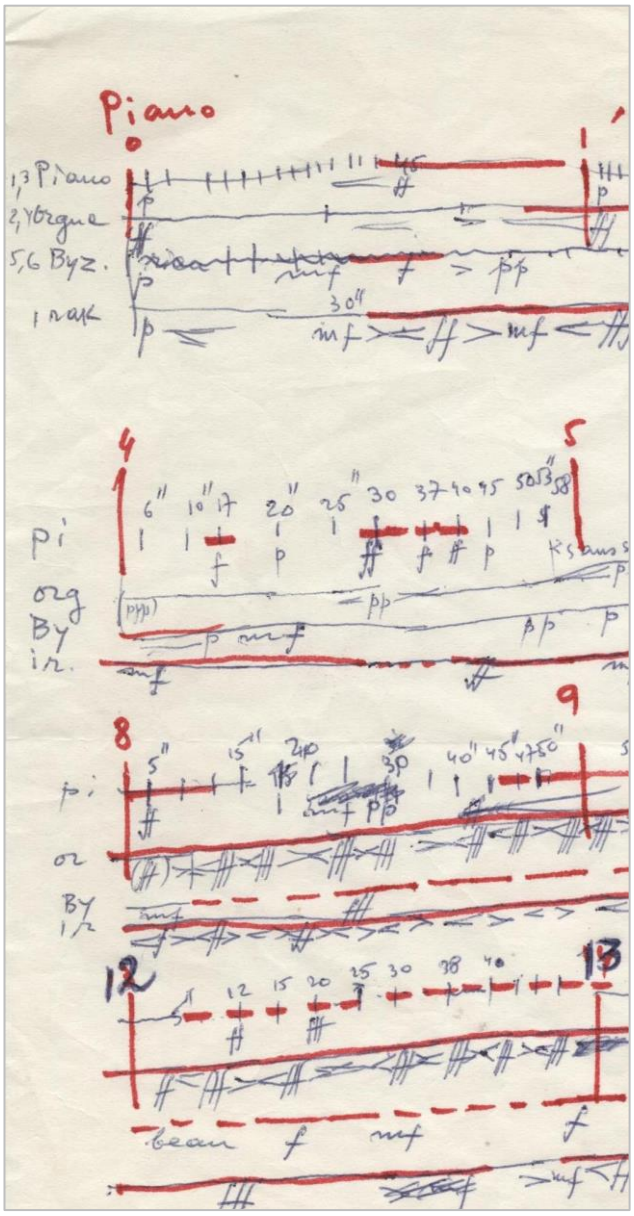

Figure 10: Detail of *Bohor*-VS-03

The tapes in the GRM archives are listed in BOH-CAT-GRM-02:

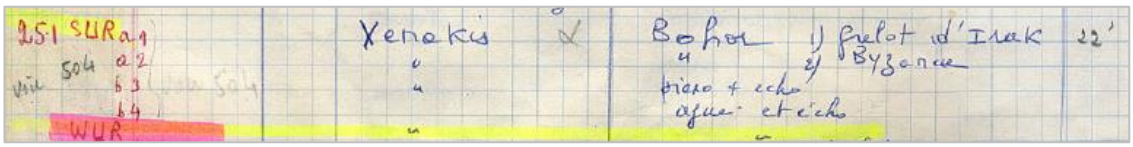

Figure 11: Detail of BOH-CAT-GRM-02

as follows:

251 SUR	a1	*Bohor*, 1) Grelot d'Irak
	a2	*Bohor* 2) Byzance
	b3	piano + echo
	b4	orgue et écho

Figure 12**:** Transcription of BOH-CAT-GRM-02

In the BOH-CAT-GRM-04 they are named:

251 SUR a	1/	a 1) Grelot d'Irak
	2/	2) Byzance
251 SUR b	1/	b 3) plan 0 + echo
	2/	4) orgue et écho

Figure 13**:** BOH-CAT-GRM-04

These indications are almost identical. “plan 0” looks like a misreading of “piano”. Pierre Couprie (Couprie 2006) mentioned an additional numbering on the boxes and a different order, when he visited the archives around 2005[131]:

1	251 SUR piano + echo [1,3]
2	orgue + écho [4,2]
3	Byzance: cloches + appl. Réverbérés [5,6]
4	Grelot d'Irak [7, 8]

Figure 14**:** Different naming in Couprie (2006)

The indications are nearly the same, except for a permutation of the numbering.

The names seem to suggest what should be on the tapes:

1) A stereo piano recording (BOH-AS-GRM-001)
2) A stereo organ recording (BOH-AS-GRM-002)
3) A stereo recording of some Byzantine jewelery & percussion sounds (BOH-AS-GRM-003)

[131] Couprie, P. (2006) Une analyse détaillée de *Bohor*, in: Solomos, M. (ed) (2005): Definitive Proceedings of the International Symposium Iannis Xenakis, www.iannis-xenakis.org, last visit September 17, 2019.

4) A stereo recording with some Iraqi jewellery & percussion sounds. (BOH-AS-GRM-004)

The examination and comparison of the tracks[132] suggests that the names are not to be taken literally. Each track shows strong echo and reverberation effects, probably combined with filtering. In detail:

1. Piano + echo (BOH-AS-GRM-001): The track does not sound like a piano, but it strangely refers to a piano sound. Most authors make reference to "probably prepared piano" or "prepared piano".

2. Organ Sounds (BOH-AS-GRM-002): Since James Brody mentions the sounds of a Laotian mouth organ in 1970[133], almost every author explains these sounds as transpositions of the recording of a mouth organ from Laos. Benoît Gibson even tries to reconstruct it via transposition and transcription of an imaginary original recording. He writes: "In *Bohor*, Xenakis improvises by playing himself the Khène [name of the Laotian mouth organ]".[134]

3. Byzance (BOH-AS-GRM-003): The track consists of bell-like sounds. Some authors mention that the term "Byzantine chant"[135] can be found in the sources, but I could neither find it there nor hear it in any acoustic source.

4. Irak (BOH-AS-GRM-004): This track sounds like different kinds of small bells and small metal percussion or jewellery.

Through listening, it is obvious that these four stereo tapes are not recorded directly, but are the result of editing, cutting, and mixing of other recordings, before echo and reverb have been added.

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[132] I used the official 8-track version, provided by Salabert in 2009.
[133] Liner notes on Nonesuch LP, 1970.
[134] Gibson, B. (2011), The instrumental music of Iannis Xenakis: Theory, practice, self-borrowing, The Iannis Xenakis series, Vol. 3, Pendragon Press, Hillsdale, NY, 87.
[135] James Harley quotes the article by Rebecca Kim and Liubo Borissov, the given internet source is no longer available and not published elsewhere, in: James Harley, Continuities and Changes in the Electroacoustic Music by Iannis Xenakis, in: Paland, R., Von Blumröder, C. (eds) (2009) Iannis Xenakis: Das elektroakustische Werk, Wien, 19.

In the archives at the Bibliothèque Nationale in Paris, there are at least 16 tapes that can be classified as material or production tapes:

Audio Source	notes on the box	notes on the bobbin
BOH-AS-BnF-007		prise de son original
BOH-AS-BnF-008	orgue et cl. grec(?)	prise de son original
BOH-AS-BnF-019	orgue et affolant I	Nagra sans réverbération
BOH-AS-BnF-020	orgue et affolant II (suite)	Nagra sans réverbération
BOH-AS-BnF-021	byzantin+Irak (sans echo)	
BOH-AS-BnF-006	Bracelets	
BOH-AS-BnF-011	Piano	copie sans réverbération
BOH-AS-BnF-012	Piano	copie sans réverbération
BOH-AS-BnF-013		copie sans réverbération
BOH-AS-BnF-014		copie sans réverbération
BOH-AS-BnF-004	bracelets+byzantin(?)	stéréo démultiplié
BOH-AS-BnF-005	cloches(?)+orgue+affollants	stéréo démultiplié
BOH-AS-BnF-017	affolants, bracelets(?) (Irak et byzantin)	stéréo démultiplié, la bande 1 est vidée
BOH-AS-BnF-018	bracelets et cloches	stéréo démultiplié,
BOH-AS-BnF-003	*Bohor* Elément 1, 2, 3	
BOH-AS-BnF-016		pseudo montage;

Figure 15: Naming of material tapes

The mentioned sound “elements” are:

- “bracelet + byzantine” [bracelet (wristband) + byzantine]
- “cloches (?) + orgue + affolants” [bells + organ + perturbing (OR: confusion)]
- “bracelets indonesiens” [Indonesian bracelets]
- “cloches sans écho” [bells without echo]
- “Affolants, bracelets(?) (Iraqi et Byzantine)” [perturbing (OR: confusion), bracelet (Iraqi and byzantine]

- “piano” [piano]
- “orgue et affolant” [Organ and perturbing]
- “orgue et cl.grec(?)”: orgue and Greek bells[136]

So, the material quoted here is:

- Indonesian bracelets
- Byzantine bracelets
- Iraqi bracelets
- Organ
- Bells
- Greek bells
- Piano
- Perturbing or confusion (perhaps just mixed material?)

The first ten of the mentioned material tapes (see table above) seem to be classified as original sound recordings (“*prise de son originale*”). Four tapes have the note “*stereo démultiplié*” (BOH-AS-BnF-017, BOH-AS-BnF-018, BOH-AS-BnF-005, BOH-AS-BnF-006), which probably means that the original recorded sounds have been “multiplied”: first copied on several tapes, then potentially transposed, and finally superposed or multiplied by the Morphophone (see below 3.3.7). This was the densification technique that Xenakis had developed as early as 1956 for his first tape composition *Diamorphoses*. Xenakis composed textures of ascending density that he then used as sound material. He “multiplied” series of prerecorded sounds by playing several asynchronous versions of it simultaneously. The result was a texture. He did the same again with the new result, so that the density increased step by step exponentially.

Another hint is a hand-written list of recordings for *Bohor*[137], indicating colours of the non-magnetic leader tapes to mark single recordings (Figure 16):

[136] Bibliothèque National, Cité Mitterand, médiathèque, DONAUD 0604-504 to DONAUD 0604-521.
[137] BOH-VS-AFX-02, see annex.

e.g. “Bande II: Byzantine – entre deux roses” (tape 2: between two pink tapes) or “Bande V: cloches – entre deux jaunes” (tape 5: between two yellow tapes), etc.

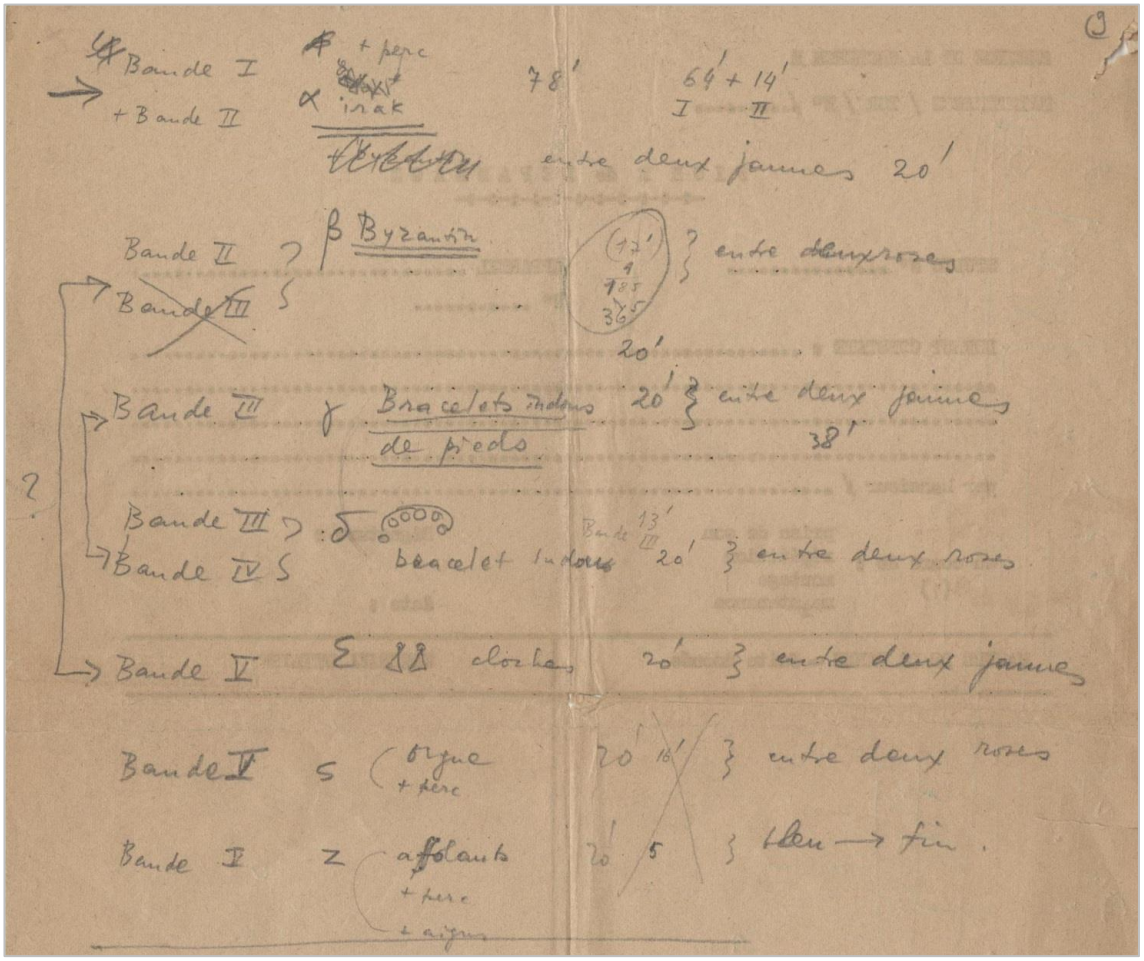

Figure 16: list of original recordings for *Bohor*, Details of BOH-VS-AFX-02.

Regarding the material on the final stereo tapes, it can be said that different recorded sounds have probably been transposed by changing the playback speed of the tape machine, then possibly layered for densification, and finally sending the result through an effects machine, adding echo, reverberation, and filtering. The filtering was probably not a separate effect but might be a sound property of the reverb and echo applied.

Concerning the original sounds, it can be stated that if the piano sounds were indeed made with a prepared piano, it is irritating that Xenakis never called them “prepared piano”. The same holds true for the organ. Xenakis never mentions a “mouth organ” or even a “Laotian mouth organ”. This is perplexing, as he very clearly mentions “Iraqi bracelet”, “bracelets indonesiens”, etc.

3.3.6. Institutional Context

There seems to be a simple explanation: almost from the outset, the GRM-composers have been very interested in recording interesting new sounds, and often used the prepared piano. The sounds produced directly on the strings of the piano often sounded so surprising, that the audiences believed they were hearing electronic sounds. This effect was welcome, as the GRM composers wanted to be honored for their electroacoustic music, not for recording instruments. So, they often kept this secret.[138] Pierre Schaeffer later even claimed that it was Pierre Henry who had invented the prepared piano simultaneously with John Cage,[139] which is not true.[140]

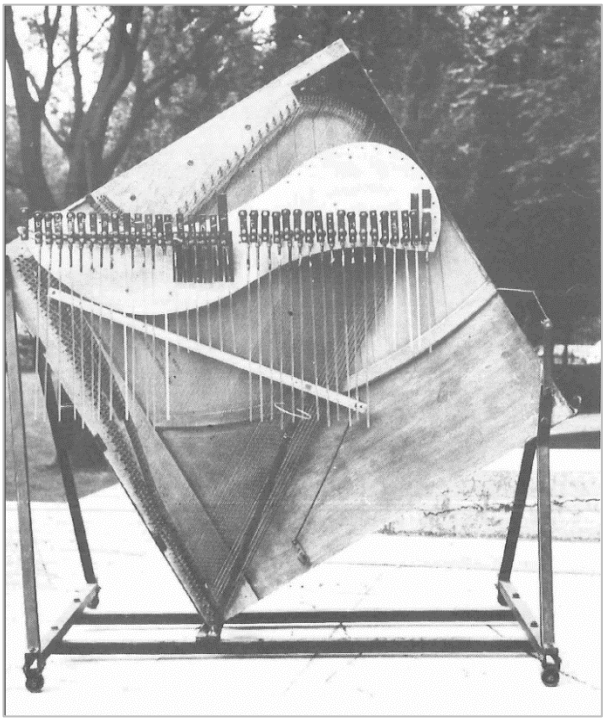

Figure 17: piano-tige by the Baschet brothers.

In the middle of the 1950s, the brothers Bernard and François Baschet began building their own instruments in Paris and were very successful. They were explicitly inspired by Musique concrète[141] and built instruments like the “piano-tige”, at times using parts of old pianos (Figure 17). They succeeded in migrating the piano-keyboard techniques and applying them to completely different sound objects.

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[138] This is shown especially for piano sounds in: Friedl, R. (2013), Das Klavier in der elektroakustischen Musik, radio script Westdeutscher Rundfunk Köln, Germany, Archivnummer: 5187 849, Broadcast October 16, 2013.

[139] Schaeffer, P. (1974) La musique concrete, Paris: Pierre Schaeffer mentions that he attended together with Pierre Henry the first prepared piano concert John Cage performed in Paris in the early fifties. This concert, however, happened in 1949.The first use of prepared piano by Pierre Henry was in 1950. Furthermore, John Cage’s Bacchanale was composed in 1940.

[140] Friedl, R. (2013), Das Klavier in der elektroakustischen Musik, radio script Westdeutscher Rundfunk Köln, Germany, Archivnummer: 5187 849, Broadcast October 16, 2013.

[141] Frauensohn, D. (2007) Bernard Baschet, Chercheur et sculpteur de sons, L’Harmattan, Paris, 41.

In some instances, the Baschet brothers not only used the piano's soundboard, but also the strings and parts of the keyboard. They combined them with different resonators, including huge iron sheets (Figure 18).

Possibly their most famous instrument was the Crystal Organ ("Orgue de Cristal") (Figure 19): The sounding elements are metal rods that are each connected to glass rods. If the glass rods are softly excited with wet fingers, the vibration is transmitted to the metal rods, which then produce defined pitches, amplified with the help of a huge metal sail as resonator.

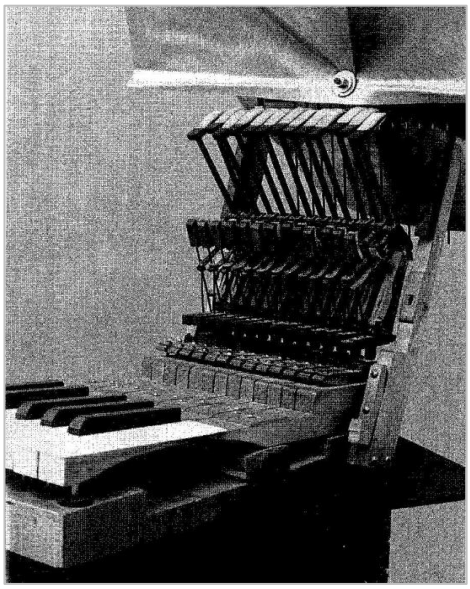

Figure 18: Piano à une octave, 1962.

Figure 19: Orgue de cristal, 1952.

Baschet[142] published detailed construction plans and photos of many instruments. Bernard and François Baschet founded the group *Les Structures Sonores* together with the composer Jacques Lasry and his wife Yvonne Lasry, a musician. They started to promote the instruments and to play concerts worldwide. In 1958, when Iannis Xenakis designed the Philips Pavilion at the World's Fair Exposition in Brussels, the Baschet brothers exhibited their instruments in the French Pavilion of the same exposition. In 1957 they released

[142] Baschet, F. (1999) Les sculptures sonores: The sound sculptures of Bernard and François Baschet, Soundworld Publishers, Chelmsford.

a first LP[143] and they also performed and recorded regularly at the French radio house, where the GRM was situated.

Their music was presented in the same radio features as musique concrète in the fifties[144]. Baschet instruments have been in the studios of the French Radio ORTF from 1961 on, or earlier, as photographs reveal[145]. It must be underlined that Pierre Schaeffer's concepts around musique concrète were never limited to electroacoustic music but should be applicable to all kinds of music[146]. Schaeffer invited Bernard Baschet to join the GRM, which was a part of the ORTF. Bernard Baschet joined the GRM on December 14, 1962 as director of the research department,[147] and was director of the GRM from 1964 to 1966.

It is beyond question that Xenakis knew the instruments of the Baschet brothers, who tried actively to convince composers to write music for their constructions. Many composers of the GRM did so, for example Luc Ferrari,[148] Bernard Parmegiani,[149] Guy Reibel, François Bayle,[150] and Beatriz Ferreyra[151].

Listening to recordings of the Baschet instruments[152] immediately evokes the sound qualities of *Bohor*. The strange vibrato of the so-called "piano sounds" in *Bohor* could not be created with prepared piano techniques or by playing on the strings, as the high tension of the piano strings does not allow such vibrato ranges. It would be most easily achieved by using an iron sheet as a swinging resonator.

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[143] https://www.discogs.com/artist/485780-Structures-Sonores-Lasry-Baschet, Les Structures Sonores (1960), LP, Président – KVP 118, Paris. Last visit : April 19, 2019.
[144] Tournet-Lammer, J. (2006), Sur les traces de Pierre Schaeffer: Archives 1942-1995, Fenêtre sur les archives de l'INA, Institut national de l'audiovisuel; Documentation française, Paris.64.
[145] Radio France, 2018.
[146] Schaeffer, P. (1966) Traité des objets musicaux, Paris.
[147] Baschet, F. (2007), Mémoires sonores, Ecarlate, Paris, 173.
[148] Luc Ferrari, *Bachiques*, 1963
[149] Bernard Parmegiani uses an "Instrument Lasry-Baschet" in his famous *De Natura Sonorum*, 1976, compare: score in INA-GRM (ed), (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris.
[150] Bayle, F. (1967) *Rebus*.
[151] Ferreyra, B. (1967) *Demeures aquatiques.*
[152] A lot of recordings can be found at https://www.pinterest.com/pin/305330049716134789/, last visit April 18, 2019; Or on LP: François Baschet And Bernard Baschet – Structures For Sound, BAM – LD 087, Vinyl, LP, 10", Trifold, France 1965.

The sounds, described in *Bohor* as “Organ”, strongly resemble the sounds of the “crystal organ”. The crystal organ also has a range of 5 octaves and can play in a much lower register than the Laotian mouth organ.

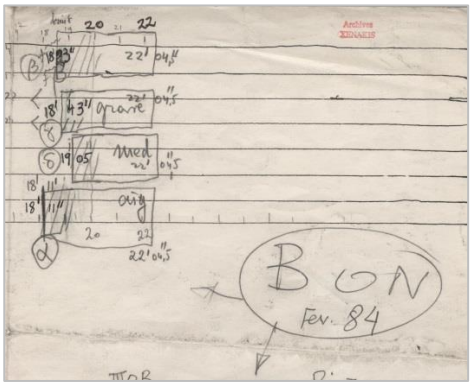

Figure 21: Detail of BOH-VS-06 [AFX - OM33-11-15bs]

During the last three minutes of *Bohor*, all tracks, one after the other, change to a broad noise, called “white noise” in most analyses. This sound is probably made with iron sheets, known in orchestras as “thunder sheets”. The final passage of *Bohor* sounds like these thunder sheets. Xenakis himself classified the three layers as high (“aigue”), medium (“medium”) and low (“grave”) (Figure 21). He may have also transposed the thunder sheet sounds.

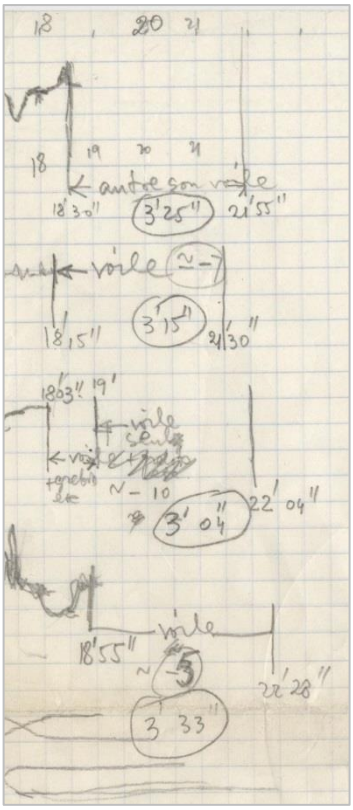

Figure 20: Detail BOH-VS-01 [AFX - OM33-11-8]

The Baschet brothers frequently integrated different kinds of thunder sheets as resonators in their early instruments. In some drafts Xenakis calls the final sounds of *Bohor* “voile”,[153] in English: sail (Figure 20). The iron sheets of most of the Baschet instruments look like sails. Xenakis calls the sound in the upper system “other sail sound” (“autre son voile”). The photograph of a “tôle sonore”

[153] BOH-VS-01, see annex.

(sheet sonore) at the GRM, constructed by Bernard Baschet can be found in the chapter “sounds for the music” in “*Les musiques éléctroacoustiques*”[154]

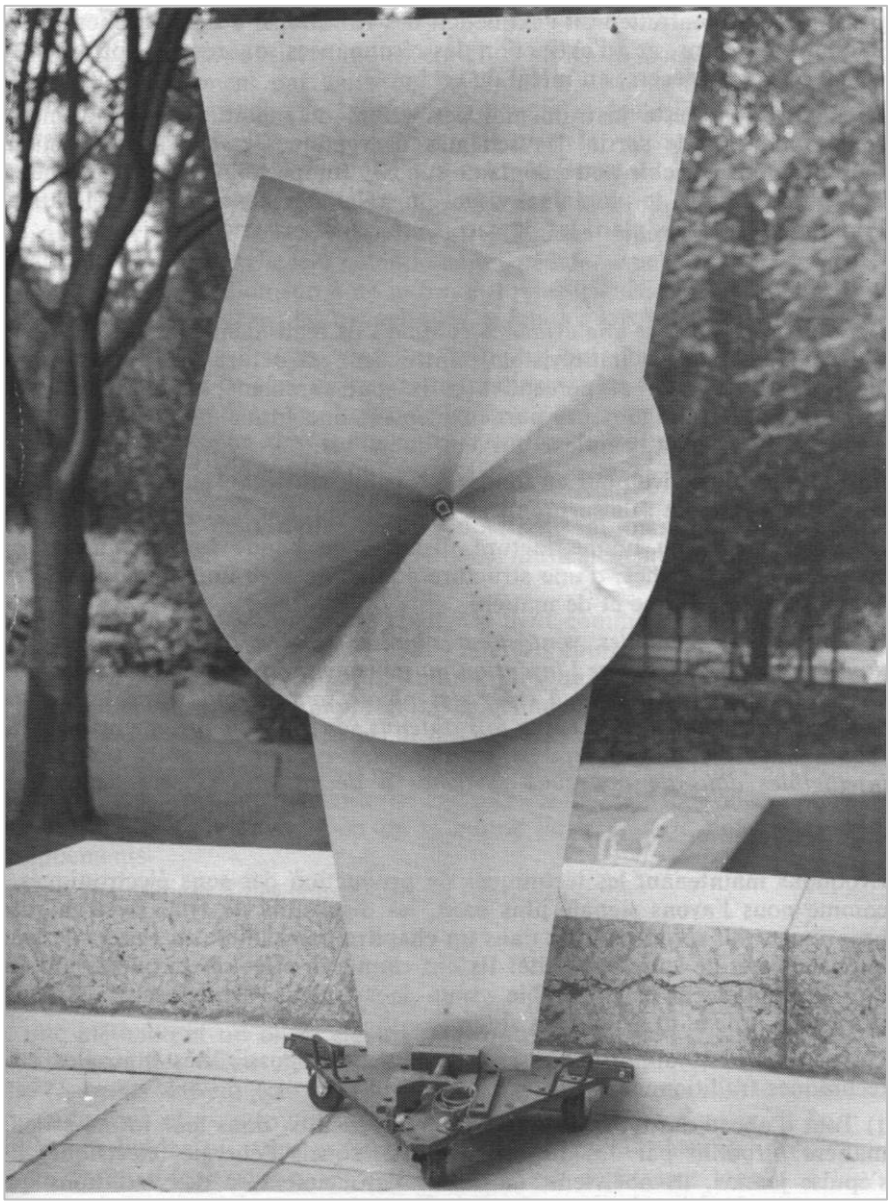

Figure 22: "tôle sonore" at the GRM.

It is likely that Xenakis never recorded a prepared piano and never played a Loatian mouth organ, but that he instead used the Baschet instruments. The names of his tracks could refer to that:

- piano: *piano-tige* or another Baschet instrument with piano

[154] Chion, M., Reibel, G. (1976) Les musiques électroacoustiques, ina-GRM, Paris, France, 215.

- organ: crystal organ
- voile: the metal sheets of the Baschet instruments

Listening to all the listed audio sources / material tapes reveals (see annex) that there is no piano recording. Instead, one finds the mentioned sounds of the Baschet instruments, especially:

- The so-called “prepared piano sounds” sound clearly like Baschet instruments (low tension of the piano strings, vibrato via metal sheets), as can be heard on the tapes titled “piano” (BOH-AS-BnF-011; BOH-AS-BnF-012 after 19:24 and BOH-AS-BnF-003 after 15:30, especially after 23:50).

- The ending sounds called “*voile*” may be metal sheets: (BOH-AS-BnF-007 after 15:08 an, BOH-AS-BnF-003 after 24:42).

- The “Laotian mouth organ sounds”: There might be an original Laotian mouth organ recording on BOH-AS-BnF-007 after 11:40, but it could also be a crystal organ, as no breathing can be heard. The deep sounds after 6:00 on BOH-AS-BnF-005 might be an original recording of a *cristal orgue* or a down-pitched Laotian mouth organ.

This shows that neither prepared piano nor white noise were used in *Bohor*, and the transposed Laotian mouth organ might be a transposed Laotian mouth organ or crystal organ. To conclude, prepared piano and white noise have not been used in *Bohor*. It seems probable that Xenakis instead used Baschet-Instruments or Baschet-inspired instruments at the GRM. Furthermore, he or somebody else recorded the Laotian mouth organ or crystal organ sound material. All sounds are recorded sounds from unconventional instruments.

3.3.7. Technical Context II

It is not clear where Xenakis recorded his sounds. On the two tapes BOH-AS-BnF-019 and -020 is noted “Nagra”. This stands for the first portable tape

machine, Nagra III Kudelski, that arrived in 1958 at the GRM[155], exactly when Xenakis began work on *Bohor*. Evelyne Gayou described it as a "revolutionary arrival": the composers now had the ability to record outside the studios.

Concerning the electronic treatment of the recorded sounds, it is again interesting to consider the technical history at GRM. In October 1961, the first electronic band pass filters arrived. Also, the first 4-track-tape-machine was acquired, and the new type of *Morphophone* was finalised. The Morphophone was a sophisticated construction to successively change the *Gestalt*, the characteristics of a looped sound. It was equipped with ten audio heads that could read the sounds in different positions simultaneously. The result could be recorded again on a looped tape. The sound could thus be transformed by ten "echo" effects gradually. This sound transformation was called "morphological transformation of a sound by multiplication" ("*transformation de la morphologie d'un son par multiplication*"). [156]

Figure 23: Morphophone with ten audio heads, GRM 1961.

[155] Gayou, E. (2007) Le GRM, Groupe de Recherches Musicales: Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris, 373.
[156] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 275.

As Xenakis used the term "*démultiplié*" several times in his listing of material tapes (BOH-AS-BnF-017, BOH-AS-BnF-018, BOH-AS-BnF-005, BOH-AS-BnF-006), it seems to be obvious, that he applied the "multiplication" with the aid of the Morphophone (Figure 23). This could be the reason for the multiple echos as well as the reverb effect. The Morphophone also had the capability of applying different filters on the different outputs of the audio heads. This might be an explication of the multifaceted delays on BOH-AS-BnF-016.

3.3.8. Genealogy

Reconsidering the different mixes and tapes now allows a more precise genealogy of the composition and the different mixes.

Most authors quote from the *Répértoire Acousmatique* (BOH-CAT-GRM-03) that three versions of *Bohor* exist:

1. an original 8-track version, consisting of four Stereo Tapes: BOH-AS-GRM-001, BOH-AS-GRM-002, BOH-AS-GRM-003, BOH-AS-GRM-004
2. reduction to 4-track, 1 inch: BOH-AS-GRM-008
3. reductions to stereo (unclear)

Entry (2) in the *Répértoire Acousmatique* is somewhat misleading, as it seems to imply that there exists a stereo and a 4-track reduction made in 1962. The *Registre des originaux* refers to a 4-track reduction ("WUR"), but only as a reference to the version realised in 1968, listed under a new number in the same register: 504 WUR[157]. In the newer excel file of the GRM, no reduction to stereo or 4-track from 1962 is listed. All stereo-versions in the archives are dated, and there is no version from 1962. So, the first 4-track reduction and the first stereo-reductions were most likely made in 1968 (Figure 24). Also, the first 4-track tape machine first arrived at GRM in 1962,[158] and was used for the first time to realise the mix of Luc Ferrari's *Tautologos I*, premiered in July 1962[159]. Xenakis had

[157] WUR stands for: 4-track 1 inch.
[158] Gayou, E. (2007) Le GRM, Groupe de Recherches Musicales: Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris, 373.
[159] INA-GRM (ed) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 266.

already left the GRM at the beginning of June 1962, and the entry of the premiere in December 1962 clearly states: 4 stereo-tracks.

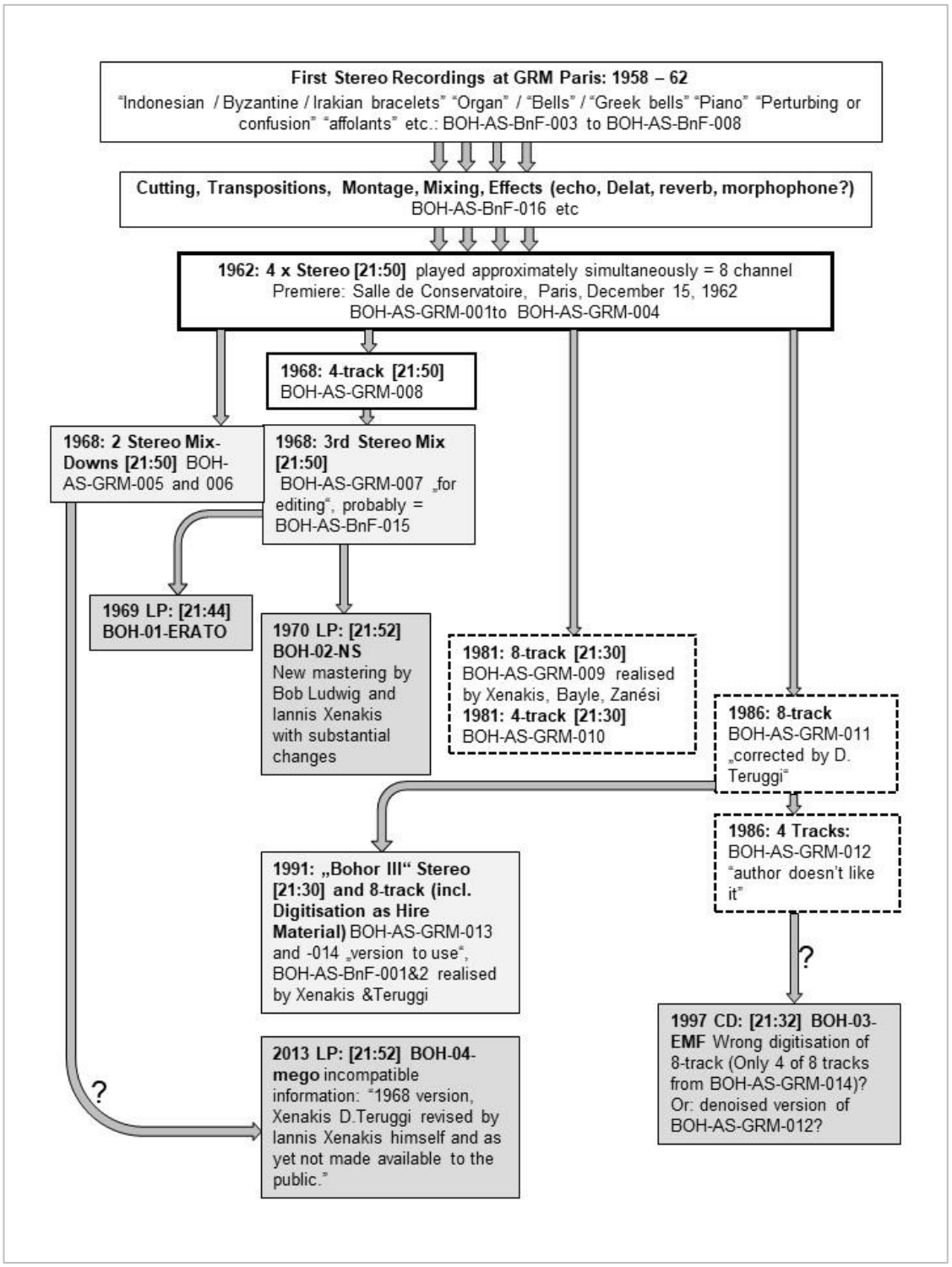

Figure 24: Genealogy of *Bohor*.

Bohor was almost forgotten for six years, until 1968, when the festival *Journées de Musique Contemporaine de Paris* was dedicated to the music of Xenakis, among others. Some transfers of the original 4 stereo-tracks happened for this occasion.

Independent transfers to stereo and to a 4-track-tape have been made. The GRM *fichier oeuvres 2012* (BOH-CAT-GRM-04) lists three stereo versions, the 3rd one made from the 4-track version ("*version stéréo d'après 4 pistes*"):

BOH-AS-GRM-005	Aug 68, A: Stéréo 38 cm/s d'après les 4 stéréos 251 SUR
BOH-AS-GRM-006	B: Dit ci-dessus
BOH-AS-GRM-007	C: version stéréo d'après 4 pistes

Figure 25: Mix-Downs 1968.

These stereo-versions were probably made when *Bohor* was to be released on LP as a part of the 5LP-Box *Xenakis* by the French label *ERATO* in 1969 (BOH-01-ERATO). How the 4 Stereo-tracks have been reduced to stereo is not documented. The US label *Nonesuch* licensed the 5th LP of this 5LP-Box for the US market and released it as *Iannis Xenakis - electroacoustic music* (BOH-AS-37-LP [Nonesuch]). This version differs slightly from the *ERATO* version, due to a new mastering by Robert Ludwig[160]:

> I am a mastering engineer, we used to cut the vinyl disks […]. I got to work personally with Maestro Xenakis in 1972 when I cut the (US) Nonesuch (H-71246) disk "Iannis Xenakis, Electro-Acoustic Music". They licensed the disk from Disques Erato in France. They no longer have this license so there would be no further re-issues of this through Nonesuch Records. The disk has interesting liner notes from James Mansback Brody on the back. We used a 1/4″ non-Dolby CCIR tape copy of the Erato master from which their original disk was cut.

[160] Also known as Bob Ludwig, but on classical music releases, he is credited as "Robert Ludwig" or "RL".

I will never forget when Xenakis came to my mastering studio for the session, we had a great time. Under his exact supervision, he had me manually slowly raised the volume of the last few minutes in a giant crescendo! It was difficult to cut into vinyl! This artistic manipulation, under the direction of the composer, was NOT on the original Erato disk, nor do I believe on any subsequent issues! The ending DOES cut off on purpose![161]

The Nonesuch release is often dated 1972 (e.g. on www.discogs.com), but as the US-American critic Alfred Frankenstein released a review in 1970, it is evident that the LP had already been released in 1970. The liner notes by Xenakis's student, James Brody, also mention the "giant crescendo". Brody describes *Bohor* as: "monistic with internal plurality, converging and contracting finally into the piercing angle of the end."[162] Thus, the version on the Nonesuch vinyl should be the one preferred by Xenakis.

In 1981 *Bohor* was programmed for a concert. As the first 8-track-tape machine had arrived at GRM in 1978, it was convenient to transfer the four stereo-tracks to a definite synchronised 8-track version, making it easier to perform live. The transfer in 1981 to 8-track (BOH-AS-GRM-009), but also a transfer to a 4-track tape (BOH-AS-GRM-010), was made by François Bayle, Christian Zanési, and Iannis Xenakis (Figure 26: WWUR 1+2 lists: Xenakis, Bayle, Zanési (Studio 116a)) – none of whom were trained audio engineers.

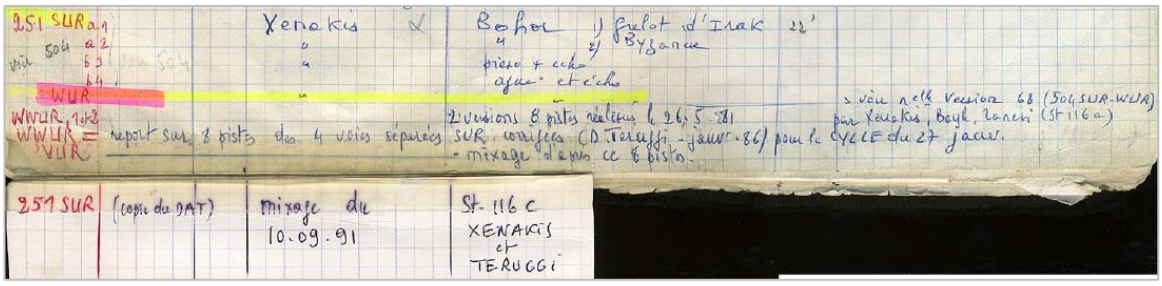

Figure 26: Detail of the *Registre des Originaux*.

[161] Email to Samuel Vriezen, no date, http://www.mombu.com/music/music/t-xenakis-*Bohor*-the-last-time-5106581.html, last visit April 17, 2019.
[162] Nonesuch H-71246 USA (1970), liner notes on LP by James Brody.

The 8-track version was probably not satisfying. Daniel Teruggi ‘corrected’ it in January 1986 (BOH-AS-GRM-011) for a concert on January 27, 1986[163] and, in 2006, discussed the mixes in an article[164]. He mentioned a “new version” in 1990, but he probably confused it with 1986, as no transfer to 8-tracks is listed in any archive for 1990, and no tape dated 1990 can be found. There is, though, a copy of a score (*Bohor*-VS-AFX-04) with hand written notes in it (Figure 27).

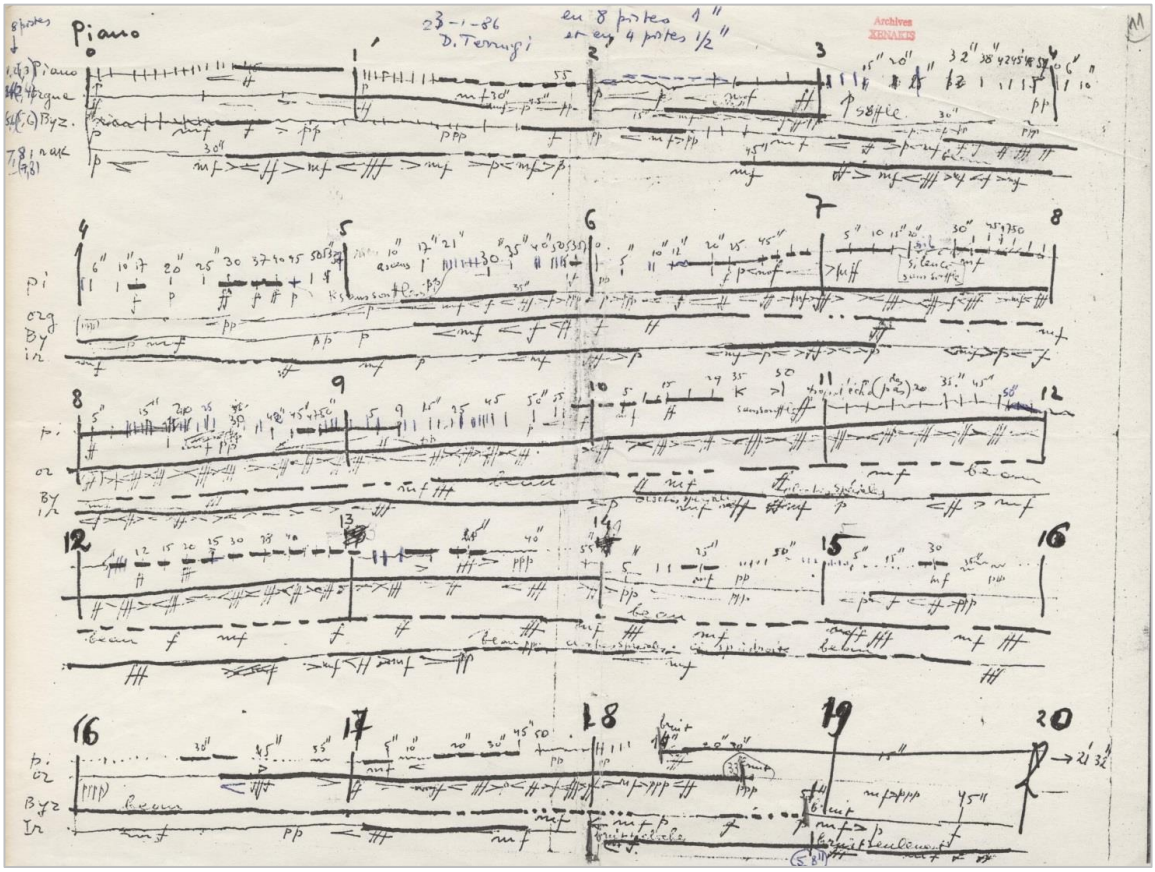

Figure 27: *Bohor*-VS-AFX-04 Mix with Teruggi January 23, 1986, face.

Daniel Teruggi is mentioned, and the given date is January 23, 1986. This might be the score Teruggi used for the mix, even though his name on the score is misspelled (Terrugi instead of Teruggi). This score indicates dynamics for each of the four stereo-tracks. It is not clear if those dynamics are the dynamics already on the stereo-tapes, or if this might be a performance score that should be

[163] pour le CYCLE du 27 janvier.
[164] Teruggi, D. (2009) Against oblivion, in: Paland, R., Von Blumröder, D. (eds) (2009), Iannis Xenakis: Das elektroakustische Werk, Wien, 28.

realised when performing the tapes live. Teruggi also did a transfer to a 4-track version in the same session (BOH-AS-GRM-012).

Nowhere is it mentioned that Xenakis participated in this mixing session with Daniel Teruggi. Teruggi himself writes that he made a mix of *Bohor* for "a concert for the 80th birthday of Pierre Schaeffer" in 1990:

> While preparing the transfer before the arrival of Xenakis, I had remarked that in the middle of the work, there is a long decrescendo in which the hiss of the tape became more important than the signal. My less experienced ears took this as a technical defect that should be corrected, so I passed quite a long time setting a new Noise-gate in order to reduce the hiss while the signal was diminishing. Xenakis was horrified when he listened to this and asked me anxiously what I had done to his music. So, I learned to understand that our ears had different impressions and that what for me was a defect, was an important part of the information for him. This was a strong lesson for the future – that I should not listen to other peoples' music merely based on my listening preferences.[165]

An additional note concerning the 4-track version from 1986 in the GRM Excel file reads: "The author does not like it".[166] It is not clear, if this 4-track version is the version Teruggi mentioned to have been criticised by Xenakis.

Teruggi also writes that Radu Stan, Xenakis's assistant at the publishing house Salabert, insisted on reorganising and arranging all the tapes in 1992[167]: "Radu Stan […] decided […] to make stereo versions of the multitrack works that would serve as references for CD publications and rentals. Also 8-track copies have been done in order to have concert copies and not to send the originals."[168] According to all archive lists, this must have happened in 1991, not in 1992. The

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[165] Ibid., 30.
[166] „L'auteuer n'aime pas", VUR 504.
[167] Radu Stan told the same history in an interview with the author, Paris, October 16, 2007; compare Teruggi, D. (2009) Against oblivion, in: Paland, R., Von Blumröder, D. (eds) (2009), Iannis Xenakis: Das elektroakustische Werk, Wien, 30-31.
[168] Teruggi, D. (2009) Against oblivion, in: Paland, R., Von Blumröder, D. (eds) (2009), Iannis Xenakis: Das elektroakustische Werk, Wien, 30-31.

date for the transition of *Bohor* can be determined exactly, as Xenakis documented the mixing session and dated it September 9, 1991 (Figure 28).

Obviously, the 8-track copy from 1986 has been used to create three copies for Salabert, including digital copies ("+ 3 numér"), probably realised for the GRM in a private studio[169] with digital techniques.[170] Moreover, a new reduction to stereo BOH-AS-GRM-013 was completed in this session on September 10, 1991, was copied on DAT, and declared as the "version to use" (BOH-CAT-GRM-04).

[169] Xenakis notes "numérique master 8 pistes studios prof. privé Paris".
[170] The first digital multitrack recording arrived at GRM only in 1992. See: Gayou, E. (2007) Le GRM, Groupe de Recherches Musicales : Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris, 259.

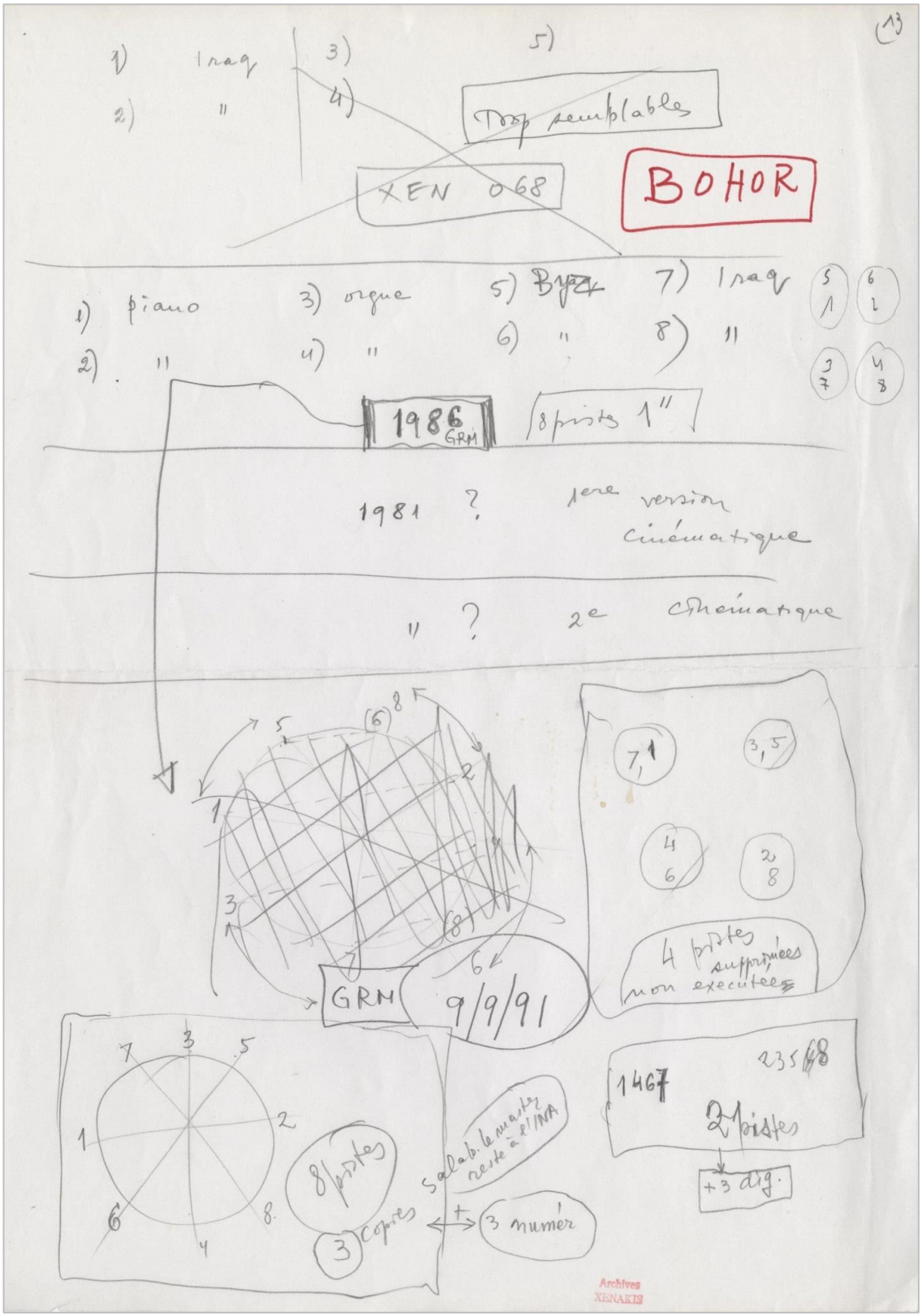

Figure 28: Xenakis's notes on the mixing session with Daniel Teruggi. *Bohor*-VS-AFX-05.

Xenakis's draft (Figure 28) probably indicates the order of the tracks for the 4-channel-reduction and the stereo reduction (lower right part of the sketch): track 1, 4, 6, 7 were transferred to the left Stereo channel, 2, 3, 5, 8 to the right channel. Xenakis was interested in keeping the stereo quality of the original 4 stereo-tapes: they are split pairwise in the left and right side.

Xenakis also mentions a 4-track version, denoted as "version cinématique".[171] He notes "1981?" (middle of the page). According to the archives (BOH-AS-GRM-010), this can only be the 4-track version realised in 1981 by François Bayle, Christian Zanési, and Xenakis, thus the second version mentioned should be the 1968 4-track version. In 1997 the first digital version of *Bohor* was released on the American label EMF (*Bohor*-AS-38-CD [EMF]). The Version of *Bohor* clearly differs from the former releases on vinyl. James Harley writes:

> Surprisingly, the digital release of *Bohor* is cut off twenty seconds too soon (from previous recordings). This last segment consists of a greatly heightened culmination of the crescendo of dynamics and density, the "piercing angle" Xenakis mentions. No explanation is given, but it certainly represents a distortion of the compositional intent.[172]

As the master tape came from the GRM, it should have been the stereo mix-down from 1991 (BOH-AS-GRM-013), denoted "version to use". The difference in length can already be seen in the 8-track version, realised in 1981 (Figure 24), which might be due to Xenakis's experience with Robert Ludwig when mastering the Nonesuch-LP, who pointed out: *The ending DOES cut off on purpose!*[173]
Benoît Gibson mentions a difference in the mix: "Xenakis reduces the presence of the low pedal notes of the organ whereas he raises the presence of the

[171] Gayou, E. (2007) Le GRM, Groupe de Recherches Musicales : Cinquante ans d'histoire, Les chemins de la musique, Fayard, Paris, 78.
[172] Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 257-258.
[173] Email from Robert Ludwig to Samuel Vriezen, no date, http://www.mombu.com/music/music/t-xenakis-*Bohor*-the-last-time-5106581.html, last visit April 17, 2019.

piano."[174] Carefully comparing this version with the official digitised 8-track version from Salabert shows that there are substantial differences. In extensive parts of the EMF-version the deep bourdon part on the organ track is simply not present. The overall sound is so weak that it seems incomprehensible that this music could cause such a scandal on the basis of its brutish sounds. Evelyne Gayou, who probably only knows *Bohor* from this CD stated that it is "not a masterwork"[175]. There might be a simple explanation:

A crucial part of the sound has been lost, the deep "organ" sound is completely missing in the beginning. Possible reasons for this could be:

1) A fault in the stereo mix-down from 1991 (BOH-AS-GRM-013)
2) Incorrect digitisation of a multitrack tape
3) Incorrect mastering

Referring to Xenakis's drafts and notes, it is not clear who made the stereo mix-down. There are some drafts, such as the mentioned 4-system score from 1986 (Figure 27).

For a concert at Columbia University on July 14, 2000[176], musicologist Rebecca Kim wrote: "For the first time, Xenakis's publisher has kindly made available the composer's own sketches for the work and these formed the basis for the following attempt to clarify the ideas underlying *Bohor*."[177] (Figure 29)

[174] Gibson, B. (2011) The instrumental music of Iannis Xenakis: Theory, practice, self-borrowing, The Iannis Xenakis series, Vol. 3, Pendragon Press, Hillsdale, NY, 88.
[175] Friedl, R. (2015) Archive elektroakustischer Musik II, radio script for Westdeutscher Rundfunk Köln, Germany, Archivnummer: 5189 960, Broadcast: March 11, 2015.
[176] http://sites.music.columbia.edu/masterpieces/ last visit March 18,2019.
[177] Program of a concert July 14, 2000 at Columbia University, online: http://sites.music.columbia.edu/masterpieces/notes/xenakis/notes.html, last visit March 18, 2019.

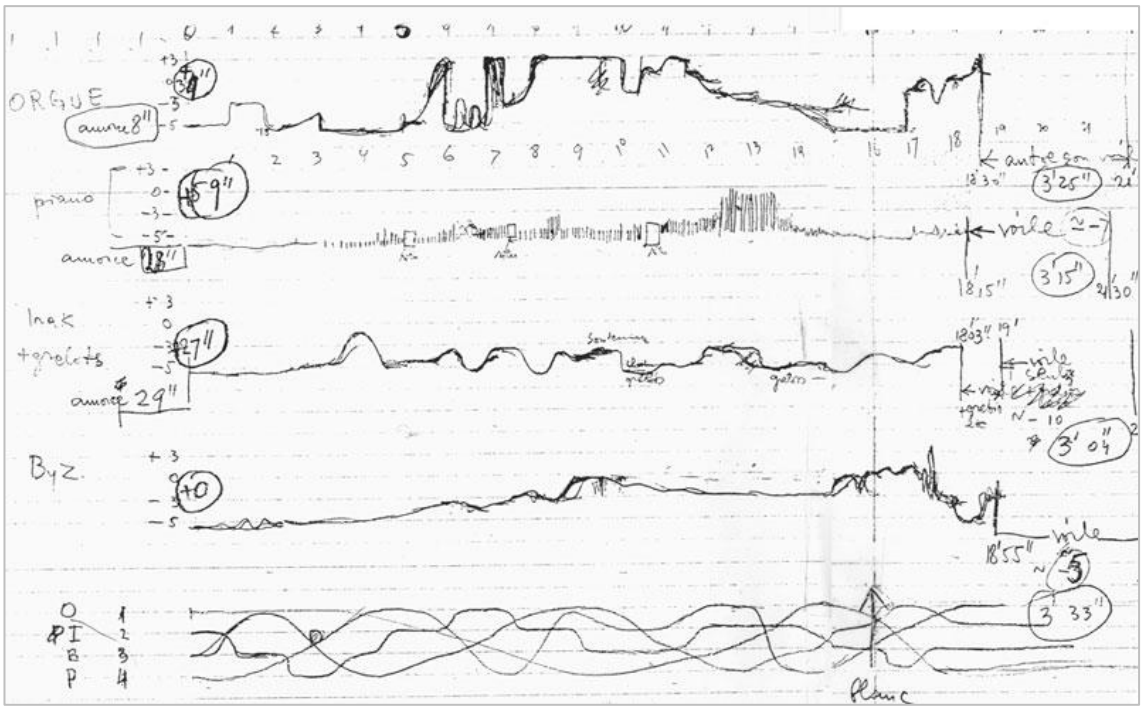

Figure 29: "score" as published by R. Kim, detail of *Bohor*-VS-AFX-01.But this “score“, also quoted and published by Charles Turner[178], is only a copied detail of *Bohor*-VS-AFX-01:

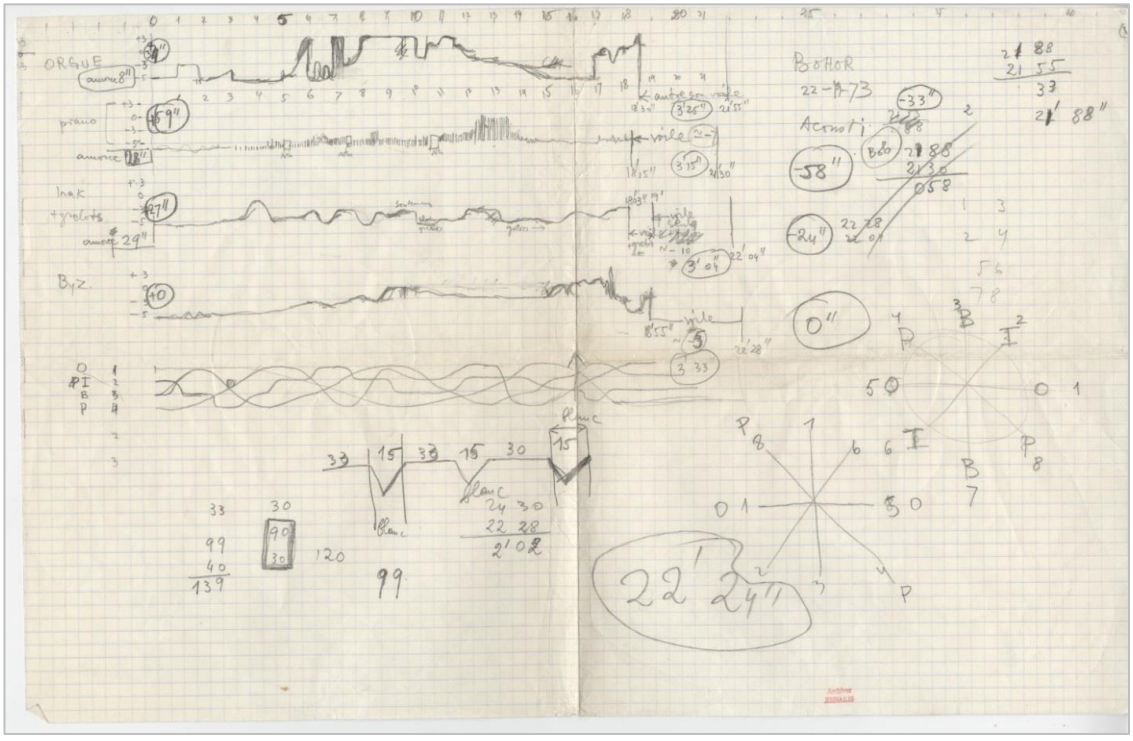

Figure 30: *Bohor*-VS-AFX-01

[178] Turner, C. (2015) Why *Bohor*? in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 99-108.

Turner believes Kim and writes: “Portion of a sketch for *Bohor*, showing the amplitude of the four sound sources graphed against time. The fifth figure graphs the stereo positioning of the four sources.”[179]

Actually, important details of this sketch are cut off. On the upper part of the right page, the date 22-11-73 is written, thus the sketch seems to stem from November 22, 1973. Therefore, it could not have served for any mixes before 1973. If the sketch shows the amplitude of the four sound sources graphed against time, as Kim states, it would be strange that the final crescendo – the one Xenakis always emphasised – is missing in all four tracks. Moreover, the scale from -5 to +3 at the left of each track suggest that not the amplitude, but the adjustment of the amplitude is shown here. -5db to +3 db would be common values in a final mixing, but there is no known mix from 1973.

It is peculiar that some handwriting on the sketch differs significantly from Xenakis’s handwriting. Xenakis normally used a middle dash for the “7” and did not write the “2” with a ribbon at the bottom. It is possible that this source is not – or not completely – written by Xenakis.

Kim interprets the fourth graph as the “stereo positioning of the four sources”. The letters on the left side obviously stand for the tracks: O for organ, I for Irak, B for Byzantine, and P for piano. Strangely, Xenakis never used these abbreviations in any other source (he used only 2 or 3 letter abbreviations), and the handwriting of these letters and the numbers 1 to 4 differs from Xenakis’s usual handwriting (especially evident: the “4” and the “B”). Also, if the graph shows a projection to stereo, why would Xenakis have used four lines (1, 2, 3, 4)? Two would have been enough to represent stereo. If this graph represents a spatialisation then it must be a 4- or 8-channel spatialisation (shown as 4 stereo channels). The graphs on the lower right side of the *Bohor*-VS-AFX-01 show 8-channel circles with four stereo tracks spread to opposite speakers. Though, to turn them around pairwise, as the graph on the left would suggest, was technically hardly possible at the time (see *La Légende d’Eer*), and no recording or mix-down with moving sounds can be found in the archives. Thus, it remains unclear what the so-called “fifth system” means.

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[179] Turner, C. (2015) Why *Bohor*? in: Solomos, M. (ed) (2015) Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 104.

In 2014 I received a digitisation of a 4-track version (unclear which one) from the GRM. This digitisation is 21’56’’ long, and must therefore be the 1986 four-track-tape BOH-AS-GRM-012, as all other versions are shorter. As can be seen in Figure 31, every track of the four tracks has been digitized in stereo. But it appears that a fault occurred, as two of the four stereo-tracks have obviously been digitised twice with slightly different levels (Figure 31): track 1 is almost identical with track 3, and the same holds for track 2 and 4. This could mean that the original tracks 3 and 4 have not been digitised at all. Another explanation could be that this digitisation is correct, and the fault occurred already through incorrect routing during the production of the 4-track tape BOH-AS-GRM-012 and only four of the eight tracks have been transferred to the analogue 4-track tape. This could explain why Xenakis did not like this 4-track version (BOH-AS-GRM-012, comment in BOH-CAT-GRM-04, see apparatus).

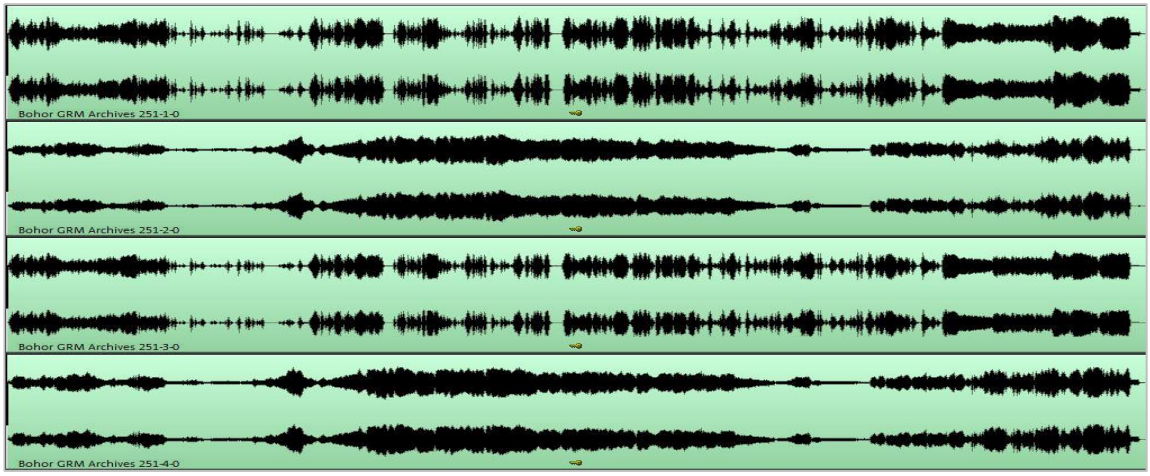

Figure 31: Digitisation of a four-track tape from GRM, version unclear.

This could also be the reason for Xenakis’s note: “*4 pistes suprimées, non executées*” (Figure 28). Comparing digitisation by listening with the EMF-CD (BOH-03-EMF), however, shows that the EMF-version is not a mix-down of this reduced multitrack; the prominent bass sound in the first minutes of the digitised four-track tape is not at all audible on the EMF-CD.

Another explanation for the missing sounds on this CD might be that the mastering Engineer Robin Aube was not accustomed to master anything other

than pop and rock music[180]. Knowing that Teruggi, in his first approach, filtered out an alleged hiss before Xenakis made it clear that it is part of the music, it seems obvious that somebody who has no experience with this kind of music, tries their best to filter out all the alleged hum and noise. If so, he succeeded. *Bohor* is bearly recognisable in this version.

The latest reissue is a vinyl edition on the Austrian label MEGO181 (BOH-04-mego). Christian Zanési writes in the liner notes: “1968 version, revised by Iannis Xenakis himself and as yet not made available to the public.”

These statement makes the assertions:

(1) The version is from 1968.

(2) Xenakis revised it himself.

(3) The mix is not published so far.

Assertion (2) is probably incorrect as Xenakis never revised any mix himself. He needed technical help to do so. The only mixes Xenakis realised (with Daniel Teruggi: Figure 24 Genealogy) have been the mixes from 1991. These mixes are based on the mixes and transfers from 1986, as Figure 24 shows. This then leads to the conclusion that the version cannot be from 1968. Furthermore, the 1991 mixes (BOH-AS-GRM-013) are 20 seconds shorter than the release. Thus, if there are no hidden mixes, never documented in the archives, the mix cannot be the one mixed by Teruggi and Xenakis together. Therefore assertions (2) must be wrong.

Looking again to the genealogy of *Bohor*, there are only two unpublished mixes (assertion 3) from 1968 (assertion 1): The two stereo-mix-downs, BOH-AS-GRM-005 and -006, that have not been used for the ERATO-5LP-Box or the Nonesuch-LP (BOH-02-NS).

[180] https://www.discogs.com/artist/918720-Robin-Aube, last visit March 18, 2019.
[181] Iannis Xenakis –GRM works 1957 – 1962 (2013), LP, recollection GRM, MEGO, ReGRM 07, Wien.

3.3.9. Conclusion

The question of the origins of the differences in the commercial versions of *Bohor* could be partly answered. The origin of the corruption of *Bohor* on the EMF-CD could not, however, be completely clarified. The later EMF-CD and the MEGO-release ignore that Xenakis, together with mastering engineer Robert Ludwig, realized the most compelling version for the 1970 Nonesuch-LP. The substantial changes have neither been properly documented for the future, nor forwarded to the publishing house Salabert. A revision of the official hire material of *Bohor* would have been necessary, including clear instructions how to perform the piece. The two main pieces of advice from Robert Ludwig are:

1) slowly raise the volume of the last few minutes in a giant crescendo!
2) The ending does cut off on purpose![182].

Today the official version, in the form of the hire material of the publishing house Durand/Salabert/Eschig, is an 8-track digitisation of the mix from 1991 (BOH-AS-GRM-14). The runtime difference of the first version (1962) can no longer occur. The analogue tapes are not accessible, and it would take a rather strict understanding of historical performance to copy the digital files back to four analogue stereo tapes in order to make this happen again.

As there is no precise description of the mixing session or the tape and how to handle it, the performer must decide how he or she will respond to the following questions:

1) Is it necessary to change the volumes of the single tracks during the performance, and if yes, why and where?
2) Is it necessary to alter the sound qualities by filtering, compression, etc. for and/or during the performance?

In 2018 I was invited to the Ultima Contemporary Music Festival in Oslo, Norway to perform *Bohor*. I attempted an “historically informed version”. My reference sound was the one of the Nonesuch-LP (BOH-02-EMF). In order to get close to this sound I had to alter the four stereo tracks separately by filtering: the

[182] Compare: Email to Samuel Vriezen, no date, http://www.mombu.com/music/music/t-xenakis-*Bohor*-the-last-time-5106581.html, last visit April 17, 2019.

digital 8-track-version sounds sharp and over-defined, the four sound-layers – already separated in space, coming from different corners – tend to fall apart. I had to reduce high frequencies and let the subbase increase only towards the end of the piece. I also changed within the volumes in a limited range: a very slight crescendo over the length of the whole piece in order to keep the listener's ear interested, and supported the final metal sheet sounds exactly as Robert Ludwig had described it: with a giant crescendo. This also means, though, that one must keep a volume headroom over the first 18 minutes. The end was an abrupt stop, almost at the point when the pain threshold was achieved. The reaction of the audience came close to what Xenakis had described: "It [*Bohor*] should penetrate the ears with sound. That's why it needs a high volume: that makes it possible to perceive all those minimal sonic details."[183]

This physical sonority combined with a climax-oriented dramaturgy, that Xenakis strengthened with Robert Ludwig, makes *Bohor* an immersive experience.

The second philological question was the origin of the pre-recorded sounds for *Bohor*. No recognisable piano recording could be found in the archives. There are, however, numerous tapes named "*Bohor*, elements" that sound like Baschet-instruments. I could not find the name Baschet in any source, though the names of the tracks ('piano' for 'piano-tige', etc.) can be read as hidden hints to the Baschet instruments' names.

On the other hand, it became clear that the sound sources given in the booklet of the Nonesuch LP (BOH-AS-02-NS) had been misleading: what is called "white noise" is clearly made with metal sheets, and metal sheets had been constructed exactly at that time by the Baschet brothers for the GRM, and were parts of most of their other instruments as resonators (crystal organ, etc.). That Xenakis did not mention those instruments at all might show us a conscious

[183] Xenakis, I., Delalande, F. (1997) Il faut être constamment un immigré : Entretiens avec Xenakis, Bibliothèque de recherche musicale, Buchet/Chastel, Paris, Bry-sur-Marne, 138. « Et là, pour *Bohor* en particulier, c'est parce que cela demande une pénétration de l'oreille dans le son. Et il faut donc du volume. Pour entendre tous ces minimes détails des sonorités, j'avais la sensation qu'il fallait plus de volume. Pour entrer dedans, tout simplement. »

attempt to keep his sound sources a secret. We will see that he did the same in *La Légende d'Eer*. It was also a normal practice at that time: sound sources were a crucial part of a composer's capital.

The answers to my two questions show that all secondary texts are at least partly based on false assumptions: corrupted sources, such as the "score" *Bohor*-VS-AFX-01, or corrupted commercial releases, such as BOH-03-EMF. Statements by the composer have sometimes been naively believed; listening carefully, one could have heard that the white noise is not white noise, but the sound of metal sheets, to give only one example. Any composer – like any author – has interests and cannot be perceived as an objective witness.

The results affirm that a philology of electroacoustic music will not replace analysis or interpretation, but also that it is indispensable in grounding further research on a solid critical base.

3.4. Paradigm 3: *La Légende d'Eer* (1978)

La Légende d'Eer is the musical part of the so-called *Diatope*, a multimedia event by Iannis Xenakis which includes four media: text, music, light and architecture.[184] The *Diatope* was commissioned by the Centre Beaubourg for the inauguration of the Centre George Pompidou in Paris in January 1977, with the musical part commissioned by Westdeutscher Rundfunk Köln (WDR), Germany. This research focusses only on the musical part *La Légende d'Eer*.

As Xenakis had to change his architectural proposals several times, the *Diatope* was premiered in Paris in July 1978. The musical part had already been premiered in the planetarium in Bochum, Germany, on February 11, 1978. In both cases, Xenakis used 8-track tapes and the sound was spatialised.

3.4.1. The philological questions

There are two different versions of *La Légende d'Eer* available on the commercial market. Comparing these existing releases, LLE-01-AM1[185] and LLE-03-Mode,[186] there are five significant differences:

1. Density of voices in the beginning:

LLE-03-Mode is denser in the beginning; several pitches enter almost simultaneously as a cluster in the beginning of the piece. In LLE-01-AM1, the different pitches enter successively.

2. Movements in the stereo panorama:

There are some movements in the stereo panorama on LLE-01-AM1, but none on the LLE-03-Mode.

3. Different pitches at the end of the piece:

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[184] Solomos, M. (2005) Le Diatope et *La Légende d'Eer*, auf <http://www.iannis-xenakis.org>, last visit November 7, 2018.
[185] Xenakis, I. (1995) *La Légende d'Eer*, Audio-CD, Auvidis Montaigne MO 782058, Paris; re-released with different cover (2002), Audio-CD, AuvidisMontaigne, MO 782144, Paris.
[186] Xenakis, I., (2005) *La Légende d'Eer*, Audio-CD, Mode Records, mode148, New York.

In the LLE-03-Mode, the end of the piece is approximately one tone lower than in LLE-01-AM1. This is a typical effect when a 48kHz-file has been decoded with 44,1 kHz.

4. Length of the piece:

The official lengths given on the covers of the releases are: LLE-01-AM1 CD: 46:00, LLE-03-Mode CD: 47:02. However, when comparing the factual lengths of the two CD versions, measuring from the first sound to the end of the last, the difference is approximately 1 minute 50 seconds.

5. The different sound qualities:

The Mode Records version has a more brilliant sound quality, probably due to the fact that the analogue tapes have been digitised with superior quality, in this case with 96 kHz, as mentioned in the CD booklet.

The first three differences are not mentioned in the CD-booklet, but the variation in length is explained on the cover of LLE-03-Mode, which states: “Use of the original master tape restored almost 2 minutes and 30 seconds to the piece, released here for the first time.”[187]

My aim was to ascertain the reasons for those differences by answering the following questions:

1) From where do the mentioned differences (1 - Density) to (3 – Different pitches) come?
2) Are there different versions of the piece with different lengths?

The task was to track the two different CD-releases back to the sources, and to reconstruct significant parts of the production process of the composition.

During the research it became clear that there are also two different versions of 8-track hire materials for concert performance. Both the publishing

[187] Announcement of the release on Mode Records (www.moderecords.com), http://www.moderecords.com/catalog/148xenakis.html, last visit March 22, 2019.

house Durand/Salabert/Eschig and Westdeutscher Rundfunk WDR provide digital 8-track-files on DVD. A third question results:

3) Which hire material is correct? Are both equally valid?

3.4.2. The Sources

There are altogether 190 acoustic sources (listed in the annex (1.3.)) stored both at Bibliothèque national de France, Paris and at Westdeutscher Rundfunk Köln (WDR), Germany. Volker Müller, the sound technician and former technical director of *Studio für elektronische Musik des Westdeutschen Rundfunks in Köln* (under Karlheinz Stockhausen's artistic direction), was involved in the production with Xenakis (his only one at WDR). After the production was finished, Müller archived all remaining magnetic tapes and catalogued them. Access to these materials was crucial; WDR not only granted access to their archives, they also gave permission for me to digitise all archived analogue tapes of *La Légende d'Eer* in a private studio,[188] and to use the material for a radio feature and further research. The resulting 113 digital sound files are also listed in the annex 1.3.d. Four kind of tapes could be classified: preparation tapes (Figure 32, 1.1. to 1.4.), material tapes (Figure 32, 2.), multitrack tapes, and stereo mix-downs.

Furthermore, the publishing house Durand/Salabert/Eschig in Paris (today part of Universal Music) provided the official performance material, the multitrack version on DVD[189] (annex 1.3.c). This allowed me to study these versions, not only by listening, but also by collating them in professional sound editing software (Samplitude Pro X3 Suite).

60 acoustic sources could be visited in the Xenakis Archives at the Bibliothèque Nationale de France in Paris (BnF). Only a part of them was accessible to listen to via media player inside the library; others have not yet been digitised (July

[188] The digitisation was realised May 2016 at the Audiosuite Cologne together with sound engineer Katja Teubner.

[189] Thanks to Eric Denut from Durand/Salabert/Eschig for his support and the first clue that this research is centred around the critical edition of electroacoustic music.

2018). All 60 sources are listed in the annex 1.3.e to give future researches the full references.

All smaller visual sources will be shown in the text and not in the annex, as they are conducive to understanding. Only the full score ("partition") or synchronisation plan[190] (LLE-VS-WDR-01) is shown in the annex. It is stored in the Xenakis Archives at the Bibliothèque Nationale in Paris[191] and in the archives of Westdeutscher Rundfunk in Cologne[192]. This so-called "score" had not been finalised when the production of *La Légende d'Eer* began. The "Müller-sounds" for example, which were conceptualized and produced in Cologne, can be found on page 1 of LLE-VS-WDR-01. The score did not exist when the studio work started. Volker Müller remembers that Xenakis had asked for a large drawing table, but that there was no table in the small room in which they were working. Volker Müller unhinged a door and put it on an old 4-track-machine which was not in use.[193] This allowed Xenakis to finish the score, which had to be delivered in order for him to be paid.[194] Hence, the score is not only prescriptive, but also a documentation of the studio work.

3.4.3. Historical Background I: The Polytopes

Polytope is Xenakis's name for a series of multi-media events. He combined music with architecture, laser-shows, dance, light-shows, etc. in special places. Several *Polytopes* originated between 1967 and 1988, when Iannis Xenakis was already a recognised composer, who mostly concentrated on composing orchestral works. At every opportunity, though, he continued to work

[190] The full musical part can also be found in: Solomos, M. (2005) Le Diatope et *La Légende d'Eer*, auf http://www.iannis-xenakis.org, last visit November 7, 2018. Extracts of the score with flashed and lasers in: Xenakis, I., Kanach, S. (ed) (2006) Musique de l'architecture, Editions Paranthèses, Marseille, 340.
[191] Thanks to Francoise et Mâkhi Xenakis for allowing me access to the Xenakis archives at the Bibliothèque nationale de France, Paris.
[192] Archiv Westdeutscher Rundfunk Köln, Germany, Orchesterpartitur 16405.
[193] Friedl, R. (2012) Was ist ein Fehler? – Xenakis' „*La Légende d'Eer*": Versuch einer kritischen Edition elektroakustischer Musik, in: Musiktexte 135 (2012), Köln, 33-39.
[194] Dr. Wolfgang Becker, who commissioned the composition, wrote in a letter to Xenakis in September 1978, several months after the premiere of *La Légende d'Eer*: The second part of his fee will only be transferred "when the score is delivered". „Die zweite Hälfte wird bei der Ablieferung der Partitur gezahlt werden", Letter from Dr. Wolfgang Becker to Iannis Xenakis from September 27, 1978, Archiv Westdeutscher Rundfunk Köln, Historisches Archiv 05623.

on his idea of multi-media art. Xenakis probably thought of it as one big project, rather than as different pieces: He called them all “Polytope” and attributed a place or number as specification. Consequently, he also used the sounds of earlier versions in almost all later versions in a kind of sound material accumulation process. New sounds were added, as soon as they were available, as for example the newly synthesised sounds in *La Légende d’Eer*. The sound material of *Concret PH* (1956), for example, the earliest predecessor of the *Polytopes,* can be found in almost every *Polytope*.

This technique corresponds with his practice of self-borrowing in his instrumental music, as shown by Benoît Gibson.[195] The concept of *Polytope* as one unique project did not keep Xenakis from releasing different versions of the musical parts of the polytopes as different electroacoustic compositions: *Persepolis* was released on LP in 1972[196], *La Légende d’Eer* was even split during the creative process; the musical part was realised separately as an electroacoustic tape composition at WDR Cologne.

The polytopes not only show Xenakis’s ongoing interest in multi-media production, but also his flexibility in re-using and recycling his own material, his openness to produce different versions for different occasions, and his pragmatism in releasing different outtakes and stereo versions of single compositions.

3.4.4. Genealogy

In 1977 Iannis Xenakis came to Cologne to produce *La Légende d’Eer* at the *Studio für Elektronische Musik des WDR Köln* with some material already prepared: new electronic sounds which he had synthesised with the help of mathematic functions in his own research center *Centre d’études de mathématique et automatique musicales (Cemamu)* in Paris[197] (Figure 32, 1.1.), as well as sounds he had used in other *Polytopes* (Figure 32, 1.2.). Another

[195] Gibson, B. (2011) The instrumental music of Iannis Xenakis: Theory, practice, self-borrowing, The Iannis Xenakis series, Vol. 3, Pendragon Press, Hillsdale, NY.
[196] Xenakis, I. (1972) *Persepolis*, LP, Philips « Prospectives 21e Siècle », Paris.
[197] Xenakis, I., Kanach, S. (eds) (2006) Musique de l’architecture, Editions Paranthèses, Marseille, 351 and 355.

prominent sound (at the beginning and end of the piece) was produced in Cologne together with the sound engineer of the studio, Volker Müller, on the Synthesizer EMS 100. In the score, Xenakis even titled this sound and its derivatives "*Müller"* (Figure 32, 1.3.). Furthermore, there is a recording of a double bass improvisation using extended techniques, played by James Whitman, an American composer, who assisted Xenakis for the production.

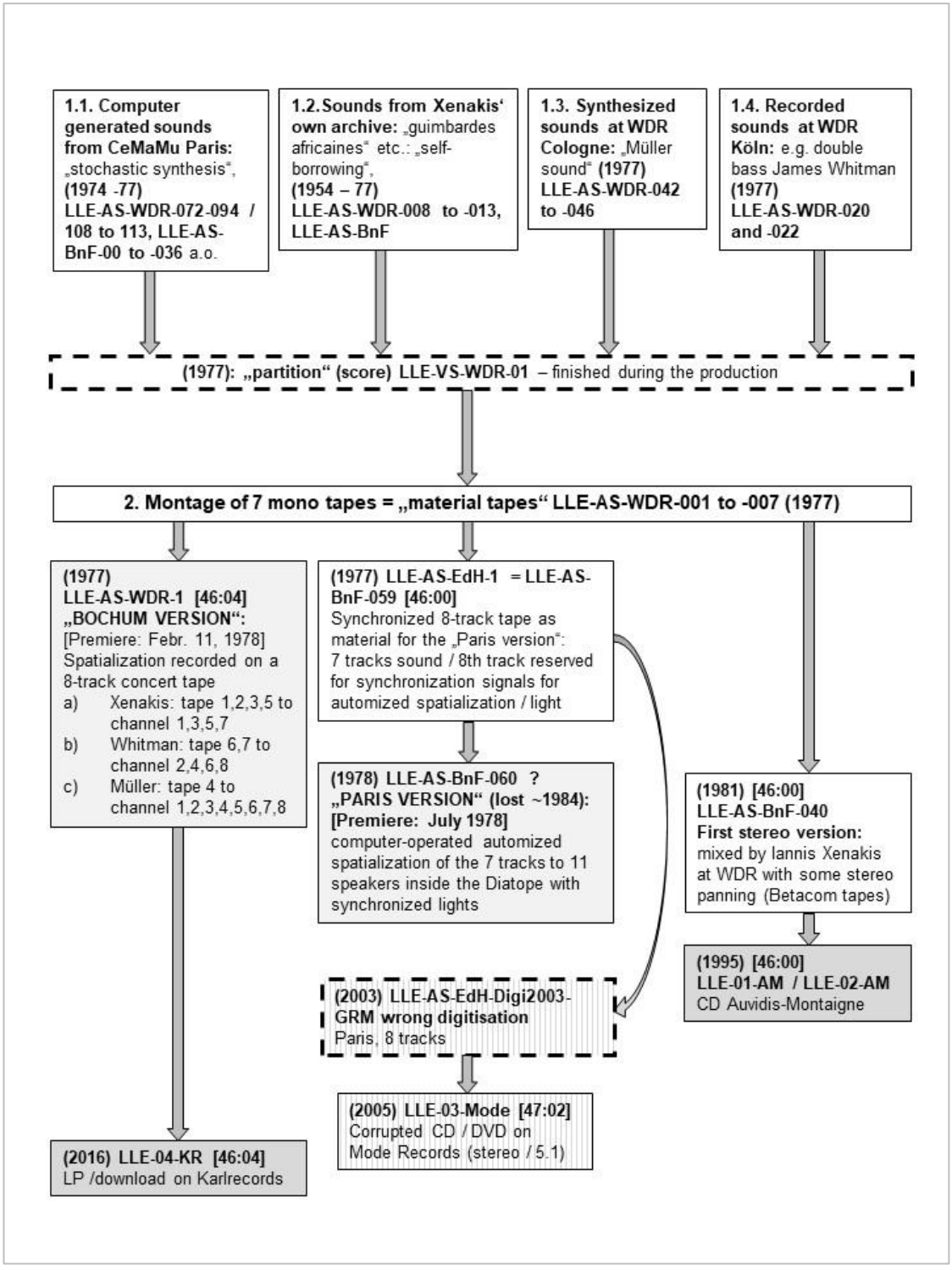

Figure 32: Genealogy of *La Légende d'Eer*.

The production proceeded in several steps: first, Xenakis and Müller manipulated different materials, including the CeMaMu-sounds, the sounds

produced in Cologne, and prerecorded sounds.[198] This included filtering, reverberation, transposition by changing the tape velocity, and various mixing techniques[199]. These materials were used to produce the single tracks which contain the sound materials in the final order of the score (Figure 32, 2.). Seven tracks had to be produced as different mono tracks, so they could be combined later. The reason for using only seven tracks was to reserve the eighth track for control of the spatialisation and the synchronisation with the visual part of the performance, which would happen later in the *Diatope*.

In a first setting, simple synchronisations of the seven mono tapes to an 8-track tape were made (Figure 32, LLE-AS-EdH-1) in order to have a definite seven track version on an eight-track tape. Xenakis took one of these back to Paris and this 8-track tape was the one in which he was most interested, according to Volker Müller[200]. This was a tape without any spatialisation of the individual tracks, but almost a one-to-one synchronisation of the seven mono tapes. This means that additional analogue control-signals were recorded on the eighth track later in Paris. Awkwardly, though, the synchronisation data, the machines, the computer for realising this synchronization, and even the information of how it all worked, appears to be lost. Although there is a tape listed at the BnF (with the curious label: '"9tracks" - have seen this tape at the Diatope"), it is not yet accessible: LLE-AS-Bnf-60. The architecture and the machines of the *Diatope* were transported to Marseille to be installed there, but some parts were lost or damaged during transport. In 1984 the remaining parts were discarded as scrap.[201] There are, however, new results by Elisavet Kiourtsoglou[202], reconstructing the first minutes of the spatialisation inside the *Diatope*.

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[198] The assistant in the studio was James Whitman, who has not left any descriptions about this work.
[199] Compare : Xenakis, I., Kanach, S. (eds) (2006) Musique de l'architecture, Editions Paranthèses, Marseille, 355.
[200] Friedl, R. (2009) Polyphone Monophonie, in: Musiktexte 122 (2009), Köln, 12-17.
[201] Xenakis, I., Kanach, S. (eds) (2006) Musique de l'architecture, Editions Paranthèses, Marseille, 355.
[202] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.

Also in 1977, another eight-track version was produced in Cologne (Figure 32, LLE-AS-WDR-1): the spatialisation of the seven mono tapes on eight outputs, recorded onto an eight-track tape. It is the so-called “Bochum Version”, as this version was premiered in the Planetarium in Bochum on 11 February, 1978. As neither appropriate software nor hardware existed at the time – except the one developed by Xenakis in 1978 for the *Diatope* in Paris – to realise this spatialisation, a very special set-up had to be created. Xenakis spatialised four of the mono tapes to four different tracks (1, 3, 5, 7) by hand, using the quadrophonic effect Generators EMS QUEG. James Whitman spatialised two more tapes to the other four tracks (2, 4, 6, 8), using two quadrophonic joysticks, and Volker Müller spatialised the remaining material tape to all eight tracks, using a normal fader box.[203] This created continuous rotating movements possible for all of the spatialised materials, even when they could not be projected onto each track. This final spatialisation had to be recorded on an 8-track-tape without interruption. There was no possibility of stopping during the piece in order to restart at a certain moment, as it was technically impossible to synchronise the mono tape machines at that time. They had to be started together by several people simultaneously operating the equipment with the help of a sophisticated communication technique. They were even positioned on different levels of the building because there was not enough space for the seven tape machines in one single room. Volker Müller recalls that the spatialisation itself was more or less improvised.

Xenakis used the same score for the Bochum Version and the *Diatope*-version with automated spatialisation: in the Xenakis archives the mentioned score can be found, extended with the movements of the electronic flashes and the laser lights[204]. The beginning of the composition is worked out in the typical geometrical way Xenakis often used – in this case with part of a circle defining the successive entrances of the single tracks in the beginning (Figure 33: LLE-VS-WDR-01).[205] The synchronisation plan for the *Diatope* uses the same score

[203] A sketch by Volker Müller and a discussion of the precise settings can be found in: Erbe, M. (2009), Klänge schreiben: Die Transkriptionsproblematik elektroakustischer Musik, Wien, 154.
[204] Xenakis, I., Kanach, S. (eds) (2006) Musique de l’architecture, Editions Paranthèses, Marseille, 340.
[205] Solomos, M. (2005) Le Diatope et *La Légende d’Eer*, http://www.iannis-xenakis.org, last visit November 7, 2018.

and adds the visual parts in an additional system.[206] Xenakis returned to Cologne from April 12 to 15, 1981[207] and worked for two days in the *Hörspielstudio* to produce several stereo versions (Figure 32, LLE-AS-BnF-040) of *La Légende d'Eer*[208], using the same synchronisation plan which he had used for the multi-track versions. He only applied slight stereo panning to the mix and did not try to approximate a translation of the eight-channel spatialisations into stereo. This became the official "Sendeversion" at WDR Cologne, and is the version subsequently released on the label Auvidis Montaigne, Paris (LLE-01-AM and LLE-02-AM).[209]

In 2005 the new version was released by the New York-based label Mode Records[210] (Figure 32, LLE-03-Mode). This version is based on the seven-track non-spatialised version which Xenakis took back to Paris and probably passed on to his publisher Salabert. This is also the tape that he used as the basic material for the spatialisation inside the *Diatope*. This tape was digitised in 2003 at the studios of the *Groupe de Musique de Recherches Musicales* (GRM) by Diego Losa, who was then responsible for the digitisation of all the analogue tapes in the GRM archives[211]. The files were given to Gerard Pape, the former director of the CCMIX (*Centre de Création Musicale Iannis Xenakis*, former *Ateliers UPIC*) in Paris, who subsequently realised new mixes in stereo and 5.1. In the attached booklet, these versions are described as an "Electroacoustic Work for 7-channel tape, New stereo mix from the original master tape" (BOH-AS-03-Mode). The label explains: "The analog master was transferred at high-resolution 96khz/24-bit sound for the optimum quality, revealing details not heard in the previous stereo CD release." And: "Use of the original master tape restored almost 2 minutes and 30 seconds to the piece, released here for the first time."[212]

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[206] Xenakis, I., Kanach, S. (eds) (2006) Musique de l'architecture, Editions Paranthèses, Marseille, 340.
[207] Letter from the assistant of Dr.Wolfgang Becker to Iannis Xenakis from March 30, 1981, confirming the hotel reservation, Westdeutscher Rundfunk Köln, Historisches Archiv 05623.
[208] As Volker Müller kept a diary during his years at WDR, this can be reconstructed precisely.
[209] Xenakis, I. (1995), *La Légende d'Eer*, Audio-CD, Auvidis Montaigne MO 782058, Paris.
[210] Xenakis, I. (2005), *La Légende d'Eer*, Audio-CD and /or DVD with 5.1-Mix, Mode Records, mode148, New York.
[211] Interview with Diego Losa by the author, March 2011.
[212] Announcement of the release on Mode Records, www.moderecords.com/catalog/148xenakis.html, last visit March 22, 2019.

3.4.5. Further Collation of Audio sources including Visual Sources

In order to find the reasons for the differences between the two CD releases, it makes sense to compare the digitised single tracks LLE-AS-WDR-001 to -007, the material tapes, with the 8-track material tape, digitised in 2003 in Paris (LLE-AS-EdH-Digi2003-GRM). The latter was not only used for the Mode version, but also became the official performance material of the publishing house Durand/Salabert/Eschig, digitised as 8 tracks on DVD. The first two mentioned differences in the beginning of this chapter are then easily explained:

1. Density of voices in the beginning:

Considering the score LLE-VS-WDR-01 (Figure 33), it is clear that LLE-03-Mode does not respect the instructions, but simply plays what is on the tape. Xenakis always followed the circle-like bow in his versions. This means that each track began in the moment the circle-like bow intersects the respective system line.

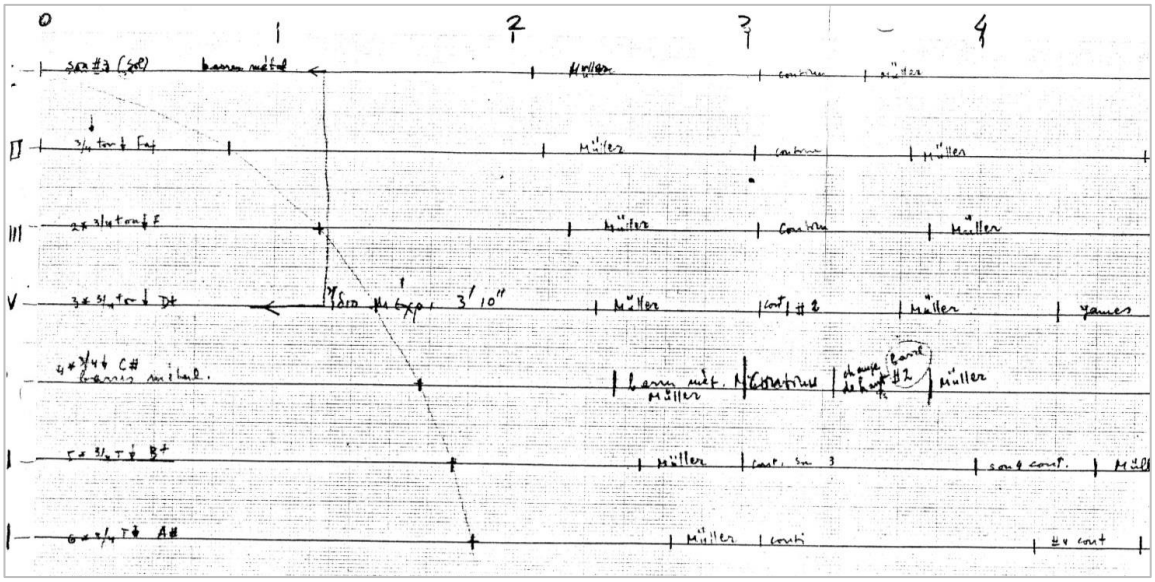

Figure 33: The beginning of *La Légende d'Eer*, LLE-VS-WDR-01.

Thus, the additional sound in the beginning of LLE-03-Mode is clearly not a result of restoration, as explained by the label, but of playing sounds that are

on the 7-channel-material-tape that were not intended to be played – at least Xenakis never did.

2. Movements in the stereo panorama:

As the 8-track material tape was never projected as it is, but automatically spatialised, it becomes clear that Xenakis tried to, at least, simulate some of this spatialisation in the stereo version he realised in Cologne in 1981: LLE-AS-BnF-040 released on Auvidis-Montaigne (LLE-01-AM). LLE-03-Mode is based on the digitisation LLE-AS-EdH-1-digi2003-GRM of the 8-track-material-tape LLE-AS-EdH-1, supposing that this was the performance tape.

Looking at the digitisation of this Paris 8-track-tape (Figure 34), used as official performance material, there are two more faults:

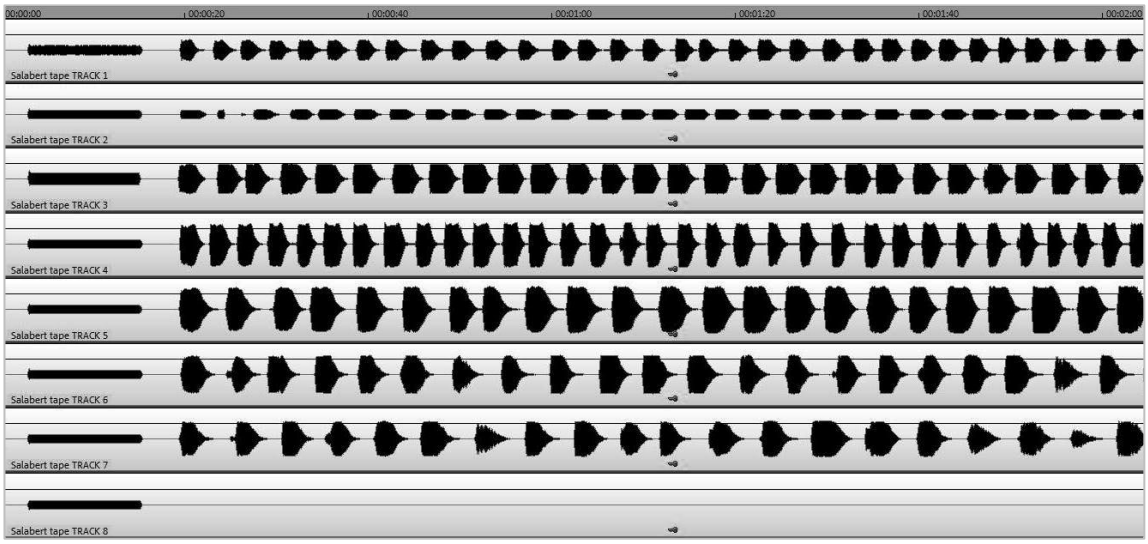

Figure 34: The beginning of the 2003 digitised version of *La Légende d'Eer*, LLE-AS-EdH-1-digi2003-GRM.

The test-tone in the beginning of the tape (Figure 34: the synchronised sounds in all 8 tracks on the left side), probably used to synchronise the speed of the different tape machines when producing the multi-track-tape (there should be no beating or amplitude perturbation when playing several tracks simultaneously), is still included in the performance material. It is easy to imagine

that somebody would mistake those sine waves as part of the piece, as the subsequent sounds are also almost sine waves.

Another fault of the 8-track production is that the 8th track has also been digitised – an apparently empty track, containing only typical cross-talk-sounds from the other tracks. Someone not familiar with the music and the associated files might even think that this piece is an 8-track-piece, and project the 8th channel as well.

So, the remaining questions concern the differences of the:

1. pitches at the end of the piece, and of the
2. lengths of the pieces.

Why is the *Mode* version LLE-03-Mode longer and the end approximately one whole tone lower than the LLE-01-AM? Such a transposition is exactly what happens when a master tape that has been produced with 48 kHz is decoded with 44.1 kHz.[213] A similar mistake occurred with the release of Xenakis's *Persepolis* on Asphodel Records[214], which is clearly an incorrect decoding with 44.1 kHz of a master tape with 48 kHz.[215] The beginnings of both versions considered here do have the same pitches, though, and the assumption that the digitisation of the whole piece was decoded at the wrong sample rate leads to a contradiction:

Reading a 48kHz file with 44,1 kHz would stretch the length with the factor

(i) 48 kHz / 44,1 kHz = 1,088

But the file length of the Auvidis version is 46:00, and 46:00 * 1,088 = 2760 sec * 1.088 = 3003 sec = 50:00. Had this error occurred, LLE-03-Mode would be 50 minutes long, but it is only 47:02. So, this cannot be the reason.

[213] A transposition with the factor 44.100 /48.000 = 0,91875.
[214] Xenakis, I. (2002), *Persepolis*, 2CD, Asphodel Records, San Francisco.
[215] Friedl, R. (2009) Polyphone Monophonie, in: Musiktexte 122 (2009), Köln, 12-17.

The differences in length and pitch between LLE-01-AM and the LLE-03-Mode are exactly the same between the 8-track-Salabert-tape LLE-AS-EdH-1-Digi2003-GRM and the material tapes LLE-AS-WDR-001 to -007. This allows us to compare the tracks one by one.

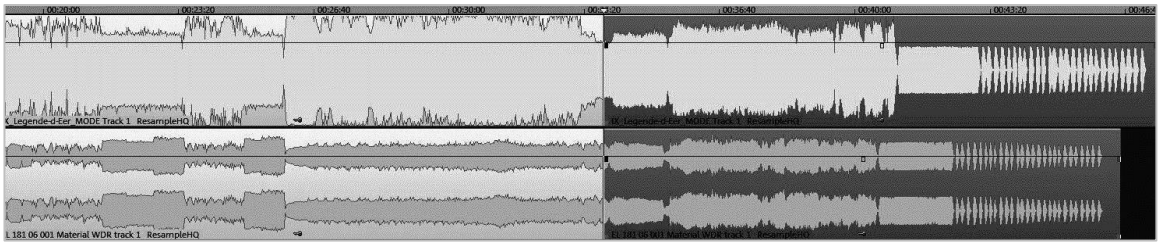

Figure 35: Collation of channel 1 of LLE-AS-EdH-1-Digi2003-GRM (upper channel) used for the Mode record CD with the material tape 1 LLE-AS-WDR-001 (lower channel).

Here it is visually obvious that there is only a stretching of the last part of the piece (Figure 35, gray background on the right side), and not of whole tracks. The same effect can be found in other tracks, for example, track 6:

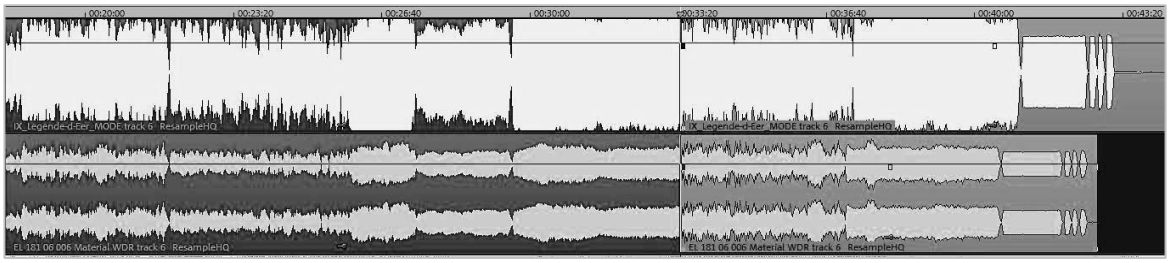

Figure 36: Collation of channel 6 of LLE-AS-EdH-1-Digi2003-GRM (upper channel) used for the Mode record CD with the material tape 1 LLE-AS-WDR-001 (lower channel).

Measuring the stretched passages reveals that the LLE-03-Mode stretched passage is 13 minutes 23 seconds long, while the corresponding LLE-01-AM passage is only 12 minutes 18 seconds long. So, the LLE-03-Mode ending passage is 13:23 = 803 sec, the LLE-01-AM ending is 12:18 = 738 sec. However:

(ii) 803 sec / 738 sec = 1,088

which is exactly the factor of an incorrect decoding with 44.1 kHz of a file with 48 kHz (compare formula (i)). Even though this looks mathematically obvious, it is still utterly unclear, how it could have occurred that only a part of a file is falsely decoded.

3.4.6. Technical Context

At the time of the production of *La Légende d'Eer*, the maximum length of tapes was about 30 minutes, but *La Légende d'Eer* had more than 45 minutes. As Volker Müller[216] remembers, two tapes had to be connected in order to realise the piece on one tape roll. Subsequently a special oversized box had to be constructed, and Müller remembers well that over decades the box of *La Légende d'Eer* did not fit into his tape archive because of its dimensions (Figure 37).

Figure 37: Original oversized 8-track tape box of *La Légende d'Eer*, Archiv WDR Cologne LLE-AS-WDR-1.

Gerard Pape collected the analogue tapes from the publishing house Salabert in Paris in 2003 and brought them to the Maison de la Radio to be digitised in the studios of the GRM. Pape could not remember whether or not there was any special tape box when he did this.[217] This clearly means, that the first and the second part of the pieces were probably digitised separately: the first part was approximately 33 minutes long, the second approximately 13:23. The digitised parts were then connected together again by overlapping a little bit. This was a common practice, as *Persepolis*, the other long electroacoustic

[216] Several Interviews with Volker Müller and the author, 2009-2012, for a radio feature on Xenakis' *La Légende d'Eer* at Westdeutscher Rundfunk Köln, Germany.
[217] Interview with Gerard Pape and the author, Paris, February 21, 2011.

composition of Xenakis, shows[218]. It was even released on two different sides of a record.[219]

As the texture in *La Légende d'Eer* is very dense between minutes 31:00 and 34:00, and the sounds are overlap with glissandi, it is almost impossible to identify the pitch shifting in this passage by ear. It is possible, though, if one attentively listens to the individual tracks of LLE-AS-EdH-1-Digi2003-GRM. So, it seems obvious, that the two tapes – the first 8-track tape with a little more than 30 minutes, and the second, with a little more than 13 minutes – were digitised separately at different sample rates. This technique was common, as can be proved by looking at LLE-AS-BnF-46 and -47: François Bayle, then director of the GRM, and Christian Zanési had already separated the same tape into two parts when mixing it to achieve a stereo version. The fault in the 2003 digitisation might have occurred while transferring the files into the ProTools project. It is known that ProTools still often gives the user no indication when there is a problem with the compatibility of sample rates.

Some of the results were presented at a conference in Paris and were published in 2015[220]. Gerard Pape, who is responsible for the mixing of the version on Mode records, disagreed with my results, so the editor subsequently invited him to publish a comment on my article in the same book.[221] Pape did so, and his comments make the necessity of a philology of electroacoustic music even more evident. Without commenting on all arguments in Pape's response in detail, it is obviously his lack of philological thinking that leads him to following assumption: "Is it not possible that the error is in the Disques Montaigne version due to an error in transferring from a 48 kHz multi-channel digital master (in those days ADATs or DA88s were digitally mastered at the sampling rate) to a 44.1 kHz CD stereo master?"[222]

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218 Friedl, R. (2009) Polyphone Monophonie, in: Musiktexte 122 (2009), Köln, 12-17.

219 Xenakis, I. (1972) *Persepolis*, LP, Philips series „Prospectives 21e Siècle", Paris.

220 Friedl, R. (2015) Towards a Critical Edition of Electroacoustic Music: Xenakis – *La Légende d'Eer*, in: Makis Solomos (ed) (2015): Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 99-108.

221 Pape, G. (2015) Questions and Remarks on *La Légende d'Eer* versions, in: Makis Solomos (ed) (2015): Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 123-124.

222 Pape, G. (2015) Questions and Remarks on *La Légende d'Eer* versions, in: Makis Solomos (ed) (2015): Iannis Xenakis, La Musique électroacoustique, Proceedings of the International Symposium 23-25 May 2012, Paris, 124.

Pape's statement that such an error is "entirely possible" is wrong. Xenakis's stereo mix – later used for the Montaigne CD - has been realised at WDR Cologne in 1981 (see Figure 32: Genealogy). DA-88 was a digital multitrack recording device introduced by TASCAM in 1993[223]. The ADAT, a competitive format for digital multitrack recording by Alesis was introduced in 1992[224]. Neither the ADAT nor the DA88 existed in 1981 when the stereo mix of *La Légende d'Eer* was made. The methodology of a philology of electroacoustic music includes respecting the historical background (see 2.3.2.2.) and technical context (see 2.3.2.5.).

Pape concludes: "Maybe the difference in pitch and length are a consequence of an error in the Disques Montaigne version? Why assume that it is the Mode version that is wrong?"

As pointed out in the methodology (see 2.3.2 Collation and Critical discussion), philological techniques allow the location of corrupted versions. The longer duration of the MODE-version is clearly a separative error, shared with no other version, including all existing analogue tapes (even the single mono tapes at WDR). Further on, all sources can be dated: all earlier sources are shorter than the MODE-version.

However, Pape clings to the idea of an "original master tape" and concludes his text with a request: "Only if you re-digitize the original master tape that is to be found in Milano in the archives of Ricordi can you know for sure whether the Mode version or the Disques Montaigne version is accurate as to the original analogue multi-channel master of *La Légende d'Eer*."

This is a typical example of the widespread naïve belief that there must always be an "original master tape" in existence. The idea of electroacoustic media as fixed media demands a definitive version fixed on media somewhere.

223 https://tascam.com/us/product/da-88/feature, last visit September 07, 2019.

224 https://obsoletmedia.org/adat/ last visit September 07, 2019.

As I argued in my article: there is no “original master tape” of *La Légende d’Eer.* What Pape addresses as “original analogue multi-channel master” is the Paris copy (LLe-AS-EdH1) that has been used for the performance in the *Diatope* as material tape (and that was never performed without spatialisation). This tape has later been stored in a common stock of the publishing houses Durand/Salabert/Eschig and Ricordi in Milano, Italy, before being shipped back to Paris for the digitisation for Pape’s mix.

Even though the philological proof is furnished, I seized Pape’s proposal to re-digitise that tape.

3.4.7. Results

Thanks to the generosity of the publishing house Durand/Salabert/Eschig in Paris[225], I was able to bring the Paris 8-track tape LLE-AS-EdH-1 (which was used for the digitisation at GRM (Figure 32)), to Cologne, where it was digitised at WDR Studio für elektronische Musik by Volker Müller and Sefa Pekelli. Pekelli is a sound engineer at WDR who specialises in digitising analogue tapes.

Figure 38: Volker Müller investigating the Paris 8 track tape LLE-AS-EdH-1

[225] Thanks to Bruno Leroy and David Bray, Universal Music, Durand/Salabert/Eschig.

Volker Müller examined the tape which he had produced himself at the WDR studio in 1977 (Figure 38). When played with exactly the same tape machine on which it had originally been produced, it had the same length as all the other Cologne tapes, almost exactly 46 minutes. As predicted the tape was made from two connected tapes, the first, approximately 33 minutes long (Figure 38: part of the tape on the right bobbin of the tape machine), the second, approximately 13 minutes long (Figure 38: the remaining tape on the left bobbin of the tape machine). The two parts of the tape must have been disconnected, as they were joined with a material never used in the WDR studios (Figure 38: Volker Müller pointing to the join). This means that they were reconnected, probably after having been digitised separately. The new digitisation also proves that there were no new sounds to discover on this tape of *La Légende d'Eer*.

In philological terms, the length of LLE-03-Mode and LLE-AS-GRM-Digi2003 and the other faults are classical 'separative errors' shared with no other source. As all other sources were produced earlier, there is no doubt about the corruption of the version on Mode records.

The remaining question is, which multi-track version of the ones existing is "the right" one? – The seven-track version LLE-AS-EdH-1 from Paris without spatialisation or the spatialised eight-track version from WDR, LLE-AS-WDR-1? Xenakis did not attempt to assign definitive versions or forbid the performance of alternate versions. Fortunately, though, with regard to *La Légende d'Eer*, at least one question can be answered: during his lifetime Xenakis never performed a non-spatialised version of *La Légende d'Eer*. A chronology of the first performances clarifies some questions.

Date of performance	**Place**	**Version**
1978, Febr 11	Planetarium Bochum, Germany	WDR Bochum Version spatialised 8-track version

1978, June 28 – Dec 21 (3 x daily)	Paris, Le Diatope (Inauguration Centre George Pompidou)	Paris version, 7 tracks, automatically spatialised
1978, August 4	Darmstadt, Germany, Internationale Ferienkurse für Neue Musik	WDR Bochum Version spatialised 8-track version

The WDR *Bochum version* (Figure 32, LLE-AS-WDR-1) was assuredly the first to be performed on February 11, 1978 in Bochum[226] (in some publications an incorrect date of February 11, 1977 appears, probably copied from a mistake in a CD text[227]). The performance was realised in the Planetarium. During this performance Xenakis sat in the central control room for the projection which accompanied this premiere. This is probably where the "Müller" sounds received their poetic Name "*étoiles filantes sonores"* (sounding falling stars)[228], as very impressive images of falling stars were projected together with the sounds, replacing the laser show that was conceived for the Paris version. In summer 1978 the delayed premiere of the *Diatope* in Paris finally took place, and it was performed three times a day from June 28 to December 31, 1978.

On August 4, 1978, a little more than one month after the premiere in Paris, Xenakis performed the WDR-version LLE-AS-WDR-1 at Darmstädter Ferienkurse[229]. He sat in the middle of the audience at the mixing desk and the musical part was performed without visual imagery for the first time. In his introductory remarks Xenakis possibly spoke about the "first version" of the composition. A critic described the multimedia nature of the *Diatope* and concluded that Xenakis had now presented "a first, purely acoustic version of the piece"[230].

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[226] Xenakis, I., Kanach, S. (eds) (2006) Musique de l'architecture, Editions Paranthèses, Marseille, 339.
[227] Xenakis, I. (1995) *La Légende d'Eer*, CD Auvidis Montaigne, Paris.
[228] Xenakis, I. (1978) *La Légende d'Eer*, Partition résumée définitive des 7 pistes sonores, Archives WDR Köln, Orchesterpartitur 16405.
[229] *La Légende d'Eer*, concert and introduction by Iannis Xenakis on August 4, 1978 as documented in the archives of Internationales Musikinstitut Darmstadt ; compare: Stoianova, I. (1996) Xenakis – vom isolierten Pionier zum Klassiker des 20.Jahrhunderts, in: Stephan, R. (ed) (1996) Von Kranichstein zur Gegenwart, 50 Jahre Darmstädter Ferienkurse, Stuttgart 1996, 421.
[230] Darmstädter Tagblatt, August 7, 1978, Archiv Internationales Musikinstitut Darmstadt.

The simultaneous presentations of different versions in Paris and Darmstadt on the very same day (August 4, 1978) demonstrate that Xenakis considered both to be valid. However, he never performed what has now become the official performance material: the seven-channel tape of the *Diatope* LLE-AS-EdH-1 without spatialisation. Therefore, this tape is nothing other than the only surviving item from the *Diatope*, which was created at a time when nobody could predict the way in which computer technologies would lose their compatibility.

Thus, the version question may be answered: the version to play is the Cologne 8-track-tape LLE-AS-WDR-1.

3.4.8. Consequences

As a curator of the *Perihel series* of Karlrecords in Berlin[231], I opted for a practical solution: the re-release of *La Légende d'Eer* in a critically edited version. Together with the sound editor Martin Wurmnest, we realised a new mix-down of the spatialised 8-track tape LLE-AS-WDR-1. This had never been done. Besides aiming for high end sound quality, we intended to map the eight tracks to stereo in a way that allows listeners to perceive the moving sounds in a similar way as in the 8-track situation. As all movements on the 8-track tape are movements in circles, the solution was simple. The WDR numbering is 1 to 8 clockwise in a circle. Hence, for the stereo mix the order of the tracks was set from in the panorama from left to right: 1 8 2 7 3 6 4 5. Tracks 2 and 3 were pulled a little to the front, 7 and 6 were pushed a little to the back. Using headphones, this setting enables the listener to perceive circular sound movements.

The second aim was to try to reconstruct Xenakis's spatialisation. As Elena Kiourtsoglou succeeded in decrypting Xenakis's spatialisation draft[232] in the BnF, the idea of the sound movements became clear for almost the first 5 minutes of the automated spatialisation. Inside the *Diatope*, all seven tracks were mainly circling on speakers hanging on two different planes.

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[231] Karlrecords Berlin, http://www.karlrecords.net, last visit September 18, 2019.
[232] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.

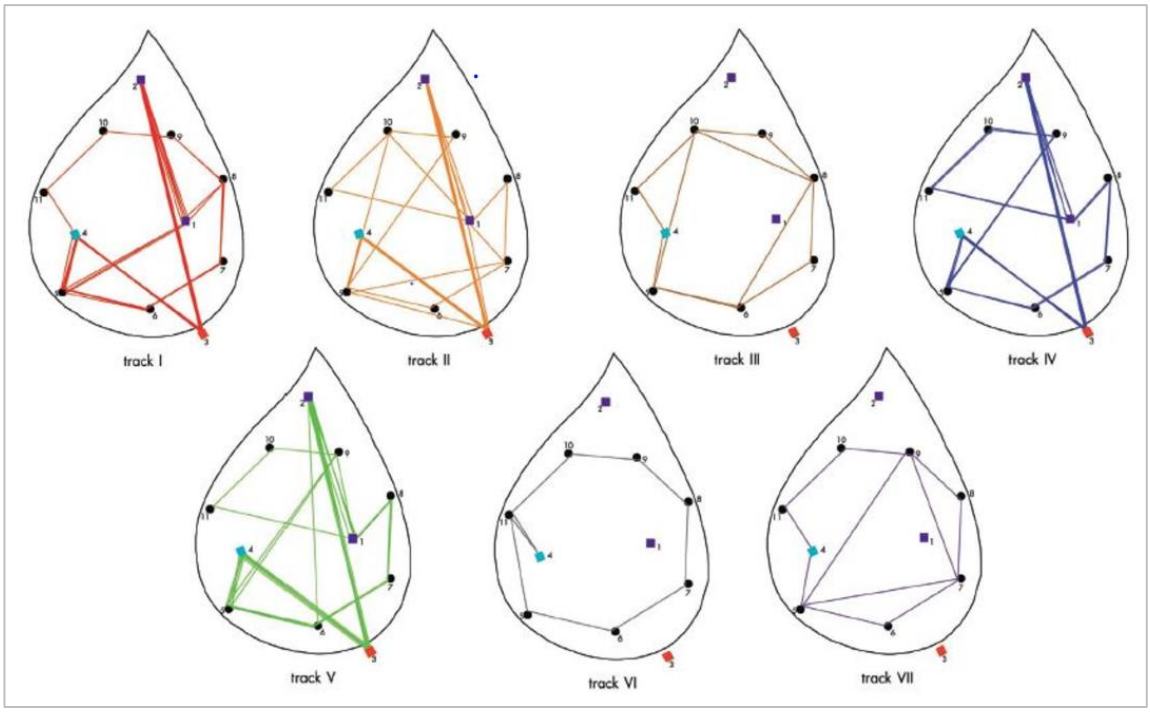

Figure 39: Spatial "transcription" of the first minutes of *La Légende d'Eer* by Elisavet Kioursoglou.

With this knowledge, I applied Xenakis's frequently used, climax-oriented dramaturgy: the initially slow movements rotate gradually faster and faster, and are become increasingly disrupted in the space, before finding their way back to vibrating rotations of the final sine waves, emphasising their interferences. This version was realised with the help of my "textural spatialisation software" developed for my Neo-Bechstein project at ZKM Karlsruhe (see practical part). With the kind permission of the Xenakis family, the result was presented as *Xenakis's Legend* in the Sound Dome at the Wunderground Festival in Copenhagen, Denmark[233].

[233] Wunderground Festival 2016, Copenhagen, Denmark.

4. Practical Part: Compositional Software Tool

The basic focus of the first part of this dissertation is based on the notion of text. This led to a philology of electroacoustic music, exemplified by Iannis Xenakis's compositions. The text of a composition has been discussed as fixed output, an inscription or notation. For the second part we will now shift to texture. The term will be discussed in detail below.

Xenakis composed the text of his electroacoustic music by using textures in several senses. On one hand, the sound material he used was clearly textural, on the other hand, even his kind of spatialisation of electroacoustic music can be considered as textural. It was also due to this textural approach that he was able to show a certain flexibility with his texts: as we have seen, he cut out the middle part of the textures of *Persepolis* and shortened the piece by 15% to release it on vinyl as a time-limited media. Xenakis also reduced the automated textural spatialisation of the Paris Version of *La Légende d'Eer* to the hand-made one in the Bochum-Version of *La Légende d'Eer*.

After a discussion of the notion of texture I will present my concept of textural spatialisation, as used in three of my compositions and realised applying my Textural Spatialisation Program (TSP). This leads to the attempt to reconstruct a spatialisation of *La Légende d'Eer* with TSP. In the following subchapter, this textural idea will be expanded to the sonic structure of textures, which led me to the development of a software application as a tool for musical composition: a Texture Transformation Machine (TTM). With the aid of this machine, a musical texture can be gradually transformed. The software is based on sculpting random distribution of the single elements of a texture, which will be exemplified in the last subchapter through my compositions *String Quartet no.3* and the composition for orchestra *KRAFFT*.

4.1. Texture

The Latin word family *texere* includes the substantives *textus* and *textura* and means tissue, mesh, coherence, structure, design, style (of a speech)[234]. Text and texture are closely related; *textus* as a Latin word did not mean "text",

[234] Compare: Knobloch, C. (2005/2010) Text/Textualität, in: Barck, J., Fontius, M. a.o. (2005/2010) Ästhetische Grundbegriffe, Stuttgart and Weimar, 23-47.

but can be translated with woven fabric, web, framework, structure, method of plaiting and joining.[235]

Texture – relating to this meaning – is a relatively young term in the context of music. Jonathan Dunsby wrote in 1989 that "to consider texture as a paradigm of musical enquiry at all appears to be rather new"[236]. Dunsby emphasises that the term 'texture' "does not appear as a separate entry in the 1954 edition of *Grove's Dictionary of Music and Musicians*, and even its treatment in *The New Grove* (1980) is innocent of much information."[237]

Due to the fact that the use of the term is rather new, there are two different notions of texture, leading to diverse definitions. The first definition emerged in the context of the theory of orchestration and considers texture as a property of every music. A musical texture denotes a facture of a given composition and is mostly divided into four categories:

1) monophonic texture
2) heterophonic texture
3) homophonic texture
4) polyphonic texture

This is how Donald Francis Tovey defines it in his book *Musical Textures*[238] from 1941. Theodor Adorno uses the German term 'Textur' in *Towards a Theory of Musical Reproduction*[239] in the same way: "Textur" is a feature of every music. In 1955, Walter Piston developed a further differentiation, significantly in a book about *Orchestration*[240]. He describes seven types of "orchestral textures":

1) unison

[235] https://www.online-latin-dictionary.com/latin-english-dictionary.php?lemma=TEXTUS100, last visit April 4, 2019.
[236] Dunsby, J. (1989) Considerations of Texture, in: Music & Letters, Vol.70, No.1, 46-58, 46.
[237] Ibid., 46.
[238] Tovey, D. (1941) Musical Textures, Oxford.
[239] Adorno, T. (2001) Zu einer Theorie der musikalischen Reproduktion, Frankfurt, 176.
[240] Piston, W. (1955) Orchestration, London.

2) melody and accompaniment
3) secondary melody
4) part-writing
5) contrapuntal texture
6) chords
7) complex texture

In this sense, ‘texture’ becomes a technical term, and has been applied in such musicological contexts as Dean Sutcliffe’s *Haydn’s Piano Trio Textures*.[241] It becomes a routine of musical analysis:

> The first step in analysis is the examination of the musical texture, apart from orchestration, to see what component elements make up the fabric of the music. As will be shown, these elements are usually few in number. They are such features as melody, harmonic background or accompaniment, contrapuntal lines, chords, etc., and in most music they are readily distinguishable.[242]

The understanding of texture focusses on perception. Accordingly, Dunsby explicitly underlines that texture is closely related to perception: “One implication of the above points is that texture, like other musical domains, depends for its meaning and differentiations on our perception of it”[243] Consequently, the term drew attention especially from Gestalt psychology. Dunsby quotes Leonard Meyer:

> Texture has to do with the ways in which the mind groups concurrent musical stimuli into simultaneous figures, a figure and accompaniment (ground), and so forth. Like other music processes textural organization, or the lack of it, may give rise to expectation.[244]

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wörter46.
[242] Piston, W. (1955) Orchestration, London, 355f.
[243] Ibid., 50.
[244] Meyer, L. (1956) Emotion and Meaning in Music, Chicago, 185; quoted from: Dunsby, J. (1989) Considerations of Texture, in: Music & Letters, Vol.70, No.1, 46-58; 50.

In a second, contradictory definition, texture is understood as a special property of only some music. Not every music can be associated with a certain kind of texture, but some music is textural, some not. With this definition, texture becomes a new musical attribute. Dunsby gives examples of the first appearance of the term ‘texture’ for phenomena of post-tonal music, but also Romantic drama (Wagner, Berlioz, etc.) and impressionist compositions (e.g. Debussy *La mer*):

> Many of the familiar terms and concepts in music criticism had become irrelevant, and in the search for an assimilation of modern music, what we now think of as texture was often the only hook on which critics, reviewers, and teachers too, were able to hang their musical understanding of the new.[245]

Rosemarie Mountain gives an extended and detailed discussion of the use of texture in contemporary post-serial music in her dissertation from 1993, focussing especially on the music of György Ligeti[246]. Mountain elaborately describes the understanding of texture in her article *Periodicity and musical texture* from 1998:

> In a general sense, musical texture refers to the temporal and registral distribution of notes in any given passage. Sparse texture consists of few notes per time unit, and/or spread over a wide registral range, where each component can be heard individually. Dense texture is composed of many notes sounding close together in time, and/or compressed into a limited portion of the registral range. Most typically, the identification of texture applies to a relatively dense backdrop to a melodic line. This is precisely analogous to the figure/ground relationships of the two-dimensional field, and the perceptual issues correspond to those developed by Gestalt

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[245] Meyer, L. (1956) Emotion and Meaning in Music, Chicago, 185; quoted from: J. (1989) Considerations of Texture, in: Music & Letters, Vol.70, No.1, 46-58, 47.
[246] Mountain, R. (1993) An investigation of periodicity in music: with reference to three twentieth-century compositions - Bartok's Music for strings, percussion & celesta, Lutoslawski's Concerto for orchestra, Ligeti's Chamber concerto, Dissertation, Ann Arbor, Michigan University, Microfiche.

> psychologists to explain visual perception. During the 20th century in particular, some composers have focussed on the design of these "background textures", even to the point of omitting the foreground melody altogether. When the listener's attention is drawn to the overall sonic image and the interplay of the component elements rather than on any one individual line, it becomes appropriate to describe the entire passage as "textural". The analysis of texture in itself is thus a natural response to the composition of texture in itself, and embraces an investigation of all the specific characteristics of a passage that can be appreciated in this more global way.[247]

Textural composition becomes a term and can be attributed to special composing styles. Mountain names them clearly: “The composition of textural passages was championed by composers such as Xenakis, Stockhausen, and Ligeti as they searched for new ways of organizing sonic material.”[248]

It is notable that all three of these composers, Iannis Xenakis, Karlheinz Stockhausen, and György Ligeti, also worked in the context of electroacoustic music. It is widely known that Ligeti‘s instrumental music – especially his famous orchestral compositions, *Apparitions* and *Athmosphères*, have been inspired by electroacoustic music. Benjamin Levy for example focusses in his article *Shapes of the Studio: Electronic Influences on Ligeti’s Apparitions*: “on the specific compositional techniques and the resulting gestures and textures which Ligeti discovered while working in electronic music and then carried over into the orchestral medium, thereby illuminating a previously neglected side of this important stylistic transformation.”[249]

It is not clear if electronic music was Ligeti`s single influence. Ligeti`s first textural orchestra composition *Apparitions* has been premiered in 1959. Xenakis

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[247] Mountain, R. (1998) Periodicity and musical texture, http://armchair-researcher.com/Rooms/Research/Rooms/writings/articles/PeriodicityMusical-Texture.pdf, last visit April 12, 2019, 1.
[248] Ibid., 2.
[249] Levy, B. (2009) Shapes of the Studio: Electronic Influences on Ligeti’s Apparitions, in: Perspectives of New Music, Vol.47, No.2, 59-87, 59.

was the first to introduce textural sound fields in contemporary music. His composition for large orchestra *Metasasis* has been composed 1953/54 and was premiered at *Donaueschinger Musiktage* in 1955. Xenakis`s second composition for orchestra *Pithoprakta* was premiered 1956 in Munich and included passages composed with stochastic functions (compare 4.2.).

James Harley writes:

> *Pithoprakta* contains a great deal of variation and formal shaping, providing for moments of relative repose where listeners can gather their bearings (silences, sustained notes, thinner textures). At the premiere, however, which took place in Munich with Hermann Scherchen conducting the Bayerischer Rundfunk Symphony Orchestra,the audience (and the orchestra!) found little in the music to re assure their traditional sensibilities. As did *Metastaseis*, the score caused an uproar, and the reaction was similar when Scherchen conducted it in Darmstadt the following year. At the same time, though, exposure to these shocking new scores was spreading, primarily through broadcasts on German radio. (*Metastaseis* was also performed and broadcast in Sweden in 1958.) Stockhausen included certain quasi-statistical textures in *Gruppen* (1957); György Ligeti featured his large masses and intricate sonic weaves in *Apparitions* (1959); and Polish composers began their striking sonic explorations soon thereafter.[250]

Ligeti himself denied any knowledge of those compositions. This is astonishing as Xenakis`s first orchestra compositions have been largely discussed and have been presented at the most prominent festivals: *Metasasis* was premiered 1955 at Donaueschinger Musiktage, Xenakis`s second composition for large orchestra *Pithoprakta* 1956. But Ligeti insisted that his influence came from electronic music and not from Iannis Xenakis, when he discussed his orchestra compositions *Apparitions* from 1959:

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[250] Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 15.

> The ability of composing something like this, or to think in this way compositionally, results above all from the experience in the electronic studio. I must for the sake of justice mention that it would be wrong to claim that I had invented the total Divisi of strings. This existed a few years earlier, I think first with Iannis Xenakis in *Metastasis*. I did not know the music of Xenakis, when I composed around 1958 pieces with total Divisi.[251]

Ligeti`s techniques might have been inspired from Xenakis`s music, but he did not use mathematical stochastic methods (see 4.2.). But soundwise, Xenakis was convinced that his compositions have been an inspiration.

From a historical perspective, the "concern with volumes and densities of sound" which Xenakis shared in common with Varèse carried on in the texture-based music of Eastern European composers such as György Ligeti and Krzysztof Penderecki. At first, Xenakis found it perplexing to learn that he himself was being imitated: "But then I thought: if others were using my methods there must be an objective need for what I was doing."[252]

It is interesting to look at the notion of texture also in the context of electronic music that inspired Ligeti. Early electroacoustic music opened up new textural possibilities: the layering of different sound strands, the cutting of shortest sound particles, such as in Stockhausen's *Konkrete Etüde*, and the stochastic densification of sound material, such as in Xenakis's *Diamorphoses*.

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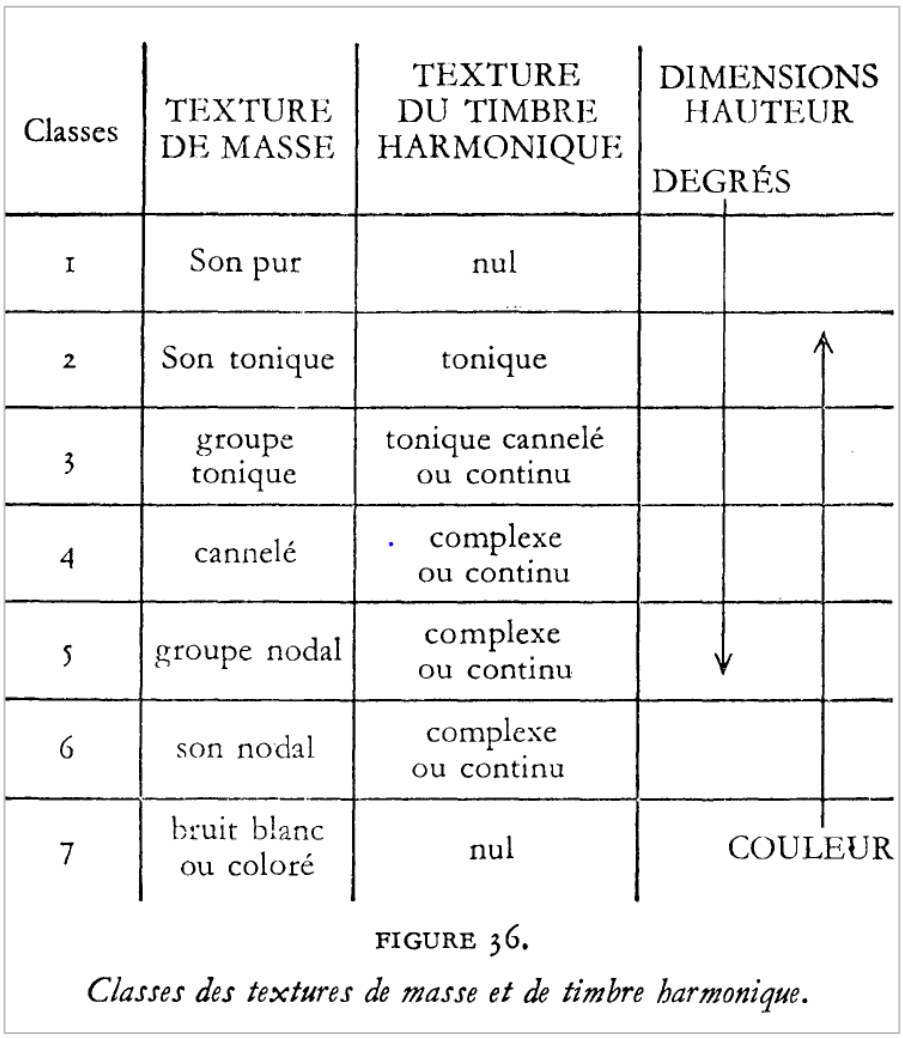
[251] Ligeti, G. (1968) Auswirkungen der elektronischen Musik auf mein kompositorisches Schaffen. In: György Ligeti: Gesammelte Schriften Vol. 2, Vol. 2, Paul Sacher Foundation, Mainz, 86-94, 87, translation by the author. „Die Möglichkeit, so etwas zu komponieren oder auf diese Weise kompositorisch zu denken, resultiert vor allem aus den Erfahrungen im elektronischen Studio. Ich muß um der Gerechtigkeit willen gleich erwähnen, daß es falsch wäre zu behaupten, ich hätte das totale Divisi der Streicher erfunden. Das gab es schon einige Jahre früher, ich glaube zuerst bei Iannis Xenakis in Metastaseis. Ich kannte die Musik von Xenakis nicht, als ich um 1958 Stücke mit totalem Divisi komponierte, aber das ist kein Milderungsgrund."

[252] Harley, J. (2006) The Creative Compositional Legacy of Iannis Xenakis, in: Solomos, M., Georgaki, A., Zervos, G. (eds) Definitive Proceedings of the "International Symposium Iannis Xenakis" (Athens, May 2005), www.iannis-xenakis.org, last visit September 20, 2019.

In the context of electroacoustic music, however, the two opposing definitions of texture can be found. Pierre Schaeffer used the term in his *Traité des objets musicaux* but did not define it explicitly.

Schaeffer used the French equivalent “texture” as a category of the sonic quality of a sound object. Texture is a property of the mass of a sound object (which should not be confused with sound masses). In this sense, texture becomes a microscopic view of a sound. Schaeffer gives seven degrees of “*texture de masse*” that gradually increase from a sine wave to white noise (Figure 40).



Classes	TEXTURE DE MASSE	TEXTURE DU TIMBRE HARMONIQUE	DIMENSIONS HAUTEUR DEGRÉS
1	Son pur	nul	
2	Son tonique	tonique	
3	groupe tonique	tonique cannelé ou continu	
4	cannelé	complexe ou continu	
5	groupe nodal	complexe ou continu	
6	son nodal	complexe ou continu	
7	bruit blanc ou coloré	nul	COULEUR

FIGURE 36.

Classes des textures de masse et de timbre harmonique.

Figure 40: Pierre Schaeffer (1966), 518.

Sound objects are defined by their texture, which means thickness, range, etc., and Pierre Schaeffer underlines that we can

> […] I differentiate a texture, a certain organisation of a mass, as for example in the sound of a bell. I could add a metal sheet or deep piano note: the texture characterising these two different sounds (different in tessitura, in thickness, etc.) is formed by a dominant base, superimposed by a brilliant layer….[253]

However, in the same book, Pierre Schaeffer uses the term "*texture sonore*" in the sense of the second definition, here to compare the characteristic sonic properties of an avant-garde concert with the ones of a bird cage: "In a bird cage, as in an avant-garde concert, the similarity of the facture between the elements of the sonic textures brings those elements closer to each other for the ear, it unifies the perception."[254]

The electroacoustic music composer Denis Smalley explicitly credits Pierre Schaeffer's *Traité des objets musicaux* for providing the foundations for his essay *Spectro-morphology and Structuring Processes* from 1986. But he elaborates on another concept of texture that is close to the aforementioned concept from Mountain (see above).

> The relationship between gesture and texture is more one of collaboration than antithesis. Gesture and texture commonly share the structural workload but not always in an egalitarian spirit. We may therefore refer to

[253] Schaeffer, P. (1966) Traité des objets musicaux, Paris, 519. Translated by the author, Original quote: « Entre l'accord ou je résous les toniques, et l'épaisseur, qui est l'aveu du flou, je distingue une texture, une certaine organisation de la masse, comme par exemple dans un son de cloche. Je peux rapprocher tôle et piano grave, disant : cette texture qui caractérise ces deux sons pourtant différents (en tessiture, en épaisseur, etc.) est formée d'un soubassement épais, surmonté d'une frange brillante... »

[254] Schaeffer, P. (1966) Traité des objets musicaux, Paris, 453. Translated by the author, Original quote: « Dans la volière comme dans la salle de concert d'avantgarde, c'est la ressemblance de facture entre éléments de la texture sonore qui, rapprochant ces éléments les uns des autres pour l'oreille, unifie la perception. »

> structures as either gesture-carried or texture-carried, depending on which is the more dominant partner.[255]

Texture is a property of certain musical passages or structures.

> Texture, on the other hand, is concerned with internal behaviour patterning, energy directed inwards or reinjected, self-propagating; once instigated it is seemingly left to its own devices; instead of being provoked to act in it merely continues behaving. Where gesture is interventionist, texture is laissez-faire; where gesture is occupied with growth and progress, texture is rapt in contemplation; where gesture presses forward, texture marks time; where gesture is carried by external shape, texture turns to internal activity;[256]

The dichotomy of texture versus gesture becomes crucial in Smalley's understanding of the term. This understanding is not limited to electroacoustic music, but is meanwhile prevalent in the contemporary music context, as Dunsby emphasises: "The large majority of dissertations in which "texture" is a keyword or a category […] turn out to be studies of the sonic aspects of music of the twentieth century, often of one composer or even one work."[257]

Returning to Xenakis, the use of the term 'texture' in Smalley's sense can be found in almost all literature about his music. Harley writes:

> Metastaseis had introduced the notion of architectural or global sonorities, where massed glissandi, for example, create a sonic entity that can only be perceived as a whole and not as a product of smaller elements. Even the quasi-serial passages were complex enough to be heard as texture rather than counterpoint.[258]

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[255] Smalley, D. (1986) Spectro-morphology and Structuring Processes, in: Emmerson, S. (ed) (1986) The Language of Electroacoustic Music, London, 61-93, 83.
[256] Ibid., 82.
[257] Dunsby, J. (1989) Considerations of Texture, in: Music & Letters, Vol.70, No.1, 46-58, 46.
[258] Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 11.

Matossian underlines the “prominence given to textures”[259], and also in writings on Xenakis’s electroacoustic music, the term “texture” is used extensively: for instance, in *Xenakis - das elektroakustische Werk*, the German equivalent “Textur” appears on thirty-five of 250 pages.[260]

It is interesting that Xenakis almost never used the term in his own writings[261], but in the secondary literature it is ubiquitous. Xenakis preferred to speak of “masses”, as he was proud to have introduced this term into the musical discussion. He told Varga about *Metastaseis*: “I wrote this piece in 1953/54 and called it a new beginning, as I introduced the notion of mass into music … Almost everybody in the orchestra becomes a soloist; the strings are completely divided and play huge masses of pizzicati and glissandi.”[262]

Xenakis’s “sound clouds” or “stochastic masses” are clearly textures in the sense of Rosemary Mountain’s definition given above: “When the listener's attention is drawn to the overall sonic image and the interplay of the component elements rather than on any one individual line, it becomes appropriate to describe the entire passage as "textural".”

Xenakis’s technique of building such sonic textures can be seen quintessentially in his electroacoustic music, particularly in the scores and drafts for his polytopes. A limited number of sound recordings are combined and superimposed, building up sonic textures. These textures slowly change through successively replaced sound material, thus leading into the dramaturgy of the

[259] Matossian, N. (2005) Xenakis, Lefkosia, 100.
[260] Paland, R., Von Blumröder, C. (eds) (2009) Iannis Xenakis: Das elektroakustische Werk, Wien.
[261] Xenakis used the term twice in: Xenakis, I. (1992) Formalized Music, Perdragon Press, Hillsdale, 83 and 199.
[262] Translation by the author from Varga, B.A., Xenakis, I. (1995) Gespräche mit Iannis Xenakis, Atlantis Musikbuch-Verl, Zürich, 54. Original text: „Ich schrieb dieses Stück in den Jahren 1953-54 und bezeichnete es als Neubeginn, weil ich dort den Begriff der Masse in die Musik eingeführt habe ... Im Orchester wird fast jeder zum Solisten; die Streicher sind vollständig geteilt und spielen große Massen von Pizzicati und Glissandi."

composition. This can be seen in *La Légende d'Eer* as well as in *Persepolis* (Figure 41).

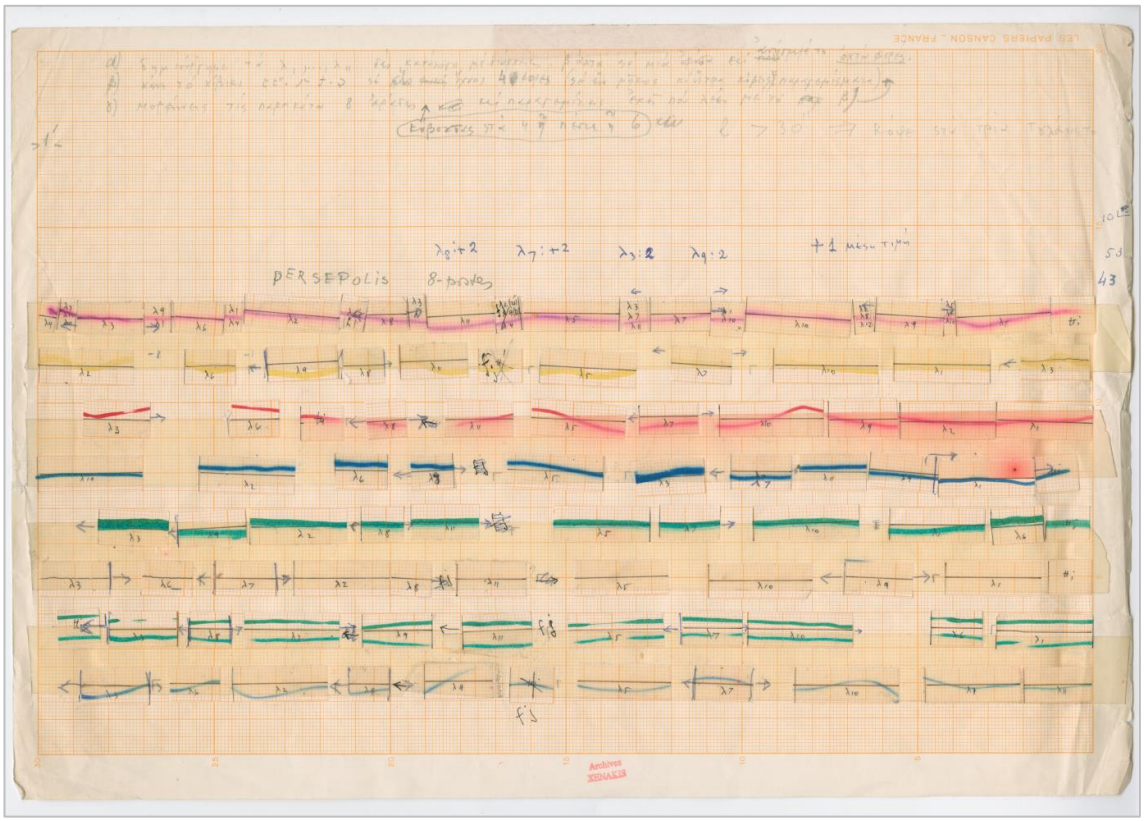

Figure 41: *Persepolis* 'score' see: Apparatus *Persepolis*, PER-VS-AFX-02.

Looking at the score of *Persepolis*, one could even say that the composition itself is a texture, made from other textures. The sound materials called λ1 to λ11 are themselves textures (see 3.2. *Persepolis*) that are combined and superimposed. The interplay of these elements becomes more important for the listener than the single materials or tracks.

Xenakis himself once called this phaenomenon "Sound Tapestry"[263], when he discussed a passage of his orchestra composition *Nomos Gamma*.

In the following chapters, I will refer to the definitions of musical texture by Mountain and Smalley, understanding texture as a set of limited sonic materials

[263] Ibid., 239.

or elements which are repeated in multifaceted variations, permutations, and superpositions, creating a special quality in terms of sound, rhythm, density, loudness, colour, etc. These textures can be superimposed and even cascaded in as meta-textures.

From the listeners' standpoint, Ralph Wood provided a good description in 1942:

> Textural listening is a way to regard any piece of music as an unwinding strip of 'texture': and just to listen to that; not to its various strands as such, not to one single strand, but to it as a whole, an unwinding ribbon, varying as it goes in width, in colour, in depth, in thickness, in weight, in character, but always a unity.[264]

But how can those textures that appear firstly as static sound fields be used as musical material and be transformed? In short: how can one compose with textures?

4.2. Texture Transformation

In 1963, Xenakis presented his ideas and approaches, inspired by probability theory, in the first French edition of his monograph *Musiques formelles*[265]. Almost all of his writings until then – most of them having already been published in *Gravesaner Blätter*[266], edited by his mentor Hermann Scherchen – appear in his book as chapters I to VI. For the English version he added several chapters in 1971, again expanding it in 1992[267] by adding four more chapters on theory of sieves and stochastic synthesis.

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[264] Ibid.
[265] Xenakis, I. (1963) Musiques Formelles, Editions Richard-Masse, Paris.
[266] See: Gravesaner Blätter 1, 6, 9, 11/12, 18, 19, 20, 21, 22, 23/24 (ed) Scherchen, H. (1955-1961)
[267] Xenakis, I. (1992) Formalized Music, Pendragon Press, Hillsdale, iv. The given publishing story does not mention Gravesaner Blätter 23/24 containing the article "Stochastische Musik" which became also part of Formalized Music.

As early as in the introduction of *Musiques Formelles* from 1963, Xenakis recalled:

> I originated in 1954 a music constructed from the principle of indeterminism; two years later I named it “Stochastic Music”. The laws and the calculus of probabilities entered composition through musical necessity.
>
> But other paths also led to the same stochastic crossroads – first of all, natural events such as the collision of hail or rain with hard surfaces, or the sound of cicadas in a summer field. These sonic events are made out of thousands of isolated sounds: this multitude of sounds, seen as a totality, is a new sonic event. This mass event is articulated and forms a plastic mold of time, which itself follows aleatory and stochastic laws. […]
>
> Here we touch one of the great problems that have haunted human intelligence since antiquity: continuous or discontinuous transformation. […]
>
> A multitude of short glissandi on strings can give the impression of continuity, and so can a multitude of pizzicati. Passages from a discontinuous state to a continuous state are controllable with the aid of probability theory.[268]

Xenakis quotes here his well-known examples for sonic textures in nature: the “sound of cicadas”, the “rain on hard surfaces”, and states that those phenomena have a certain form in time: a “plastic mold”.

Thinking of the mentioned “discontinuous” and “continuous states” as textures, Xenakis asserts that such texture transformations are shapeable with techniques provided by probability theory. Admitting that “large sets of granular and/or continuous sounds” and “sonic substances” are other terms for textures, Xenakis faced the problem of texture transformations explicitly in the texts he published before 1963:

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[268] English translation quoted from Ibid., 8-9.

> We can control continuous transformations of large sets of granular and/or continuous sounds. In fact, densities, durations, registers, speeds, etc., can all be subjected to the law of large numbers with the necessary approximations. We can therefore with the aid of means and deviations shape these sets and make them evolve in different directions. The best known is that which goes from order to disorder, or vice versa, and which introduces the concept of entropy. We can conceive of other continuous transformations: for example, a set of plucked sounds transforming continuously into a set of arco sounds, or in electromagnetic music, the passage from one sonic substance to another, assuring thus an organic connection between the two substances. To illustrate this idea, I recall the Greek sophism about baldness: "How many hairs must one remove from a hairy skull in order to make it bald?" It is a problem resolved by the theory of probability with the standard deviation, and known by the term 'statistical definition'.[269]

Xenakis gives a few examples throughout *Formalized Music*. A main example is a passage of his composition for string orchestra *Pithoprakta* (1956). Direction and range of consecutive glissandi of every single string instrument are not only calculated with the help of probabilities, but the progression of these sonic events is moulded in a certain way. "If glissandi are long and sufficiently interlaced, we obtain sonic spaces of continuous evolution."[270]

Looking at this "evolution" we can see that the range of sounds of a huge string orchestra diminishes: the lowest and highest registers are disappearing. The passage is astonishingly short even though the precise length remains unclear. In *Formalized Music* from 1991, bars 52 to 57 of *Pithoprakta* are shown, the graphical presentation is also credited as bars 52 to 57[271], but bars 51 to 59 are displayed. This becomes clear through comparison with the earlier

[269] Ibid., 16.
[270] Ibid., 10.
[271] Ibid., 18

publication in *Gravesaner Blätter*[272] in 1956, where the score of the complete passage from bar 51 to 59 is shown. It seems clear, though, that a “continuous evolution” is occurring. The sounds contract toward the middle of the pitch space. This effect is probably due to entropy, as the applied “[…] chain of reasoning borrowed from Paul Levy was established after Maxwell, who, with Boltzmann, was responsible for the kinetic theory of gases.”[273]

Xenakis defined range and direction of the glissandi as “speed” and could therefore transpose the kinetic model into his musical structure: “The speeds determine a "temperature" which is subject to local fluctuations. Their distribution is Gaussian.”[274]

Due to entropy, speed and temperature would diminish over time, and that would correlate to the shown graph and score. Xenakis does not explain how he achieved the result exactly, nor does he answer the question of how he treated results of his calculation that allocated to single instruments pitches out of range, or how exactly he defined the progression of the probabilities in order to make the entropy occur. Xenakis summarises: “We can therefore with the aid of means and deviations shape these sets and make them evolve in different directions. The best known [is] that which goes from order to disorder, or vice versa, and which introduces the concept of entropy.”[275]

Later in the same chapter, Xenakis lists the “Fundamental Phases of a Musical Work”:[276]

1. Initial conceptions (intuitions, provisional or definitive data);
2. Definition of the sonic entities and of their symbolism communicable with the limits of possible means (sounds of musical instruments, electronic sounds, noises, sets of ordered sonic elements, granular or continuous

[272] Xenakis, I. (1956) Manipulation und Konzeption, in: Gravesaner Blätter 6, (ed) Scherchen, H., Mainz, 34-37.
[273] Ibid., 15.
[274] Ibid., 15.
[275] Ibid., 16.
[276] Ibid., 22.

formations, etc.);

3. Definition of the transformations which these sonic entities must undergo in the course of the composition […];

4. Microcomposition (choice and detailed fixing of the functional or stochastic relations of the elements of 2.) […];

5. Sequential programming of 3. and 4. (the schema and pattern of the work in its entirety);

6. Implementation of calculations, verifications, feedbacks, and definitive modifications of the sequential program;

7. Final symbolic result of the programming (setting out the music on paper in traditional notation, […];

8. Sonic realization of the program […]

5. to 8. are more or less technical issues: programming of the mathematical models, transferring the output in order to obtain an acoustic result. 1. is also self-explanatory. The remaining points in Xenakis's concept here are:

(i) Definition of the sounding entities.

(ii) Transformation of those entities.

(iii) Microcomposition (choice and detailed fixing of the functional or stochastic relations of the sounding entities' elements)

To relate this, we could say that texture would be an entity defined in (i) and structured with (iii). And in (ii) Xenakis asks for transformation of those entities, including textures.

It is astonishing that he neither included this transformation idea more prominently in his software approaches, nor in his mathematical models. The reason might be found in his education as an engineer, combined with his quasi-naturalist approach to probability theory. Xenakis, almost right throughout his work, remained faithful to a few standard probability distributions that are classically used in practical contexts as risk calculations in engineering. This might be related to his education in engineering, where he presumably already

came in to contact with those kinds of probability distributions. As a young engineer, Xenakis joined the team of the French architect Le Corbusier in Paris in 1947, remained for the following twelve years, and was soon known for his interest in these topics:

> It was the first time since his studies in engineering that Xenakis found himself in a professional situation which provoked stimulating argument. From time to time intellectual bait was inadvertently thrown his way; engineering problems which were puzzling the team, questions of statics and structure captured his attention.[277]

The mathematical standard probability distributions for risk calculations – widely used in statics – are the “Poisson distribution” and the “Normal” or “Gauss distribution”. Without going into too much detail, these distributions are the ones Xenakis principally applies in his compositional work. He hardly discusses any other distribution in the context of sonic textures. Other models he proposes, such as the Markow chains, also refer to these distributions or are serving other purposes, as for example, the model of binomial random walk used for his late sound synthesis (*Gendy 3*). That Xenakis usually calls these distributions “laws”[278] suggests that he probably took them as inevitably given. For example, he states: “The frequencies in this matrix are distributed according to Poisson's formula, which is the law for the appearances of rare random events.”[279]

He adds: “But in this axiomatic research, where chance must bathe all of sonic space, we must reject every distribution which departs from Poisson's law.”[280]

It seems that probability distributions are not a flexible concept in Xenakis’s thinking. This might derive from a thinking that connects probabilities with natural or physical processes, to some “laws”, for example, entropy. When Xenakis gives

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[277] Matossian, N. (2005) Iannis Xenakis, Moufflon Publications, Lefkosia, 49.
[278] See especially: Xenakis, I. (1992) Formalized Music, Perdragon Press, Hillsdale, 31-39.
[279] Ibid., 25.
[280] Ibid., 31.

examples for stochastic phaenomena, he usually refers to nature: his most known examples are the sound of thousands of cicadas[281], the sound of rain dropping, etc. (see above). Furthermore, even when modelling his probability properties, he often returns to very concrete phaenomena in nature, borrowed from physics, chemistry, or kinetics: an example is the Maxwell–Boltzmann distribution or his frequent use of the Poisson distribution, his so-called “law”.

It might be possible that this preference for naturalist references limited Xenakis’s probability models. It is astonishing that he asked for “Definition of the transformations which these sonic entities must undergo in the course of the composition”, but in his implementations limited these transformations to entropy. Arbitrary processes between different textures or entities have not been explored.

In another attempt, Xenakis focused on Markov chains, but also in this model he came back to entropy effects. In chapter II of *Formalized Music* he discusses the transformations from different screens or combinations of screens by Markovian processes. A screen is defined as follows:

> The screen is the audible area (FG) fixed by a sufficiently close and homogeneous grid as defined above, the cells of which may or may not be occupied by grains. In this way any sound and its history may be described by means of a sufficiently large number of sheets of paper carrying a given screen S. These sheets are placed in a fixed lexicographic, order.[282]

[281] Ibid., 16.
[282] Ibid., 51.

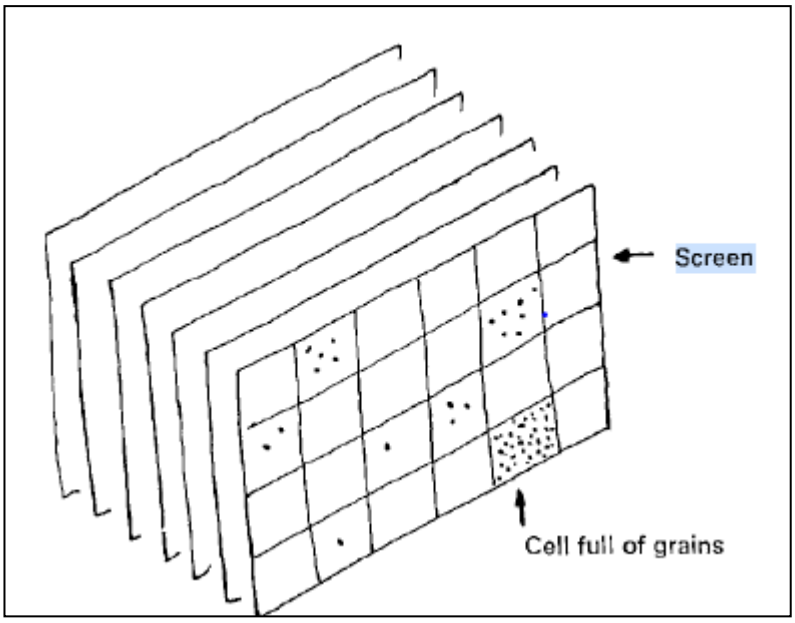

Figure 42: screen[283].

An instrumental composition is made out of a sequence of these screens, the grains are single sound events played by instruments or realised as an electroacoustic composition. A Markov chain is defined by defining probabilities to all possible successors for all screens. Each screen depends on the preceding screen. In this sense the procedure has a “memory”. The interesting property of a Markov chain is its behaviour: does the evolving series of screens converge to a certain screen? And if yes, when and to which one(s)? Xenakis was well aware of this property and discussed it in the context of his composition *Analogique A* for string orchestra and *Analogique B* for sinusoidal sounds (1959). “After several more or less long oscillations, the stationary state, if it exists, will be attained and the proportions of the screens will remain invariable.”[284]

And here again Xenakis focusses on entropy: “Now that we know how to calculate the stationary probabilities of a Markov chain we can easily calculate its mean entropy.”[285]

[283] Ibid., 53.
[284] Ibid., 90.
[285] Ibid., 86.

Xenakis uses this property of Markov chains musically to construct periods of perturbation and periods that return to equilibrium.[286] Entropy is thought of as a process that leads from a discontinuous to a continuous, from an unstable to a stable state. He uses the immanent behaviour of special probability models as a transformation tool. What he does not do, is to think about transformation as such, a transformation of arbitrary given textures. Nevertheless, Xenakis's probability models are based on the modular idea of creating a composition as a sequence of successive states of defined length. This length was fixed in the first essays, as for example in *Achorripsis* (1957).

> *Achorripsis* is simply structured as a succession of twenty-eight short sections, each of an equal duration of fifteen seconds. Seven sonic entities are established, forming a kind of "orchestra," and five levels of density are generated according to a Poisson function, to be distributed across the matrix of temporal and sonic units.[287]

The 28 sections can be seen in Figure 43.

[286] Ibid., 103, Fig. III-15.
[287] Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 22.

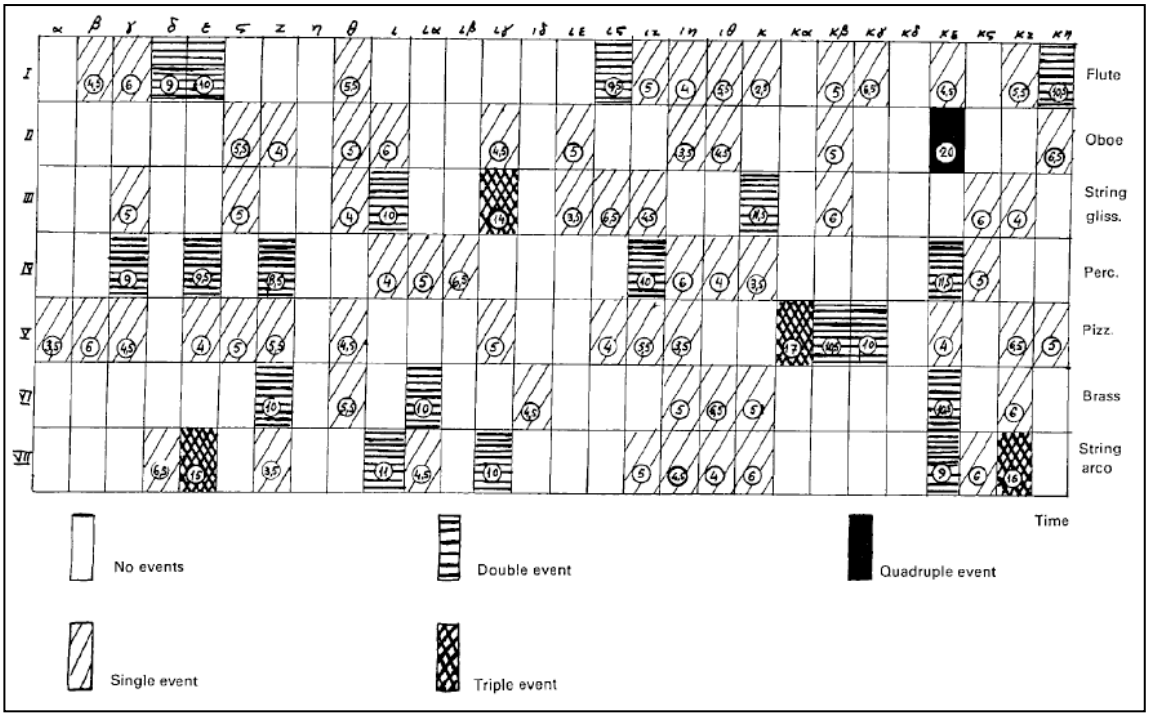

Figure 43: Matrix of *Achorripsis*[288]

The “short sections” are texturally defined by their density. There is no transformation from one to the next one, they are just compound and superimposed. But the textures are characteristic, as Xenakis stated:

> In fact, the data will appear aleatory only at the first hearing. Then, during successive rehearings the relations between the events of the sample ordained by "chance" will form a network, which will take on a definite meaning in the mind of the listener, and will initiate a special "logic", a new cohesion capable of satisfying his intellect as well as his aesthetic sense;[289]

The ST-Algorithm, which Xenakis later used to create (more or less) entire compositions of his ST-series[290], is an elaboration of the “fundamental phases of a musical work” used for the composition of *Achorripsis,*[291] as James Harley underlines:

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[288] Xenakis, I. (1992) Formalized Music, Perdragon Press, Hillsdale, 28.
[289] Ibid., 37.
[290] For a full list see: Harley, J. (2004) Xenakis: His life in music, Routledge, New York, 28.
[291] Ibid., 27.

There are advances on *Achorripsis* — the variability of section length, for example — but basically the process is the same. Once the program is run through the computer, the numerical output must be transcribed into music, allowing Xenakis to apply his own judgment to the results, changing details, or reordering events, as he saw fit.

Summarising, we have to conclude that Xenakis, already in 1956, was a visionary in formulating the problem of transforming one stochastic material into another, of one "sounding entity" into another, as he called it; of one texture into another, as we could say.

It remains a peculiar contradiction that he did not conceive a computer program for this problem. On the one hand he constrained his approaches to processes as convergence of some probability models, connected to entropy. On the other hand, it seems that he kept to a restricted repertoire of random distributions due to his engineering background, where they were considered as "laws". It might be significant that Xenakis considered other distributions in the context of sound synthesis in the chapters added to the last version of *Formalized Music* from 1991, especially in the very brief chapters IX[292] and XIII[293]. Xenakis even proclaims then: "Every probability function is a particular stochastic variation, which has its own personality (personal behaviour of the particle). We shall then use any one of them."[294]

And it seems that Xenakis was well aware of the promising future of the use of all kinds of probability distributions augmented to macro composition. "Further manipulations with classes of distributions […] introduce us to the domain of macrocomposition. But we will not continue these speculations since many things that have been exposed in the preceding chapters could be used fruitfully in obvious ways."[295]

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[292] Ibid., New Proposals in Microsound Structure, 242-254.
[293] Ibid., Dynamic Stochastic Systems, 289-293.
[294] Ibid., 246.
[295] Ibid., 249.

With the background of all the impressive works and composition Xenakis could conceive and compose with the help of his restricted models, it makes sense to follow these visionary proposals and to refer to his initial motivation to structure “mass event and form a plastic mold of time”;

As we will see in 4.4., I developed the model for a Texture Transformation Machine (TTM) in this sense. It allows modulation of probabilities of a given set of sonic events, step by step, and automatically. This is realised with the aid of a flexible graphic approach to probability distributions – as Xenakis proposed: “We shall use any of them”!

4.3. Preliminary Annotation: A Textural Spatialisation Programme

The textural nature of Xenakis’s spatialisation of his electroacoustic music will be discussed using the example of his composition *La Légende d’Eer* (that has already been addressed philologically in chapter 2.4.). I will then present the Textural Spatialisation Program (TSP) I had developed before knowing Xenakis’s spatialisation concepts. Two compositions will be briefly presented to exemplify the use of TSP. The similarities between TSP’s spatialisation concept and that of Xenakis become apparent, leading to a vicarious reconstruction of the lost automated spatialisation of *La Légende d’Eer*.

4.3.1. Xenakis’s Spatialisation of *La Légende d’Eer*

Elisavet Kiourtsoglou reconstructed the first 4 minutes and 50 seconds of the spatialisation of Xenakis’s *La Légende d’Eer* from Xenakis’s sketches (Figure 44)

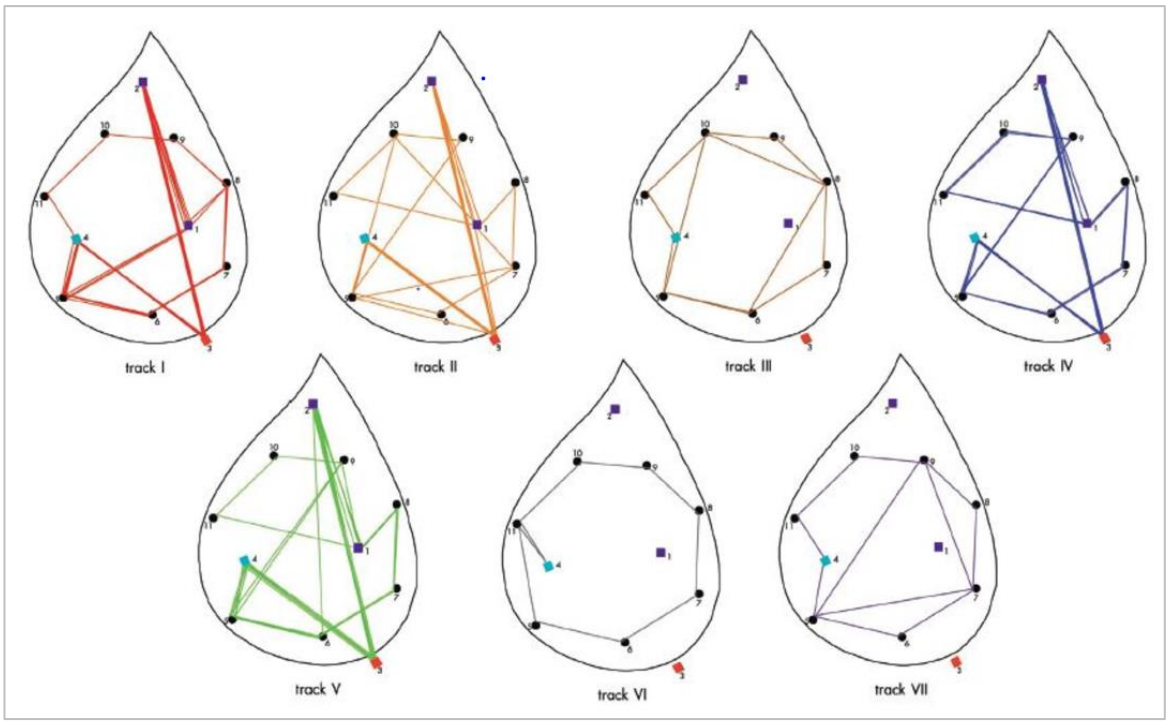

Figure 44: Spatial "transcription" of the first minutes of *La Légende d'Eer* by Elisavet Kioursoglou

This was discussed at the end chapter 3.4. on *La Légende d'Eer*. In the following I examine the given spatialisation patterns more closely, and study whether such patterns constitute a spatialisation *texture*. To recall, *La Lègende d'Eer* was the musical part of Xenakis's *Diatope*, that was commissioned for the inauguration of the Centre George Pompidou in Paris, 1978 (Figure 45).

Figure 45: Xenakis's *Diatope* in Paris, 1978, courtesy of *Friends of Xenakis.*

The seven asymmetric forms in figure 44 each show the ground plan of the *Diatope*. The points, numbered one to eleven, stand for the speaker positions, and the coloured lines map the movements of the seven tracks on the eleven speakers. These speakers were spread inside the *Diatope* on two different levels: 1, 2, 3 and 4 on a higher level; the rest – 5 to 11 – almost in a circle on the ground.

Three properties of the given traces of the single tracks on the speakers are of interest:

1) The sound source is not projected to a virtual point in the room, but always goes directly from one speaker to another.
2) All traces include rotations, clearly visible for track III, VI, and VII (for the other tracks, it might be clearer if we consider that the speakers are hung in two levels), and each track is using almost all speakers. (III, VI, and VII are not projected to speakers 1, 2, and 3, which were possibly those on the higher level.)[296]
3) The similarity of the movements: tracks I, II, IV, and V are very alike, and the same goes for tracks III, VI, and VII. They only differ slightly.

These observations illustrate that Xenakis's spatialisation was textural; imagining that all seven tracks are played and projected simultaneously, the perception of the overall sound must have been similar for all listeners: a mass of a limited number of sounds spatialised predominantly by varying rotations.

Mountain's definition again holds true: the spatialisation draws "the listener's attention […] to the overall sonic image and the interplay of the component elements rather than on any one individual line", the component elements now being the single sound traces in the room. This kind of spatialisation is textural.

[296] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.

In the next subchapter, I will discuss how this observation allowed me to use this tool to spatialise *La Légende d'Eer* in 2015 in reference to the characteristic properties of Xenakis's spatialisation.

In 2018, Kiourtsoglou finally released a more detailed analysis of the spatialisation as a result of her dissertation. It confirmed the above-noted observations. She quotes Xenakis's fragmented descriptions, and discusses further archival findings, such as drafts and other documents. She concludes:

> …tracks I, II, IV, and V are […] following the trajectory 1–2–3–4 many times. This means they are moving over the upper loudspeakers and then more or less forming circles over the floor-based loudspeakers. At the same time, tracks III, VI, and VII form circles on the floor-based loudspeakers without using the suspended loudspeakers (with the exception of speaker 4). Xenakis's notes describing the first minutes of the piece also indicate these movements: "On the upper four and then circle" or "galactic dust . . . from the upper loudspeakers." […] In addition, their sound speed is almost the same (movement between two loudspeakers in 5 seconds). Nevertheless, we cannot say if the sound movements of the numerical sound score were kept unchanged, as in the same folder at CEMAMU's archives we also find "sound tests" using slightly different rates for the sound speed and the duration of sound movements. This does not prevent us, though, from assuming that the movements described here could be very close to the ones conceived and followed during the whole or a part of the performance.[297]

[297] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.

4.3.2. Textural Spatialisation Programme

I began to develop a textural spatialisation programme (TSP) in 2004, and have used it since in several compositions[298] (programming: Sukandar Kartadinata with pure data, later versions in Max). TSP was created with a simple aim: to avoid the problem of there being only one ideal listening position in the middle of the surrounding speakers. This ideal position is not attainable in a performance space for more than one person in the audience. The idea of assigning a virtual position in space to each sound is the classical starting point of many spatialisation programmes. Here, another approach has been chosen for two reasons: firstly, to bannish the idea of one single, privileged listener – the only listener who can perceive the ideal virtual positioning of sound in space; secondly, because every definition for a virtual sound position of an acoustic event hampers other possible definitions for similar sound positions. A result of this situation is a serious limitation, where the utilisation of many possible loudspeaker combinations is no longer possible. During an initial working period with Peter Segerstrom in San Francisco at the Recombinant Media Labs[299] in 2004, I set up a simple experiment to prove this.

The virtual movement of a sound from one speaker to the opposite in a symmetric eight speaker situation is normally programmed as a crossfade between the channels of the opposite speakers. Theoretically, the result of a completely different movement should have exactly the same result (see Figure 46): two rotations of exactly the same single sound starting simultaneously from the same speaker in the same velocity, but in opposite directions. The experiment demonstrated that the perception is not at all the same; the resulting spatialisations sound different. Programming spatialisation with the traditional virtual positioning concept makes it neither possible to have two simultaneous rotation movements, nor any other possibilities of attaining the same virtual crossfade. Therefore, the typical approach of having only one, and always the most mathematically simple, possibility for defining the virtual position of a sound

[298] Neo-Bechstein, (2005), revised version as Golden Quinces, Earthed… (2015); String Quartet No.2 (2008) for Quatuor Diotima, Eight Equidistant Pure Wave Oscillators, While Slipping Very Slowly To A Unison, Textually Spatialised On Eight Speakers (2012).
[299] http://www.rml-cinechamber.org/about.html, last visit April 13, 2019.

in a room, is clearly reductionist: thousands of other positioning possibilities are lost.

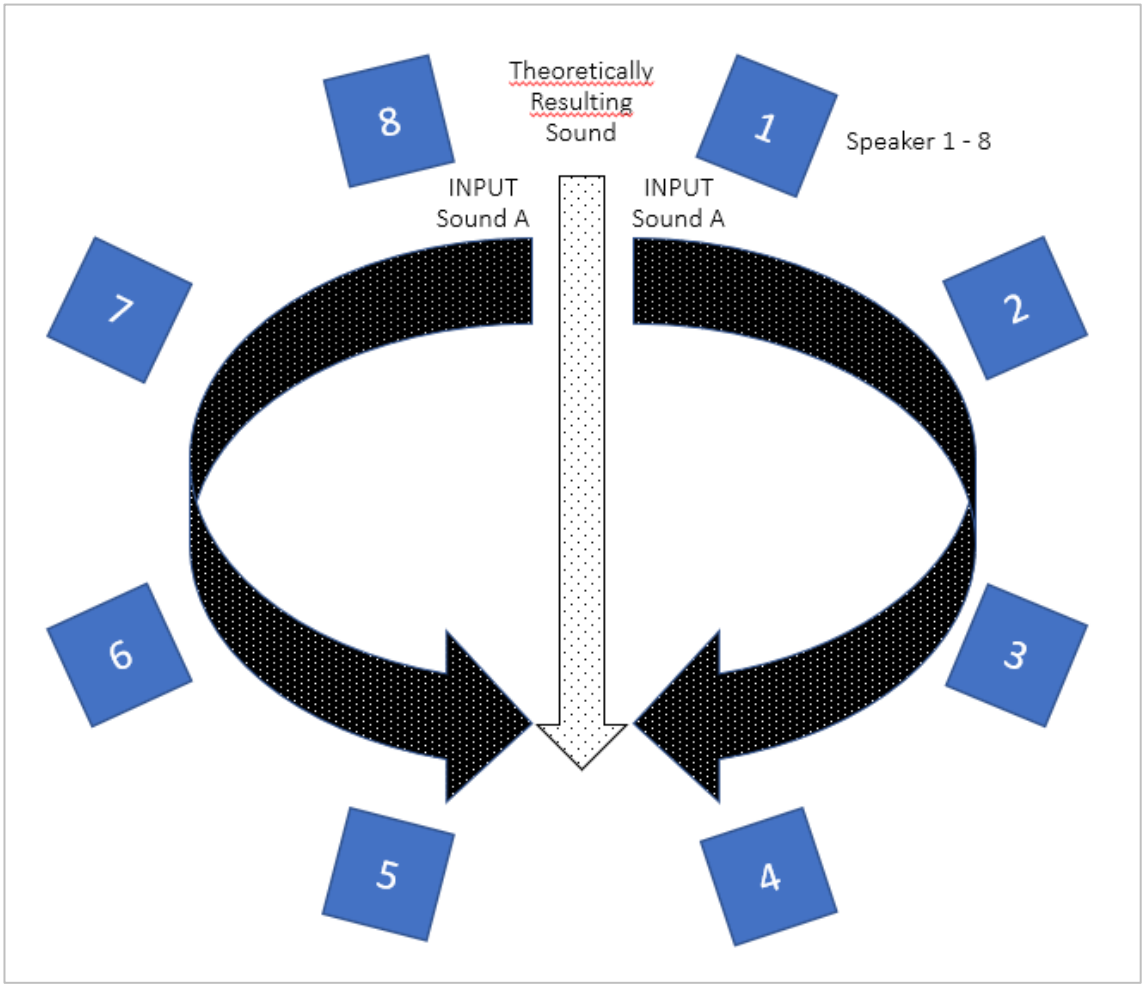

Figure 46: Sound A moving in two opposite directions simultanuously.

My conclusion was to think directly in terms of the actual speakers as musical instruments, and to begin with an 8×8 matrix: eight channels are spatialised to eight speakers, and not, as is implemented in many software approaches, to a virtual position in the room. Continuous and non-continuous movements between the speakers can be realised: rotations, jittering (jumping randomly inside a given angle), and the width of the sound protection as primary modules. All parameters can be changed, including velocity and direction of the rotations. Moreover, the form of jittering can be sculpted by using different random functions for changing the probabilities of hitting different positions inside a given angle. All these functions can be combined and cascaded. The individual parameters such as rotation speed, spread factor, jitter, loudness, and width can be controlled directly via the software, or in real-time with a fader board. With

these functions and their potential combinations, it becomes possible to create spatial textures for the whole audience, not only for the 'best seat in the hall'[300]. Auditors sitting in different places in the room do not hear exactly the same acoustic results in the same moment, but they hear the same kind of movements: they hear the same textural spatialisation.

Technically, it was necessary to include a third spatialisation parameter because only a certain width of a given signal makes it possible to perceive a rotation, instead of a jumping in a circle from one speaker to the next. Furthermore, a meta-function was added to make an additional variation of the main functions (rotation, jittering) possible. This function defines the divergence between the parameter values of the main functions for the single tracks. This makes it possible, for instance, to have eight different equidistant velocities of rotation simultaneously.

The parameters of the functions can be listed as follows:

1) rotations:
    - direction
    - velocity
2) jittering (jumping randomly inside a given angle)
    - angle
    - velocity
    - random distribution
3) width of the sound projection
    - angle
4) variation as meta function: deviation of single track parameters
    - difference (parameter value of track n $t_n = t_{n-1} + \varepsilon$, with ε being the difference between the values of velocity or other parameters).

[300] A term coined by Nicholas Cook in: Cook, N. (2013) Beyond the Score, Oxford University Press, Oxford, 374.

As already discussed, all these functions can be combined. For example: a rotation can jitter slightly around the rotating position (which is actually the same as a rotating jittering within a given angle), or the width of a jittering can close and then open again, making the jittering more or less perceptible. Or, to avoid identical rotation velocities, which would just rotate the whole room, the additional variation function (4) can be used to control the deviation of the single velocities of the eight channels. The tracks will then rotate at different velocities, some will overtake others.

Real-time piloting of the spatialisation is done by using a commercial 16-channel fader-board to control the individual parameters (rotation speed, spread factor, jitter, loudness, and width). In the first example, *Golden Quinces, Earthed…* this was applied in combination with an historical electroacoustic piano, the Neo-Bechstein. In the second example, *Eight Equidistant Pure Wave Oscillators, While Slipping Very Slowly To A Unison, Textually Spatialised On Eight Speakers, Concret, 60 Minutes*, the spatialisation is automated and becomes the crucial part of an algorithmic composition. Finally, TSP has also been used to realise an automated spatialisation of *La Légende d'Eer* for an 8-channel-surround sonification in the sound dome at the Wundergrund Festival in Copenhagen in 2015. The result is available as an 8-track file[301].

4.3.3. Example 1: *Golden Quinces, Earthed*

Golden Quinces, Earthed is a composition for spatialised Neo-Bechstein. It was produced by Maerzmusik, Berliner Festspiele[302], the ZKM[303] in Germany, and the Recombinant Media Labs in San Francisco[304] in 2004/2005. This composition combines the mentioned approach to spatialisation with the unique qualities of an instrument from the late 1920s, the Neo-Bechstein[305] grand piano (Figure 47).

[301] 8-track-files included in "Related Materials".
[302] https://www.berlinerfestspiele.de/de/maerzmusik/start.html, last visit April 13, 2019.
[303] Zentrum für Kunst und Medien, Karlsruhe, Germany, www.zkm.de, last visit April 13, 2019.
[304] These studios have been a part of the Asphodel Label, directed by Naut Human, http://www.rml-cinechamber.org/about.html, last visit April 13, 2019.
[305] A good presentation of the instrument can be found in: Donhauser, P. (2007) Elektrische Klangmaschinen, Wien, 83-99.

Being one of the first instruments with electro-magnetic amplification, its set of 18 pickups was converted from the original mono wiring to a fully polyphonic configuration. The resulting transparency of the individual string groups is further enhanced by projecting them into the performance space through the discussed spatialisation matrix. The individual spatialisation parameters of TSP are controlled by a fader-board.

The main compositional work was to focus on the question of which spatialisation textures work with which sound material. An interesting result was that some spatialisation textures support the character of certain sound materials, even to the point that audiences have often been convinced of hearing additional electronic effects that were non-existent. Examples of such psychoacoustic phenomena include: very fast random jittering in a completely open angle with a very small width, creating an apparent granulation with certain sounds; long, bowed piano tones in the lower register, rich in overtones, and sounding almost like harmonic analysis when spatialised with a fast vibration on a very narrow angle at different corners. These examples of granulation effects and the transparent allusion to a harmoniser sound are just two examples of the new sound dimensions made possible by this system.

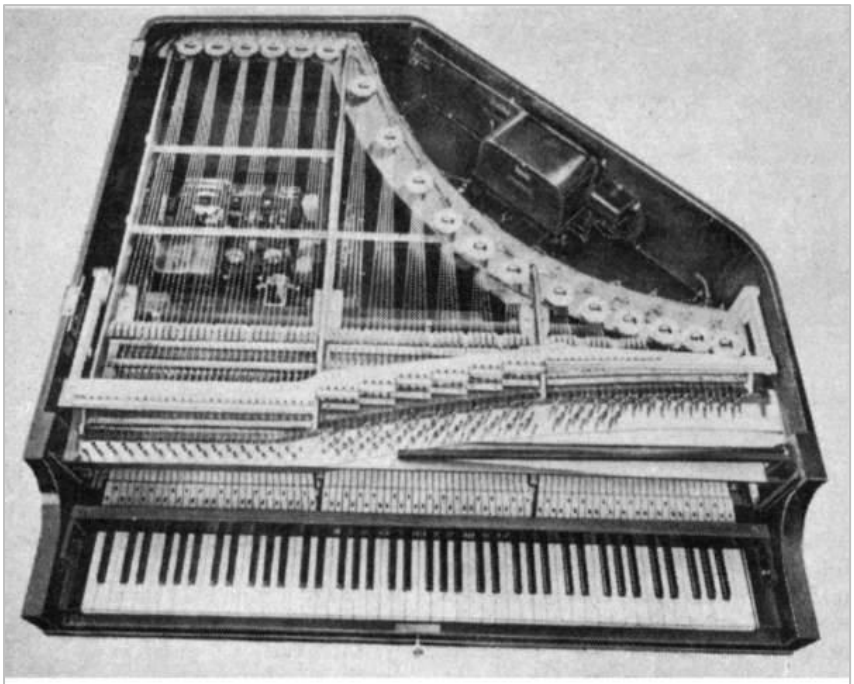

Bild 1. Ansicht des geöffneten Nernst-Flügels

Figure 47: The Neo-Bechstein piano from 1929.[306]

The composition itself features five sound families on the Neo-Bechstein, combined with different spatialisation settings:

1) Strange, unclear, atmospheric sounds, realised by bowing the piano strings with small pieces of wood at the beginning of the piece, starting with very slow rotations in different directions and at different speeds

Figure 48: Small piece of wood for bowing strings.

[306] https://www.radiomuseum.org/forum/neo_bechstein_fluegel_mit_radio.html, last visit April 13, 2019.

2) heavy stones vibrating in defined places on the strings, the spatialisation changing gradually to a completely open, very fast jittering, almost frazzling the already percussive sounds

Figure 49: Stones on the bass strings of the Neo-Bechstein.

3) bass strings played with mallets, gradually entering one by one, spatialised on simple opposite ping-pong-fades, but using four sub woofers.

4) noise glissando passage, using a metal tube and mallets, the spatialisation a complex combination of jittering and different fast rotations

5) quasi-singing metal tube played on the bass strings with gradually increasing defined vibrations in different corners, rotating very slowly in different velocities and directions

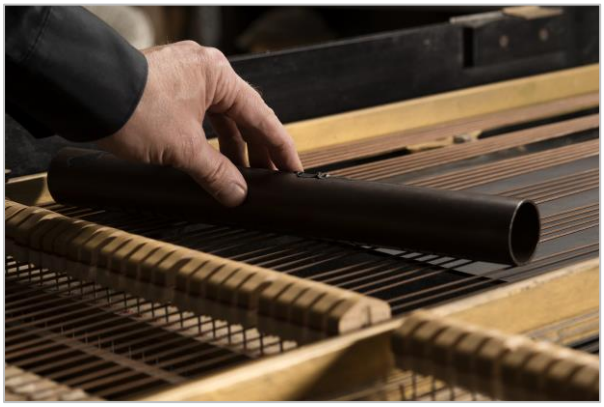

Figure 50: Metal tube on bass strings.

The transitions between the different sections are fairly gradual, with a few exceptions: as there are always five strings amplified by one humbucker pickup,

it is possible, for example in the transition from section 2 to section 3, to do this slowly in single 5-string groups, with simultaneously changing spatialisations for each group. Also, the abrupt spatialisation change between section 3 and section 4 is marked by a huge *sforzato*.

This composition should not be performed onstage, but in the middle of the audience. I usually perform it on the Neo-Bechstein, sitting close to Sukandar Kartadinata performing the composed spatialisation on the fader-board.

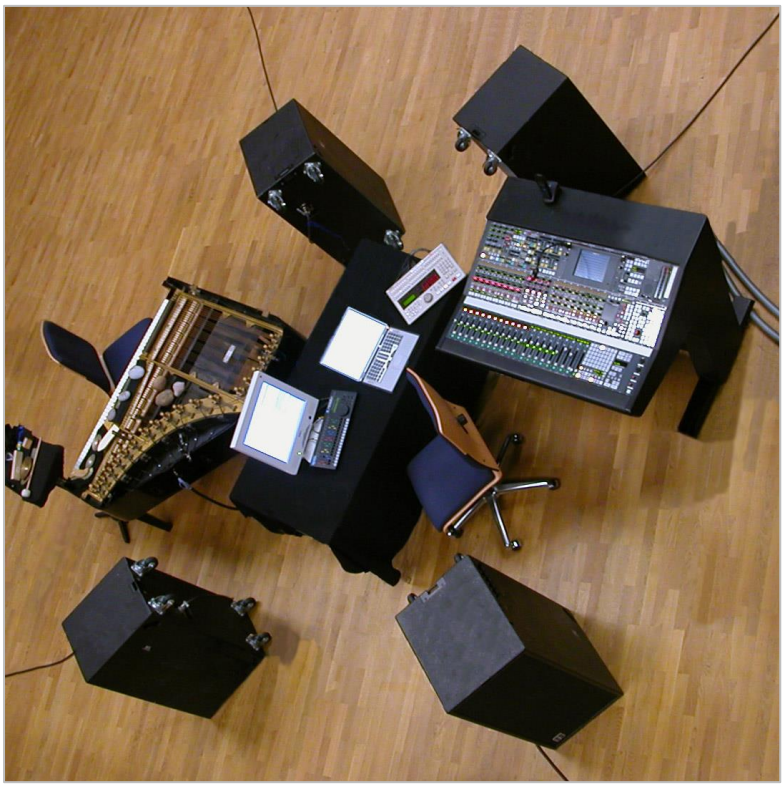

Figure 51: Set-up at ZKM Karlsruhe.

A recording was made with a 12-channel set-up at Elektronisches Studio der Technischen Universtität, Berlin[307] and released on CD in 2015[308]. The individual channels were recorded, and additional microphones were placed in the room to record the spatialisation on twelve UPL-1 Meyer speakers. Rashad Becker was responsible for the set-up of the microphones, recordings, mixing, and mastering. The stereo recording included in the additional material gives an

[307] https://www.ak.tu-berlin.de/menue/elektronisches_studio/, last visit April 13, 2019.
[308] Friedl, R (2015): *Golden Quinces, Earthed for spatialised Neo-Bechstein*, CD, Bocian Records – bcRF, Warsaw. Reinhold Friedl - neo-bechstein, Sukandar Kartadinata - fader-board, recorded, mixed and mastered by Rashad Becker.

impression of the spatial version, interleaving the channels so that the spatialisation is perceptible. It was released on Bocian Records[309], Warsaw, in 2016. 12-track, 8-track, and 5.1 versions are also available for live projections without the Neo-Bechstein on site.

4.3.4. Example 2: *Eight Equidistant Pure Wave Oscillators…*

I realised this algorithmic composition with the full title *Eight Equidistant Pure Wave Oscillators While Slipping Very Slowly To A Unison, Texturally Spatialised On Eight Speakers, Concret, 60 Minutes* in the Studios of the Groupe de Musique Expérimentale de Marseille (GMEM) in South France, using the same spatialisation programme I had originally developed for *Golden Quinces, Earthed*. The programme was readjusted with the help of the programmer Charles Bascou (GMEM Marseille) in 2011.

The compositional idea was to go to the other extreme: instead of using very rich sound textures, as in *Golden Quinces, Earthed…* , reducing the sound material to sine waves only. This would allow a pure presentation of the spatialisation. Subsequently, *Eight equidistant pure wave oscillators, while slipping very slowly to a unison, texturally spatialised on eight speakers, concret, 60 minutes* became an algorithmic composition for eight speakers, and is exactly what the title describes:

- 8 oscillators as input, each executing a linear glissando over 60 minutes to the same final pitch
- The spatialisation is automated and follows the plan, given in figure 52.

[309] See related materials.

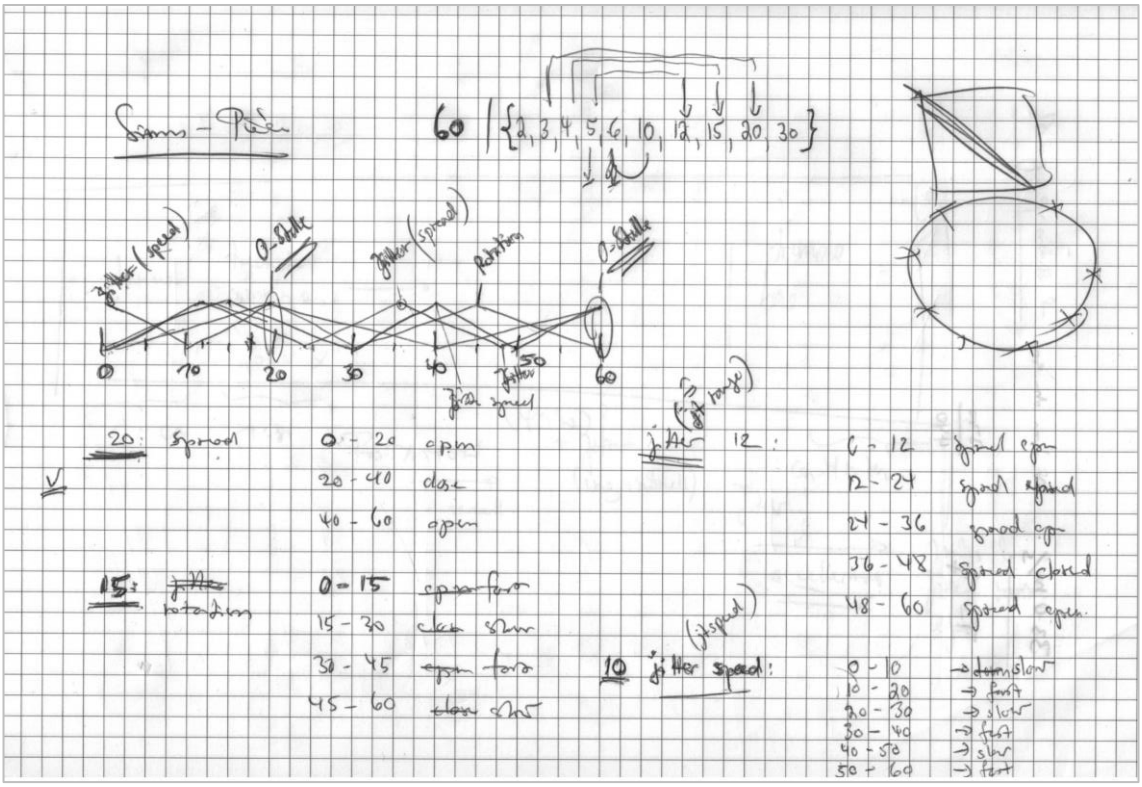

Figure 52: Spatialisation plan of Eight Equidistant Pure Wave Oscillators, While Slipping Very Slowly To A Unison, Textually Spatialised On Eight Speakers, Concret, 60 Minutes.

The plan is constructive. The first line shows a factorisation of 60, the length – in minutes – of the composition. This prime factorisation enables us to construct an overlapping progression of the single parameters with the following properties:

1. Each parameter has a symmetric progression.
2. No combination of parameter values appears more than once.
3. The spatialisation starts with the eight sine waves without rotation, without jittering (in the beginning the jittering is maximum, but the jittering angle is 0°). It ends in the same way, except that the width is now maximal (this means all oscillators are in unison on all speakers).

In detail, this means:

- The width (“spread” in Figure 52) changes 3 times linearly over intervals of 20 minutes:
  - 00:00 – 20:00: from 0° to 360°

    - 20:00 – 40:00: from 360° to 0°
    - 40:00 – 60:00: from 0° to 360°

- The rotation velocity (“rotation” in Figure 52, pairwise in opposite directions) changes 4 times linearly over intervals of 15 minutes:
    - 00:00 – 15:00: from 0 to maximum
    - 15:00 – 30:00: from maximum to 0
    - 30:00 – 45:00: from 0 to maximum
    - 45:00 – 60:00: from maximum to 0

- The jitter angle changes linearly 5 times over intervals of 12 minutes:
    - 00:00 – 12:00: from 0° to 360°
    - 12:00 – 24:00: from 360° to 0°
    - 24:00 – 36:00: from 0° to 360°
    - 36:00 – 48:00: from 360° to 0°
    - 48:00 – 60:00: from 0° to 360°

- The jitter speed changes linearly 6 times of intervals of 10 minutes:
    - 00:00 – 10:00: from 0 to maximum
    - 10:00 – 20:00: from maximum to 0
    - 20:00 – 30:00: from 0 to maximum
    - 30:00 – 40:00: from maximum to 0
    - 40:00 – 50:00: from 0 to maximum
    - 50:00 – 60:00: from maximum to 0

As the eight speakers are treated as instruments, though, and not as producers of virtual sound positions, it seemed consequent to simply record the speakers like instruments. Two high quality microphones were placed in the centre of a circle of eight speakers in the studio to record the composition.

Interesting effects resulted, as interference effects are strong but change constantly due to the constantly changing positions of the speakers and the slowly shifting pitches. An 8-channel textural spatialisation creates the sonic

texture for a stereo composition. This stereo composition was released on the Australian label *Room 40*.[310]

4.3.5. Example 3: *Xenakis's Legend*

When studying how Xenakis treated his spatialisation in *La Légende d'Eer*, I became aware of the similarities between TSP and his textural concept, as described above. As Xenakis's automated spatialisation of *La Légende d'Eer* inside the *Diatope* is lost, it seemed obvious to conceive a spatialistion of *La Légende d'Eer* with the help of TSP.

As already discussed, there were two references: on the one hand, sources such as drafts and plans, but also descriptions of the automated spatialisation inside the *Diatope*; on the other hand, the spatialised Bochum version on 8 tracks (see chapter 2.4.).

This means that Xenakis himself realised an 8-track version and did not limit the performance or projection of the composition to the situation inside the *Diatope*. His foci were varied rotations and textural phaenomena, such as "galactic dust".[311]

Furthermore, Kiourtsoglou could reconstruct the sound movements during the first 4 minutes and 50 seconds with a certain precision. She is convinced that - despite some slightly inconsistent sources in the archives - her reconstruction should be pretty close the original spatialisation.[312]

I obtained permission from the Xenakis family to perform *La Légende d'Eer* in a spatialised version. TSP allows some of the main properties of Xenakis's own automated spatialization to be respected:

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[310] Friedl, R. (2013) Eight Equidistant pure wave oscillators, while slipping very slowly to a unison, texturally spatialised on eight speakers, concret, 60 minutes, released on the Australian label Room 40, Sydney. http://emporium.room40.org/products/508069-reinhold-friedl-eight-equidistant-pure-wave-oscillators-while-slipping-very-slowly-to-a-unison-textually-spatialised-on-eight-speakers-concret-60-minutes, last access April 25, 2019.
[311] Kiourtsoglou, E. (2018) An Architect Draws Sound and Light - New Perspectives on Iannis Xenakis's Diatope and *La Légende d'Eer* (1978), in: Computer Music Journal 41, 4/2018, 8-31.
[312] Ibid., 23.

1) The sound source is not projected to a virtual point in the room, but always goes directly from one speaker to another.
2) All traces include rotations.
3) The similarity of the movements of the seven projected tracks only differ by slight variations.
4) The spatialisation could be automated.

My further approach was based on the following ideas:

- to connect certain spatialisation textures to certain sonic material.
- to take over as much as possible from the reconstructed first five minutes: slow rotations enhance the transparency of the high-pitched, sine-wave-like sounds.
- to enhance the dramaturgy of the composition.
- to keep the spatialisation textural, which means not applying any sudden changes – in fact, to keep the changes of the spatialisation so slow that it is never immediately audible.

This led to the following decisions: as the piece ends with the same sounds as those with which it starts, I used almost the same spatialisation at the end as at the beginning – a slightly jittering rotation, reinforcing the spatial transparency. Furthermore, I assigned the jittering to the nervous electronic sound material in the middle of the composition, dominating the climax around minute 33. I also tried to intensify this dramaturgy by slowly going to the maximum spread (angle) of the jittering, combined with minimum width, to achieve maximum definition.

Even though this spatialisation is related to Xenakis's ideas and notes, and uses the original sound material in the form of the seven tracks from the 8-track material tape (see Chapter 2.4.), the authorship is not clear. It is neither a precise reconstruction of any pre-existing version, nor is it authorised by the composer. Consequently, is was announced in accordance with the Xenakis family under the new title *Reinhold Friedl - Xenakis's Legend*, and the audience at the

performance in Copenhagen in 2015 was provided with a text explaining the background and history of the project.

4.4. The Software: Texture Transformation Machine (TTM)

The inspiration for this software emerged from the desire to develop a composition tool that can gradually transform a given texture into another texture. TSP could do this with spatial textures, but not with sound material.

The composition of my first String Quartet[313] was based on the idea of a slow transition from one texture into the next. At the same time, I wanted to avoid audible symmetries in the sense of rhythmic, melodic, or otherwise repeated patterns. Figure 53 shows a texture comprised of five different elements per instrument. No combination is repeated, and we can observe that elements in the lower range become more frequent.

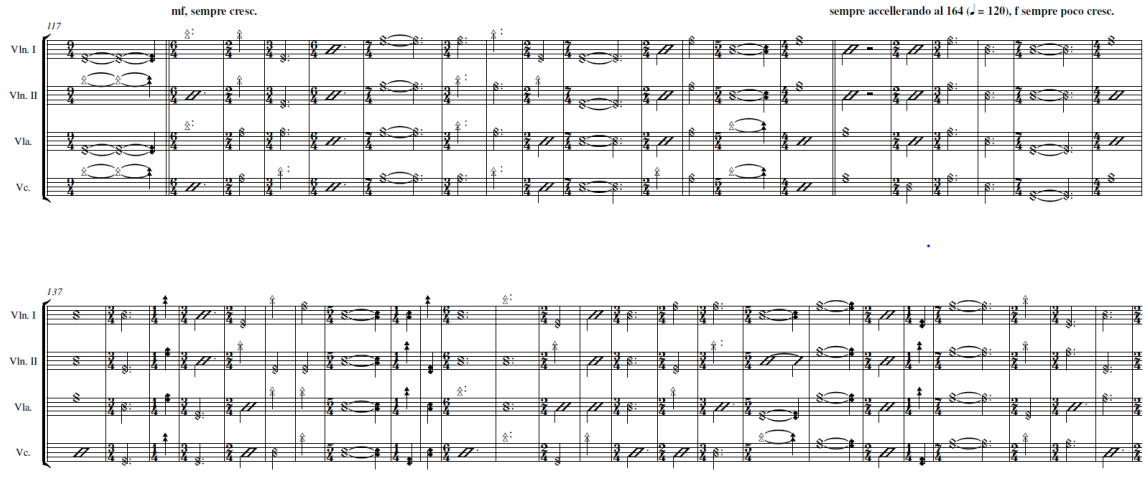


Figure 53: Reinhold Friedl - String Quartet No 1, bar 117 - 160.

[313] String Quartet No 1, commissioned by BBC London, dedicated to Anton Lukoszevize, premiered London, 2007. Releasd on: Quatuor Diotima - Reinhold Friedl String Quartets, La Muse en Circuit, Paris, 2017.

This process successively leads to the composition's final structure, where only two sound elements are left over (Figure 54). The transition between the two textures had to be composed manually, attentively avoiding any symmetry.

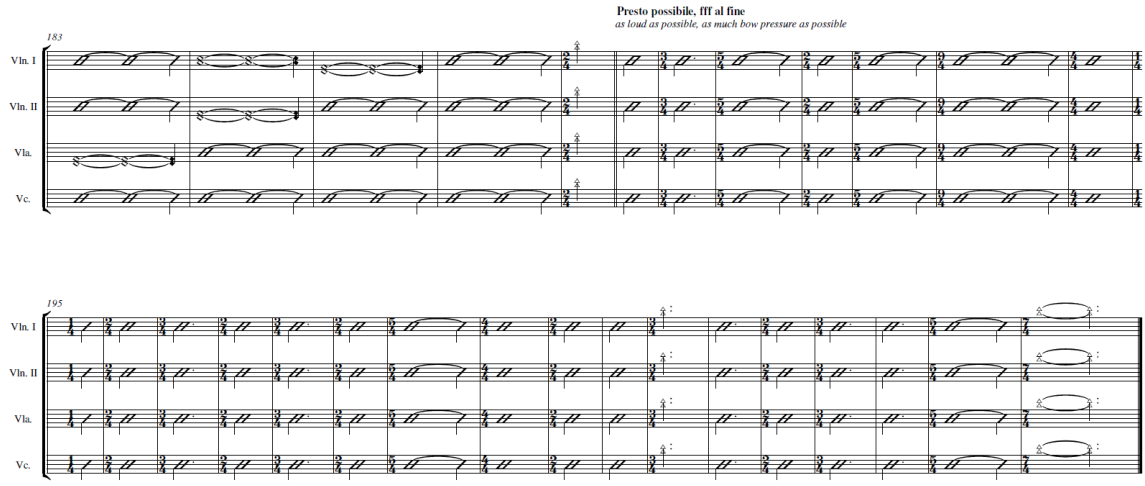


Figure 54: Reinhold Friedl - String Quartet No 1, ending, bar 183-211.

As I encountered similar problems in others of my compositions, I wanted to construct a flexible compositional tool which would be able to transform textures, understood against the backdrop of Xenakis's textural composing. I therefore developed the following model.

4.4.1. The model

The supposed function of the tool is to gradually transform a texture T1 into a texture T2. Consequently, the probabilities of all elements of texture T1 have to reach value 0 successively, and the probabilities of the elements of texture T2 would need to increase.

Here, texture is understood as a set of arbitrary elements (sounds, tones, noises, sound objects) with an assigned probability for each of the sounds to appear at a given moment. A simple example would be a set of 5 sounds, that have the same probability of 1/5 = 0.2. That is, the texture is fixed, but the elements of the texture are not, as they are distributed randomly depending on their probability.

Due to the probability definition, the sum of the single probabilities p_i of i elements of a given texture is

$$\Sigma_i\, p_i = p_1 + p_2 + \ldots + p_i = 1.$$

If these two conditions are combined, it is sufficient to consider the union of the two texture sets, containing all elements of texture 1 and texture 2. Then a probability progression needs to be assigned to the single elements: some of them – in this case the probabilities of the elements of texture 1 – need to decrease to 0, while the probabilities of the elements of texture 2 need to increase from 0 to x (x < 1).

As the sum of all probabilities must always be 1, there could be a simple graphic solution for linear probability progressions: a box with height 1, divided by straight lines into several surfaces (with no intersection of the lines).

To give the simplest example: a texture made of two elements with the same probability $p_1 = p_2$ can be shown as a box with heights 1, divided in the middle by the straight line g_1 (Figure 55).

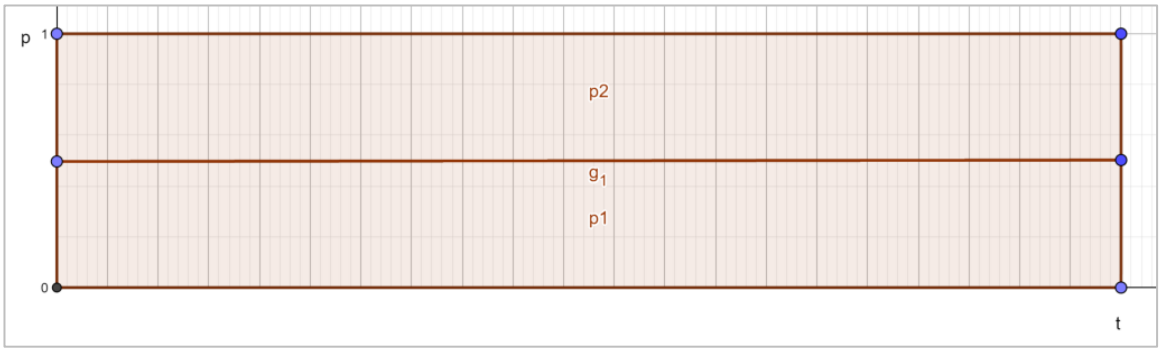


Figure 55: Probability distribution of 2 events.

The probability p_1 is represented by the rectangle p_1, and is throughout $p_1 = 0.5$.

The same holds for $p_2 = 0.5$.

This means probability functions can be defined by straight lines crossing a rectangle with the overall height 1.

A fixed texture, not changing over time, is constructed with parallel straight lines with gradient 0. A texture of five elements which all have the same probability could be shown in a rectangle intersected by 4 straight lines (Figure 56).

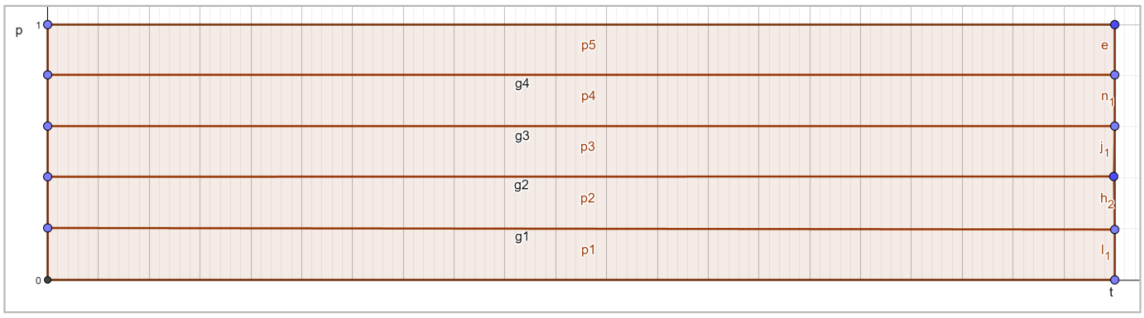


Figure 56: Fixed texture of five elements with the same probability 0.2.

As the idea is to develop a basic machine transferring one texture to another, fixed textures are not of further interest. This means we do not need to look at straight lines with gradient = 0.

Once we use straight lines with gradient > 0 (the same holds for < 0), at least two probabilities will change over time (time running from left to right). In Figure 57 we can see that the probabilities p_4 and p_5 are decreasing, p_3 is stable (as the straight lines g_2 and g_3 are parallel), and p_1 and p_2 are increasing.

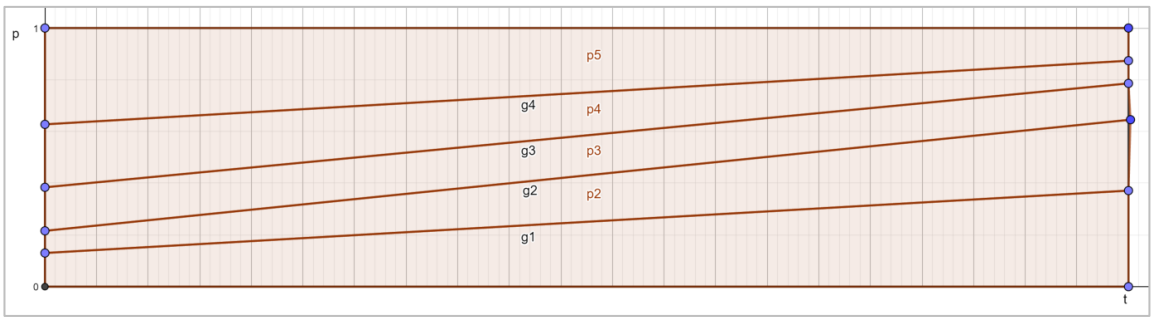


Figure 57: Texture with increasing and decreasing probabilities of single elements.

The value of the single probabilities at a given point t_0 can be calculated:

$p_n(t_0) = g_n(t_0) - g_{n-1}(t_0)$

This gives us an example of a texture with n elements, that can be transformed gradually into another texture with the same elements.

As a next step, we can now let some elements from a first texture disappear, and let in new elements from a second texture (Figure 58).

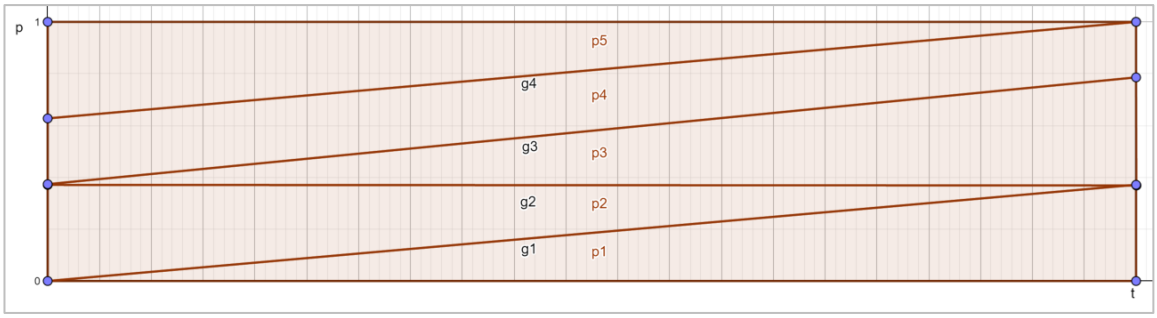


Figure 58: Texture with elements disappearing and new elements coming in.

Here, probabilities p_5 and p_2 decrease down to 0 while p_1 and p_3 increase from 0 and p4 remains stable. This means this probability model transforms a texture containing three elements (e_2, e_4, e_5) to a texture containing other elements (e_1, e_3, e_4).

Figure 59 gives an example of two textures without common elements:

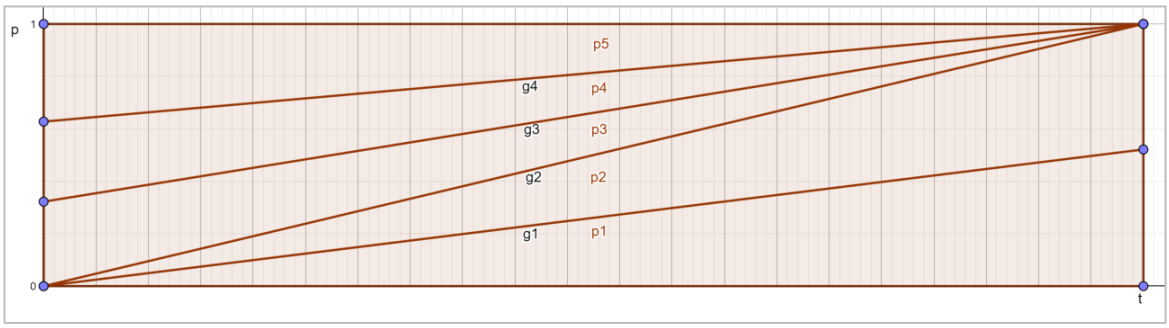


Figure 59: Texture without common elements.

Here, p_5, p_4 and p_3 decrease to 0 while p_1 and p_2 increase from 0. Texture 1 has no common elements with Texture 2.

In a last step, a texture could be transferred into another by passing through other textures (in terms of elements).

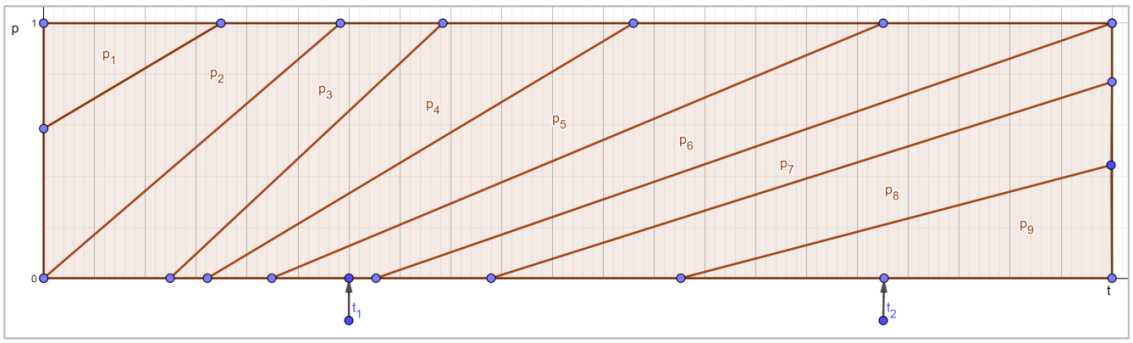


Figure 60: Texture transforming through other textures.

Here (Figure 60), a texture is shifting successively though textures with other elements. At t_1, there is no remaining element from the opening texture (e_1 and e_2), and at t_2, there is no remaining element from the transitory texture at t_1 (e_3 to e_6).

Hereby we have a basic model to transform a texture into another texture. Moreover, the following rules are defined:

1) probabilities can only change linearly.
2) two straight lines cannot intersect, as the probability would become negative behind the point of intersection.
3) the output of our model is a series of whole numbers, which needs to be matched to the sounding events e_1 to e_n.

The linearity of the model is not a linearity of the output numbers; a statistical dispersion cannot be linear. Therefore, it will not be too apparent. Furthermore, using nonlinear functions for this model would cause serious technical problems, as those functions would not be allowed to intersect either. It was on this basis that I decided that linear functions are sufficient for this purpose.

4.4.2. The software

The software Texture Transformation Machine (TTM) is based on the previously described model and was programmed by Sukandar Kartadinata and me. I developed the idea of the program including the graphic approach in order to find a simple way to have changing probabilities for fixed sonic events.

Sukandar Kartadinata implemented and programmed the ideas in Max/MSP. We worked already together in several projects, including the Textural Spatialisation Program, presented in Section 4.3. and toured together with the Golden Quinces, Earthed (4.3.3.) throughout Europe. The final TTM program has been developed in close cooperation and steady feedback: Beside the initiation of the main idea, I tested all changes and new possibilities in the practical work and came back with new wishes and details. I'm very thankful to Sukandar Kartadinata for his great help and technical realisation.

In the beginning several pragmatic decisions have been made:

1) The output of the software should be MIDI notes. This enables a direct data import into a notation software (used here: *Sibelius Ultimate*[314]).
2) Only families of straight lines as defined below are used to sculpt the probability progressions.

[314] Sibelius Ultimate (2017) Avid Technologies Inc., Version 2018.7.

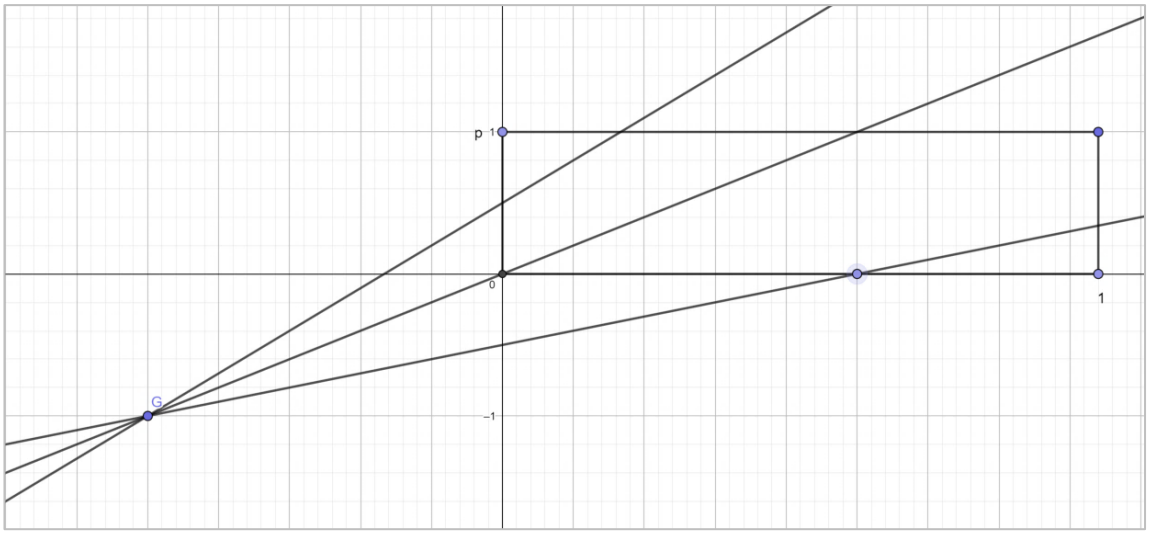


Figure 61: Family of straight lines crossing the probability rectangle.

A single straight line is defined as g(x) = m * x + b with

(i) m: the gradient

(ii) b: y-intercept

A family of straight lines is here defined as:

$g_n(x) = (m + n*\Delta_m)\, x + b + n*\Delta_b)$

with:

(i) n: Number of events. This defines the number of straight lines between the event surfaces (n-1).

(ii) m: Gradient m of the first line.

(iii) Δ_m: increment of the gradient for the next lines.

(iv) b: offset (-b).

(v) Δ_b: increment (-Δb).

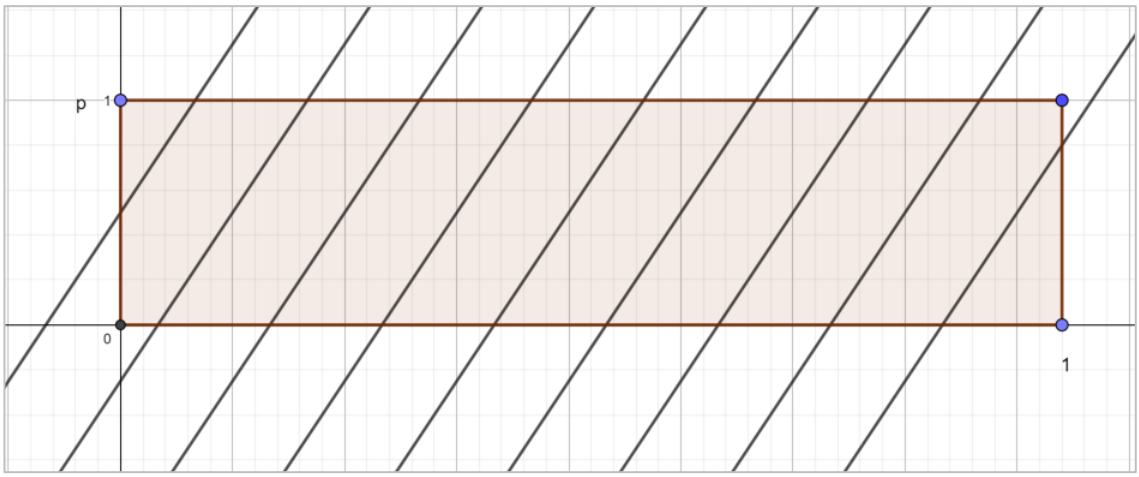


Figure 62: Family of parallel straight lines (for $\Delta_m = 0$).

This can either be a family of straight lines intersecting at the same point (Figure 61), or a family of parallels as shown in Figure 62.

As the graphic model functions well as an intuitive visual representation of the progression of the texture, it has been adapted for the software. Thus, on the user interface of TTM, the rectangle is represented visually, combined with sliders for the parameter values for the families of straight lines.

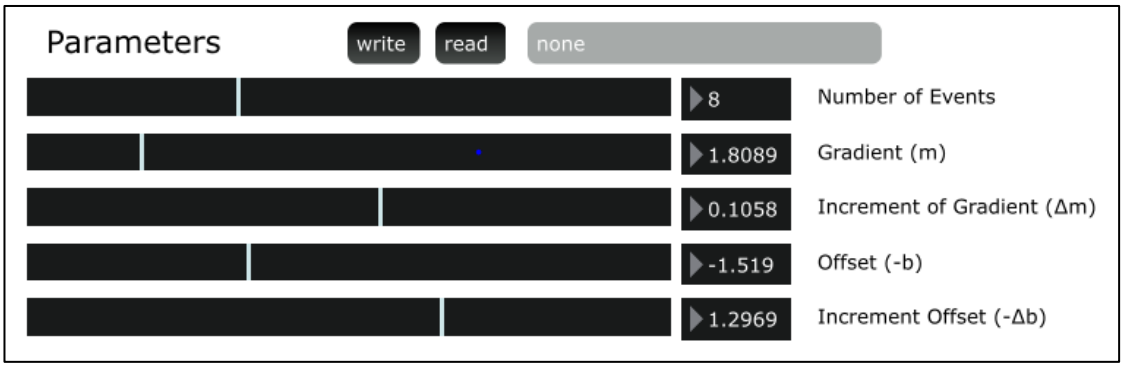


Figure 63: Slider Board for Parameters.

In the visualisation, three musical parameters are superimposed and shown in three different colours:

(1) metric: red

(2) pitch: grey

(3) duration: blue

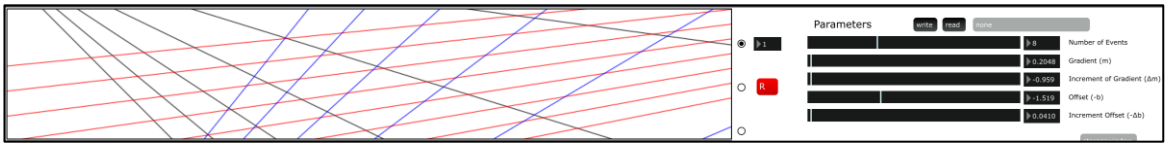


Figure 64: TTM Channel 1 with three parameters, detail of the right side below in Figure 65.

Metric is defined as the number of beats (quarter notes) until the next event.

Pitch is defined as the MIDI-pitches from 1 to 127.

Duration is the length of the note in sixty-fourth notes.

It is important to notice that the probability progressions of the single parameters are independent of one another. This means, for instance, that a given pitch can coincide with different durations, etc.

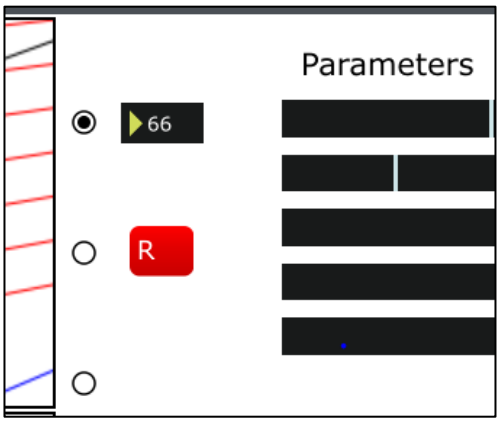


Figure 65: Detail of Figure 64.

The three round switches to the right (Figure 65) switch between the three musical parameters, downwards: pitch, metric, and duration. The number in the small box (“66” in Figure 65) gives the number of voices that will be calculated with the aid of the same probability progression, which means for each of the 66 voices a separate output is compiled on the basis of the same probability progressions. The “R”, if illuminated in red, indicates unrendered changes of the parameters. Once the rendering is complete, the button changes to black.

In order to compensate for the loss of some possibilities due to the restriction to defined families of straight lines, four probability progressions can be visualised and compiled simultaneously (Figure 66), and afterwards, can be transferred as a MIDI-File into the same musical score. This allows the application of at least four completely independent straight lines and the connected probability processes.

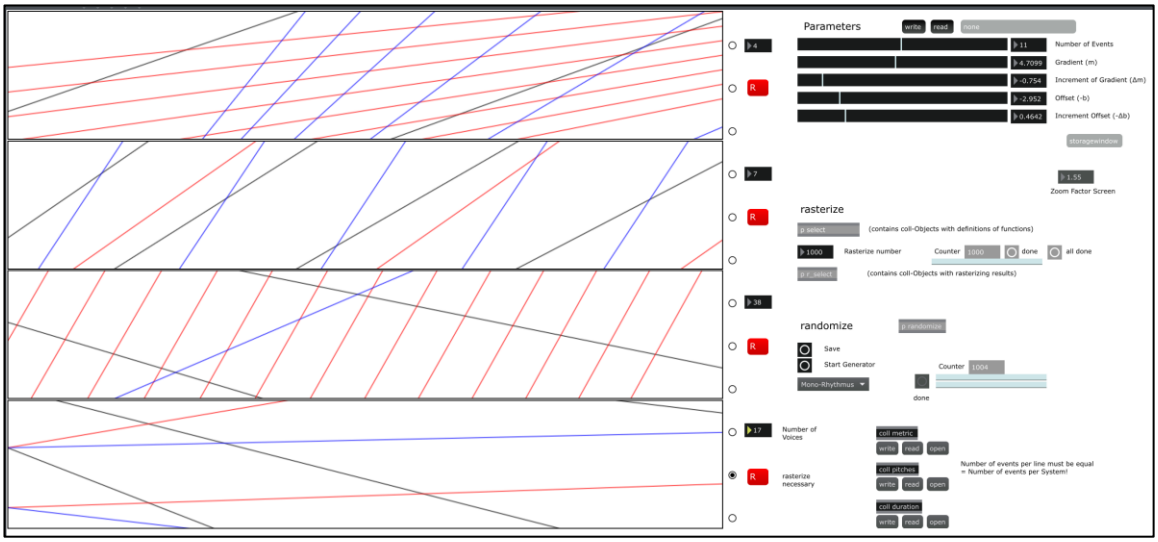


Figure 66: Full Patch with four probability progressions, three musical parameters each.

Once the probabilities are defined and rendered, the desired amount of different values can be defined. The rectangle may be rasterized with a maximum of 1000 steps. The number of steps can be defined in the rasterize field (Figure 67).

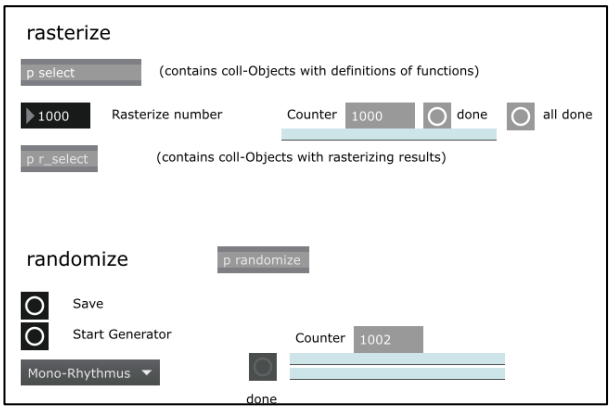


Figure 67: Detail of Figure 66.

At every step from left side to the right, a probability value is received for each event, thus a list of probabilities at every rasterized step t_s. This serves a compilation of a concrete series of events appropriate to these probability values.

The series will differ every time they are compiled. They are different random driven results of the same probability progression.

Once the rendering of the probability progressions is complete, the events need to be defined. The events are limited to MIDI parameters and are fixed with the aid of the three routines “coll metric”, “coll pitches”, and “coll duration” (“coll” for “collection”, see Figure 68).

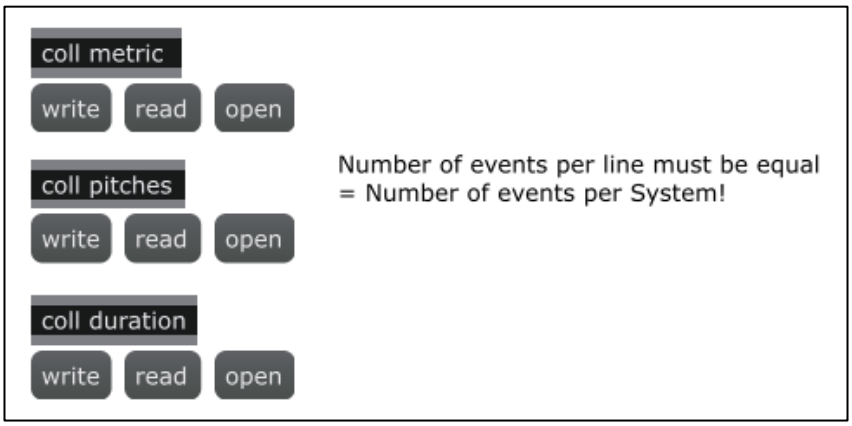


Figure 68: Detail of Figure 66, lists of events.

These parameter collections of possible events need be fixed in three tables. The number of events must equal the one defined in the parameters of the probability progressions (See Figure 65 “number of events”).

Once this has been done for all progressions, the randomize generator can be started (Figure 67) and will produce the required MIDI-File. This file is named and saved by selecting the corresponding button, and may, in a further step, be loaded into a notation software.

4.4.3. Two Examples

The following two examples demonstrate the relation between the probability progression and the musical result.

4.4.3.1. Example 1

The starting point was a musical imagining of a group of similar instruments (here 32 violins) shifting successively from a cluster of five lower

pitches to five higher pitches. The metric and the duration should be a simple *ritardando*, made from only three metric values and only four increasing durations. Notes will gradually become higher and longer.

25 pitches are given in the “coll pitches” table in the order low to high. The appropriate stripes are integrated in the probability progression (Figure 69, in black). From left to right, there are always five possible pitches, the 25th pitch coming in at the very end on the right (small triangle).

The probability progression for the metric is defined by the two red lines. As we only want three different values, the two lines are sufficient; the metric will gradually change from almost only metric value 1 to almost only metric value 3.

Thus, the duration in blue needs three lines and increasing values in the “coll durations” table.

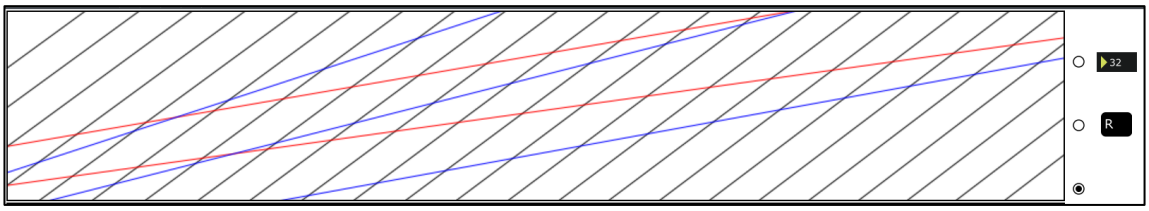


Figure 69: Example 1 - probability progressions.

As we only want a short example, the rasterizing is here limited to 50 steps and gives the result shown in Figure 70 (Audio file: “9-1b TTM Example 1”).

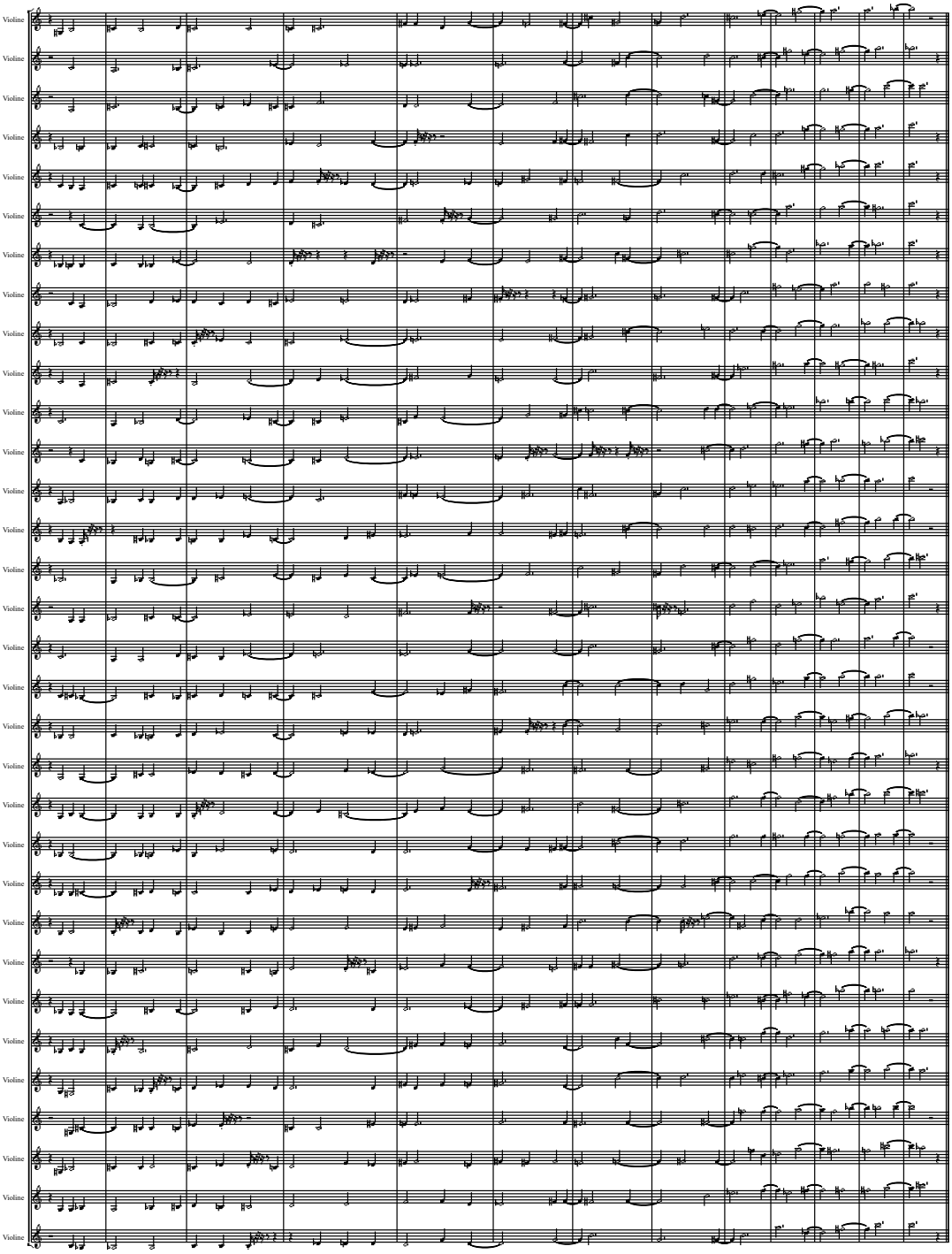


Figure 70: Example 1, score for 32 violins.

4.4.3.2. Example 2

This example demonstrates a more transparent texture with fewer voices and events. The number of pitches shall be limited to four (three grey lines) with a slow turn from pitch set (1, 2, 3) to pitch set (2, 3, 4): the first pitch is disappearing, the last one increasing. The pitches chosen in the table are a transposition of Bb-A-C-B.

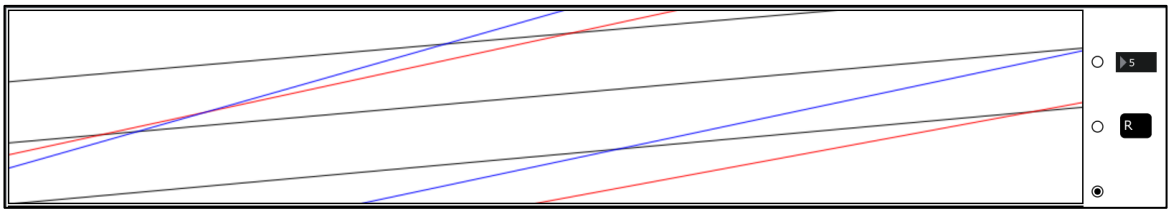


Figure 71: Example 2 Probability progressions.

The metric, represented by the red lines, is limited to three values, but should significantly increase. The same goes for the durations (blue lines in Figure 71). The rasterizing was also 50.

This example was generated and transferred into the notation software five times, three times with the exact same settings. As we can see (Figure 72 – 74, for a larger version see annex 5, Audio File: “09-2-PR1 Example Polyrhythm Output 1”, “09-2-PR2 Example Polyrhythm Output 2”, “09-2-PR3 Example Polyrhythm Output 3”), the result is a light texture that might evoke the impression of a free counterpoint due to the limited pitch and duration material varied throughout. This effect is enhanced if we compare it with the other two outputs: they are ‘strange’ variations of the first version. According to my definition, though, they are texturally identical.

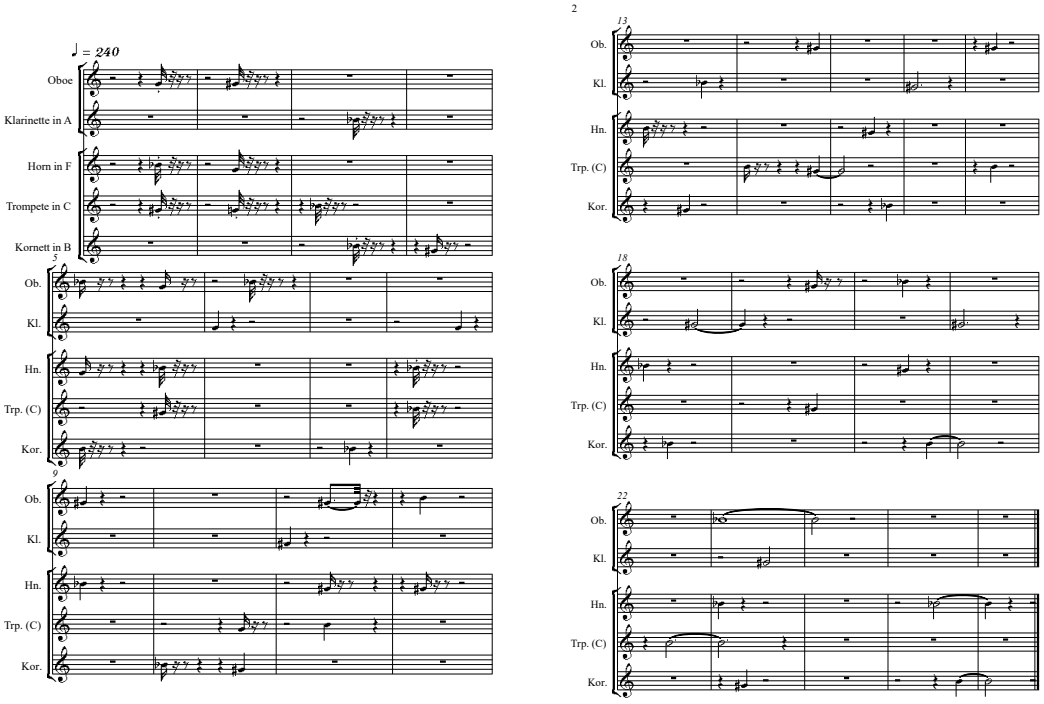


Figure 72: Example 2, Polyrhythm, Output 1.

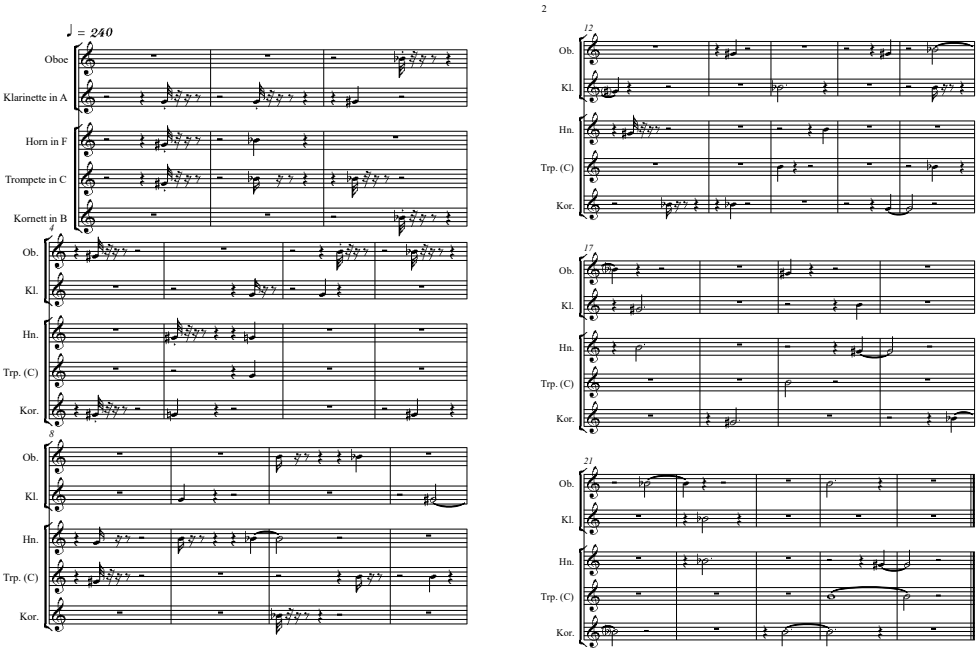


Figure 73: Example 2, Polyrhythm, Output 2.

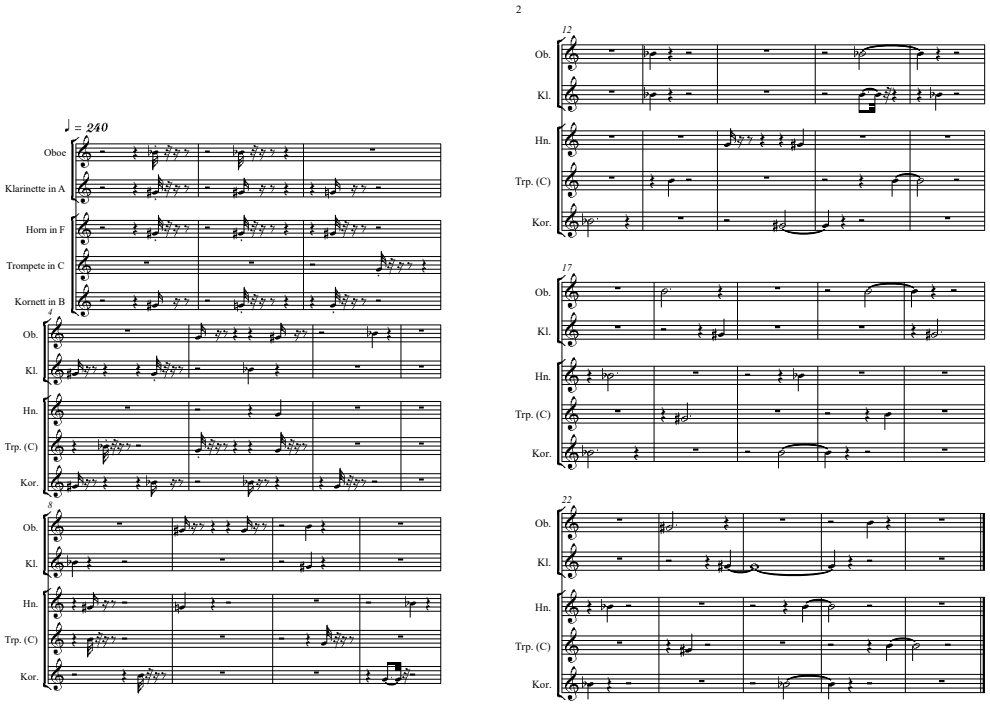


Figure 74: Example 2, Polyrhythm, Output 3.

The next two examples were generated and transferred into the notation software with exactly the same settings, except for one little detail.

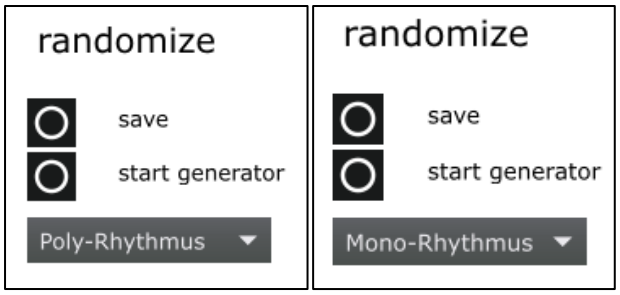


Figure 75: Polyrhythm versus Monorhythm.

Before starting the generator, it is possible to choose between “polyrhythm” and “monorhythm” (Figure 75). “Polyrhythm” means that the metric and duration values are separately generated for every voice. That means that the five voices are rhythmically independent. “Monorhythm” is the opposite: all voices generated from the same system will be synchronised, as they are based on the same metric and duration values, calculated only once at the beginning of the generation procedure.

We can see this in Figures 76 and 77 (larger images in the annex 2.1.).

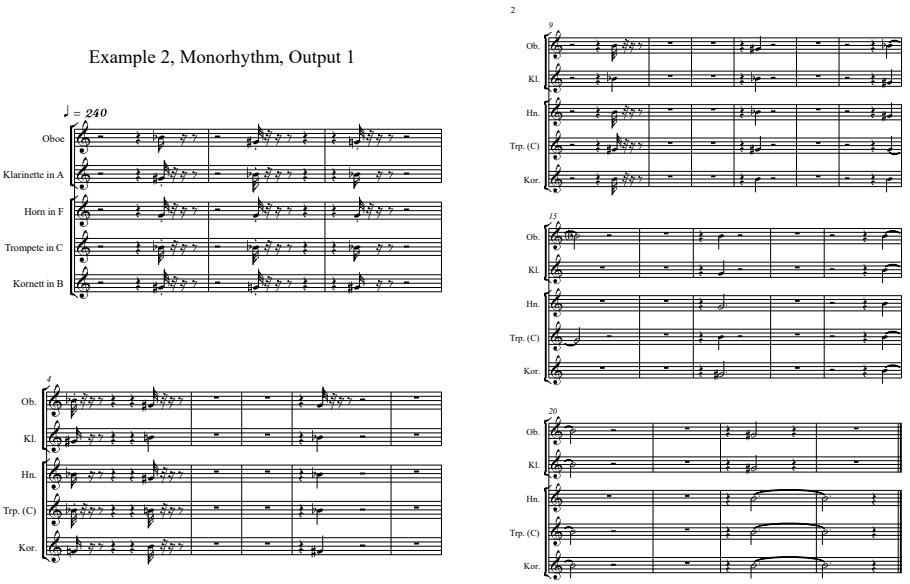


Figure 76: Example 2, Monorhythm, Output 1.

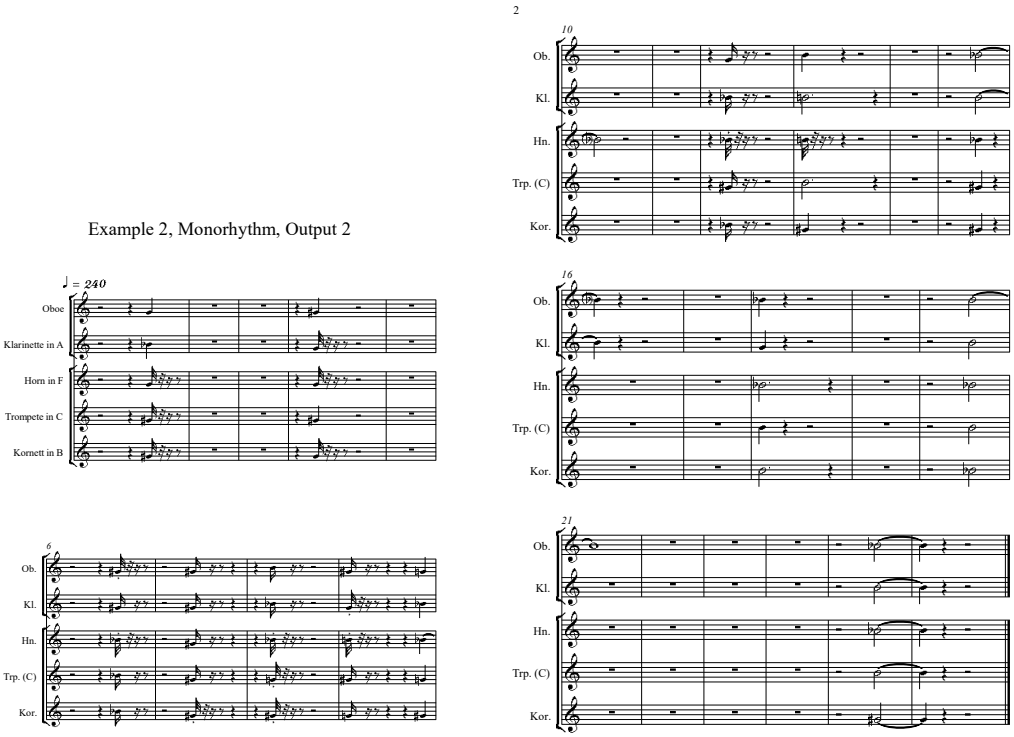


Figure 77: Example 2, Monorhythm, Output 2.

Again, the effect is the same texture, but different texts which seem to be variations of each other.

4.5. Musical Results

I used TTM for several of my compositions, of which I will discuss two: *String Quartet No. 3* and the orchestral piece *KRAFFT*. The compositions do not significantly differ from each other in terms of the compositional idea: they are minimalistic in the strictness of the sonic progressions. The sound material and the applications of TTM are very different though.

String Quartet No. 3 uses only traditionally bowed string sounds and harmonics, whereas KRAFFT for orchestra is based on a lot of action notation, mostly denoting extended playing techniques, often inspired by electronic music.

This had the practical consequence that *String Quartet No. 3* could be transferred directly from the MIDI-files into the score. In *KRAFFT*, however, traditional notes – as they are the only MIDI-output – had to take the role of placeholders for action notation or other readings, to be replaced later.

4.5.1. Reinhold Friedl *String Quartet No. 3*

My *String Quartet No. 3* was composed for the French Quatuor Diotima in 2016[315] and revised for the recording session in Paris in 2017. (Full score in the Annex 6, the recording in “Related material” for download).

The idea of the composition was simple: all four string instruments should play in rhythmic unison throughout the piece. The rhythm should only be defined via the metric.

[315] Reinhold Friedl String Quartets; re-release on Bocian Records, Warsaw, Poland, LP 12” vinyl (BC RFQ), July 2018. (released on: CD Quatuor Diotima – Reinhold Friedl String Quartets, released on La Muse in Circuit (ALM008), Paris, March 2017.

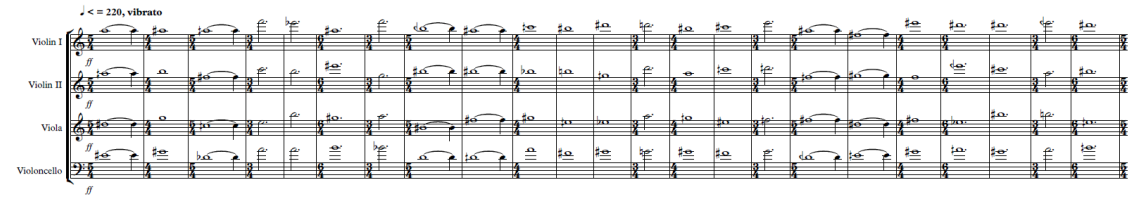


Figure 78: *String Quartet No. 3*, bar 1-23.

The composition should start with high *fortissimo* clusters (Figure 78) and gradually descend to the lowest possible notes on the instruments while playing more and more harmonics on those notes (Figure 79).

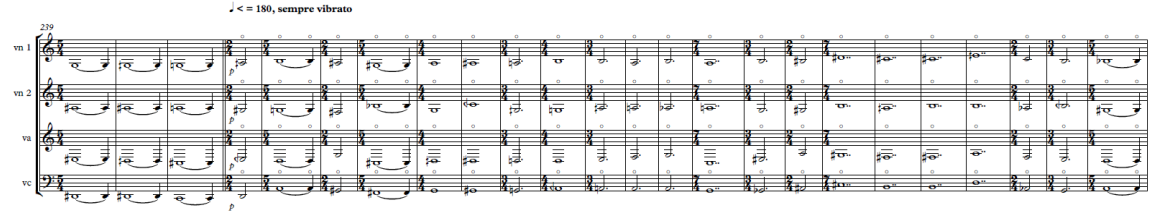


Figure 79: *String Quartet No. 3*, bar 239-262.

The chords then ascend, but are only used as a basis for harmonics (Figure 79, after the double bar line), ending on the highest notes (Figure 80) of the instruments.

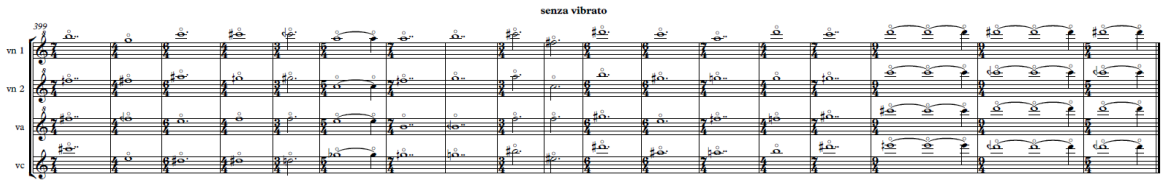


Figure 80: *String Quartet No, 3*, bar 399-416, ending.

The shifting of the pitches gradually descending and ascending can be represented by the following probability progression (Figure 81).

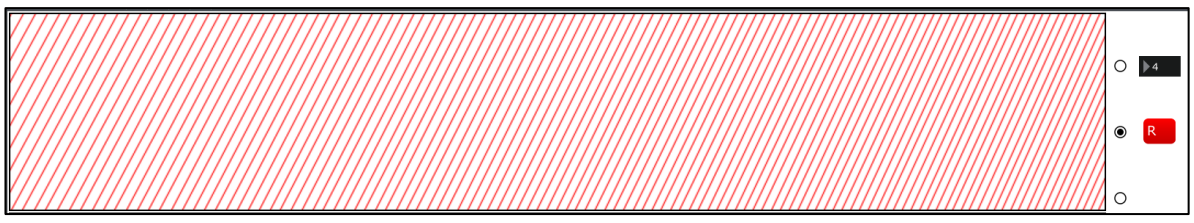


Figure 81: TTM pitch probability progression.

The pitch movement gradually passes through all the states indicated by the stripes. And if we address the right pitches in the “coll pitches” table by starting with high pitches, descending toward the middle and ascending toward the end, they will perform the desired collective movement. For the string quartet, the pitch range was defined for the violin. Four voices were generated, one for each string instrument. Violin 2, viola, and violoncello were then transposed to their final position (violin 2, viola, violoncello) and slightly corrected by hand (e.g. to avoid repetition of the same note).

As described, the metric changes slightly throughout the piece (Figure 82).

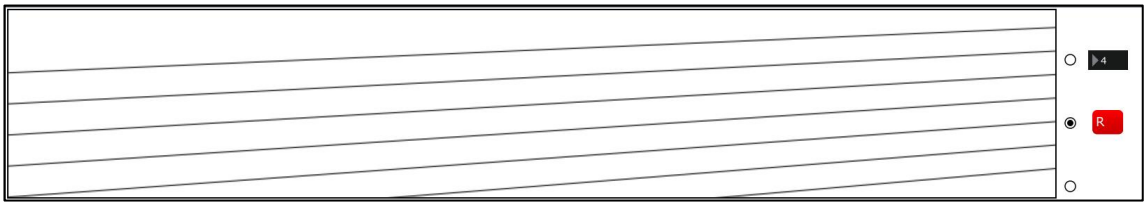


Figure 82: TTM metric probability progression, complete composition.

To recall: In TTM the metric is defined as the number of quarter-note beats until the next event. The “coll metric” here consists of the row: 4, 1, 2, 3, 5, 6, 7, 8, 9.

The order, beginning with 4, ensures that the 4/4 bars are more probable throughout the composition but are more and more integrated (upper triangle). In the lower row we can see how 7/4, 8/4, and finally 9/4 bars (last triangle on the lower right side) enter successively as the composition evolves. It is only at the very end of the piece that almost all of them have the same probability (right, Figure 82).

The generator was monorhythmic: the metric is directly created from the output of TTM. Only the result had to be transformed from the implemented 4/4 output into a metric in the notation software: MIDI cannot create different metrics, but the output can be adapted by defining each entry of a new note as the beginning of a new measure with appropriate length.

A separate setting was used for a special effect that I call “injection”: once the first probability progression was generated and transferred into the score, a second one was used to alter the first. A simple increasing probability progression

with two events served to indicate common harmonics before bar 242: two assigned notes (Midi pitch 1 and 127) were interpreted as “harmonic” or “natural” sound of the already calculated notes.

The same procedure was applied for the injection of quartertones during the composition, using three values in the table for “quartertone down”, “quartertone up” and “neutral”. Four voices were generated to apply these alterations to the existing voices.

4.5.2. Reinhold Friedl – *KRAFFT* for Orchestra

KRAFFT for orchestra was composed in 2016 as a commission of the French State[316], and was premiered in Paris and Marseille, France. The composition has a similar kind of metric structure as *String Quartet No. 3*: all instruments play in rhythmic unison throughout. The full musical score and recording are available for download.[317]

The subject of *KRAFFT* was power and force,[318] and I wanted the listener to feel exposed to a kind of sonic undertow. The notion of huge power and force is often connected to the existence of clandestine and somehow unpredictable rules controlling the world around us; something is happening, but we do not know exactly what, when or how.

KRAFFT enforces textural listening. It is worthwhile to recall Ralph Wood’s definition:

> Textural listening is a way to regard any piece of music as an unwinding strip of 'texture': and just to listen to that; not to its various strands as such, not to one single strand, but to it as a whole, an unwinding ribbon, varying

[316] Commande d’Etat of the French ministry of cultural affairs for the Ensemble 2e2m, Paris and zeitkratzer. conducted by Pierre Roullier; CD release previewed for October 2019. Premiered and recorded in Paris, Festival “Extensions”, La Muse en circuit and Festival Les Musiques, GMEM Marseille, May 2016.
[317] See Annex 1.
[318] KRAFFT is an onomatopoetic wrong spelling of the German term “Kraft”, meaning “power” or “force”.

as it goes in width, in colour, in depth, in thickness, in weight, in character, but always a unity.[319]

Translated into compositional thinking, this would mean that on the one hand, no single sonic element of the composition should draw too much attention, and on the other hand, that every sonic element inside the texture should draw the same attention. Therefore, I made four main decisions:

a) All instruments play in rhythmic unison throughout. The metric structure is always asymmetrically changing, causing an irregular regularity.
b) To construct the main textures with a maximum complexity – to superimpose and to overlap textures, to inject them into other textures, etc.
c) To intervene manually, where necessary, especially at the seams of different textures, to ensure continuity of sound.
d) To set the overall dynamic structure as a *decrescendo*, followed by a gradually accelerating huge *crescendo*.
e) To deliver the music with a steadily increasing *accelerando* throughout the composition.

In *String Quartet No. 3*, the use of TTM became close to that of an algorithmic composition software, but in *KRAFFT*, TTM was applied in another way: it served as multifaceted compositional tool on several levels.

First, the metric structure was realised with the same procedure as in *String Quartet No. 3* for several progressions in the different parts of the composition.

As a next step, further probability progressions were combined in a modular way. The instruments were divided into very traditional groups: strings, winds, 2 percussion, 2 pianos, and guitar. The sonic materials of these groups

[319] Wood R. (1942) Psychology and Musical Texture, in: The Musical Times, Vol. 83, No. 1191, 140-141.

were sectionally defined and linear progressions were assigned to these sections.

The four main sections are divided by double bar lines:

- Bar 1-241
- Bar 242-363
- Bar 364-500
- Bar 501-606

A simple probability progression can be found in the beginning in the two percussion voices which start with three sonic elements:

- an ascending *glissando* on the timpani
- a descending *glissando* on the timpani
- pause

As duration is not of interest (all instruments always play full bars in the already defined metric structure), it is sufficient to consider here the pitch progression used (Figure 83). It is rather basic: the two lower surfaces represent the progressions of the timpani *glissandi*, the higher surface the progression of the pauses. The timpani interventions become more frequent.

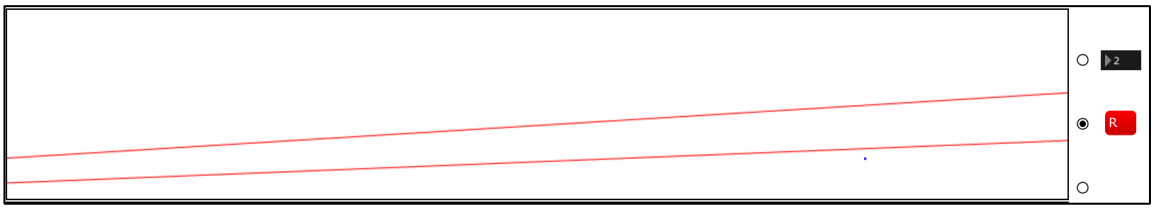


Figure 83: Probability progression for 2 perc, bar 1-180.

From bar 181 to bar 241 the timpani fade out, glockenspiel and gran cassa gradually enter. Because of the linearity of the model, this development could not be shaped in the same probability progression. A short probability progression from bar 181 to bar 241 had to be connected directly to the previous one.

Another more complex example is the parallel construction of the texture of the wind instruments in bars 1-241:

The initial probability progression for all six wind instruments (Figure 84, 6 voices) is similar to the one we know from the beginning of *String Quartet No. 3*.

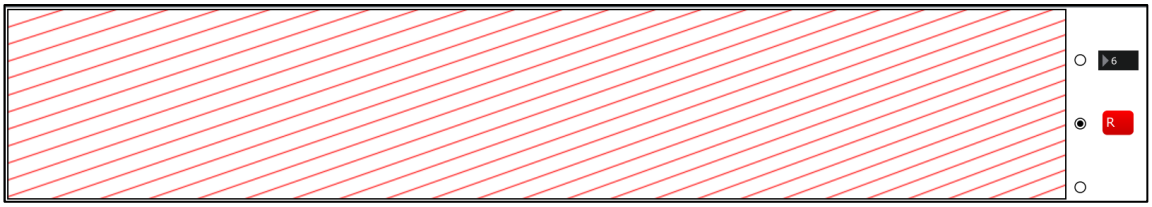


Figure 84: Initial probability progression wind instruments, bars 1-241.

Here, the pitches are not descending groupwise, but gradually ascending through multiple transitions. Furthermore, a larger number of different pitches are simultaneously required and thus, the gradient of the straight lines needed to be smaller.

The six monorhythmic voices, one for each instrument, could then be generated with a rastering of 241. From bar 242, a completely other sound material follows: breathing sounds in different registers (see explanations, annex 2.3.). A compositional problem occurred: I wanted to have this new sound material dominate the texture from bar 242 onwards, but did not want an abrupt change at the end of bar 241 either.

This problem could be solved by using an additional “dominant” probability progression: from bar 180 to 242, four of the upcoming breathing elements should already emerge (two more are saved for later use after bar 242, in order to ensure continuation of the progression). Thus, the following probability progression (Figure 85) was rasterized with 62 (the required number of bars):

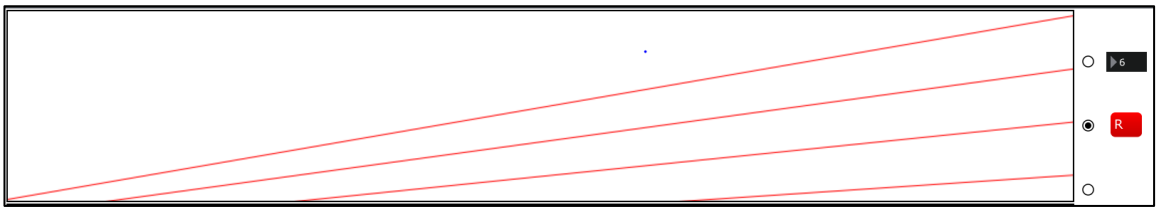
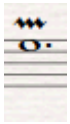


Figure 85: Probability progression of the dominant breathing sounds, bars 180-242.

The upper large triangle in Figure 85 stands for “leaving the initial events”. The four lower surfaces show the new breathing sounds entering successively. The resulting MIDI-file was transferred in temporary, additional systems in bars

180 to 242. The notes in these systems were then changed into the breathing signs, and afterwards transferred manually into the initial texture. The new events replaced the initial ones, they dominated the initial texture.

Furthermore, indications for *vibrato*



appear shortly after bar 100, with increasing frequency up to bar 152. From bar 153 onwards, all notes from the wind instruments are to be played with *vibrato*. To realise this additional differentiation of a pre-existing texture, the same probability progression (Figure 85) was used, but rasterized with 52, to attain an exact output of 52 bars. The result was copied again into temporary, additional systems, and transferred manually as *vibrato* signs in the initial texture. However, this additional texture was not a dominant texture, replacing earlier elements by new elements, but a superimposing texture, refining the initial texture.

Thus, the resulting texture of the wind instruments is comprised of three textures: an initial texture, a dominant texture, and a superimposed texture. This gives a pragmatic idea of how the other passages and layers in the composition were constructed (Full score for download in related materials 1.3.).

The last example is the final injection of an “irritating texture” into the whole composition. A very simple probability progression was applied to inject the ¼ bars into the musical stream, which are especially prominent at the very end of the piece, sounding like short high screams. As this was supposed to have surprising effects (often supported by a *sforzato* articulation), there should not be too many (Figure 86).

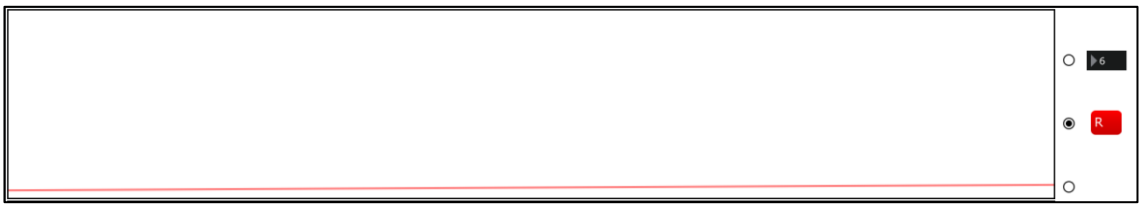


Figure 86: Probability progression of the intersection with 1/4 bars.

The sonic material of these interjections was not attributed beforehand but defined due to the context. This explains, for example, all breathing intervention of the wind players in bar 234. I primarily used those interjected bars as short flashbacks of already used sound material – a memory of sounds that had already occurred – or as an anticipation of sounds to come. The rhythmic signal character is clearly audible and supported by the contrasting sound quality of these interventions.

5. Conclusion

The Texture Transformation Machine can be used very flexibly. It can serve as a quasi-algorithmic composition tool and trigger relentlessly precalculated processes, as in *String Quartet No. 3*. On the other hand, TTM can be used as a composition tool to build complex textures of non-linear nature. This can be realised by connecting consecutive textures, superimposing or overlapping textures, dominating textures with others, injecting textures into given structures, etc.

The simplicity of TTM has many advantages: the linear nature and the graphic representation allow a simple and direct approach to shape the probability progressions. This also allows quick control of the results: even though the output into a MIDI-file is a clear limitation, the results can be heard directly and related to the settings of the parameters. This enables the user to approach the desired result stepwise.

However, the limitations also become obvious. One example: once a metric is set throughout a composition it is not possible to generate new series of events with the same metric structure (the metric parameter is randomly driven and will not produce the same result twice). This means, that a part of additional results need to be transferred into the score manually. Although, as shown in the discussion of *KRAFFT*, this can be easily done, and is still an appropriate alternative to manual transfer from random tables.

An alternative approach would have been to directly generate a musical score, but secondary manipulations of once-calculated textures would no longer be possible. This would be a great loss and would need to be compensated by

additional and more sophisticated functions within the software. This would definitely affect the fast adaptability and the direct feedback between parameter changes and musical result.

Furthermore, TTM can be easily expanded in the future. It could be used not only to generate written musical scores, but also for piloting musical samplers or other musical devices, for instance. TTM could control sound installations or other automated processes: imagine steady transformations of hundreds of textures consisting of a huge amount of sample collections in an exhibition space. Another possible development could open the parameter inputs for other data provided from sensors or other interactive devices. Thus, a texture could be transformed with probability progressions shaped in real time.

Finally, this brings us back to the question about the nature of texture. In the chapters about the software and the examples, the terms “texture transformation” and “texture” increasingly merged. The texture transformation model defined here was a texture changing over time. Only the starting point and the end point can be considered as fixed textures. But even those fixed textures (defined by the parameter values at the beginning and the end of the probability progression) are defined only by their probability structure, and are thus flexible and always changing in detail.

In his article “texture and form”, the electroacoustic music composer Raul Minsburg asks for a future concept of textural modulation:

> This concept precisely defines these transitional moments which are characteristic of any modulation. It is in these moments that the most ambiguous situations occur but at the same time the richest ones from an artistic perspective, since the new textural setting is not defined yet nor is the previous one abandoned. […] This also means that texture is not something that occurs in a certain moment and that we can measure second by second.[320]

[320] Minsberg, R. (2016) Some ideas concerning the relationship between form and texture, in: Emmerson, S., Landy, L. (eds) Expanding the Horizon of Electroacoustic Music Analysis, Cambridge, 102-120; 118.

Flexibility is crucial in a concept of texture, and, inversely, texture allows flexibility. That is how Xenakis could release such different versions of his textural electroacoustic compositions, as discussed in the first part of this dissertation.

The philology of electroacoustic music developed in this thesis has many features differing from ‘classical’ philology of music. Electroacoustic music has no written text or music score as in traditional philology; the work itself is not paper based, but inscribed electromagnetically on other media, such as tape, hard discs, etc. These inscriptions are notations and can be considered as texts. Therefore, we can apply comparative philological methods.

Electroacoustic music ‘texts’ show one fundamental difference though: we cannot read them without a machine and secondary information about the media samplerate, velocity, etc. Meta information and/or technical assistance are indispensable. Thus, “reading” in this context has two different meanings: it can mean looking at a visualisation of acoustic signals or listening to the machine’s output. Comparative listening becomes as crucial as comparing meta information (length, date, etc.).

Xenakis’s tape music shows that studio work is performative. We often tend to assume that electroacoustic compositions are fixed on a sound carrier once and for all[321]. The existence of two differing versions of a work already puts this into question. A philological research study shows us how the production of a composition was performed. In Xenakis’s case, there have been different performances due to the necessities of the occasion: performances with stereo or 5.1. output for commercial releases, different concepts of spatialisations for different rooms and technical conditions. In this very sense, his oeuvre is flexible and not fixed in one finite version on one definite sound carrier.

On the other hand, philological research allows the detection of errors and misunderstandings. All three compositions discussed have been released in corrupted versions. Numerous musicological articles (on *Bohor* and *La Légende d’Eer*) and critiques (*Persepolis*) have been based on these corrupted versions. A discussion and philological research of those sources did not take place.

[321] Compare: Chion, M. (1991) L’art des sons fixés ou La Musique Concrètement, Fontaine, 7.

Philology of electroacoustic music is an indispensable method to reconstruct genealogies of electroacoustic music, and enables us to critically discuss the sources for further research or analysis. It became evident that the time for critical and historically informed editions of electroacoustic music has come – and that there is an absolutely urgency to do so while there are still contemporary witnesses.

Two critical editions of Xenakis's electroacoustic work have been produced as a result of this research. Besides this practical outcome, Philology of electroacoustic music allows new perspectives on a composer's oeuvre. Due to its technical conditions, electroacoustic music is usually constructed step-by-step from sound material up to the final composition. Philology of electroacoustic music allows us to look inside this construction process; a genealogy can go down to the first sound material tapes and make a partly reconstruction possible. From this we can learn how music has been composed, which concepts have been applied, which sound material used, etc. Philology of electroacoustic music gives an insight into the composer's workshop. Philology of electroacoustic music is *philologie génétique*: the focus is on the genesis of a composition, not on a "final version".

Moreover, these kinds of discoveries enrich the analysis of electroacoustic music and bring out new aspects. For instance, the question of the author and his notion of oeuvre is directly tackled. Our notion of 'the original' is even more crucial – as Mode label's comment on their re-release of *La Légende d'Eer* shows[322], we still tend to think that there must be "an original" in electroacoustic music. But there are often multiple originals. Nevertheless, this does not mean "anything goes", but asks for even more precision. The tape used for the Mode-Version of *La Légende d'Eer* is an 'original' tape, in the sense that it is not corrupted, it is authentic, but was never a 'master tape' or a final version of the composition. We also tend to think that machines are objective, as the same statement shows: "The analog master was transferred at high-resolution 96khz/24-bit sound for the optimum quality, revealing details not heard in the

[322] "Use of the original master tape restored almost 2 minutes and 30 seconds to the piece, released here for the first time", Announcement of the release on Mode Records, www.moderecords.com/catalog/148xenakis.html, last visit March 22, 2019.

previous stereo CD release.” How could we really believe that a higher resolution transfer reveals new details?

Further on, composers – like all authors – have secrets, and tend to hide sensible details. The reasons are multifarious: ideological, commercial, etc. Electroacoustic composers particularly mask the provenance of their sounds, as Beatriz Ferreyra, another long-term member of GRM, underlines.[323] Xenakis evidently put out incomplete sound listings that can be interpreted in this way. Parallel to the idea of the existence of “the original” we often tend to think of the electroacoustic composer as reliable. But composers preserve their interests. Thus, we should also question their statements critically.

Philology of electroacoustic music also has a political impact. A vast number of possible objects of research will soon disintegrate. The durability of the first generations of magnetic tapes has already reached its limit. A large part of important sources is neither rescued and stored in good conditions, nor digitised. There is no central institution archiving the electroacoustic music sources as sound carriers, equipment, etc. Digitisation and collecting of meta information is not yet unified and often forgotten. What use are digital files if we do not know how to read them? The Betamax-tapes with Xenakis’s *La Légende d’Eer* at WDR are already unreadable. The machines to read them are rare. Imminent solutions to save this electroacoustic music heritage are urgent.

[323] Ferreyra, B. (2018) in Friedl, R. (2018) Die Baschet Instrumente in der elektroakustischen Musik, Radio-Feature, WDR Köln.

Annex

1. List of additional digital materials for download / on USB-Stick

0. PDF-file of this dissertation with figures in colour.
    - 00 PHD 2019 - FRIEDL R - Towards A Philology of Electroacoustic Music - Xenakis's Tape Music as Paradigm.pdf

1. Reinhold Friedl: *Golden Quinces, Earthed for spatialised Neo-Bechstein*, CD, Bocian Records – bcRF, Warsaw. Reinhold Friedl - neo-bechstein, Sukandar Kartadinata - fader-board, recorded 2015, mixed and mastered by Rashad Becker.
    - 01a Friedl - Golden Quinces Earthed.wav
    - 01b Friedl - Golden Quinces Earthed.mp3

2. Reinhold Friedl: *Eight Equidistant pure wave oscillators, while slipping very slowly to a unison, texturally spatialised on eight speakers, concret, 60 minutes,* released on the Australian label *Room 40*, Sydney.
    - 02a Friedl - Eight Equidistant Pure Wave Oscillators.wav
    - 02b Friedl - Eight Equidistant Pure Wave Oscillators.mp3

3. Reinhold Friedl: *Xenakis's Legend*, spatialized version of Xenakis's *La Légende d'Eer.*
    - 03 Friedl – Xenakis Legend Spatialisation Score.pdf
    - 03-1 Friedl – Xenakis Legend Channel 1.mp3
    - 03-2 Friedl – Xenakis Legend Channel 2.mp3
    - 03-3 Friedl – Xenakis Legend Channel 3.mp3
    - 03-4 Friedl – Xenakis Legend Channel 4.mp3
    - 03-5 Friedl – Xenakis Legend Channel 5.mp3
    - 03-6 Friedl – Xenakis Legend Channel 6.mp3
    - 03-7 Friedl – Xenakis Legend Channel 7.mp3
    - 03-8 Friedl – Xenakis Legend Channel 8.mp3

4. Reinhold Friedl: *string quartet no 3*, released on La Muse in Circuit (ALM008), Paris, March 2017.
    - 04a Friedl – String Quartet No3 Score.pdf
    - 04b Friedl – String Quartet No3.wav
    - 04c Friedl – String Quartet No3.mp3

5. Reinhold Friedl: *KRAFFT*, for eighteen musicians, premiered and recorded in Paris and Marseille by ensemble *zeitkratzer* and *2e2m*, Paris.
    - 05a Friedl – KRAFFT Explanations.pdf
    - 05b Friedl – KRAFFT Score.pdf
    - 05b Friedl – KRAFFT.wav
    - 05c Friedl – KRAFFT.mp3

6. LP Release *Persepolis*, Perihel Series curated by Reinhold Friedl, Karlrecords – KR044, March 2018.
    - 06 Xenakis – *Persepolis* KARLRECORDS KR044.mp3

7. LP Release *La Legende d'Eer* Perihel Series curated by Reinhold Friedl, Karlrecords – KR024, July 2016
    - 07 Xenakis – La Legende dEer KARLRECORDS KR024.mp3

8. TSP-Software
    - 08a TSP controle.maxpat
    - 08b TSP engine.maxpat

9. TTM-Software:
    - 09 TTM
    - 09 START FILE.json
    - 09 START Coll durations.txt
    - 09 START Coll metrik.txt
    - 09 START Coll pitches.txt
    - 09-1a Example 1 Score

- 09-1b Example 1.mp3
- 09-2-PR1 Example 2 Polyrhythm Output 1.mp3
- 09-2-PR2 Example 2 Polyrhythm Output 2.mp3
- 09-2-PR3 Example 2 Polyrhythm Output 3.mp3
- 09-2-MR1 Example 2 Monorhythm Output 1.mp3
- 09-2-MR2 Example 2 Monorhythm Output 2.mp3

2. Apparatus *Persepolis*

i. Acoustic sources (AS)

a) Commercial Releases							
Name	**Title**	**Label**	**Signature**	**Media**	**Date**	**Tracks**	**Length**
PER-01-Ph-F	Iannis Xenakis - *Persepolis*	Philips France	6521-045	LP	1972	stereo	22:50+23:50 = 46:40
PER-02-Ph-JP	Iannis Xenakis – *Persepolis*	Philips Japan (license for Japan)	SFX-8683	LP	1974	stereo	22:50+23:50 = 46:40
	= PER-02-Ph-F						
PER-03-Fract	Iannis Xenakis - *Persepolis*	Fractal Records, Belgium	FractalOX	CD	2000	stereo	55:06
	„Continuous version, without interruption between part I and part II, realized in June 1999 and mixed to stereo 8 channel in April 2000 at the "Studio für Elektronische Musik des Instituts für Neue Musik der Staatlichen Hochschule für Musik Freiburg im Breisgau", Germany“						
PER-04-RZ	Iannis Xenakis	Edition RZ, Germany	Ed. RZ 1015-16	2CD	2003		50:49
	„Persépolis (Version "Avec Mouvement") Licht- Und Klangkomposition Mit Elektroakustischer Musik Auf 8-Kanal-Tonband (1971)“						
PER-05-Asph	Iannis Xenakis *Persepolis* GRM Mix	Asphodel, USA	ASP2005	2CD	2005	stereo	60:40
PER-06-KR	Iannis Xenakis *Persepolis*	Karlrecords, Germany, (~30” overlapping on each side).	KR	LP	2018		31:28+24:36 = 55:06

b) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
PER-AS-BnF-001	DONAUD 0604-136	Xen139	7' - 38 cm/s		22'50	*Persepolis*, 1st side of the record on both tracks	
PER-AS-BnF-002	DONAUD 0604-136	Xen140	7' - 38 cm/s		23'50	*Persepolis*, 2nd side of the record on both tracks	
PER-AS-BnF-003	DONAUD 0604-467	Xen481	10 1/4 in		20'30	Voie A1	Teige: *Persepolis*
PER-AS-BnF-004	DONAUD 0604-468	Xen482	10 1/4 in		29'29	Voie AII	Teige: *Persepolis*
PER-AS-BnF-005	DONAUD 0604-469	Xen483	10 1/4 in		30'30,	Voie BI	Teige: *Persepolis*
PER-AS-BnF-006	DONAUD 0604-470	Xen484	10 1/4 in		29'29	Voie BII	Teige: *Persepolis*
PER-AS-BnF-007	DONAUD 0604-471	Xen485	10 1/4 in		26'29	Voie CI	Teige: *Persepolis*
PER-AS-BnF-008	DONAUD 0604-472	Xen486	10 1/4 in		28'30	Voie CII	Teige: *Persepolis*
PER-AS-BnF-009	DONAUD 0604-473	Xen487	10 1/4 in		26'31	Voie DI	Teige: *Persepolis*
PER-AS-BnF-010	DONAUD 0604-474	Xen488	10 1/4 in		28'30	Voie DII	Teige: *Persepolis*
PER-AS-BnF-011	DONAUD 0604-475	Xen489	10 1/4 in		?	Voie A,B,C,DI	Teige: *Persepolis*
PER-AS-BnF-012	DONAUD 0604-476	Xen490	10 1/4 in		?	Voie A,B,C,DII	Teige: *Persepolis*
PER-AS-BnF-013	DONAUD 0604-477	Xen491	10 1/4 in		29'	Voie EI	Teige: *Persepolis*
PER-AS-BnF-014	DONAUD 0604-478	Xen492	10 1/4 in		30'54	Voie EII	Teige: *Persepolis*
PER-AS-BnF-015	DONAUD 0604-479	Xen493	10 1/4 in		29'	Voie FI	Teige: *Persepolis*
PER-AS-BnF-016	DONAUD 0604-480	Xen494	10 1/4 in		31'	Voie FII	Teige: *Persepolis*
PER-AS-BnF-017	DONAUD 0604-481	Xen495	10 1/4 in		?	Voie E&FI (stéréo)	Teige: *Persepolis*
PER-AS-BnF-018	DONAUD 0604-482	Xen496	10 1/4 in		?	Voie E&FII (stéréo)	Teige: *Persepolis*

b) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
PER-AS-BnF-019	DONAUD 0604-483	Xen497	10 1/4 in		32'30	Voie GI	Teige: *Persepolis*
PER-AS-BnF-020	DONAUD 0604-484	Xen498	10 1/4 in		22'29	Voie GII	Teige: *Persepolis*
PER-AS-BnF-021	DONAUD 0604-485	Xen499	10 1/4 in		?	Voie HI	Teige: *Persepolis*
PER-AS-BnF-022	DONAUD 0604-486	Xen500	10 1/4 in		?	Voie HII, 16.03.1971	Teige: *Persepolis*
PER-AS-BnF-023	DONAUD 0604-487	Xen501	10 1/4 in - 38 cm/s	mono	?	*Persepolis* Eléments Alpha, Béta	des précisions techniques d'enregistrement figure au dos du boîtier
PER-AS-BnF-024	DONAUD 0604-488	Xen502	10 1/4 in - 19 et 38 cm/s		?	*Persepolis* Eléments Delta, Béta, Gamma, Epsilon	des précisions techniques d'enregistrement figure au dos du boîtier
PER-AS-BnF-025	DONAUD 0604-489	Xen503	10 1/4 in		18'	*Persepolis* Eléments Lamda 1, 2, 3, 5, 6	des précisions techniques d'enregistrement figure au dos du boîtier
PER-AS-BnF-026	DONAUD 0604-489	Xen504	10 1/4 in		?	*Persepolis* Eléments Lamda 7, 8, 9, 10, 11	des précisions techniques d'enregistrement figure au dos du boîtier
PER-AS-BnF-027	DONAUD 0604-522	Xen544	7',5 - 38 cm/s	stereo	24'10	*Persepolis* (1)	réduction stéréo d'après 4 pistes (le boîtier porte une étiquette d'enregistrement INA/GRM)

b) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
PER-AS-BnF-028	DONAUD 0604-522	Xen545	7',5 - 38 cm/s	stereo	24'30	*Persepolis* (2, suite)	réduction stéréo d'après 4 pistes (le boîtier porte une étiquette d'enregistrement INA/GRM)

ii. Visual Sources (scores, draftes etc.) [VS]:

- **PER-VS-AFX-01**

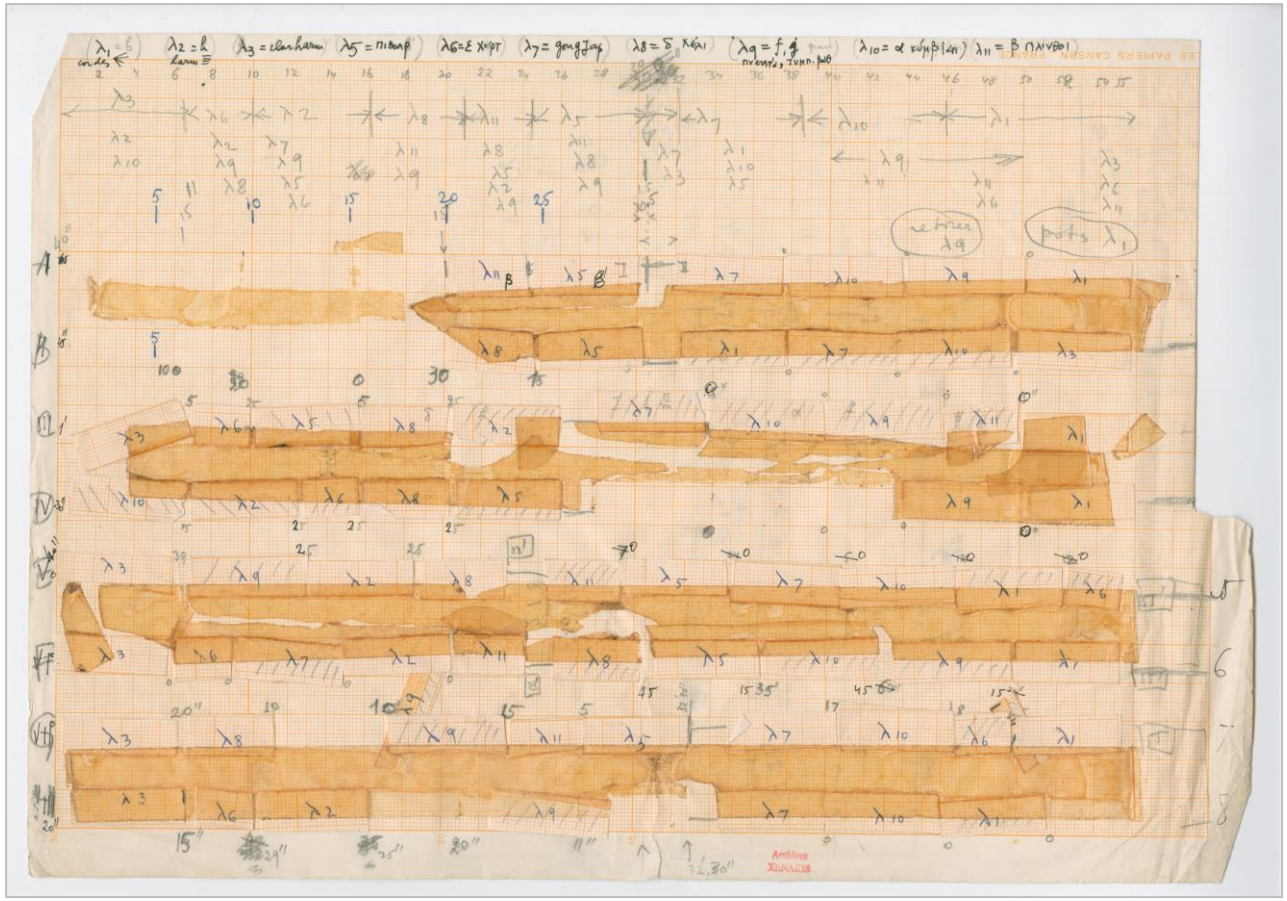


Figure 87: *Persepolis* ‘Score’, Archives of the Xenakis family (AFX), OM 27-4-3, 01; ca 33cm x 23cm.

- **PER-VS-AFX-02**

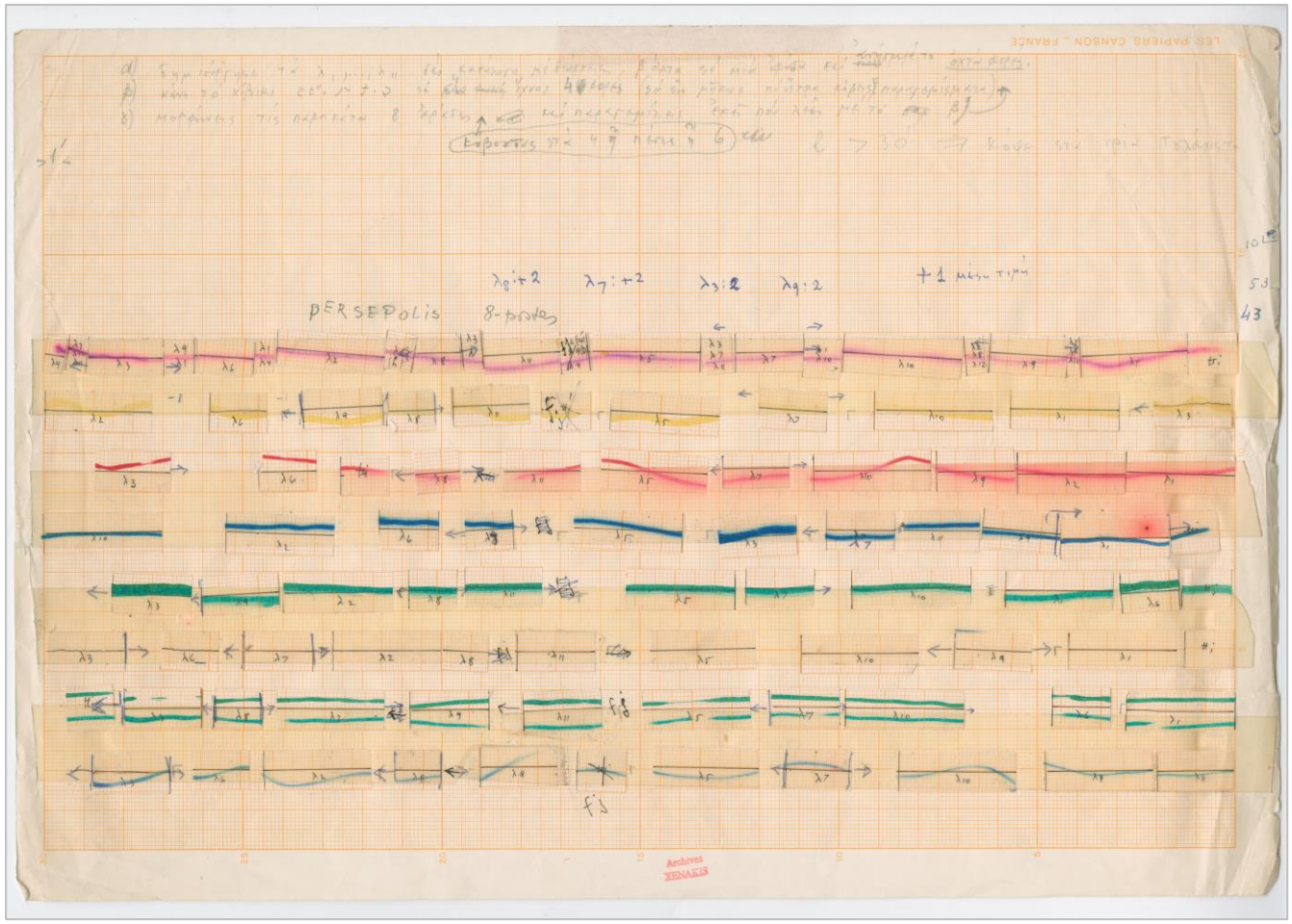


Figure 88: *Persepolis* ‘Score’, Archives of the Xenakis family (AFX), OM 27-4-3, 03; ca 33cm x 23cm.

- **PER-VS-AFX-03**

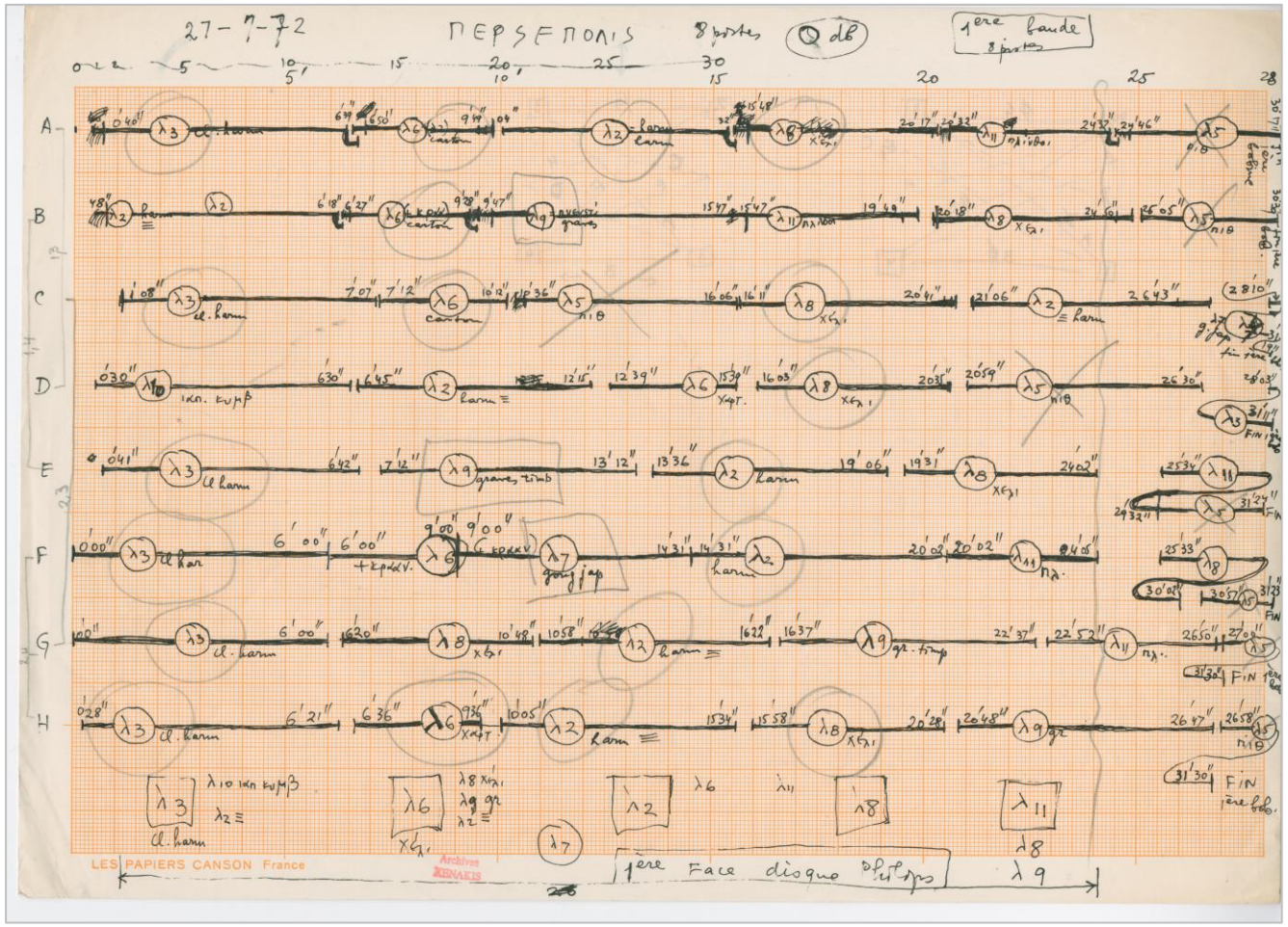


Figure 89: *Persepolis* ‘Score’, Archives of the Xenakis family (AFX), OM 27-4-3, 04; ca 30cm x 21,5cm.

- **PER-VS-AFX-04**

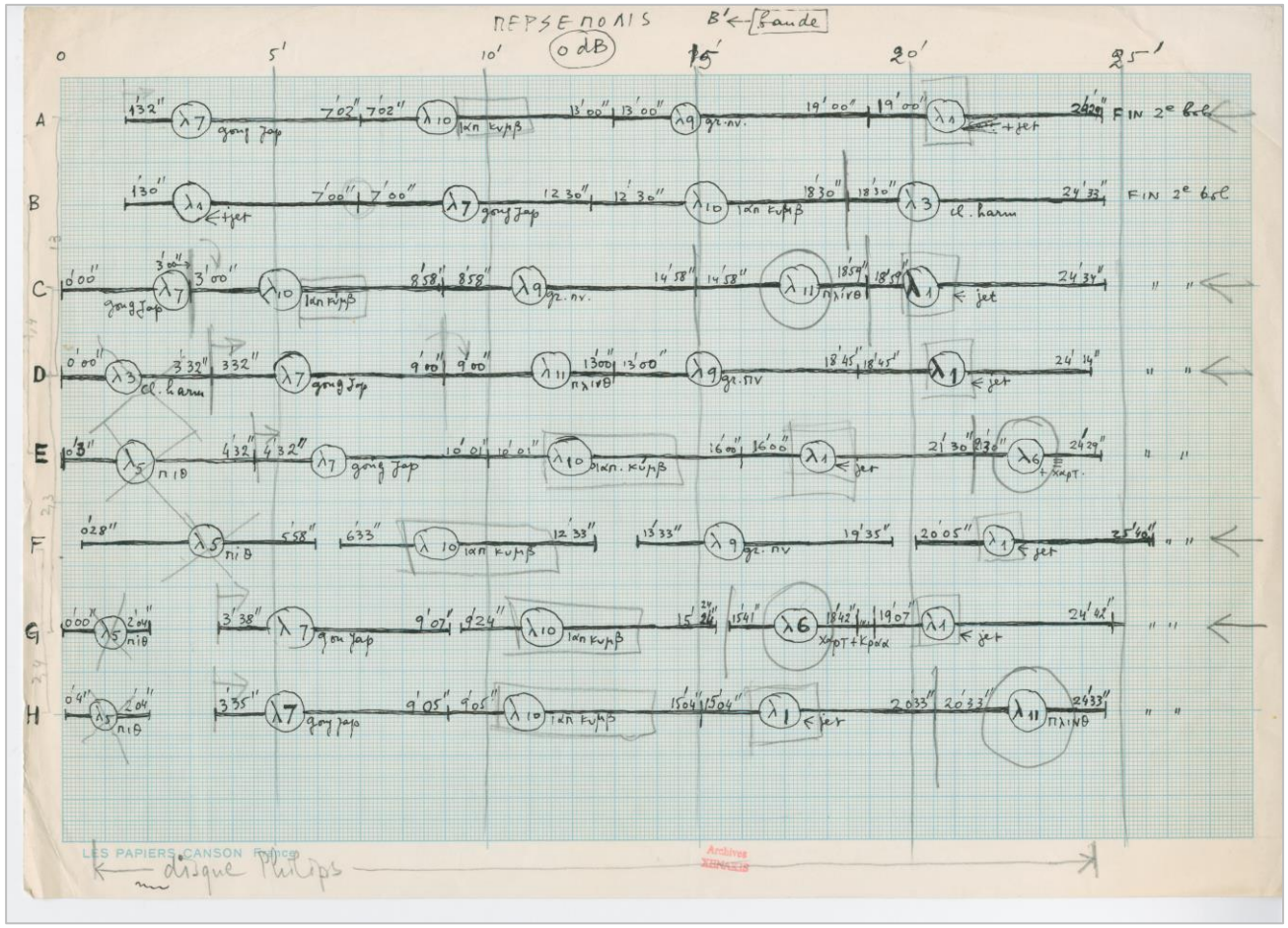


Figure 90: *Persepolis* 'Score', Archives of the Xenakis family (AFX), OM 27-4-3, 06; ca 30cm x 21,5cm.

- **PER-VS-AFX-05**

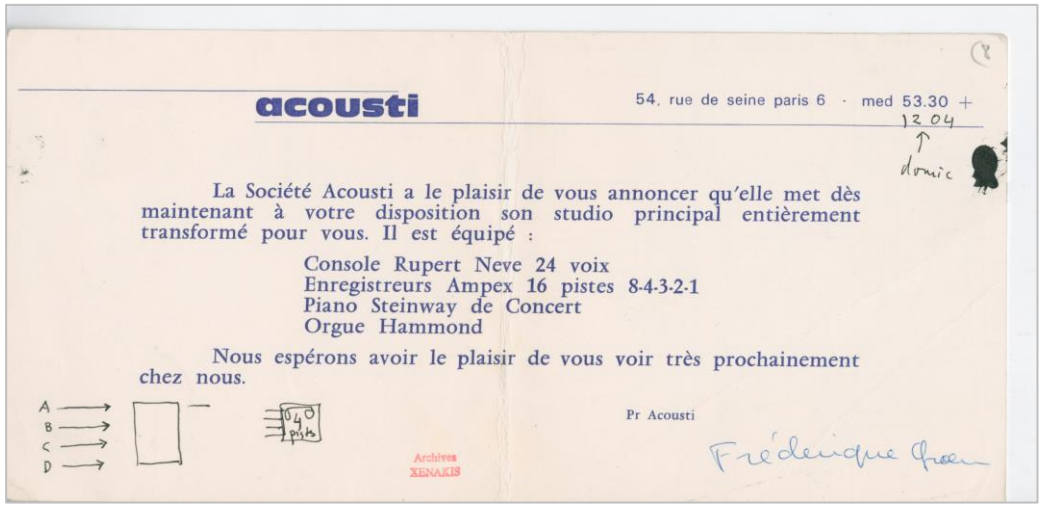


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Figure 91: Acousti Studio Card, Front; Archives of the Xenakis family (AFX), OM 27-4-2, 48; ca 22,6 cm x 10,9 cm.

- **PER-VS-AFX-06**

Figure 92: Acousti Studio Card, Front; Archives of the Xenakis family (AFX), OM 27-4-2, 47; ca 22,6 cm x 10,9 cm.

3. Apparatus *Bohor*

Acoustic sources (AS)

a) Commercial Releases							
Name	**Titel**	**Label**	**Signature**	**Media**	**Date**	**Tracks**	**Length**
BOH-01-ERATO	Iannis Xenakis	ERATO, France	STU 70530 France	5LP Box	1968	stereo	21:50
BOH-02-NS	Xenakis Electroacoustic Works	Nonesuch, USA	H-71246 USA	LP	1970	stereo	21:30
BOH-03-EMF	Xenakis Electronic Music Works	Electronic Music Foundation (EMF), USA	EMF CD003	CD	1997	stereo	21:36
BOH-04-mego	Xenakis – GRM works 1957 - 1962	Mego, Austria	REGRM 007	LP, download	2013	stereo	21:50

b) Publishing house Durand/Salabert/Eschig Paris, France (EdH)							
Name	**Titel**			**Media**	**Date**	**Tracks**	**Length**
BOH-05-EdH	Iannis Xenakis - *Bohor*	Probably from BOH-AS-GRM-013 (see below)	Digitisation 96 kHz	DVD	1991 or later	8	21:50

c) Archives Groupe de Recherches Musicales Paris (GRM)							
Name	**GRM #**	**Tracks**	**Length**	**Date**	**BOH-CAT-GRM-02**	**BOH-CAT-GRM-03**	**BOH-CAT-GRM-04**
BOH-AS-GRM-001	251 SUR	stereo	22:00	1962	a1 - *Bohor*, 1) Grelot d'Iraq, 22', (voie 504)	251, 1 ; 4 voies, 2p. 22'; première oeuvre conçue pour 8 canaux (quadruple stéréo). Dispositif de diffusion pour la création: 4 canaux stéréophoniques circulaires. Ed. Salabert. Oaris, Salle des Conservatoires 15 décembre 1962	251SUR a1) Grelot d'Irak
BOH-AS-GRM-002	251 SUR	stereo	22:00	1962	a2 - *Bohor* 2) Byzance (voie 504)	251,1; 4 voies, 2p. 22'	251SUR 2) Byzance
BOH-AS-GRM-003	251 SUR	stereo	22:00	1962	b3 - piano et echo (voie 504)	251,1; 4 voies, 2p. 22'	251SUR b3) plan 0 + echo
BOH-AS-GRM-004	251 SUR	stereo	22:00	1962	b4 - aigu et écho (voie 504)	251,1; 4 voies, 2p. 22'	251SUR 4) orgue + echo
BOH-AS-GRM-005	504 SUR	stereo	21:50	1968	A - Xenakis *Bohor* (version 1968) 21'50	251,3; réduction 2 p. Dis	Aug 68, A: Stéréo 38 cm/s d'après les 4 stéréos 251 SUR
BOH-AS-GRM-006	504 SUR	stereo	21:50	1968	B - Xenakis *Bohor* (version 1968) 21'50	251,3; réduction 2 p. Dis	B: Dit ci-dessus (1ère version voir 251/p.4)

c) Archives Groupe de Recherches Musicales Paris (GRM)							
Name	**GRM #**	**Tracks**	**Length**	**Date**	**BOH-CAT-GRM-02**	**BOH-CAT-GRM-03**	**BOH-CAT-GRM-04**
BOH-AS-GRM-007	504 SUR	stereo	21:50	1968	[x] C - Xenakis *Bohor* (version 1968) 21'50	251,3; réduction 2 p. Dis	C: version stéréo d'après 4 pistes, [X] pour editing, Oeuvre au catalogue Salabert depuis le 22/5/79
BOH-AS-GRM-008	504 SUR	4	21:50	1968	WUR	251,4 1968 révision 4 p. 1 pouce	4 pistes
BOH-AS-GRM-009	251 WWUR 1+2	8	21:30	1981	2 versions 8 pistes réalisées le 26.5.81 par Xenakis, Bayle, Zanési (Studio 116a)		21'30
BOH-AS-GRM-010	251WUR	4	21:30	1981	voir nouvelle version 68: (504 SUR - WUR)	251,2; version 4p., 1 pouce	1981, 21'30
BOH-AS-GRM-011	251 WWUR =	8		1986	report sur 8 pistes de 4 voies séparées SUR, corrigés par D.Teruggi janvier 86 pour le cycle de 27 janv. 86		Report sur 8 pistes des voies séparées corrigées par Daniel Teruggi. Jan 86
BOH-AS-GRM-012	251 VUR	4		1986	mixage d'après ce 8 pistes		Mixage d'après ce 8 pistes (Xenakis - Teruggi) l'auteur n'aime pas
BOH-AS-GRM-013	251 SUR	stereo		1991	(copie du DAT) mixage du 10.9.91, St. 116c, Xenakis et Teruggi		Mixage St.116C Xenakis - Teruggi (version à utiliser)

c) Archives Groupe de Recherches Musicales Paris (GRM)							
Name	**GRM #**	**Tracks**	**Length**	**Date**	**BOH-CAT-GRM-02**	**BOH-CAT-GRM-03**	**BOH-CAT-GRM-04**
BOH-AS-GRM-014	Not mentioned	8		1991	Only mentioned in *Bohor*-VS-AFX-05: “8 pistes, 3 copies Salab. le master reste à l’INA”. „+ 3 numér”; “		

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
BOH-AS-BnF-001	DONAUD 0604-352	Xen362	10 1/4 in - 38 cm/s	stereo	21'30	*Bohor* III, Version A, 251 SUR, Septembre 1991	le boîtier porte l'indication: Réduction du 8 pistes (1986)
		1986er Version 1 - für EMF CD (Datierung 1991) ??					
BOH-AS-BnF-002	DONAUD 0604-353	Xen363	10 1/4 in - 38 cm/s	stereo	21'30	*Bohor* III, Version B, 251 SUR, Septembre 1991	le boîtier porte l'indication: Réduction du 8 pistes (1986)
		1986er Version 2 (mehr Hall?) - für EMF CD (Datierung 1991) ??					
BOH-AS-BnF-003	DONAUD 0604-504	Xen525	10 1/4 in - 19/38 cm/s	stereo	26'34	*Bohor* Eléments 1, 2, 3	2 fiches accompagnent la bande (indications de durées d'enregistrement et ordre de montage des Eléments avec amorce)
		00:00 - 02:25 Material of Concret PH?					
		02:38 Sounds like „Bracelet“					
		03:51 Only small bells in variations					
		05:28: More bell sounds					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		08:09 - 10:40 Thumb piano? A little distorted					
		10:45 The same densified?					
		12:20 - 13:30 Concret PH material?					
		13:33 Distorted? Cracle sounds like Concret Ph					
		15:30 Sounds like Baschet's piano-tige					
		17:07 single sounds piano-tige (?): arpreggios					
		18:08 Piano-tige (?): more arpreggios, different registers					
		20:57 Piano-tige (?): lowder and more noise-like					
		21:38 Piano-tige (?): chords and arpeggios, glissandi!					
		23:50 Piano-tige (?): characteristic glissandi!!					
		24:41: „voile" = metal sheet !! very clear!!!					
BOH-AS-BnF-004	DONAUD 0604-505	Xen526	5' - 38 cm/s	stereo	8'11	*Bohor* bande 3, bracelets+byzantin(?)	l'étiquette du boîtier porte l'indication: stéréo démultiplié
		00:00 - 01:45 Small bells / "Bracelets" (compare notes on box) superimposed, accelerated					
		02:11 - 05:14 Small bells / „Bracelets": oringinal, dann stereo vervielfacht !!!					
		05:25 - Small bells / „Bracelets": very clear, different pitches, fast – played with a kewboard? Assembled?					
BOH-AS-BnF-005	DONAUD 0604-506	Xen527	7' - 19 cm/s	stereo	17'34	*Bohor* bande 5, cloches(?)+orgue+affollants	l'étiquette du boîtier porte l'indication: stéréo démultiplié
		00:00 Small bells with reverb, superimposed. Sounds like played on an instrument! Baschet-instrument with bells? After 2:00 superimposed loops or played on an instrument? Performed on metal bars of a Baschet instrument?					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		After 4:30 with glissandi! Damping effect with pedal?					
		05:11 - 05:30 Deep „rumatori“, sounds like elephants!					
		06:00 Deep sounds, sound like an harmonium! One tone only.					
		07:00 Deep harmonium, several tones					
		10:43 Harmonium, theme?					
		11:17 Harmonium with interference					
		13:08 -14:50 Even deeper harmonium / Baschet crystal organ?					
		15:14 Clearly thunder sheets! With crescendo					
BOH-AS-BnF-006	DONAUD 0604-507	Xen528	7',5 - 38 cm/s stéréo	stereo	22'10	*Bohor*, bracelets	
		00:00 – Small Bells, bracelets: sounds like played on a thumb piano or Baschet instrument.					
		03:45 Clearly two different layers! Small bells					
		After 09:15 continuous shift of intensity: slower deep layer, high pitched layer with hall plate (sounds like Muhal Richard Abrams Bird-Song)					
		From 19:03 to 22:06 „voile“ = metal sheet, crescendo (two layers already like in the composition): montage tape?					
BOH-AS-BnF-007	DONAUD 0604-508	Xen529	7',5 - 38 cm/s	stereo	18'28	*Bohor* II (bande original) Novembre 1962	l'étiquette du boîtier porte l'indication: prise de son original
		00:00 Small bells with little distorsions, high pitched, aggressive, chimes?					
		02:09 Voice "Melange des deux"! Recorded inside the recording room, stereo!					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		03:37 Voice: "Est-ce-que le choc entre les cloches est intéressant?"					
		04:19 - 07:28 "Prise des sons en Phase" Laothian mouth organ? No audible breathing. (Harmonium?)					
		7:30 more versions ot the same sounds (Harmonium?)					
		Around 10:00 Cluster, chords, wilder.					
		11:42 Voice: "Tu vas encore?"					
		11:55 - 15:30 Voice: "Séquence hors phase"					
		15:09 - 18:20 Metal sheet played with keybord?					
BOH-AS-BnF-008	DONAUD 0604-509	Xen530	10 1/4 in - 19 cm/s	stereo	32'57	*Bohor* I (bande original), orgue et cl. grec(?)	l'étiquette du boîtier porte l'indication: prise de son original
		00:00 - 01:13 Concret PH ? Jewellery (cl.grec)?					
		01:14 Voice: "Il y a des petits crachements dans mon haut-parleur"					
		01:15 - 03:01 Concret PH like					
		03:10 New variation, two layers					
		04:30 With movements in the stereo panorama					
		05:40 More vivid					
		08:40 Again wild stereo panning (sounds like a rotation)					
		10:08 Break					
		10:13 - 12:01 New version of Concret PH-like sounds (“Bracelets”?)					
		12:02 - 15:01 The same with more definition, more grip.					
		15:03 Another version, tingling					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		18:15 Disturbing noise					
		23:06 Suddenly more presence, crispier					
		25:11 Suddenly panorama movements					
		26:46 Xenakis's Voice: "C'est une cloche que j'ai amené du Japon. Un souvenir quoi"					
		28:05 Xenakis's Voice: "Il faut que la résonance…. Je vais trop vite je crois, n'est-ce pas?"					
		30:57 New take, bell with glissando					
		31:53 - 32:53 More rhythmic / aggressive interferences					
BOH-AS-BnF-009	DONAUD 0604-510	Xen531	10 1/4 in		11:21	*Bohor*	sans autre indication
	BOHOR played in double speed	00:00 sounds like piano-tige, playing the chromatic glissando part from the beginning					
		01:22 Organ sound added					
		Probably *Bohor* played with double speed- Metal sheet at the end now sound clearly like a real metal sheet. Cut 11:14 The end would then be: 22:28)					
BOH-AS-BnF-010	DONAUD 0604-511	Xen532	7,5 - ?	stereo	21'41	*Bohor*, 1) bracelets indon(?) 2) cloches (sans écho)	
		00:00 - 11:45 Densified bell sounds? With panorama movements 01:30 Second layer added: Concret PH sound soundso r „bracelets"					
		11:55 Resonating bells with interferences - Baschet-instrument with resonator?					
		17:50 Fast & repetetiv! Mit Tasten zu spielen!!! Das geht nicht mit Händen.					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
BOH-AS-BnF-011	DONAUD 0604-512	Xen533	7',5 - 38 cm/s 9 1/2 38 cm/s copie	stereo	23'29	*Bohor* II/3, piano	l'étiquette de bande porte l'indication: copie sans réverbération
		00:00 Sounds like piano-tige: probably opening melody from *Bohor* chromatically going down.					
		03:18 Single chords and tones					
		04:45 Two times: short interferences					
		06:01 - 7:48 New Take: Glissando (Beginning Piano-Tige?)					
		07:50 New version more grainy, playing the metal rods too!					
		09:30 With reverb (Piano-Tige?)					
		12:00 More like a litany					
		16:30 Clearly audible that htis is no piano! Too little string tension (Piano-tige)					
		17:33 With rustling					
		19:40 More aggressive with loud side noises and ricochet effects.					
		20:30 Rustling again, glissando in the background					
		21:12 Theme Piano-tige?					
BOH-AS-BnF-012	DONAUD 0604-513	Xen534	7',5 - 38 cm/s 9 1/2 38	stereo	30'11	*Bohor* I/3, piano	l'étiquette de bande porte l'indication: copie sans réverbération

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
			cm/s copie				
		00:00 - 2:47 Continuation of tape 533, sounds like single strings! Not like the three strings of each note in a piano (Piano-tige?)					
		2:48 Short Cut, continuation with rustling					
		4:00 Developing chromatic gestures					
		08:35 With side noise					
		09:30 Chromatic glissando, Theme!					
		13:00 - 16:13 A little bit wilder, sounds like two instruments?					
		16:14 - 17:45 New improvisation, calmer than before.					
		17:46 - 18:06 Cut, new versions, guitar-like					
		19:35 Glissando					
		20:44 New beginning, sounds like glissando on the metal rods: 22:00 piano-Tige?)					
		22:18 New trial, single sounds! (piano-Tige?)					
		23:06 - 25:07 Slow glissando! Original material used in the pices? (piano-Tige?)					
		25:08 Theme? (piano-Tige?)					
		25:52 Theme? (piano-Tige?)					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
BOH-AS-BnF-013	DONAUD 0604-514	Xen535	7',5 - 38 cm/s 9 1/2 38 cm/s copie	stereo	27'05	*Bohor* I/1	l'étiquette de bande porte l'indication: copie sans réverbération (les autres informations portées sur le boîtier ne concernent pas la bande)
		00:00 - 17:06 Bells either played with a keyboard or densified, very uniform, played for a long time. Perhaps even no bells but strings?.					
		17:06 - 20:00 Modulating, deeper noises, sounds like an original recording!					
		20:00 - 22:20 Keyboard playing cymbals? Or cymbal played with sticks?					
		22.20 Cymbal with high noises, nervous: keyboard on aluminium? Sounds like metal played with a keyboard? Becomes wilder.					
		26:11 very wild, metal sheet /thunder sheet = voile? Possibly pitched up an octave?					
BOH-AS-BnF-014	DONAUD 0604-515	Xen536	7',5 - 9 1/2 38 cm/s copie	stereo	27'45	*Bohor* II/1	l'étiquette de bande porte l'indication: copie sans réverbération
		00:00 - max 10:00 Montage tape? Sounds like several layers with loud attacks.					
		6:58 First metal sheet sound? (“voile”?)					
		10:00 Only bell solo, close-miked interference, or single notes from piano-tige?					
		16:15 Other bells / other single sounds from piano-tige? Sounds more like a bell, must be an original recording (no montage): 16:48 audible steps in the recording room.					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		17:00: Two different bells or tones.					
		21:00 Two tones toether?					
		22:00 Reverb with interference, metal rods? Clearly no bells!					
		24:44 Break					
		25:03 Original piano-tige? With deep bell-like sound! 25:30 YES! That might be the original “piano” recording! (piano-tige)					
		27:41 End					
BOH-AS-BnF-015	DONAUD 0604-516	Xen537	7',5 - ?	stereo	21'50	*Bohor*	le boitier porte une étiquette de bande ORTF, notée: SUR, R.C. (54) le 17/07/71
	BOHOR Version before 1971 (ERATO-Box? Nonesuch?? Sounds from the beginning much more bassy!	Compare with version from 1991: Much more bass! Also in the ending much more bass!					
BOH-AS-BnF-016	DONAUD 0604-517	Xen538	10 1/4 in - 19 cm/s	stereo	53'42	*Bohor*	l'étiquette de bande porte l'indication: pseudo montage;

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
	Digitised with half speed? Or perperatory montage: metal sheets, piano-tige. Deep harmonium sound missing completely.	00:00 Dense with reverb.					
		01:40 Sounds like Baschet‘s crystal organ, strange reverberating bass sounds.					
		05:00 Could be the original recordin of the piano-tige					
		08:14 Piano-tige? Extrem reverb! (recorded in an exposition hall or an industrial building?)					
		16:38 New part, high noises and percussion-like sounds					
		21:00 Original piano-tige with reverb?					
		24:26 Original piano-tige!					
		25:18 Piano-tige					
		20:00 Sounds clearly like the Baschet-insturments!					
		31:00 Singing sounds in the background					
		32:34 Chromatic part.					
		33:40 Single chords with reverb					
		34:00 Clear chords					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		35:40 Single tones					
		36:21 Chromatic glissando up!!!					
		39:40 Strange singing sounds combined with tingling sound					
		41:40 unclear					
		42:00 Strong arpreggios					
		43:15 High single sound					
		43:46 Single notes					
		44:38 That should be the original recording, used in *Bohor*!					
		47:00 or this one!					
		48:00 or this one!					
		53:15: Small glissando piece!					
BOH-AS-BnF-017	DONAUD 0604-518	Xen539	7',5 - 38 cm/s	stereo	13'59	*Bohor* bande 2, affolants, bracelets(?) (Irak et byzantin)	l'étiquette du boîtier porte les indications: stéréo démultiplié, la bande 1 est vidée
		00:00 - 0043 Pause					
		00:43 Metal sound, multiplication?					
		06:09 Accent, the becoming more crispy - 07:35					
		07:48 New track: probably another densification? Higher pitch than before? Reminds me Concret PH, probably „Bracelets Irak“ etc.					
		13:00 sparse, ending.					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
BOH-AS-BnF-018	DONAUD 0604-519	Xen540	10 1/4 in -		24'50	*Bohor* bande 4, bracelets et cloches	l'étiquette du boîtier porte l' indication: stéréo démultiplié,
		00:00 Wrong start.					
		00:22 Small bell and pitched-down voice! (no “bracelets!)					
		02:00 Bell solo or single notes piano-tige					
		03:16 with additional interferences					
		05:52 Voice commenting! Single bell sounds (Xenakis's voice?)					
		13:16 Several bells simultaneously with distorsion and interference					
		17:12 New take, close-miked bells with reverb-glissando					
		20:08 Good recording small bells					
		22:00 Dense bell sounds					
		24:00 Second sound added 24:41 End					
BOH-AS-BnF-019	DONAUD 0604-520	Xen541	7',5 - 38 cm/s 9 1/2 38 cm/s	stereo	26'54	*Bohor*, orgue et affolant I	l'étiquette de bande porte l'indication: Nagra sans réverbération
	NAGRA: first transportable tape machine!	00:00 “Affolant” means „confusing, nervous”. Thumb piano / noise of Baschet instruments?					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		3:50 With resonance					
		10:30 short freak-out!					
		11:15 Two strokes on resonating body					
		12:32 With distorsion					
		14:20 With tingling sounds					
		20:12 Guitar-like					
		21:55 Sounds like Concret PH again					
		23:01 Faster, noisier					
		23:57 With noisy sounds added, Baschet instruments?					
		26:00 Fast repetitions etc. Baschet's piano-tige ?					
BOH-AS-BnF-020	DONAUD 0604-520	Xen542	7',5 - 38 cm/s 9 1/2 38 cm/s	stereo	23'39	*Bohor*, orgue et affolant II (suite)	l'étiquette de bande porte l'indication: Nagra sans réverbération
	NAGRA: first transportable tape machine!	00:00 Very wild! Direct continuation from Xen541, pretty noisy (Metal sheet played directly?)					
		03:15 Change of sound: more metallic, uncut, Passage with bells					
		05:14 Wild glissandi					
		06:18: Pause					

d) Archives Xenakis - Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF #**	**Tape #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Further Notes**
		06:20 nervous, “affolant”, with little freak-outs					
		08:25 Even wilder with distorsion					
		11:01 Pretty effusive! Single siffling tones added					
		12:50 More variants, quieter, less noisy					
		18:20 Only creaking sound with rhythmical structure					
		21:30 Einzene KKRZZZZER-Schläge - EINGESETZT IM MIX????					
BOH-AS-BnF-021	DONAUD 0604-521	Xen543	10 1/4 in	stereo	28'03	*Bohor*, byzantin+Irak (sans echo)	les autres informations portées sur le boîtier ne concernent pas la bande
		00:00 Jewellery: „byzatin-Irak“, fast, nervous.					
		07:00 extrem panorama movements - 11:44 cut					
		11:46 The same as before with added noisy part, bell sounds integrated, probably „demultiplié“, Strong panorama movements. Might be a montage tape.					
		22:00 sound clearly lake a montage					
		24:00: wild panorama-ping-pong !!					

i. Catalogues and Data Bases (CAT):

- **BOH-CAT-RIME-01**

Xenakis	Bohor	C	1962	22'	4x2

Figure 93 **:** Répertoire Internationales des Musiques Electroacoustiques / International Electronic Music Catalogue, p76.

First printed Catalogue of Electronic Music *Répertoire Internationales des Musiques Electroacoustiques / International Electronic Music Catalogue*[324] was compiled by Hugh Davies and published by Le Groupe de Recherches Musicales GRM de l'O.R.T.F. Paris and The Independent Electronic Music Center, New York, 1968.

- **BOH-CAT-GRM-02**

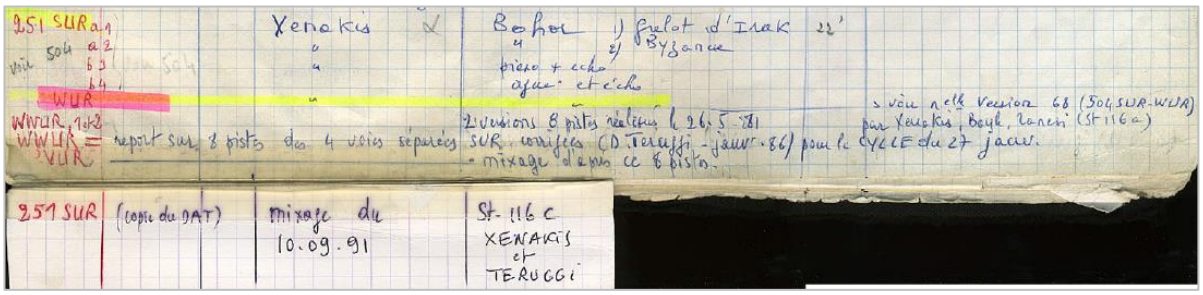

Figure 94: Handwritten GRM catalogue *Registre des Originaux*[325].

Pdf-File. No page numbers, 1429 entries.

Date: Started by Geneviève Bayle-Mâche around 1970[326].

Digitisation received from Geneviève Bayle-Mâche, Paris 2017.

Unpublished. Courtesy Geneviève Bayle-Mâche / GRM.

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[324] Hugh Davies (ed), (1968) Répertoire Internationales des Musiques Electroacoustiques / International Electronic Music Catalogue, Paris & New York.
[325] Registre des Originaux, digitisation, courtesy of Geneviève Bayle-Mâche.
[326] Email to the author from Geneviève Bayle-Mache to the author from April 11, 2016.

- **BOH-CAT-GRM-03**

XENAKIS	251	BOHOR			. Première oeuvre conçue pour 8 canaux (quadruple stéréo). Dispositif de diffusion pour la création : 4 canaux stéréophoniques circulaires. Ed. Salabert.
		,1 4 voies, 2 p.	Par 22'	. PARIS, Salle des Conservatoires 15 décembre 1962	
		,2 version 4 p. 1 pouce			
		,3 réduction 2 p.	Dis		
		,4 1968. révision 4 p. 1 pouce	21'50		

Figure 95: *GRM Répertoire Acousmatique 1948 – 1980*, 67.

Bohor is listed in the GRM catalogue[327] *GRM Répertoire Acousmatique 1948 - 1980* from 1980 in 4 versions.

- **BOH-CAT-GRM-04**

Data base called *GRM fichier oeuvres 2012*.[328] (excel file) received in 2016 from Daniel Teruggi (Director of GRM from 2001 to 2018). The entries have been made at GRM around 2012 and can be found above in the last column of the table acoustic sources (c).
Unpublished.

[327] Mâche, G., Vande Gorne, A. (eds) (1980) GRM Répertoire Acousmatique, Ina-GRM, Paris, 67.
[328] Excel file 2016 at the GRM by courtesy of Daniel Teruggi (director GRM), Yann Geslin (responsible for the archives at GRM).

iii. Visual Sources (scores, draftes etc) [VS]:

- **BOH-VS-AFX-01**

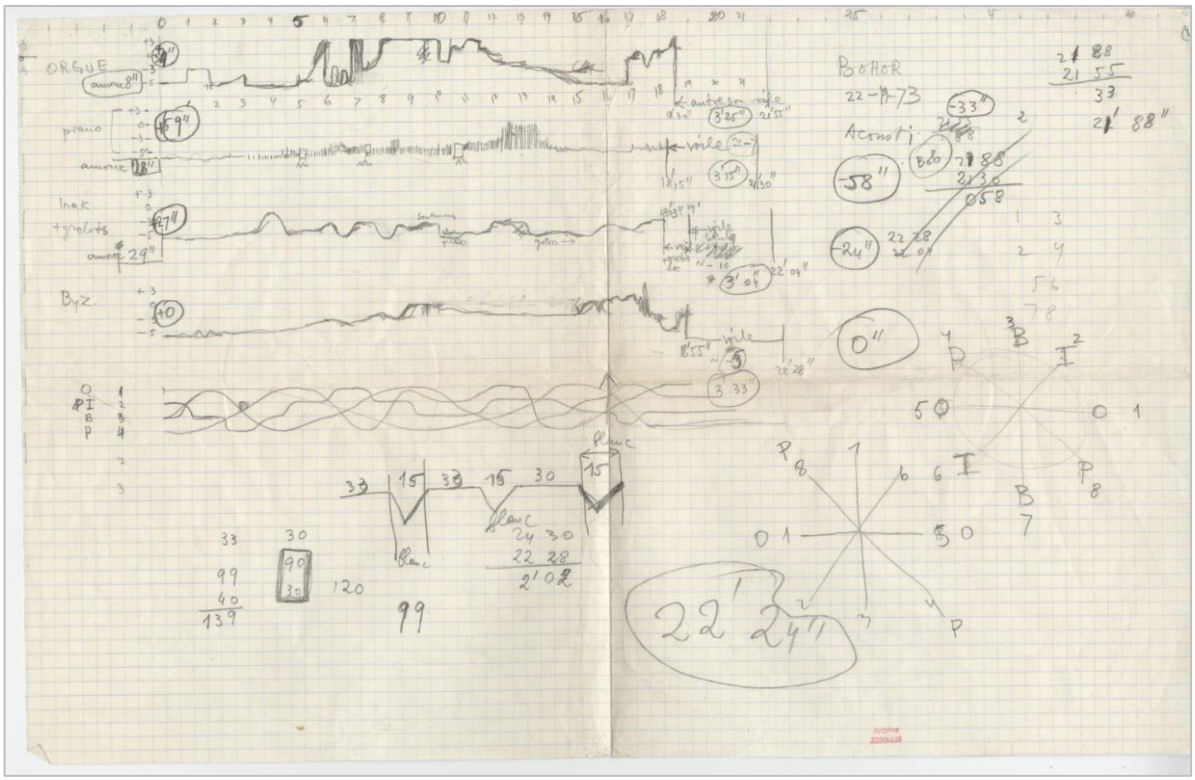


Figure 96: Archives of the Xenakis family (AFX), OM 33-11, 8.

Material: Pencil on paper

Measure: DIN A3; 42 cm * 29,7 cm.

Date: 22-11-73 (upper right side)

Digitised by Mâkhi Xenakis and Reinhold Friedl, 2017

Unpublished. Courtesy Mâkhi Xenakis.

- **BOH-VS-AFX-02**

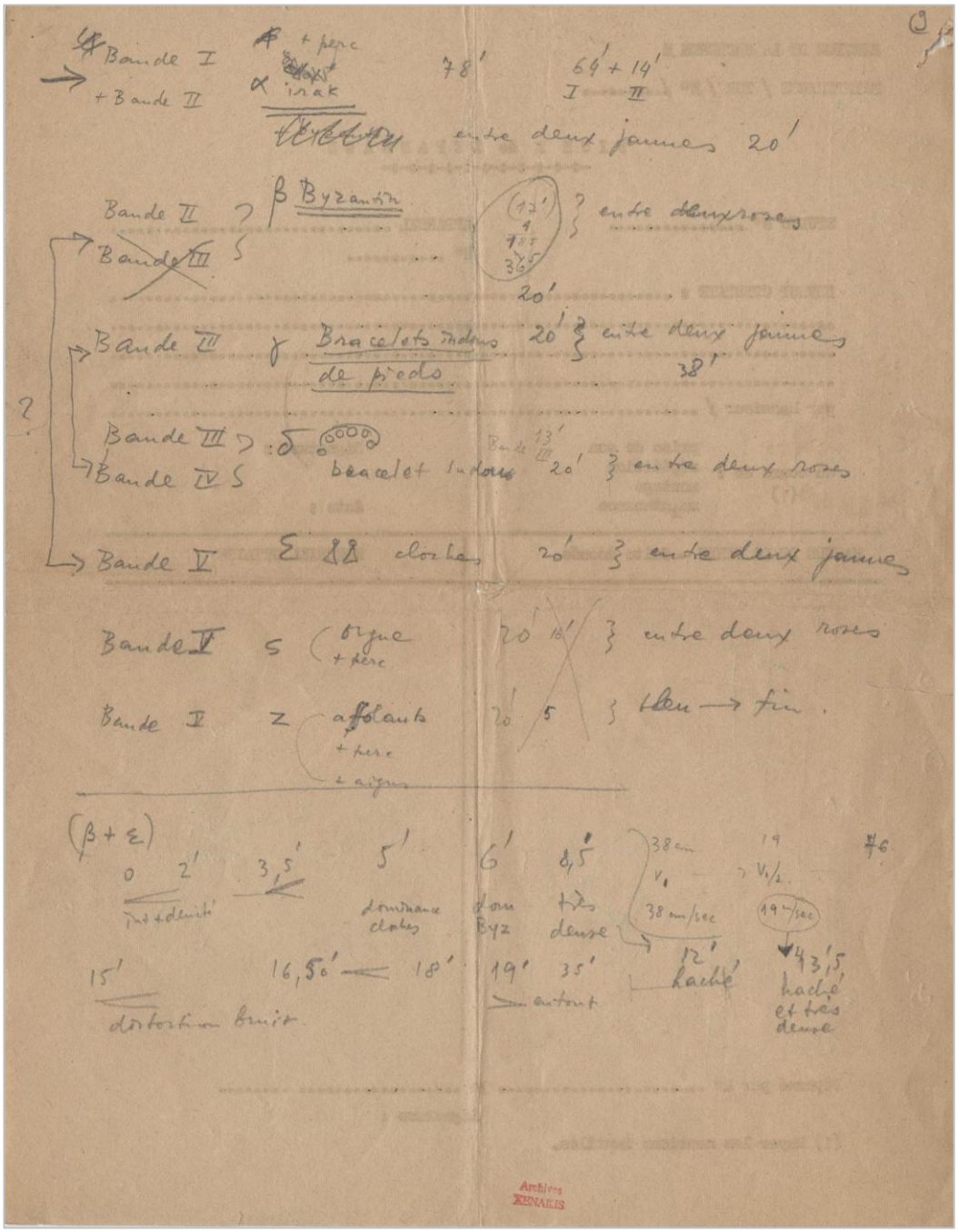


Figure 97: Archives of the Xenakis family (AFX), OM 33-11, 9.

Material: Pencil on paper

Measure: DIN A4; 21 cm * 29,7 cm.

Not dated.

Digitised by Mâkhi Xenakis and Reinhold Friedl, 2017

Unpublished. Courtesy Mâkhi Xenakis.

- **BOH-VS-AFX-03**

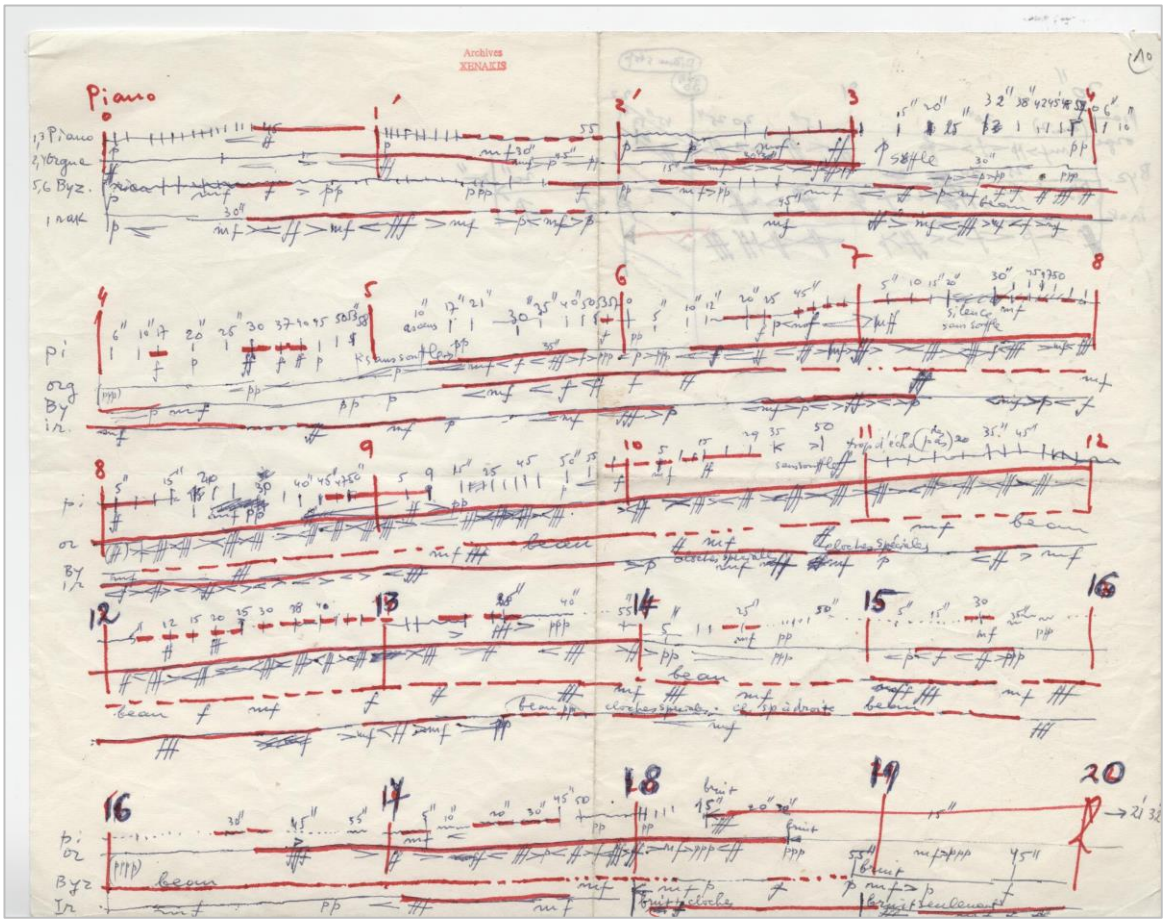


Figure 98: Archives of the Xenakis family (AFX), OM 33-11, 10.

Material: Ballpen/ink on paper, coloured with red felt pen

Measure: DIN A4; 29,7 cm * 21 cm.

Not dated.

Digitised by Mâkhi Xenakis and Reinhold Friedl, Paris 2017

Unpublished. Courtesy Mâkhi Xenakis.

- **BOH-VS-AFX-04**

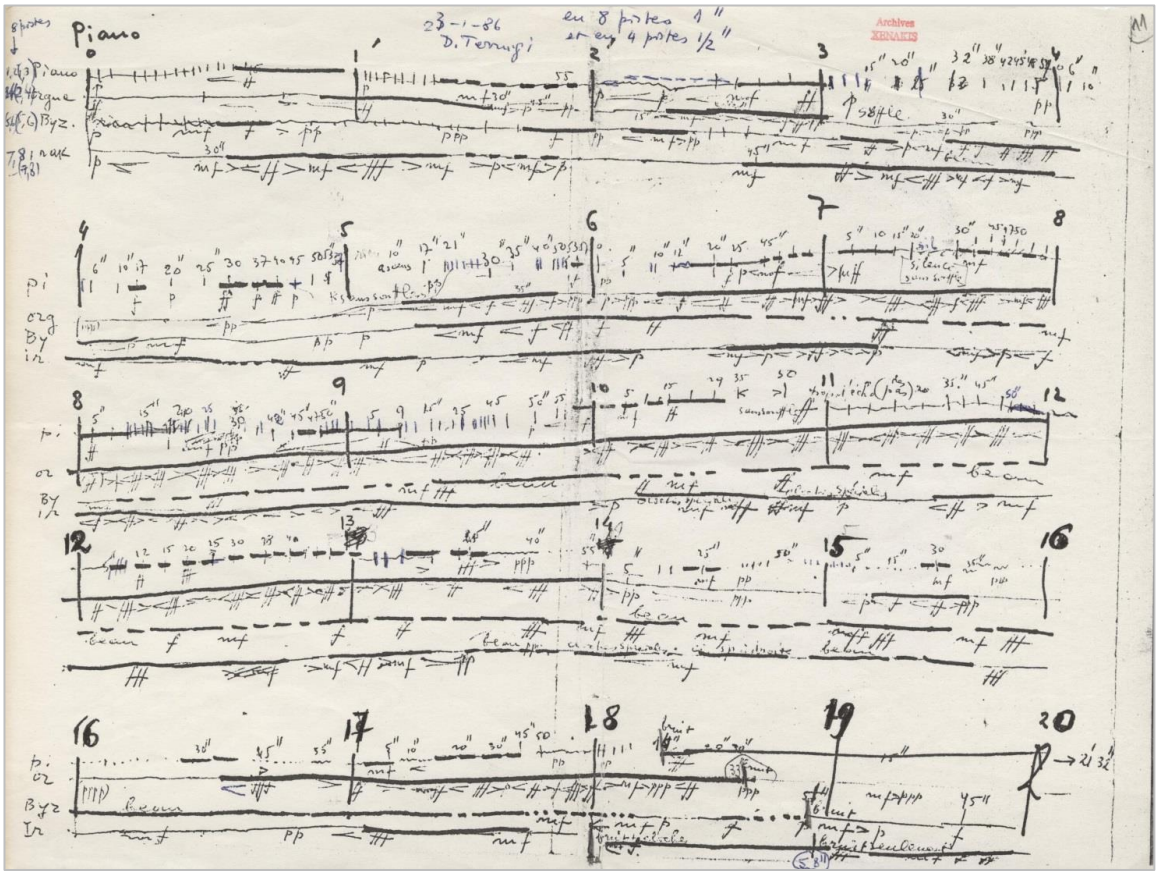


Figure 99: Archives of the Xenakis family (AFX), OM 33-11, 11.

Material: Ballpen on photocopy of *Bohor*-VS-AFX-03

Measure: DIN A4; 29,7 cm * 21 cm.

Date: 23-1-86 D. Teruggi

Digitised by Mâkhi Xenakis and Reinhold Friedl, Paris 2017

Unpublished. Courtesy Mâkhi Xenakis.

- **BOH-VS-AFX-05**

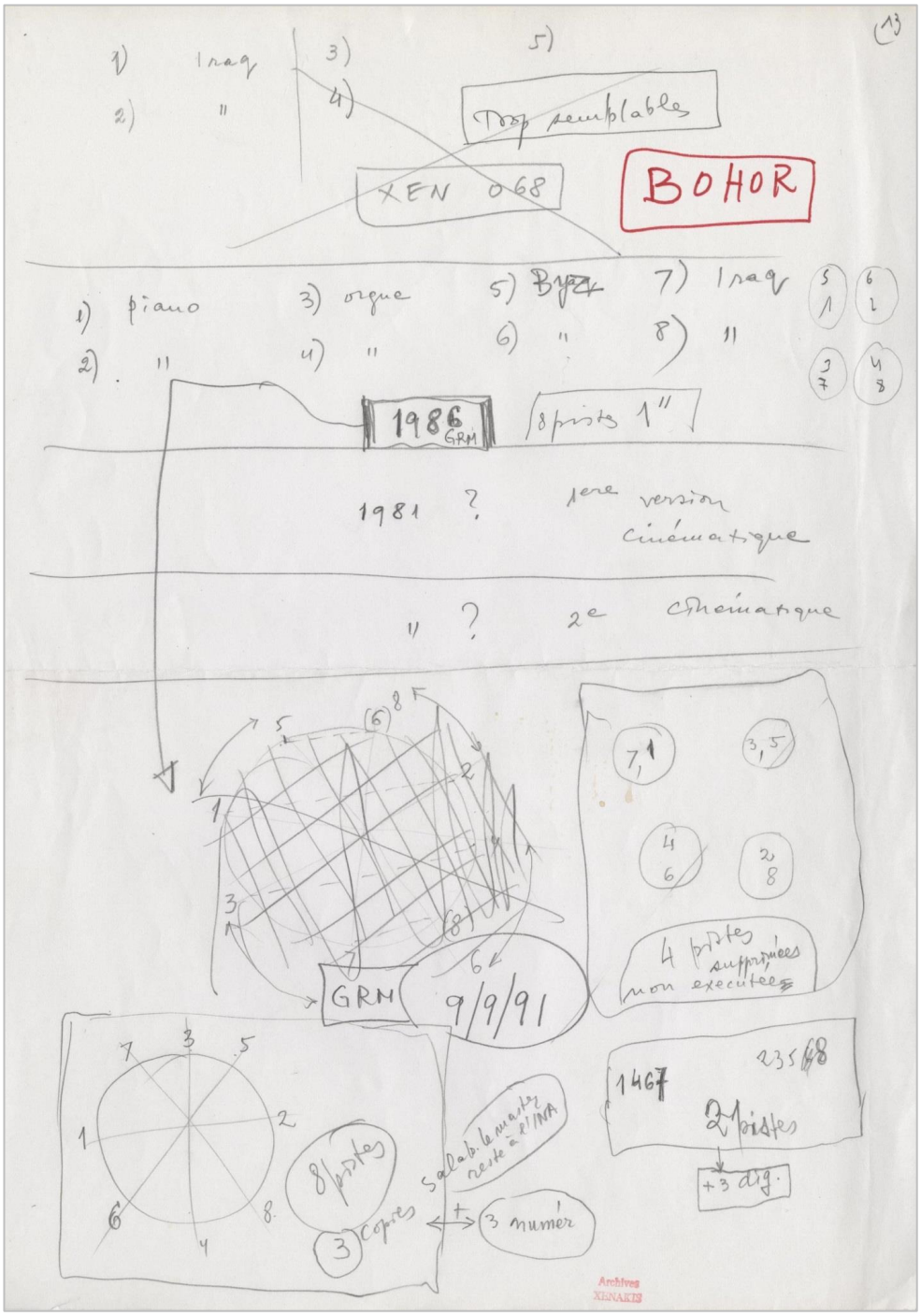


Figure 100: Archives of the Xenakis family (AFX), OM 33-11, 13.

Material: Pencil on paper, red felt pen.

Measure: DIN A4; 21 cm * 29,7 cm.

Date: GRM 9/9/91 (lower middle of the page)

Digitised by Mâkhi Xenakis and Reinhold Friedl, 2017

Unpublished. Courtesy Mâkhi Xenakis.

- **BOH-VS-AFX-06**

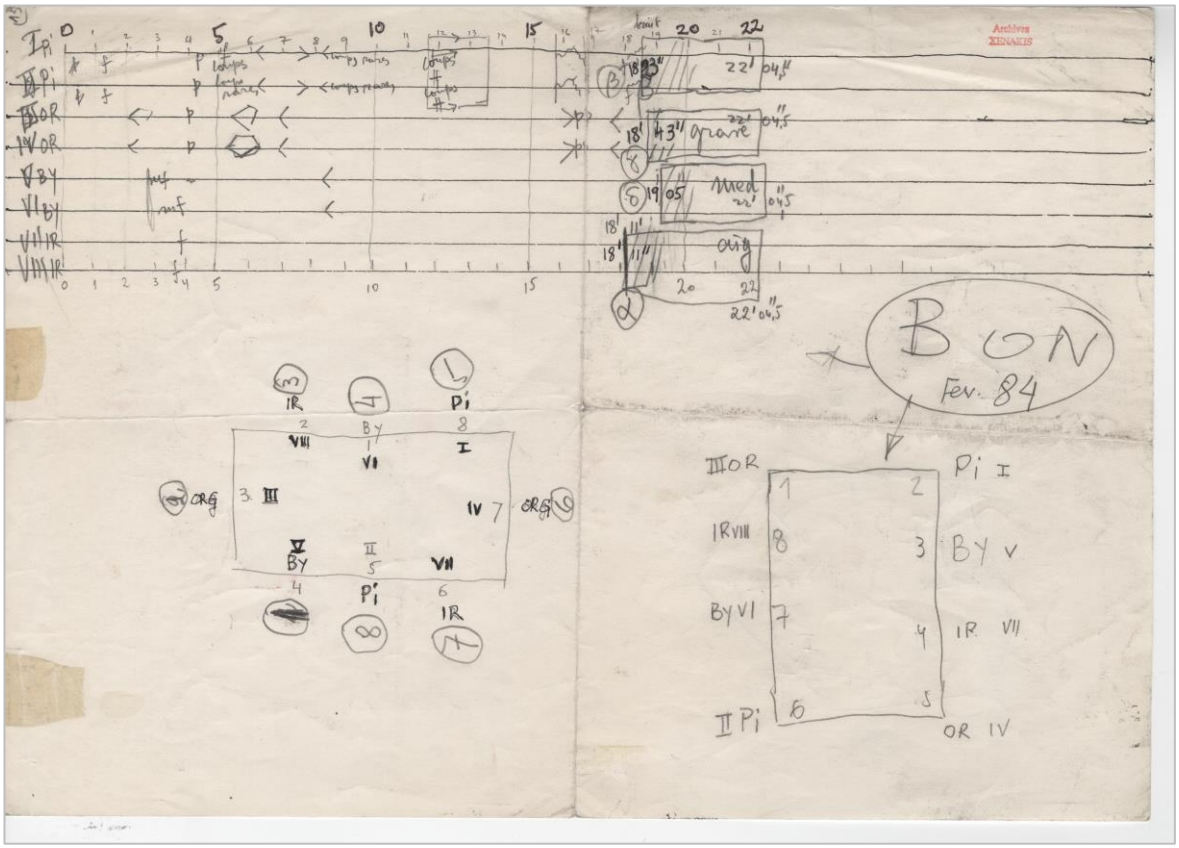


Figure 101: Archives of the Xenakis family (AFX), OM 33-11, 15, backside.

Material: Pencil on paper

Measure: DIN A3; 29,7 cm * 21 cm.

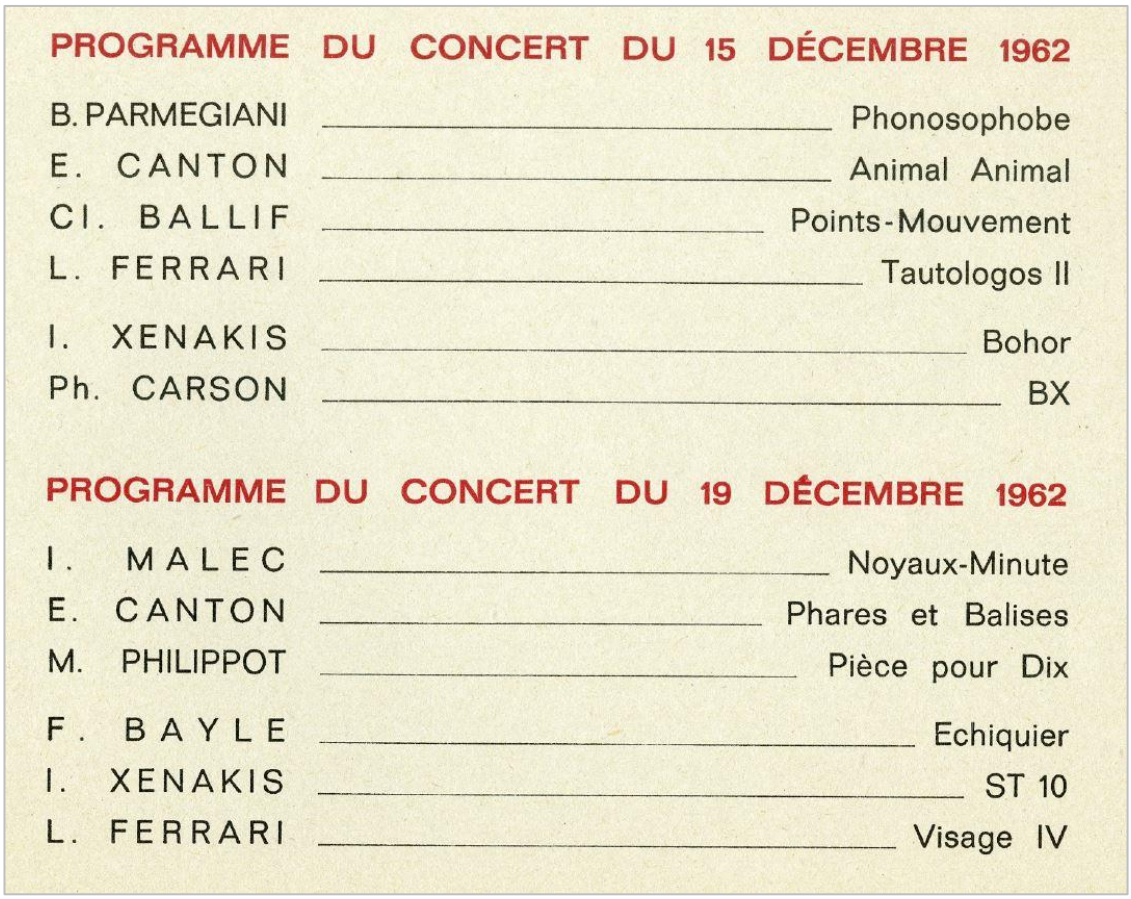
Date: Fev.84 (middle of right side)

Digitised by Mâkhi Xenakis and Reinhold Friedl, 2017

Unpublished. Courtesy Mâkhi Xenakis.

iv. Text Sources [TS]:

- **BOH-TS-GRM-01**



PROGRAMME DU CONCERT DU 15 DÉCEMBRE 1962

B. PARMEGIANI _____ Phonosophobe
E. CANTON _____ Animal Animal
Cl. BALLIF _____ Points-Mouvement
L. FERRARI _____ Tautologos II

I. XENAKIS _____ Bohor
Ph. CARSON _____ BX

PROGRAMME DU CONCERT DU 19 DÉCEMBRE 1962

I. MALEC _____ Noyaux-Minute
E. CANTON _____ Phares et Balises
M. PHILIPPOT _____ Pièce pour Dix

F. BAYLE _____ Echiquier
I. XENAKIS _____ ST 10
L. FERRARI _____ Visage IV

Figure 102: Printed Programme of the premiere of *Bohor* 1962.

Archive GRM 2018. Digitised by François Bonnet (Director GRM) Paris 2018.

Unpublished. Courtesy GRM.

4. Apparatus *La Légende d'Eer*

i. Acoustic sources (AS)

a) Commercial Releases *La Légende d'Eer*							
Name	**Titel**	**Label**	**Signature**	**Media**	**Date**	**Tracks**	**Length**
LLE-01-AM1	Iannis Xenakis - *La Légende d'Eer*	Auvidis Montaigne, France	MO 782058	CD	1995	stereo	46:00
LLE-02-AM2	Iannis Xenakis - *La Légende d'Eer*	Auvidis Montaigne, France	MO 782144	CD	2002	stereo	46:00
LLE-03-Mode	Iannis Xenakis - *La Légende d'Eer*	Mode Records, USA	Mode 148	CD, DVD	2005	stereo	47:02
LLE-04-KR	Iannis Xenakis - *La Légende d'Eer*	Karlrecords, Perihel Series, Germany	KR024	LP, download	2016	stereo	A 23:58/ B 21:55, 46:00

b) Old Analogue Hire Tape by Publishing house Durand/Salabert/Eschig Paris					
Name	**EdH Name**	Inch	Tracks	**Length**	**Comment**
LLE-AS-EdH-1	„Bande Master"	1	8		
LLE-AS-EdH-digi2003-GRM	Digitisation at GRM 2003		8	47:02	Corrupted digitisation
	Digitised by Volker Müller & Reinhold Friedl, WDR Cologne 2015:				
LLE-AS-EdH-1-1	DONAUD 0604-167	96 kHz	1/8	46:00	

b) Old Analogue Hire Tape by Publishing house Durand/Salabert/Eschig Paris					
Name	**EdH Name**	Inch	Tracks	**Length**	**Comment**
LLE-AS-EdH-1-2	DONAUD 0604-167	96 kHz	2/8	46:00	
LLE-AS-EdH-1-3	DONAUD 0604-168	96 kHz	3/8	46:00	
LLE-AS-EdH-1-4	DONAUD 0604-169	96 kHz	4/8	46:00	
LLE-AS-EdH-1-5	DONAUD 0604-170	96 kHz	5/8	46:00	
LLE-AS-EdH-1-6	DONAUD 0604-172	96 kHz	6/8	46:00	
LLE-AS-EdH-1-7	DONAUD 0604-173	96 kHz	7/8	46:00	
LLE-AS-EdH-1-8	DONAUD 0604-174	96 kHz	8/8	46:00	

c) Official Hire Material by Westdeutscher Rundfunk Köln, Germany (WDR)						
Name	**WDR #**	**Inch**	**Tracks**	**Length**	**Notes**	**Digitized**
LLE-AS-WDR-1	EL1800001	2	8	46:04	Spatialized 8-track version, spatialised by Xenakis / Müller / Wittman	2 DVDs
LLE-AS-WDR-1-1	EL18190 Mat 1	96kHz 24bit	1	46:04	EL18190 Mat 1-4 DVD L01	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-2	EL18190 Mat 2	96kHz 24bit	1	46:04	EL18190 Mat 1-4 DVD L01	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-3	EL18190 Mat 3	96kHz 24bit	1	46:04	EL18190 Mat 1-4 DVD L01	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-4	EL18190 Mat 4	96kHz 24bit	1	46:04	EL18190 Mat 1-4 DVD L01	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-5	EL18190 Mat 5	96kHz 24bit	1	46:04	EL18190 Mat 5-8 DVD L02	by Volker Müller WDR Mai 18, 2005

c) Official Hire Material by Westdeutscher Rundfunk Köln, Germany (WDR)						
Name	**WDR #**	**Inch**	**Tracks**	**Length**	**Notes**	**Digitized**
LLE-AS-WDR-1-6	EL18190 Mat 6	96kHz 24bit	1	46:04	EL18190 Mat 5-8 DVD L02	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-7	EL18190 Mat 7	96kHz 24bit	1	46:04	EL18190 Mat 5-8 DVD L02	by Volker Müller WDR Mai 18, 2005
LLE-AS-WDR-1-8	EL18190 Mat 8	96kHz 24bit	1	46:04	EL18190 Mat 5-8 DVD L02	by Volker Müller WDR Mai 18, 2005

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-001	EL18106001	N1291	1/4"	mono	45:46	Track I, 45'46"	
LLE-AS-WDR-002	EL18106002	N1292	1/4"	mono	43:15	Track II, 43'15"+[YT]	
LLE-AS-WDR-003	EL18106003	N1293	1/4"	mono	42:56	Track III, 42'56"+[YT]	
LLE-AS-WDR-004	EL18106004	N1294	1/4"	mono	42:42	Track IV, 42'42"+[YT]	
LLE-AS-WDR-005	EL18106005	N1295	1/4"	mono	42:26	Track V, 42'26" yellow and red tape	
LLE-AS-WDR-006	EL18106006	N1296	1/4"	mono	42:17	Track VI, 42'17"+[YT]	
LLE-AS-WDR-007	EL18106007	N1297	1/4"	mono	43:10	Track VII, 43'10"+[YT] counting in (beeps)	
	Box 11, 1" containing 6 mono tapes:						
LLE-AS-WDR-008	EL18111001	N1288	1/4"	mono	06:13		GUIMB 2 6'
LLE-AS-WDR-009	EL18111002	N1288	1/4"	mono	03:12		GUIMB 3 13'
LLE-AS-WDR-010	EL18111003	N1288	1/4"	mono	12:27		GUIMB 4 1/2+1/2 12',5

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-011	EL18111004	N1288	1/4"	mono	04:50		Guimbardes #4 4'35" used in track IV at 16'16
LLE-AS-WDR-012	EL18111005	N1288	1/4"	mono	08:04		GUIM. 4 Dens. Double
LLE-AS-WDR-013	EL18111006	N1288	1/4"	mono	08:10		GUIM 5 8'
	Box 12, 1" containing 6 mono tapes:						
LLE-AS-WDR-014	EL18112001	N1289	1/4"	mono	01:53		Ts[gamma]z
LLE-AS-WDR-015	EL18112002	N1289	1/4"	mono	03:19		2 take from [star] fill. 100 * 7'42" p[?]88 shooting stars
LLE-AS-WDR-016	EL18112003	N1289	1/4"	mono	07:14		B KERAM ([arrow down]teity 4:47 (C[arrow down] tphy) [arrow down]8 9'5" below: -2'10"
LLE-AS-WDR-017	EL18112004	N1289	1/4"	mono	02:47		[star] Mix of 7 tracks (transposed pitches)
LLE-AS-WDR-018	EL18112005	N1289	1/4"	mono	04:06		PIL 1+2+?+4, Pill.- 1'
LLE-AS-WDR-019	EL18112006	N1289	1/4"	mono	07:23		PIL 2
	Box 13, 1" containing 6 mono tapes:						
LLE-AS-WDR-020	EL18113001	N1290	1/4"	mono	04:14		X[alpha][phi]TONI, NOTE RF: James Wigman DOUBLEBASS !

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-021	EL18113002	N1290	1/4"	mono	00:56		sw. {41} 2d track 22'00" [arrow to] 29'57"
LLE-AS-WDR-022	EL18113003	N1290	1/4"	mono	13:33		pel. Bany copie 1/1 permutée 1/2 [doublearrow] 1/2; NOTE RF: James Wigman DOUBLEBASS !
LLE-AS-WDR-023	EL18113004	N1290	1/4"	mono	02:40		Guimbardes #3
LLE-AS-WDR-024	EL18113005	N1290	1/4"	mono	07:16		PIL 4
	EL18113006	N1290	1/4"	mono	10:17		Fg 1, 2, 3, 4, 5
LLE-AS-WDR-025		[YT]			02:18		
LLE-AS-WDR-026		[YT]			01:37		
LLE-AS-WDR-027		[YT]			02:25		
LLE-AS-WDR-028		[YT]			01:35		
LLE-AS-WDR-029		[YT]			02:19		
	EL18114001	N1298	1/4"	mono		{{5}} {20} [alpha]=10 from tape#2; Fagott low sounds Log.reruns; sound {20} [alpha]=10, {20} [alpha]=15, {21} [alpha]=10, {21} [alpha]=15, {23} [alpha]=10, {23} [alpha]=15, {24} [alpha]=10, {24} [alpha]=15	
LLE-AS-WDR-030		[YT]			01:50		
LLE-AS-WDR-031		[YT]			18:30		

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
	Box 1/4" with 3 tapes:					DROPS DRY REVERB [other text crossed out]	
LLE-AS-WDR-032	EL18115001	N1299	1/4"	mono	06:20		DROP DRY
LLE-AS-WDR-033	EL18115002	N1299	1/4"	mono	06:22		DROPS=II REVERB I
LLE-AS-WDR-034	EL18115003	N1299	1/4"	mono	06:23		DROPS reverb II = I
	Box 1/4" with 4 tapes:						
LLE-AS-WDR-035	EL18116001	N1300	1/4"	mono	06:22		CP#5 {2} transp - 4,5 ~6' - 30''
LLE-AS-WDR-036	EL18116002	N1300	1/4"	mono	05:28		CP#5 {3} [arrow down]1,5 s/ttransp 5'15''
LLE-AS-WDR-037	EL18116003	N1300	1/4"	mono	04:33		CP#5 {5} -1,5 transp
LLE-AS-WDR-038	EL18116004	N1300	1/4"	mono	05:33		CP#5 {7} 5'22'' - 5,5 s/t transp
LLE-AS-WDR-039	EL18117001	N1301	1/4"	mono		50Hz from Tape #5 {38} [alpha]=15 ~11', {39} [alpha]=10 ~5' [arrow] motre 7', 7' [arrow to] 11'30'', {41} [alpha]=10 ~5' ~10' in 19s/c See following tape; From CRB reel 1 {2} [alpha]=10, {3} [alpha]=10 2'20''	NOTE RF: looped material
LLE-AS-WDR-040		[YT]			12:50		NOTE RF: looped material
LLE-AS-WDR-041		[YT]			25:01		NOTE RF: looped material
	EL18118001	N1302	1/4"	stereo		Stereo Shooting [star] Etoiles filantes, something in greek	Shooting stars originals, something in greek

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-042		[YT]			11:38		NOTE RF: Shooting stars
LLE-AS-WDR-043		[YT]			07:48		NOTE RF: Shooting stars
LLE-AS-WDR-044		[YT]			08:29		NOTE RF: Shooting stars
LLE-AS-WDR-045		[YT]			04:47		NOTE RF: Shooting stars
LLE-AS-WDR-046		[YT]			04:22		NOTE RF: Shooting stars
LLE-AS-WDR-047	EL18119001	N1303	1/4"	stereo	08:31	From CRB reel 1 {7}model [alpha]=10 8'22" 4'40" - 6' {used}	NOTE RF: looped material
LLE-AS-WDR-048	EL18120001	N1211	1"	4		Xenakis (in griechisch) 0 - 3'40"	NOTE RF: probably rehearsal spatialisation (Voice Müller)
LLE-AS-WDR-049	EL18121001	N1212	1"	4		24.1. [other text unreadable]	Turning by hand + tape {{2}} quadrophonic on the (sound {11}, 4 chanels sound # 8 1'32", transformed by the synthi 100, NOTE RF: probably rehearsal spatialisation (Voice Müller)
LLE-AS-WDR-050	EL18122001	N1189	1/4"	mono	03:56		C Fg 76 4s [?]
LLE-AS-WDR-051	EL18123001	N1190	1/4"	mono	03:34		
LLE-AS-WDR-052	EL18124001	N1191	1/4"	mono	11:02		IV, KERAM 8[arrow down] 7'17" 3'52, 10'43 [et plus en grèque]
LLE-AS-WDR-053	EL18125001	N1192	1/4"	mono	01:52		[Unreadable]

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
	EL18126001	N1193				NOTE RF: TAPE MISSING	
LLE-AS-WDR-054	EL18127001	N1194	1/4"	mono	02:06		CFg original end the VII track
LLE-AS-WDR-055	EL18128001	N1195	1/4"	mono	11:48		{4} Log reverb 5'-10' 1st [?]-Filter ohne ryth
LE-AS-WDR-056	EL18129001	N1196	1/4"	mono	11:56		Diatope rods + str. untransform. Copied
LLE-AS-WDR-057	EL18130001	N1197	1/4"	mono	07:17		PIL 3
LLE-AS-WDR-058	EL18131001	N1198	1/4"	mono	04:09		FCL homoge,-neise 4'1"
LLE-AS-WDR-059	EL18132001	N1199	1/4"	mono	09:15		I [?], KERAM 8[arrow down] 6'21" 10'9" [et plus en grèque]
LLE-AS-WDR-060	EL18133001	N1200	1/4"	mono	07:56		Alpha KERAM. C + C[arrow down] 3'48" 11'40"
LLE-AS-WDR-061	EL18134001	N1201	1/4"	mono	01:07		[star image] (attacks); NOTE RF: Voice Xenakis ! (EMS100?)
LLE-AS-WDR-062	EL18135001	N1202	1/4"	mono	01:52		c[?]# #49 L.JC. [?]
LLE-AS-WDR-063	EL18136001	N1203	1/4"	mono	02:55		{51} #6 -55" Drop Log-Rer-
	EL18137001	N1204	1/4"	mono	08:02		{4} (take III 3x)
LLE-AS-WDR-064		[YT]			03:54		
LLE-AS-WDR-065		[YT]			04:08		

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-066	EL18138001	N1205	1/4"	mono	00:04	contains: 1 x 1/4" + LOOP = a) u. b)	NOTE RF: LOOP !
LLE-AS-WDR-067	EL18138002	N1205	1/4"	mono	03:06		Grincement (original permuté); NOTE RF: LOOP recorded?
	EL18139001	N1206				NOTE RF: TAPE MISSING	
LLE-AS-WDR-068	EL18140001	N1207	1/4"	mono	07:09		Filt. Rods + str. w/silences cut out ca. 7'
LLE-AS-WDR-069	EL18141001	N1208	1/4"	mono	00:17		FCL waves 4',"
LLE-AS-WDR-070	EL18142001	N1209	1/4"	mono	00:54		C = TS[Gamma]2
LLE-AS-WDR-071	EL18143001	N1210	1/4"	mono	11:10		continous [star]
	EL18144001	N1213	1/4"	mono	11:32	L. Reruns Originals {1} Tape #1 {11}, {16}, {17} ["sounds" over arrow in both directions] {20} [alpha]=1, {20} [alpha]=2, {20} [alpha]=3, {21} [alpha]=1, {21} [alpha]=2, {21} [alpha]=3, {23} [alpha]=1, {23} [alpha]=2, {23} [alpha]=3, {24} [alpha]=1, {24} [alpha]=2, {24} [alpha]=3, Tape #5 {46} {440 #2} [alpha]=1 1'30"	
LLE-AS-WDR-072		[YT]			01:07		{1}
LLE-AS-WDR-073		[YT]			00:23		
LLE-AS-WDR-074		[YT]			00:22		

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-075		[YT]			00:23		
LLE-AS-WDR-076		[YT]			00:21		
LLE-AS-WDR-077		[YT]			00:22		
LLE-AS-WDR-078		[YT]			00:21		
LLE-AS-WDR-079		[YT]			00:22		
LLE-AS-WDR-080		[YT]			00:21		
LLE-AS-WDR-081		[YT]			00:21		
LLE-AS-WDR-082		[YT]			00:11		
LLE-AS-WDR-083		[YT]			00:20		
LLE-AS-WDR-084		[YT]			00:31		
LLE-AS-WDR-085		[YT]			00:12		
LLE-AS-WDR-086		[YT]			00:24		
LLE-AS-WDR-087		[YT]			00:36		
LLE-AS-WDR-088		[YT]			00:10		
LLE-AS-WDR-089		[YT]			00:21		
LLE-AS-WDR-090		[YT]			00:31		
LLE-AS-WDR-091		[YT]			00:12		
LLE-AS-WDR-092		[YT]			00:22		
LLE-AS-WDR-093		[YT]			00:33		
LLE-AS-WDR-094		[YT]			01:16		

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
	EL18145001	N1214	1/4"	mono		TR{I,II,III,IV} 29'52" on one real sound {11} old ones unbalanced, not to be used	TRK I old, 29'52"
LLE-AS-WDR-095		[YT]			02:16		
LLE-AS-WDR-096		[YT]			02:22		
LLE-AS-WDR-097		[YT]			02:28		
LLE-AS-WDR-098		[YT]			02:45		
	EL18146001	N1215	1/4"	mono		N1 does not ?, {2} attached N2 Dopesheet, 24.1. 9 takes Mono copies of {11} #8 sound with rohring? 1'32" in all transformed by Synthi 100, {Log reruns} Exists also on 4tracks QUEG	
LLE-AS-WDR-099		[YT]			01:34		
LLE-AS-WDR-100		[YT]			00:52		
LLE-AS-WDR-101		[YT]			00:50		
LLE-AS-WDR-102		[YT]			00:43		
LLE-AS-WDR-103		[YT]			01:30		
LLE-AS-WDR-104		[YT]			01:05		
LLE-AS-WDR-105		[YT]			01:31		
LLE-AS-WDR-106		[YT]			01:29		

d) Archives Westdeutscher Rundfunk Köln, Germany (WDR)							
Name	**WDR #**	**SEM #**	**Inch**	**Tracks**	**Length**	**Notes on Box**	**Notes on Bobbin**
LLE-AS-WDR-107		[YT]			01:31		
	EL18147001	N1216	1/4"	mono		II1 L.Reruns sound N. {11} (from tape #1) transformed at teh Synthi by hand I, II, III, IV, V, VI (VII, VIII) harsher {3} Dopesheet N3	{3} -20" I,II,III, IV, V, VI, VII
LLE-AS-WDR-108		[YT]			01:37		
LLE-AS-WDR-109		[YT]			01:33		
LLE-AS-WDR-110		[YT]			01:12		
LLE-AS-WDR-111		[YT]			01:11		
LLE-AS-WDR-112		[YT]			01:19		
LLE-AS-WDR-113	EL18148001	N1217	1/4"	mono	14:38	From Tape #5 {42} [Alpha=1] 1'2" {image}, [arrow] take also {49} from {4} {{6}}, from CRB reel 1 {1} [alpha=1], 1'25", {5} [alpha=1] 3'55", {6} [alpha=1], 3'11", reel 2 {8} [alpha=1] 3'31 AND MORE	{6}

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-001	DONAUD 0604-166	Xen 171	7"	mono		Function - unit 1	
LLE-AS-BnF-002	DONAUD 0604-167	Xen 172	7"	mono		Function - unit 2	
LLE-AS-BnF-003	DONAUD 0604-168	Xen 173	7"	mono		Function - unit 3	
LLE-AS-BnF-004	DONAUD 0604-169	Xen 174	7"	mono		Function - unit 4	
LLE-AS-BnF-005	DONAUD 0604-170	Xen 175	7"	mono		Function - unit 5	
LLE-AS-BnF-006	DONAUD 0604-171	Xen 176	7"	mono		Cologne	sans autre indication
LLE-AS-BnF-007	DONAUD 0604-172	Xen 177	7"	mono		Interlocked Functions 1	Interlocked Functions: Cauchy – Exp arcsine Cauchy arcsine Cauchy hyc. (une fiche accompagne la bande précisant les caractéristiques techniques des sons enregistrés)
LLE-AS-BnF-008	DONAUD 0604-173	Xen 178	7"	mono		Functions Interlocked 1	
LLE-AS-BnF-009	DONAUD 0604-174	Xen 179	7"	mono		Lg. Reruns #1 (CP #3)	
LLE-AS-BnF-010	DONAUD 0604-175	Xen 180	7"	mono		Lg. Reruns #2 (CP #3)	
LLE-AS-BnF-011	DONAUD 0604-176	Xen 181	7"	mono		Lg. Reruns #3	
LLE-AS-BnF-012	DONAUD 0604-177	Xen 182	7"	mono		Lg. Reruns #4	
LLE-AS-BnF-013	DONAUD 0604-178	Xen 183	7"	mono		Lg. Reruns #5 (CP #3)	
LLE-AS-BnF-014	DONAUD 0604-179	Xen 184	7"	mono		Lg. Reruns #6 (CP #3)	
LLE-AS-BnF-015	DONAUD 0604-180	Xen 185	7"	mono		Lg. Reruns #7 (CP #3)	
LLE-AS-BnF-016	DONAUD 0604-182	Xen 187	7"	mono		ST - Reel 1	

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-017	DONAUD 0604-184	Xen 189	7"	mono		Function - unit - Cntr. 1	
LLE-AS-BnF-018	DONAUD 0604-185	Xen 190	7"	mono		Function - unit - Cntr. 1	
LLE-AS-BnF-019	DONAUD 0604-186	Xen 191	7"	mono		Function - unit - Interpolation, Reel 1	audio tape #1, sans autre indication
LLE-AS-BnF-020	DONAUD 0604-189	Xen 194	7"	mono		Log. Reruns	une fiche accompagnant la bande, précise les élements suivants par piste: 1st: 61520 TT1, 2nd: CPC1
LLE-AS-BnF-021	DONAUD 0604-190	Xen 195	7"	mono		CPT #3	tape 1, sans autre indication
LLE-AS-BnF-022	DONAUD 0604-191	Xen 196	7"	mono		CPT #5, Reel 1	
LLE-AS-BnF-023	DONAUD 0604-192	Xen 197	7"	mono		CP #3 (COR.), Reel 1	
LLE-AS-BnF-024	DONAUD 0604-193	Xen 198	7"	mono		CP #3A, Reel 1	
LLE-AS-BnF-025	DONAUD 0604-194	Xen 199	7"	mono		CP #3B, Reel 1	le boitier porte l'indication: Log. Switching
LLE-AS-BnF-026	DONAUD 0604-195	Xen 200	7"	mono		CP #5, Reel 1	L'étiquette de bande porte l'indication: Unit model log. rer.
LLE-AS-BnF-027	DONAUD 0604-196	Xen 201	7"	mono		CP #6 (CRB.), Reel 1	
LLE-AS-BnF-028	DONAUD 0604-197	Xen 202	7"	mono		CP #6 (CRB.), Reel 2	

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-029	DONAUD 0604-198	Xen 203	7"	mono		Logistic Reruns, demonstration tape	le boîtier contient 8 bandes+ 1 sachet de chutes (les deux bandes suivantes, Xenakis 598 et 599, étaient à l'origine contenues dans le même obîtier) 3 feuilles accompagnent la bande: une feuille précise les données d'enregistrement (Log. Reruns #1/CP #3, Log. Reruns #2/CP #3, variantes Log. Reruns #6/CP #3, variantes CP #5 unit model) les deux autres feuilees portent des élements de constructions sonores
LLE-AS-BnF-030	DONAUD 0604-344	Xen 353	6"	mono		Kumb (C, C#, D)	
LLE-AS-BnF-031	DONAUD 0604-345	Xen 354	7"	mono		Kumb	
LLE-AS-BnF-032	DONAUD 0604-346	Xen 355	7"	mono		Kumb (A#)	
LLE-AS-BnF-033	DONAUD 0604-347	Xen 356	7"	mono		Cymb (C#)	
LLE-AS-BnF-034	DONAUD 0604-348	Xen 357	7"	mono		Cymb (D#)	
LLE-AS-BnF-035	DONAUD 0604-349	Xen 358	5"	mono		Kumb (C+A#+B)	
LLE-AS-BnF-036	DONAUD 0604-350	Xen 359	4"	mono		Kumb (A, B, C))	
LLE-AS-BnF-037	DONAUD 0604-373	Xen 387	10 1/4"	stereo		Légende d'Eer, Version I	enregistrement WDR
LLE-AS-BnF-038	DONAUD 0604-374	Xen 388	10 1/4"	stereo		Légende d'Eer, Version II	enregistrement WDR

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-039	DONAUD 0604-375	Xen 389	10 1/4"	stereo		Légende d'Eer, Version III	enregistrement WDR la bande rangée à l'origine dans le boîtier, bande Orient-Occident/version Film (cotée Xenakis 507) ne correspond pas au boîtier
LLE-AS-BnF-040	DONAUD 0604-376	Xen 390	10 1/4"	stereo		Légende d'Eer, Version IV, Spring 1981	enregistrement WDR
LLE-AS-BnF-041	DONAUD 0604-419	Xen 433	10 1/4" 38 cm/s	stereo		Légende d'Eer?	Tracks I+II (la bande ne porte pas d'indication de titre)
LLE-AS-BnF-042	DONAUD 0604-420	Xen 434	10 1/4" 38 cm/s	stereo		Légende d'Eer?	Tracks III+IV (la bande ne porte pas d'indication de titre)
LLE-AS-BnF-043	DONAUD 0604-421	Xen 435	10 1/4" 38 cm/s	stereo		Légende d'Eer?	Tracks V+VI (la bande ne porte pas d'indication de titre)
LLE-AS-BnF-044	DONAUD 0604-422	Xen 436	10 1/4" 38 cm/s	stereo		Légende d'Eer?	Tracks VII (la bande ne porte pas d'indication de titre)
LLE-AS-BnF-045	DONAUD 0604-464	Xen 478	10 1/4" 38 cm/s	stereo		Légende d'Eer	bande réalisée au GRM (les indications portées au dos du boîtier ne concernent pas la bande)
LLE-AS-BnF-046	DONAUD 0604-495	Xen 515	10 1/4" 38 cm/s	stereo	46' (1ère+ 2ème partie)	Légende d'Eer (1ère partie) 23/07/1981 (F. Bayle/Zanesi)	copie de la réduction stéréo du 7 pistes (le boîtier porte une étiquette d'enregistrement INA/GRM)

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-047		Xen 516	7" 38 cm/s	stereo	46' (1ère+ 2ème partie)	Légende d'Eer (2ème partie) 23/07/1981 (F. Bayle/Zanesi)	copie de la réduction stéréo du 7 pistes (le boîtier porte une étiquette d'enregistrement INA/GRM)
LLE-AS-BnF-048	DONAUD 0604-556	Xen 580	7,5" 19 cm/s			ER III+IV	ER: titre initial de *La Légende d'Eer*
LLE-AS-BnF-049	DONAUD 0604-557	Xen 581	7,5" 19 cm/s			ER VII	ER: titre initial de *La Légende d'Eer*
LLE-AS-BnF-050	DONAUD 0604-558	Xen 582	7,5" 19 cm/s			ER I+II	ER: titre initial de *La Légende d'Eer*
LLE-AS-BnF-051	DONAUD 0604-559	Xen 583	7,5" 19 cm/s			ER V+VI	ER: titre initial de *La Légende d'Eer*
LLE-AS-BnF-052	DONAUD 0604-561	Xen 585	10 1/2"			Légende d'Eer WDR, 1979	l'étiquette du boîtier porte l'indication: copie equivalente au Master n° 1 de la WDR, 1979 (vérifié le 10/09/91 au GRM) l'interieur du boîtier porte l'indication, B
LLE-AS-BnF-053	DONAUD 0604-562	Xen 586	10 1/2"			Ionosphère+classement de Sons divers	une fiche accompagne la bande portant les indications: Fulch: classe(ment) de sons divers + Front grave + Ionosph(ère)

e) Archives Xenakis – Bibliothèque Nationale de France, Paris (BnF)							
Name	**BnF#**	**old#**	**inch**	**tracks**	**length**	**notes on box**	**further notes**
LLE-AS-BnF-054	DONAUD 0604-573	Xen 597	7,5", 5", 3", 5/4"	mono		Polytope Eléments (chutes)	3 bandes ne portent aucune indication, la bande de 5' en plastique est la suite de la bande "carton" (morceau cassé/rembobiné)
LLE-AS-BnF-055		Xen 598	7,5“	mono		Polytope Eléments (chutes)	sans autre indication
LLE-AS-BnF-056		Xen 599	7,5“	mono		Polytope Eléments (chutes)	l'étiquette de bande porte l'indication Xenakis: I, II
LLE-AS-BnF-057	DONAUD 0604-599	Xen 625	10 1/4"			ST 1	sans autre indication
LLE-AS-BnF-058	DONAUD 0604-609	Xen 635	10 1/2"	8		Xenakis (bande Truchet)	la bande porte l'indication: Truchet, 99999 (bande à 8 eb. Par éch.)
LLE-AS-BnF-059	DONAUD 0604-610	Xen 636	10 1/2"			Flashes+Sound (FL - Son) 27/04/79 10/08/1979	la bande porte deux étiquettes de dates différentes et l'indication: this tape +lasers=full spectacle
LLE-AS-BnF-060	DONAUD 0604-611	Xen 637	10 1/2"	„9 tracks“		Bande - CALC (tentacule sequence) 27.11.1978	une fiche acompagne la bande portant l'indication: "keep this tape, tentacule sequence (1'45) - have seen this tape at the Diatope"

ii. Catalogues and Data Bases:

- **CAT WDR SEM**

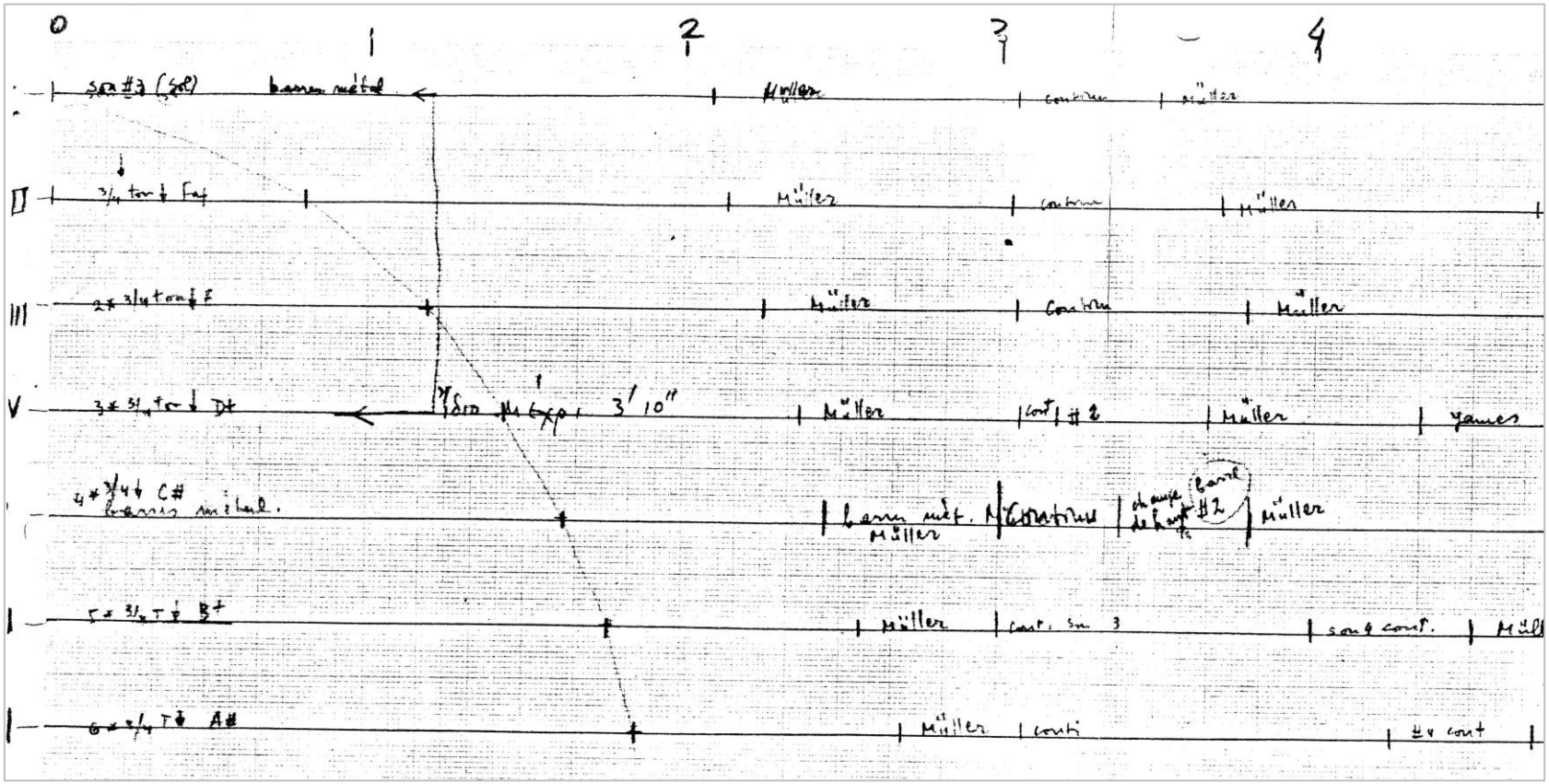
Xenakis *La Légende d'Eer* – Archivbänder WDR Studio Elektronische Musik
Unofficial catalogue received from sound technician Volker Müller
Excel File (completed by Reinhold Friedl during digitisation)
Unpulished.

- **CAT BnF AX**

Fonds Xenakis Oeuvres electroacoustiques
Excel File (further specified by Reinhold Friedl during listening sessions)
Unpublished.

iii. visual sources (photos etc):

- **LLE-WDR-VS-01**



Xenakis, I. (1978) *La Légende d'Eer*, *Partition résumée définitive des 7 pistes sonores*, Archives WDR Köln, Orch.Part. 16405.

5. TTM Examples

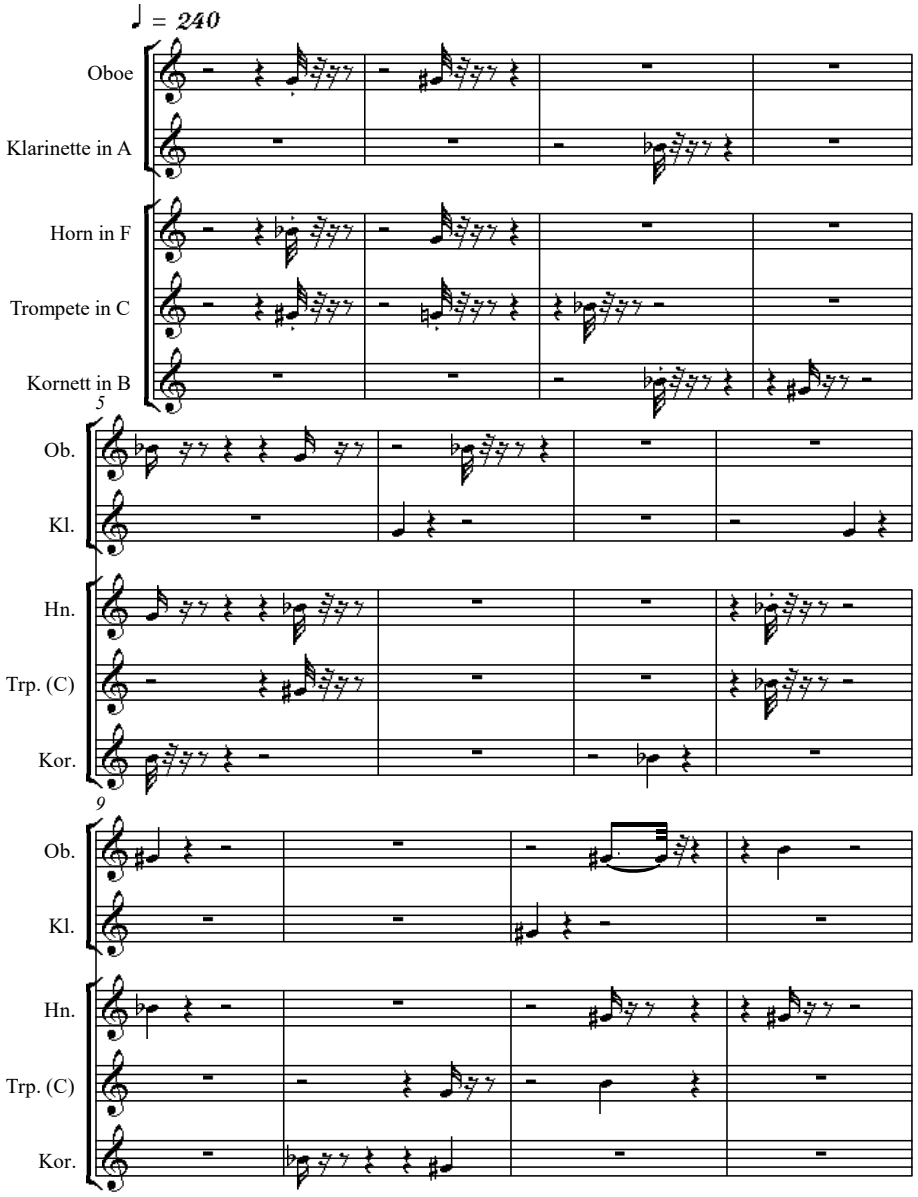


Figure 103: Example 2, Polyrhythm, Output 1, 1.

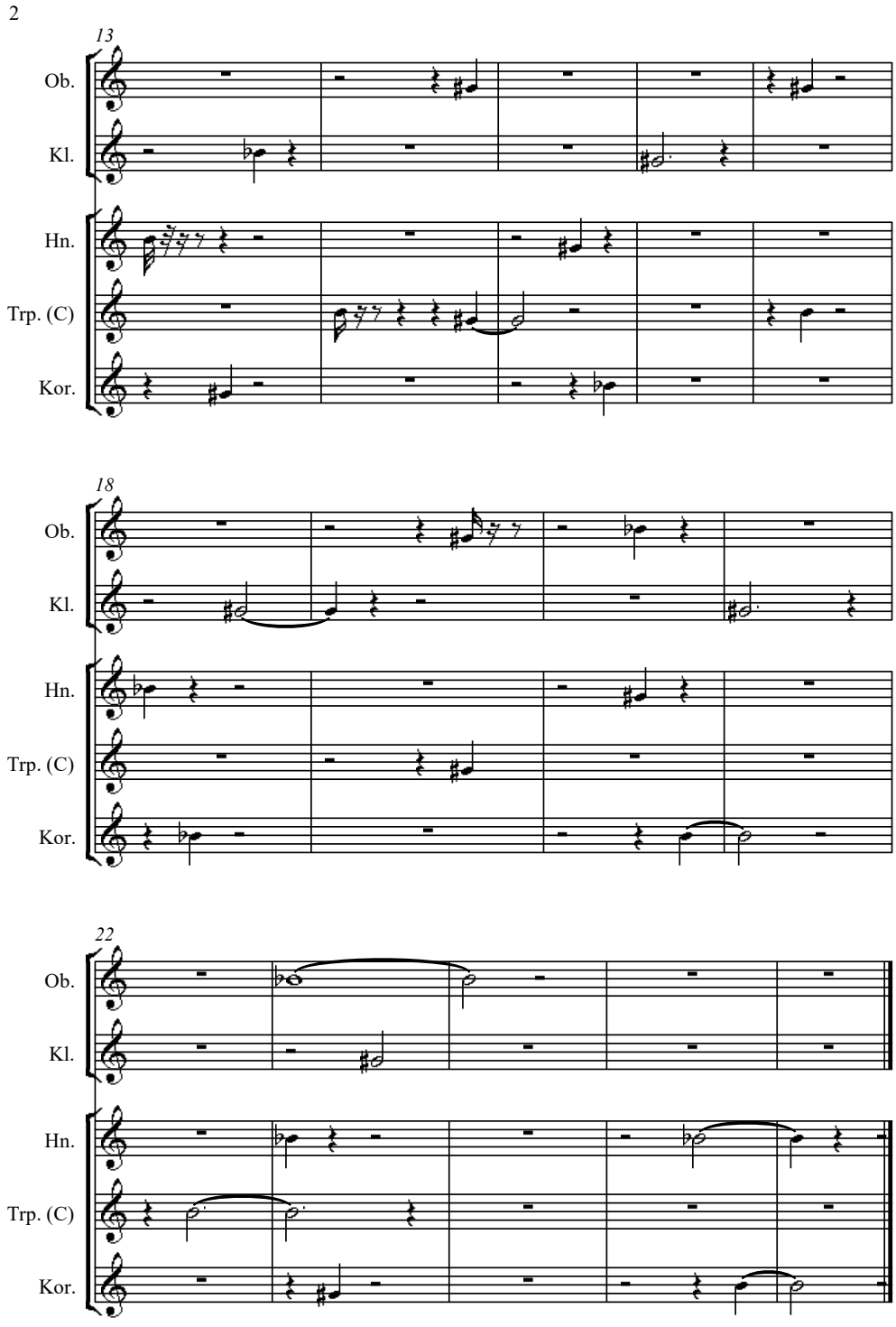


Figure 104: Example 2, Polyrhythm, Output 1, 2.

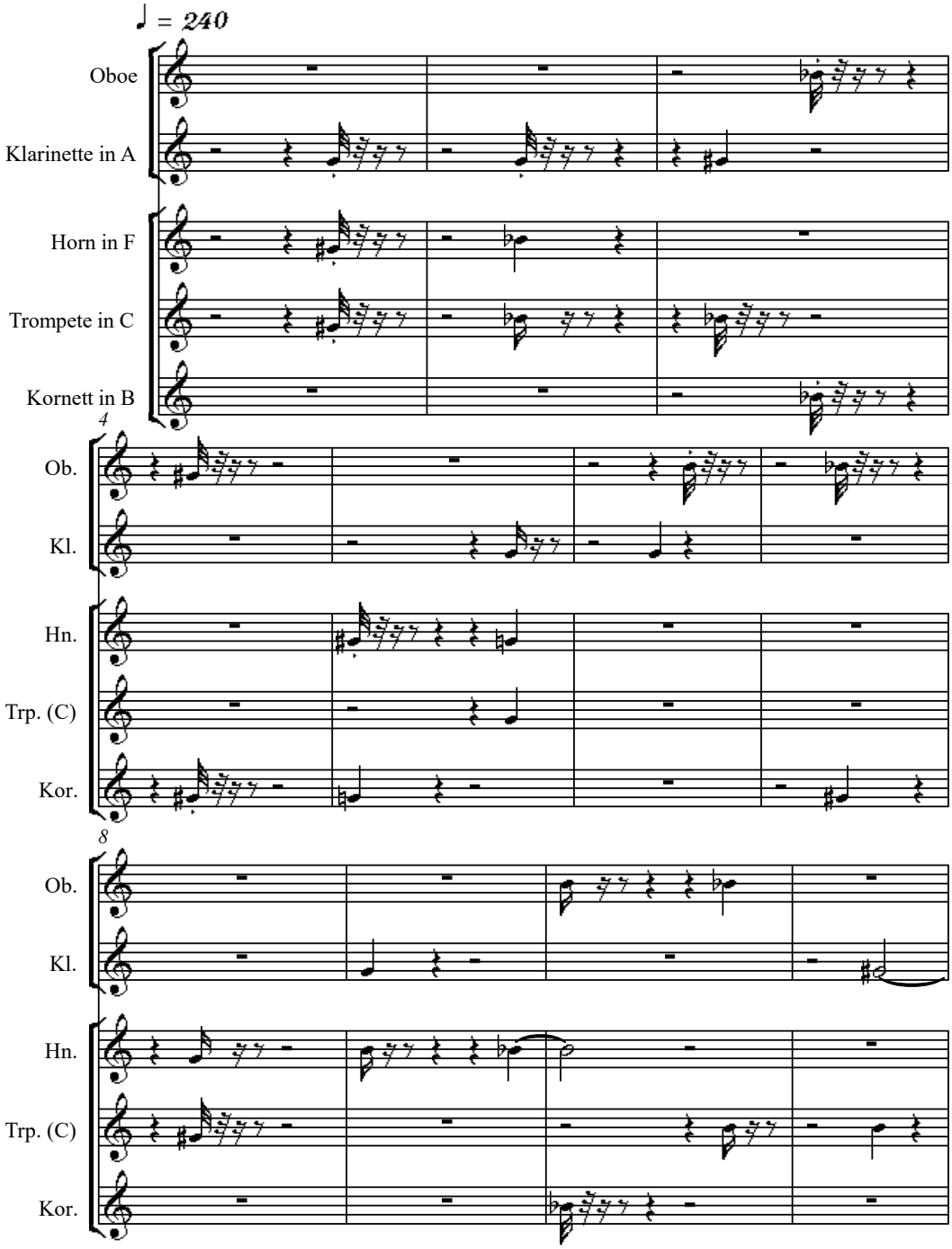


Figure 105: Example 2, Polyrhythm, Output 2, 1.

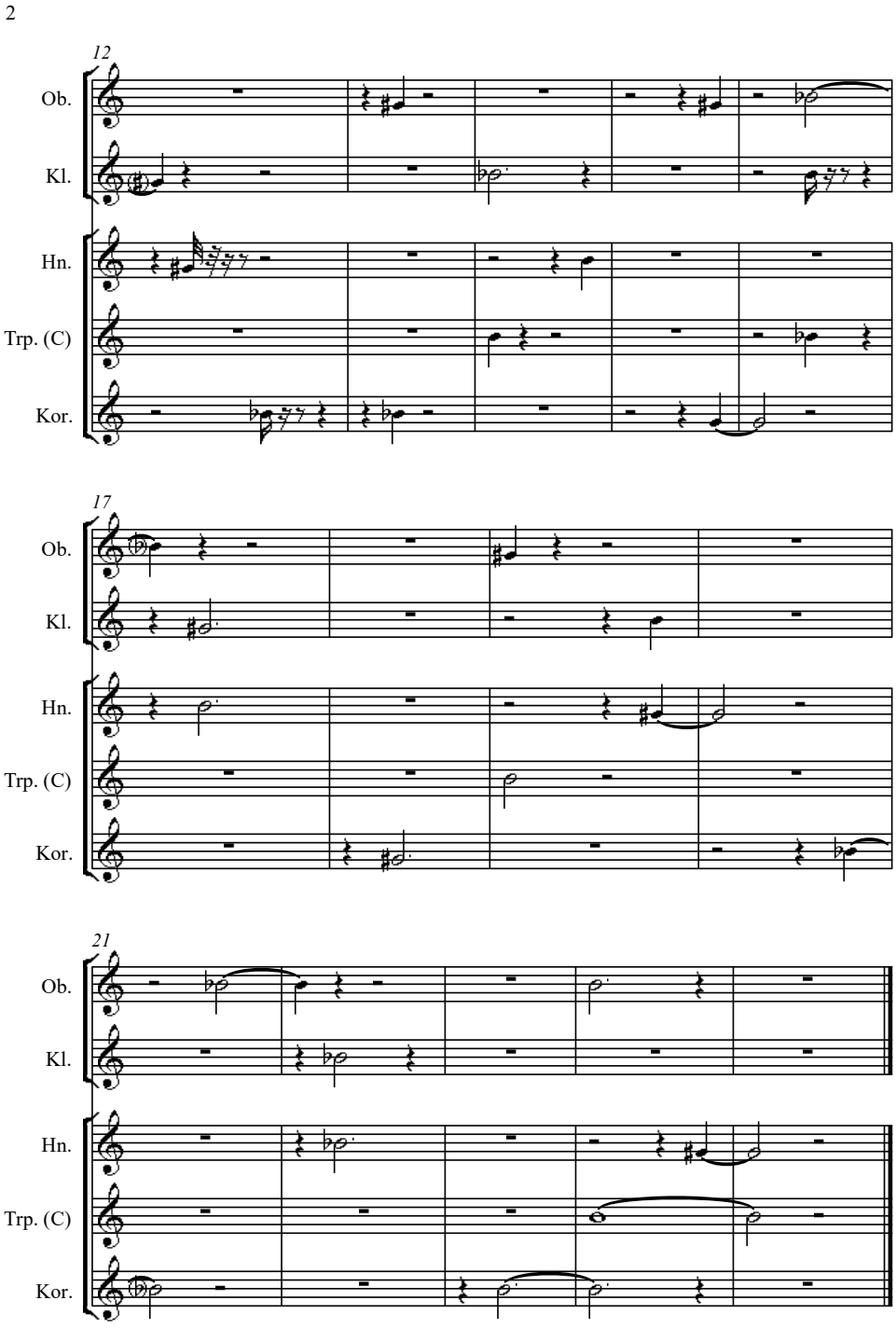


Figure 106: Example 2, Polyrhythm, Output 2, 2.

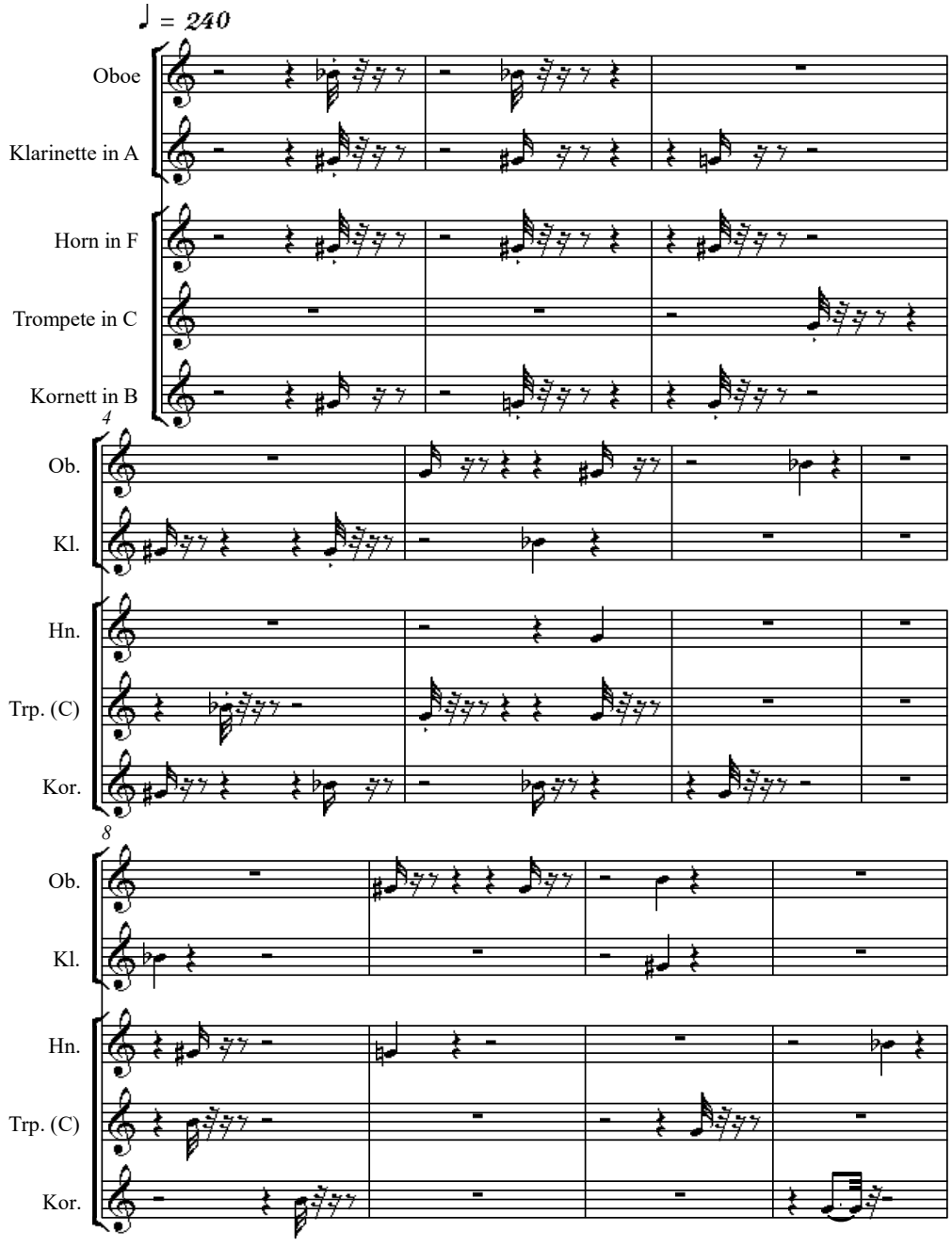


Figure 107: Example 2, Polyrhythm, Output 3, 1.

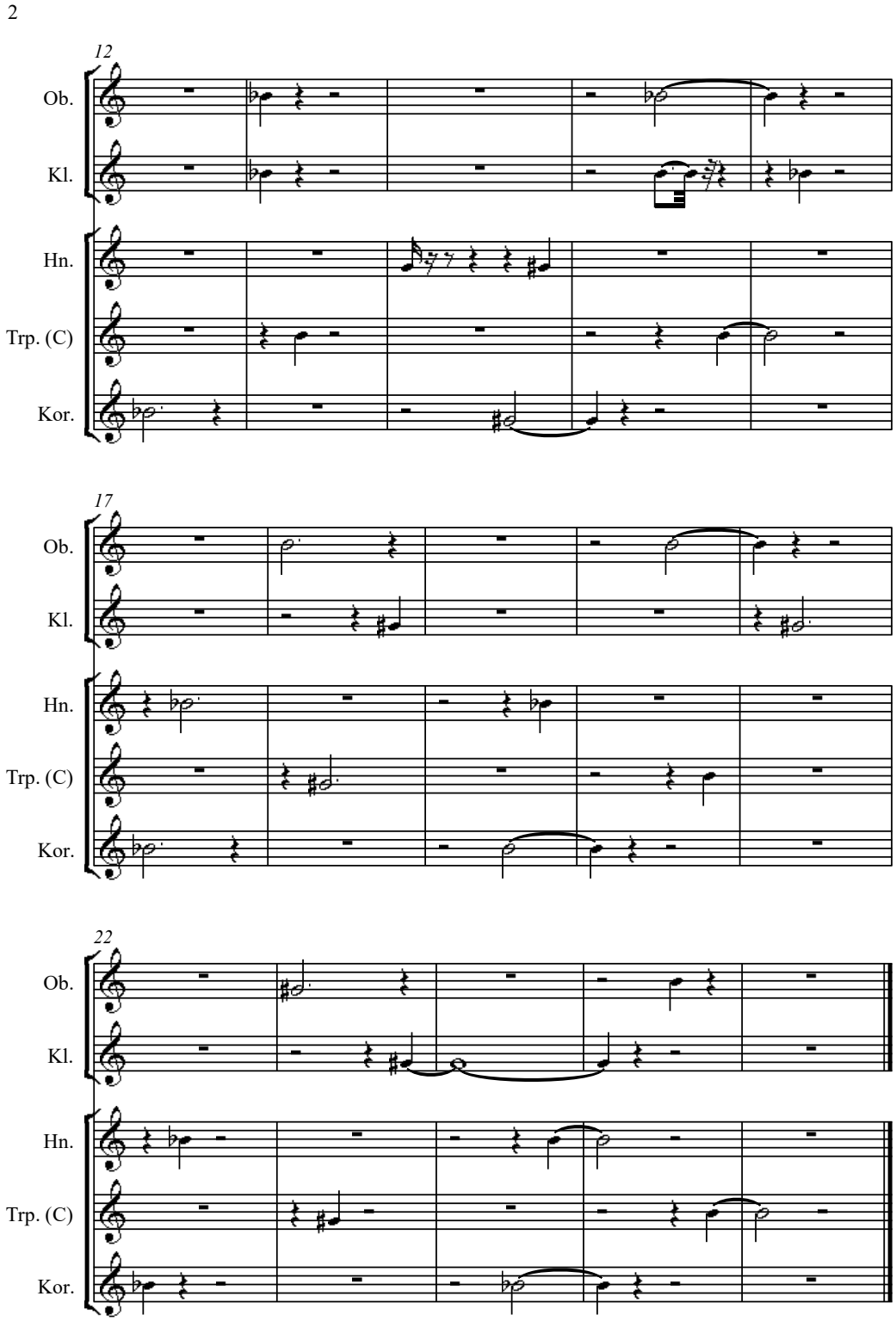


Figure 108: Example 2, Polyrhythm, Output 3, 2.

Example 2, Monorhythm, Output 1

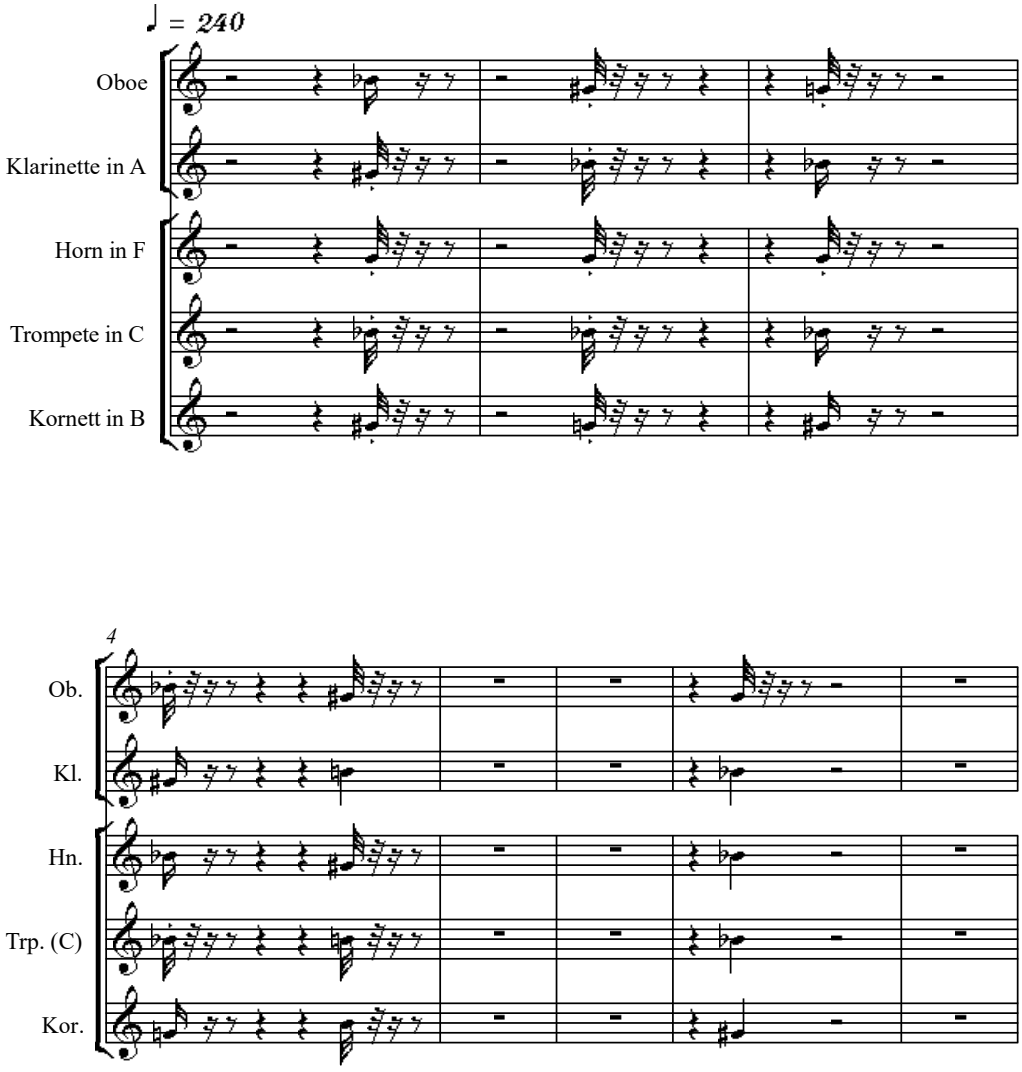


Figure 109: Example 2, Monorhythm, Output 1, 1.

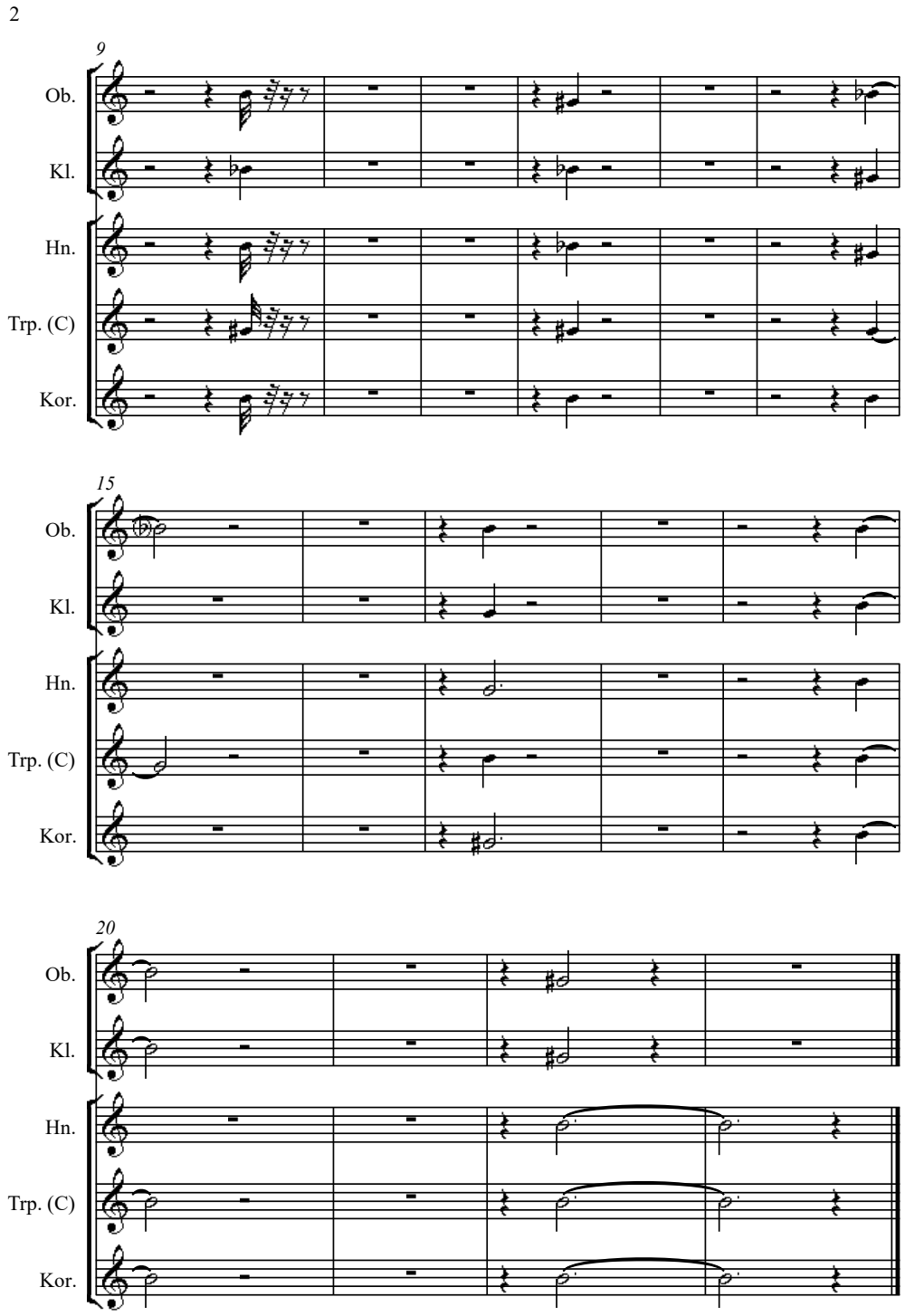


Figure 110: Example 2, Monorhythm, Output 1, 2.

Example 2, Monorhythm, Output 2

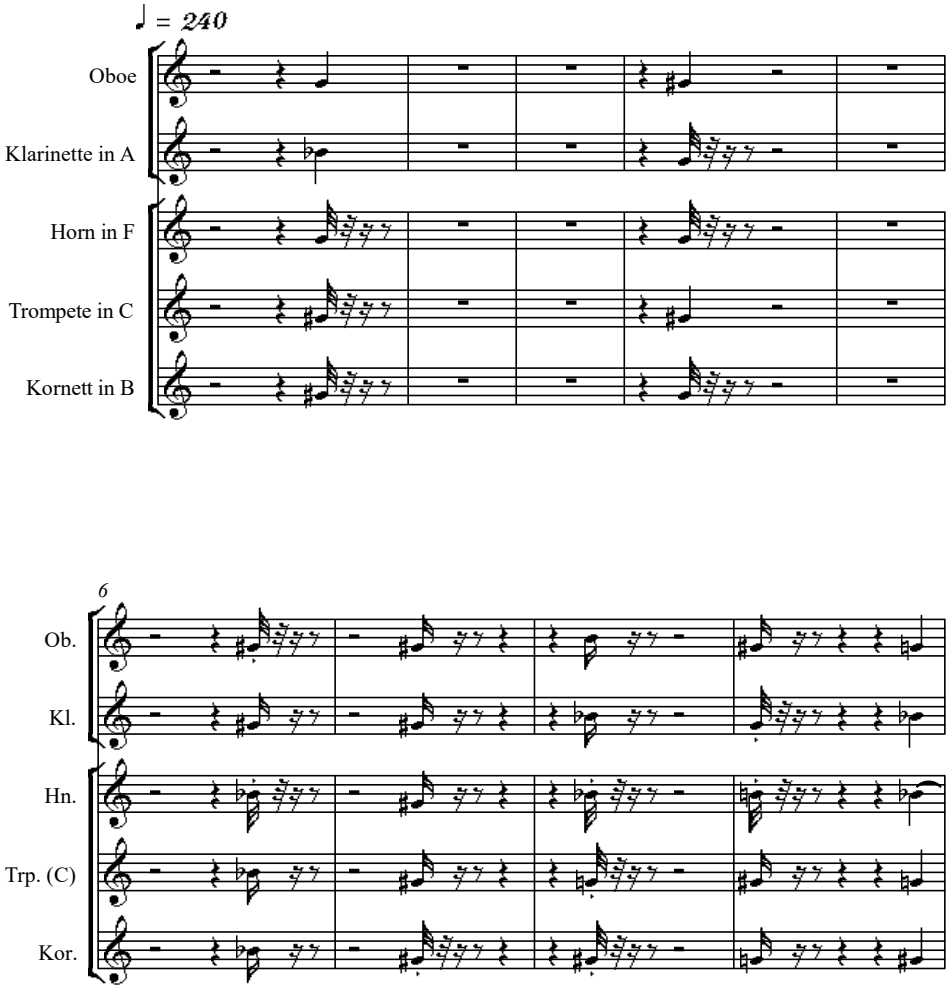


Figure 111: Example 2, Monorhythm, Output 2, 1.

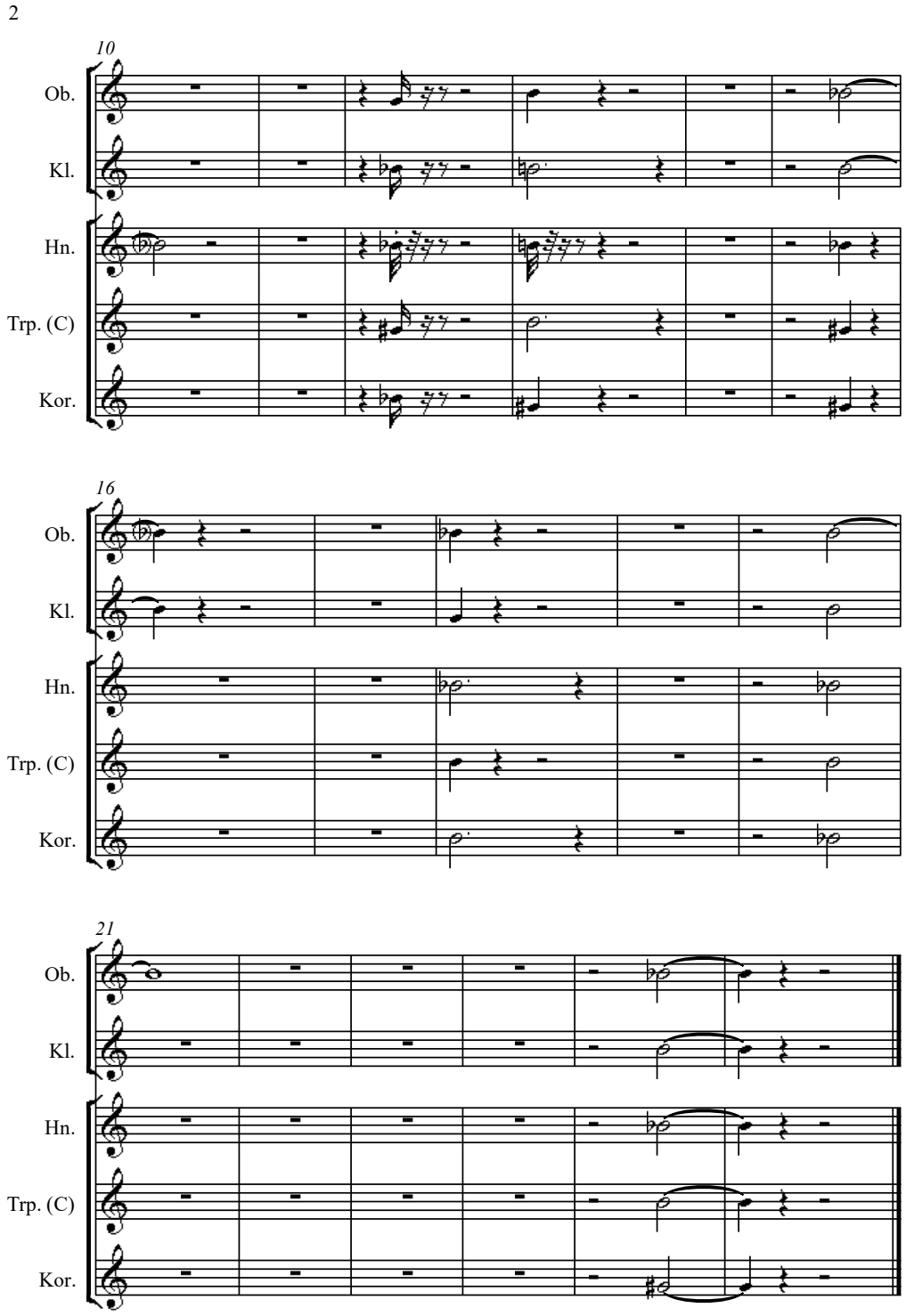
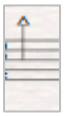


Figure 112: Example 2, Monorhythm, Output 2, 2.

6. Reinhold Friedl – *String Quartet No. 3*

(Full score also available in Related Material for Download.)

Explications:

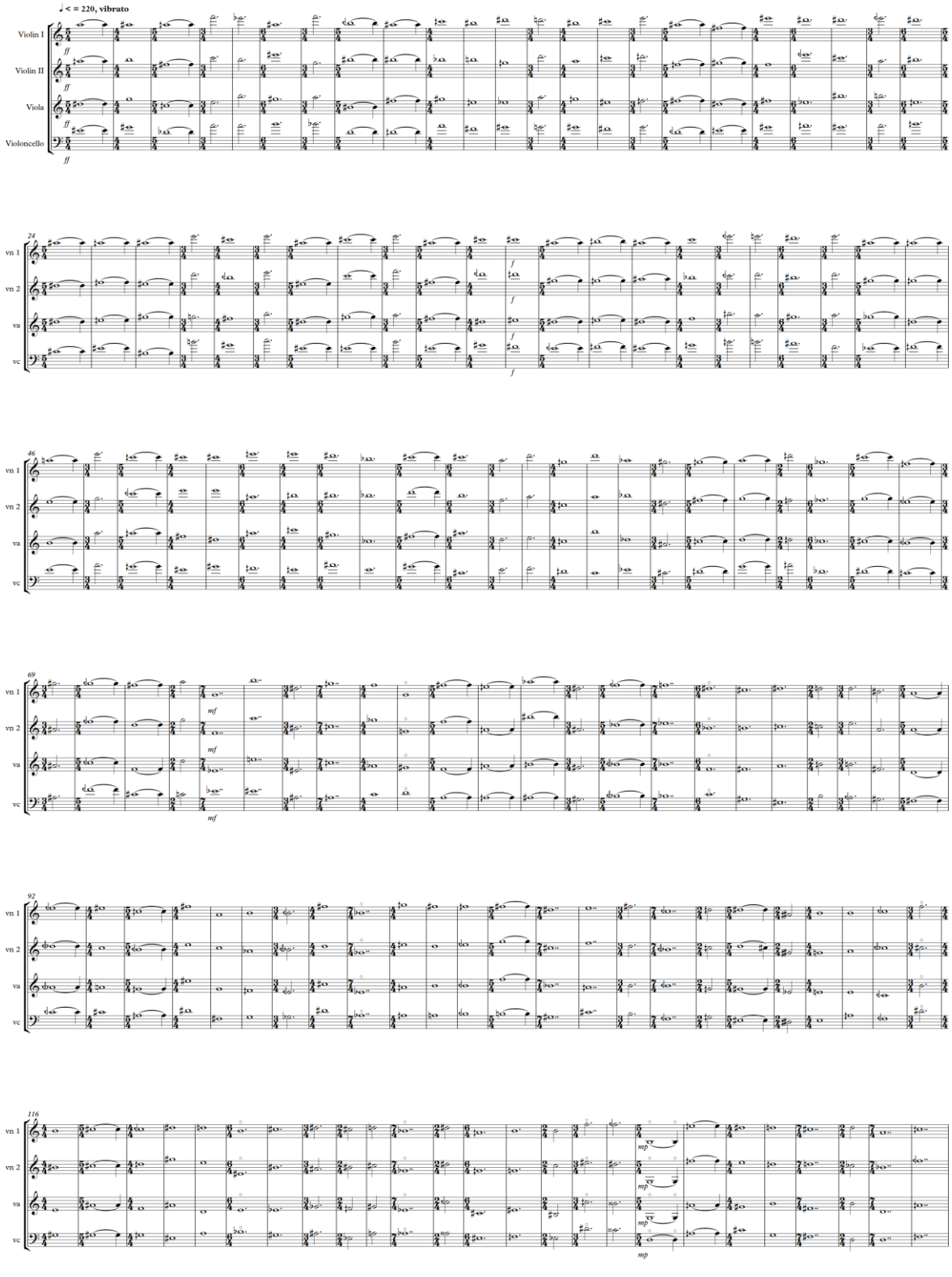
 highest note on the instrument

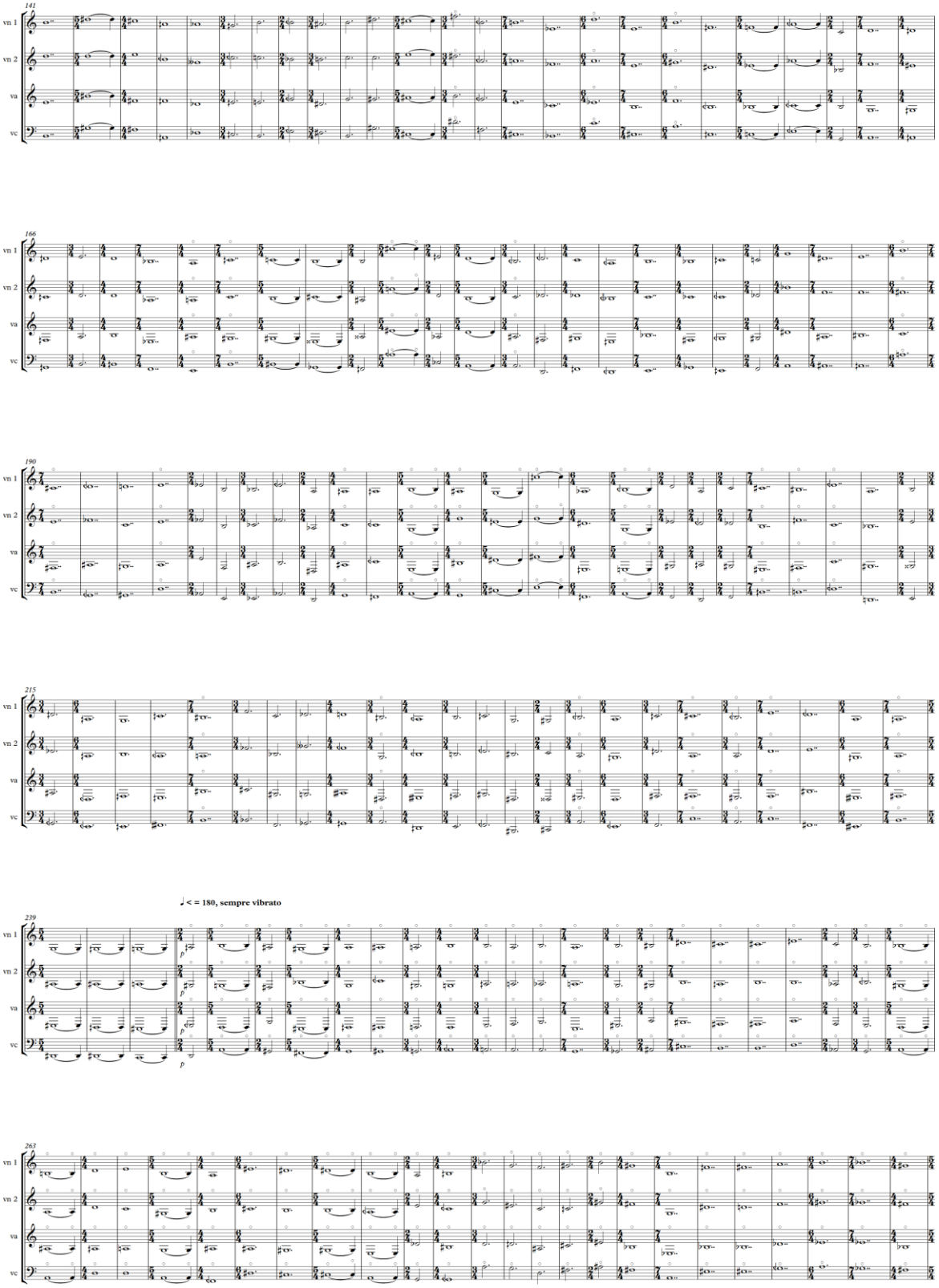
Quartertones are intended to be played approximately.
Tempo indications are maximum tempo indications.

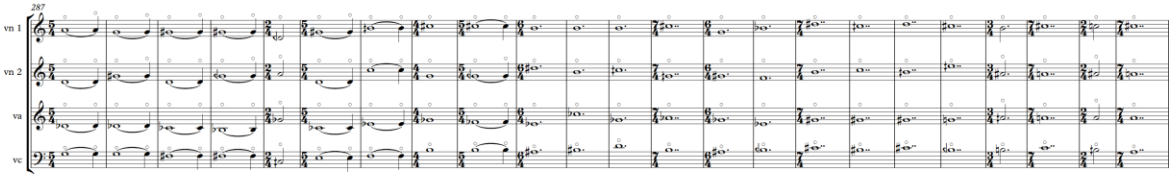
 play the lowest harmonic [flageolet] possible and comfortable to play

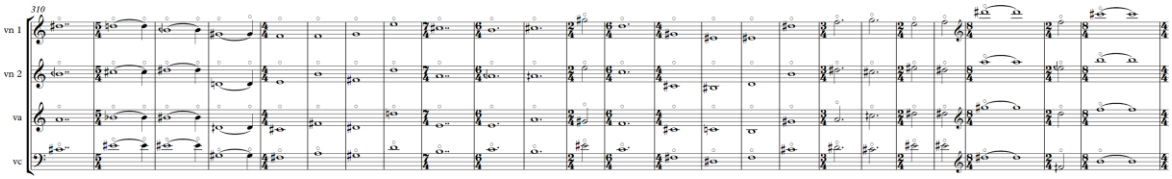
on the given note.

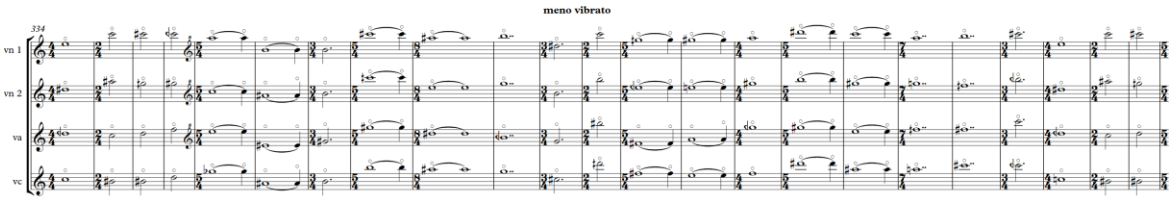
Reinhold Friedl

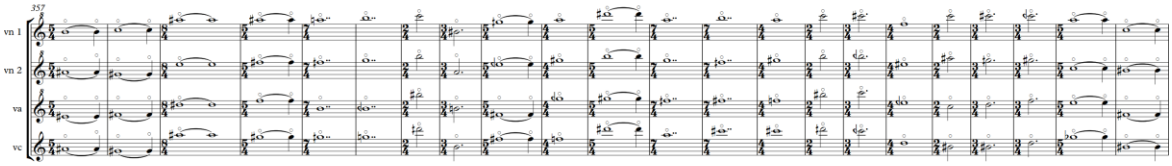


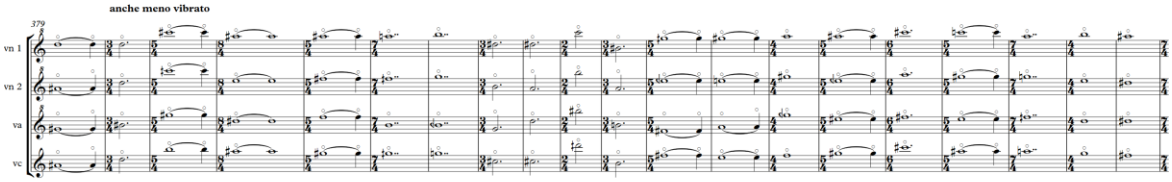

141
166
190
215
♩ < = 180, sempre vibrato
239
263
vn 1
vn 2
va
vc

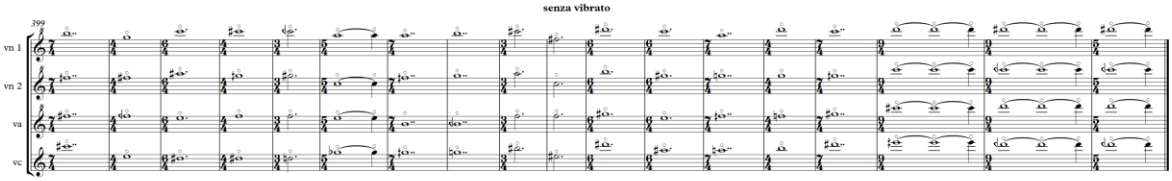

287
vn 1
vn 2
va
vc


310
vn 1
vn 2
va
vc


meno vibrato
334
vn 1
vn 2
va
vc


357
vn 1
vn 2
va
vc


anche meno vibrato
379
vn 1
vn 2
va
vc


senza vibrato
399
vn 1
vn 2
va
vc

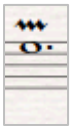
7. Reinhold Friedl – *KRAFFT* for Orchestra

Explications:

 highest note on the instrument. For reeds: bitten note
Quartertones are intended to be played approximately

A) Wind instruments

There are no breaks given, apply circular breathing where possible. If you interrupt for breathing, always pause for a whole bar! Breathing strategy should be prepared beforehand.

 very slow and sweet vibrato on the given note

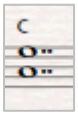
 breathing sound sharp [sssssssssss]

 breathing sound [voiced sss]

 breathing sound soft

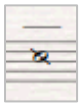
 breathing sound very soft [“djdjdjdj”]

 lowest tone breathing sound with flutter-tongue and singing

 split sound

 ordinary note plus singing [rhombus]

The given multiphonics (bcl, a-sax) are samples: you can choose other multiphonics in the same range and a similar interval structure with the necessary dynamic properties (#1: mp to f, #2: mf to ff, #3: f to ff)

 Didgeridoo-like sound on the given note [“aiaiaiai”]

B) Strings

 play any harmonic [flageolet] on the given note

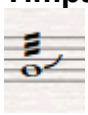
 bowing a circle on the given open strings, strings damped with the left hand

 noise-tremolo in the given strings [the two lowest]

 resonance frequency [wolf] of the instrument or similar penetrating sound

C) Percussion

Timpani:

 glissando in the given time, use the whole range of the instrument up or down

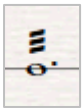
Gran Cassa:

 use brush or jazz broom for a breathing-like, noisy sound

Tam-Tam:

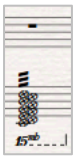
 normal beat, let it always sound, never damp

 scratching sounds with wood on the Tam-Tam

 beating constantly (using two beaters if possible)

D) Piano

 hit strings with the hand, lowest register, cluster

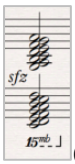
 same with fast beatings

 bowing the strings with wood in the lowest register at a right angle (harmonic fields) [wood can be provided]

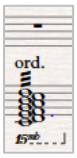
 bowing the string in the middle register with a metal sheet at a right angle (high piping sounds) [metal sheet can be provided]

 bowing high note in the lowest register with wood along the string (aggressive piping sound) [wood can be provided]

 bowing high note in the lowest register with wood along the string (squeaking sound) [wood can be provided]

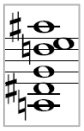


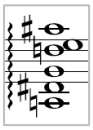
chromatic double arm cluster

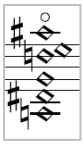


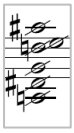
fast repetition of lowest chromatic notes of the piano or cluster tremolo (fff)

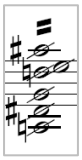
E) Guitar

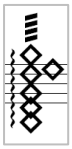

Tuning of the open strings (bass-clef, sounding pitch)


loose 4-finger arpeggio (Flamenco like, but slower)


undefined harmonics, bowed


bowing with pressure, noisy


bowing with pressure, tremolo, noisy


4-finger noisy tremolo on empty strings

PDF-File of the Score added separately! (see related material).

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