1. Introduction

1.1. Overview:

During the 20th Century, electronic technology has dramatically affected the music of today. It has taken the age old traditions to new and exciting dimensions from which the music of old may barely be recognised. Opinions vary greatly on the benefits and lasting effects that this combination has, and continues to provide. This report is constructed to give an overview to the reader of the important issues involved in this subject.

1.2. Literature Review:

Manning [1]: An excellent source on the fundamental principles of technology used in hardware systems such as computers and samplers and their relationship to the composer's needs.

'Sound on Sound' technical articles are an imperative guide for the full spectrum of the topics covered in this report.

1.3. Methods of Investigation:

In order achieve an understanding on the topics covered in the following report, several sources were required. The first were historical, and these were used to place modern day music in context with the past. The second group of resources were technical; these came in the form of documents printed in journals, magazines and text books. Finally, the third source was direct from the composers themselves in the form of interviews. Of the three interviews I conducted, two came through e-mail, and the other was in person; furthermore I constructed a questionnaire that would provide some statistical data on the matters at hand.

2. Terms of Reference:

2.1. Introduction

The purpose of the investigation was is to discover the ways electronic technology has altered music. The areas of study are:

a. The history of electronic composition
b. The amount of electronic technology in modern day composition/production
c. The influence of electronic technology on modern day composition/production
d. The methods used by the composer in electronic composition/production
e. The avenues opened to the composer from the use of electronic technology

2.2. Limitations

Electronic music can be of various genres, and the proportion of electronic technology within these can vary: For example the recording of a traditional folk song by a single singer/musician in one take demonstrates minimal use of electronic technology in production. At the opposite end of the scale, a production where many musicians and singers are all recorded on different tracks in isolation from the other contributors, and where the tracks are later collated in the second phase of production when the contributors have left the studio, is an example of a much greater involvement of electronic technology in production. These distinctions are also apparent in electronic compositions, for example: the acoustic properties of an electric violin have more influence over the sound, and are more dependent on the playing of the instrument than the electronic principles of the pick-ups; to the synthesized violin, where the electronic aspect is fundamental to the generation and performance of the sound.

The aspects of electronic music that contain only minute elements of technology will be considered less here than those which have a higher proportion. Furthermore the production aspect of electronic music will be focussed on less that the composition aspect. Although interesting and related to this subject, specific production techniques are not the focus of this report, and as such are not considered here.

The terms electronic music and computer music embrace a wide variety of compositional and performance activities. These range from the automatic generation of conventionally notated scores from data entered into the computer, to the synthesis of foreign sounds; from live performance techniques that will give the audience a sense that the music is essentially 'live', to the multitracking of several sound sources in the studio which could never co-exist unless digital techniques were used. These technical activities exist across a wide range of music genres and formats (film and television, computer games, ring tones for mobile phones); in this report only a selection of these formats are examined, although the selections made are intended to give the reader a broad scope of subject area.

Finally, the range of tools available to the composer is so vast that it would not be possible to comment on them all. This report does not mention electric guitars for example, nor does it investigate in any detail the technical developments of the computer. I have tried instead, to raise associated issues, and provide the reader with some reference to which he or she can refer to for further information.

3. Origins of Music: The Influence of Ancient Greece

3.1 The Scale and Harmony

Between the 5th and 6th centuries BC, Pythagoras discovered the harmonic intervals of the western scale. Recognising fundamental relationships between the length of a vibrating string and arithmetic ratios, for example the octave (2:1) and the fifth (2:3), he constructed tuning systems which the temperaments of most western instruments are based on.

If we analyze the waveform from a plucked string we can see that the concordance of the Pythagorean intervals is rooted in its harmonic content.

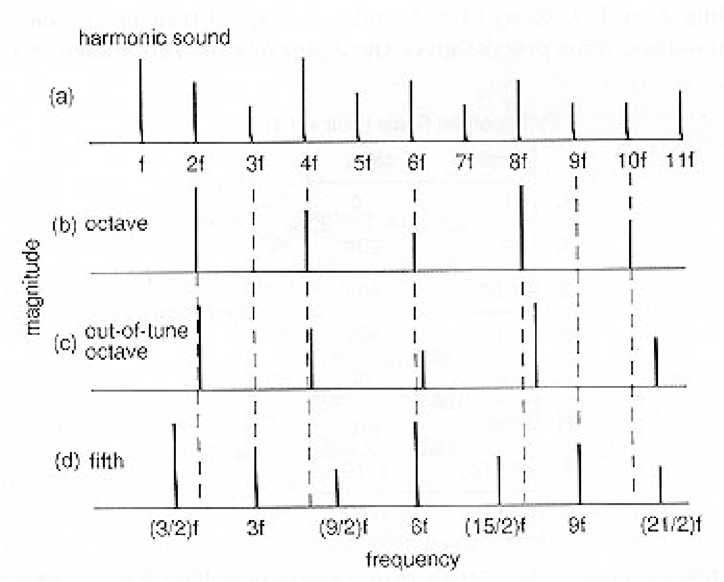

Figure 3.1.1: Harmonic Spectra of a Musical String, demonstrates the fundamental relationships as discovered by Pythagoras taken from Sethares.[1] The harmonic sound (a) is produced by plucking a string. When the string is played at the octave (b), we see that its partials line up with the original sound thus causing the octave and its tonic to fuse perceptually. When the octave is slightly detuned as shown by (c) the partials tend to beat against one another and are no longer harmonious. In the example of the fifth (d), we see that alternating partials correspond with the tonic, and the erroneous partials are far enough apart in frequency to not interact in a discordant manner. The fifth is also a concordant interval.[2]

Pythagoras' observations on the harmony of his intervals were based therefore on the physical properties of the string, in particular its harmonic properties.

[1] Sethares. W. A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p51
[2] Sethares. W. A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p51-52

3.2 Sound Spheres

Boethius and Pythagoras recognised that all movement caused sound, for it was believed in Ancient Greece that even the motion of the planets yielded specific pitches and harmonies, although they are too high pitched for us to perceive. Boethius divided sound into three general categories:

Musica Mundana *(the harmony and rhythm of the universe)*
Musica Humana *(proportions of the body)*
Musica Instrumentalis *(vocal and instrumental music)*

Table 3.2.1: The three fundamental categories of sound as stated by Boethius and Pythagoras[3]

[3] Ernest. D, The Evolution of Electronic Music, Schirmer Books, 1977, p. xv

4. The Metamorphosis of Music

4.1 Microtones

‘Scales partition pitch space into chunks’[4]. They have evolved and reproduced themselves with a great deal of variety since Pythagoras. There are scales based on overtones, scales generated from a single interval or a pair of intervals scales without octaves, scales arising from mathematical formulas, scales that reflect cosmological or religious structures[5]. Although there are a variety of scales across the globe, they have in common the principle that they all use a small number of partitions. Western scales use 12 divisions per octave, Gamelan music uses 7 divisions per octave, most Arabic traditions use 22 divisions, and parts of Africa and Asia use 24 divisions.

The “Archicembalo” build in 1555 divided the octave into 31 pitches, its design led to the invention of several micro-tonal instruments which are influential in the circles of electronic music, since they broadened Western composers’ attitude towards pitch.[6] The desire to compose with the complete range of pitches was alluded to as early as the 1624 by the Philosopher Sir Francis Bacon in his book *‘The New Atlantis’*:

“We have sound houses, where we produce and demonstrate all sounds, and their generation.”[7]

4.2 Awareness of Timbre

The science of acoustics became the ascendant concern of investigations towards the mid point of the 17th century. The most important theses that concern electronic compositional techniques were written by Jacques Rouhault and Claude Perrault. Rouhlant “was concerned with aural perception and its relationship to the brain, manifest by the resonant capacity of the ear.”[8] Perrault determined that timbre was affected by the presence of upper-partials in addition to subsidiary noises associated with percussive, blown, bowed sounds.[9] Up to and beyond this era composers where often uninterested in the timbre of sounds:

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[4] Sethares. W. A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p49
[5] Sethares. W. A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p49
[6] Ernest. D, The Evolution of Electronic Music, Schirmer Books, 1977, pxvii
[7] Wow/en, History of Electronic And Computer Music Including Automatic and Composition Machines, 2001, web R. [1]
[8] Ernest. D, The Evolution of Electronic Music, Schirmer, 1977, pxix
[9] Ernest. D, The Evolution of Electronic Music, Schirmer, 1977, pxix

“Bach sometimes composed without specifying the instruments: he was not interested in the sound of his music.”[10]

By the nineteenth century when technology and music began to merge, tonality was exhausted and several musicians began looking elsewhere for sources of inspiration. Debusy used the six note scale, Bartok experimented with mode and Varése early in the 1900's experimented with timbre. Varése is of particular interest; he altered the attack characteristics of a Brass instrument by suppressing the initial transient with an entry sound of piano, and by heavily accentuating the central portion with heavy crescendo. The resultant sound was very similar to the effect achieved by playing a recorded note in reverse, where the attack portion becomes the decay portion and vice versa[11].

4.3 Delineated Compositional Methods

Adjacent to the experiments with sounds and scales, a diversity of compositions began to emerge. Influential in this field was Helmholtz whose book 'Sensations of tone' “delineated new compositional techniques for composers of future generations.”[12] Such composers include Varése who, among many others, began to base their music on concepts of 'organized sound':

“With the aid of effects such as sirens, whips, a lions roar, and sleigh-bells he struggled to develop a compositional art which integrated the natural sounds of the environment with more traditional sources of expression in an attempt to extract an artistic perspective from the universe of sound…”[13]

In western music we have tended to stress a teleological progression within our songs, where climaxes are achieved by fulfilling or disappointing expectations generated by the previous progress of the music. These progressions have been somewhat removed by new ideas in compositions. Brian Eno draws an analogy between his compositions and the way a frog receives visual stimuli:

“One of the interesting things about the ears is that they work in the same way as a frog's eye works...A frog's eyes don't work like ours. Ours are always moving: we blink. We scan. We move our heads. But a frog fixes its eyes on a scene and leaves them there. It stops seeing all the static parts of the environment, which become indivisible, but as soon as one element moves, which could be what it wants to eat - the fly - it is seen in very high contrast. [When listening to a phasing piece] our ears behave like frogs eyes. Since the material is common to both tapes, what you begin to

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[10] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]

[11] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p6-7

[12] Ernest. D, The Evolution of Electronic Music, Schirmer, 1977, pxxii

[13] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p6-7

notice are not the repeating parts but the sort of ephemeral interference pattern between them."[14]

[14] Korner. 'Aurora Musicalis', Quoted in Stevenson. B [6], pp21-22

5. Early Electronic Composers

The music of the earliest electronic composers was sometimes “unmusical”, and unpleasing to the ear, however until the 20th century, no form of electronic sound existed. The invention of electronic production and recording techniques expanded the possible tones and tools available to composers, who were previously confined to conventional instruments and traditional song structures. “Thrown into this entirely new sonic world, musicians occupied themselves mainly with creating previously unheard tonalities (some of which now sound commonplace) and were unable (or uninterested) to make them conform to traditional musical notions.”[15]

5.1 Futurists

The Futurist movement originated in Italy at the beginning of the 20th century, they indulged in various art forms and were concerned with the glorification of speed and the machine and the inevitable destruction of history[16]. Varése states the cause for this attitude clearly: “speed and synthesis are characteristics of our era.”[17]

During the time of the Futurists there was a calling for new musical instruments:

“What we need is an instrument that will give us continues sound at any pitch. The composer and electrician will have to labour together to get it.”[18]

Furthermore in 1916 the N.Y. Telegraph is found to say:

“…our musical alphabet must be enriched...We need new instruments badly.”[19]

Prattela advocated that these new instruments should use microtones (enharmonic pitches), furthermore he emphasised the need for experimentation with a found sound that is from an everyday object, as a sonorous source. It was during this time that Russlo developed the line note to signify duration.

The Futurist made noises, and they were best at demonstrating their ideas on stage. The art of noises concert in Milan in 1913 was purely a collection of whistles and

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[15] Sarig. R, Early Electronic Music Comes of Age, 2000, web R. [3]
[16] Ernest. D, The Evolution of Electronic Music, Schirmer, 1977, pxxiv- xxv
[17] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p6
[18] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p6
[19] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p6

buzzers played at random intervals. It is dubious whether the effect was audibly aesthetic but it was making a statement.[20]

5.2 Elktronische Musik

Elktronische Musik began in Germany and was pioneered by several interested parties drawn from both musical and technical backgrounds. They often applied very strict scientific principles to their processes and documented everything they did. Primarily they were concerned with sound that could be generated and were the first to appreciate white noise as the bases for subtractive synthesis and the Sine wave as the most fundamental sound source for additive.[21] Manning describes the typical trends, and concerns of the electronic composers of this era:

"...an increasing desire to exercise control over every aspect of musical composition led to a keen interest in the possibilities of electronic synthesis, for such a domain eliminated not only the intermediate processes of performance but also the need to accept the innate characteristics of natural sound sources."[22]

5.3 Music Concrete

Pioneered by Pierre Schaeffer in France, it began in the 1930's. Using tape as a medium he recorded sounds from the real world and tried to manipulate them into a form of music. Examples include *'Etude aux chemins de fer'* which is a track based around the sampled sounds of six steam engines leaving the Gare des Batignolles, Paris; *'Étude pour piano et orchestre'* which combined sounds of an amateur orchestra tuning up with a spontaneous piano improvisation by Grunenwald. Schaeffer was often disappointed by the lack of musicality in his compositions and came to realise the problems of association when using sounds whose sources could easily be recognised. His methods involved the manipulation of recorded sound furthermore he would often try to articulate the sound of nature into music:

"Sound is the vocabulary of nature...noises are as well articulated as the words in a dictionary....Opposing the world of sound is the world of music."[23]

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[20] Ernest. D, The Evolution of Electronic Music, Schirmer, 1977, pxxiv-xxviii
[21] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p43-78
[22] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p46
[23] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]

Like many artists of that era he was attempting two things at once. First, to come to grips with the technology; second, was to escape the "stifling world of DOREMI."[24] He explains that:

"...in a period of high technology; either technology itself comes to the rescue of art - which is in a state of collapse, or it's the ideas of technology, ideas from mathematics, ideas with a scientific aura...given an unreal relevance to art which is seeking its discipline..."[25]

Fifty years on Schaeffer states, that he was trying to make music, but could never get to music, and points to his achievements in terms of the technological boundaries that he overcame.[26]

The experiments of these early composers have been very influential to today's composers. They merged the world of sound to music in ways that people's ears were unaccustomed to, and from this point it very difficult for later composers to ignore the possibilities that are opened by the medium. I have included two tracks on the C.D. that illustrate the influence of music concrete and Elktronische Musik today. The first track is by Ned Boulassa (track 2), it is called *'impulse'*; the second track is by Aphex Twin (track 3) it is called *'track 01'*. C.D. track 1 is an extract from Pierre Schaeffer's *'Etude aux chemins de fer'*.

[24] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]
[25] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]
[26] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]

6. Aspects of Technology and Its Influence on Music

The following section is a brief overview of the technology that has affected modern day compositions. I acknowledged the brevity of the details included here in my terms of reference, however should the reader wish for more information on the following, Peter Manning's 'Electronic and Computer Music' [1], is an excellent source of reference.

6.1 Tape

The invention of the tape machine in the 1930's was to revolutionise composition methods and until the1970's it remained the most used recording and editing device. It provided the composer with a compositional tool on which sound could be recorded, edited and structured. As Brian Eno states:

"I realised that [with magnetic tape] you could mess with time - storing it and then distorting it in any way you wanted - and this turned music into a plastic art."[27]
"When you work on tape as I do, it means that music has become a physical material: a substance which is malleable, mutable, cuttable and reversible."[28]

A composer can use tape to adjust the sonic characteristics of a sound. This is achieved by manipulating the physical material in some way. Illustrated below is an indication of how attack and decay was treated using different angles of tape cuts/spices:

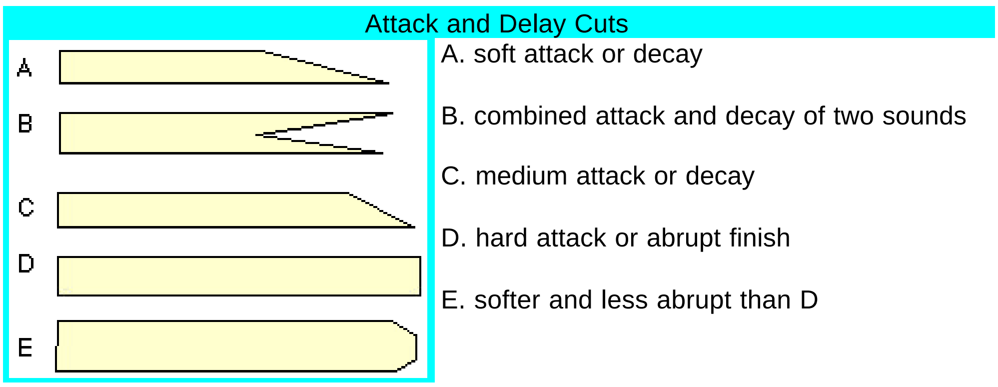

Table 6.1.1: An indication of the methods used to alter the sonic characteristics of a sound.[29]

The altered sonic characteristics of the recorded sound could then be recorded onto another tape deck; a collection of sounds might then be used in a loop. Creating a

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[27] Interview by Demorest. S, The Discreet charm of Eno: an English pop theorist seeks to redefine music, Horizon xxi, 1978, Quoted in Paintings in Sound[1], p24
[28] Interview by Zwerin. M, International Herald Tribune, 1983, Quoted in Paintings in Sound [1], p24
[29] Synder. J, Music Concrete, Lebanon Valley College, 2002, web R. [4]

loop often meant using long amounts of tape that would stretch out of the studio and further down the corridor. Tape Loops were used by artists such as Pink Floyd on ‘Dark Side of the Moon’, the Beatles on ‘Sergeant Peppers Lonely Hearts Club Band’, and Steely Dan created the perfect Drum Loop long before the invention of the Drum machine[30]. C.D track [4] is an example of a tape loop being used as an instrument in a song in a live situation - the recording is from a Pink Floyd concert.

Some of the early tape manipulations like reverse, echo and flange, have reincarnated in the digital domain and are common in many software and hardware packages. The tape operator would use techniques that involved the manual manipulation of material to create these affects, for example to create a flange the composer would gently touch the reel of the tape, causing the reels to slow slightly thus distorting the sound. The composer who is using digital technology has a variety of sonic options open to him from the algorithmic manipulation of sound. Tape was thus superseded by these Digital Recording and editing techniques in the late 70’s and early 80’s.

6.2 Voltage Controlled Synthesizer

The Voltage Controlled Synthesizer offers a variety of control options to the composer, including dynamics, pitch and timbre. Its’ designs were often modular and were therefore also transportable, this contributed to its popularity. Previous to this time there were no lightweight units that could be taken out of the studio with ease. The Voltage Controlled Synthesizer owes much of these advantages to the transistor, invented in the 1950’s, however it lost much of its popularity in the 1980’s with the invention of the microprocessor.[31]

6.3 Music Instrument Digital Interface (MIDI) Synthesizer

The primary advantage of Musical Instrument Digital Interface (MIDI) synthesizers over the Voltage Controlled Synthesizer was its affordability. At a fraction of the cost it would take to make an analogue equivalent, the same synthesis options could be offered by specially fabricated chips. The circuits themselves use frequency modulation techniques to generate timbres rather than additive methods used previously by analogue counterparts. Considerable thought was given to the facilities for controlling the frequency and amplitude settings for each oscillator. Since a fundamental purpose of most synthesizer voices is that they will transpose across the keys consistently, the basic frequency settings for each oscillator are specified in the form of ratios that can be limited to simple multiples to create harmonically related spectra or complex sounds dependent on how the system is used[32]. A fundamental shortcoming to typical synthesis methods, is a “lack of any connection to the natural

[30] Synder. J, Music Concrete, Lebanon Valley College, 2002, web R. [4]
[31] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, pp.117-155
[32] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p.292

sound world and the processes of sound generation associated with it…"[33] This trait led to the invention of digital sampling techniques.

6.4 Digital Sampler

Recording sounds at one pitch and reproducing them scaled across a keyboard is fundamental to all samplers, as is the ability to process the sampled sounds before they are re-synthesized. Problems have been encountered in the past with the storage space needed to process and keep so many sounds in a system, however the technology to store complex files has been improved alongside the ability of the technology to carry out complex processes. One feature of the sampler where these advancements can be noted is their looping system. The prevailing problem with any looping system is that some sounds can not be subjugated to such treatment. A system that allows the user to adjust the start and end point of the loop is needed, furthermore, although the smoothest join will be near perfect, changes in the overall amplitude or pitch envelope of the sound, especially at the beginning or the end, will result in a pulsing which may be undesirable. The system must therefore be able to cross fade. Basic manipulations such as altering the attack and decay characteristic of a sound are also imperative to a good sampler, as they allow "sound sources to be dynamically shaped in a consistent manner."[34] Some further examples are: applying a Low Frequency Oscillator (LFO) to give a vibrato effect; setting the keys on the keyboard to respond to velocity. These latter methods help to improve the dynamic performance of the sampler.

6.5 The Computer

The computer can be regarded as the most important tool in composition today. Software methods are often used to manipulate sound with multiple variations. Programmes like 'Reaktor' and 'Absynth' are among the more popular examples, 'Reaktor' is a cross breed synthesizer, sampler and FX programme; 'Absynth' is a frequency modulator, ring modulator, envelope 'looper' hybrid synthesizer. When the computer is not used for synthesis, sampling or manipulating the sonic character of a wave, it is often used as a multi-tracker for digital audio. In such a system sound files can be arranged and corrected easily with visual representation that allows the user to see the wave. Examples of these sequencers are 'SoundScape'[35] and 'Logic Audio'[36]. Furthermore a computer can be used as a control system for live performances and for automatic music generation with the use of compositional algorithms.

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[33] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p.295
[34] Manning. P, Electronic and Computer Music 2nd Edition, Clarendon Press, 1993, p.295
[35] For more details see Web R. [16]
[36] For more details see Web R. [17]

7. New Sounds and Instruments

In electronic compositions the sounds are often modelled and shaped. However there exists no empirical method to working with the sound. Ned Boulassa describing his principles, demonstrates how varied these processes can be:

"Often how I use a sound will be directly related to its shape. But I also enjoy giving a new shape or texture to a sound using Digital Signal Processing (DSP)."[37]

The following sections investigate some methods that composers may use or might like to use when writing music. They are based around aspects of sound as my research has led me to believe this is an important feature of today's technology and compositions. Readers who wish to further investigate methodologies concerning the use of technology in music should refer to the Sound on Sound magazine[38]

7.1 Building a New Instrument

William Sethares [4] describes a working practice that the composer can adopt when using a sampler. In his example he uses recordings of the musical rocks from Chico Canyon in New Mexico. These rocks are non-harmonious and pitched ambiguously but are very resonant[39]. Figure 9.1.1, shows the waveform:

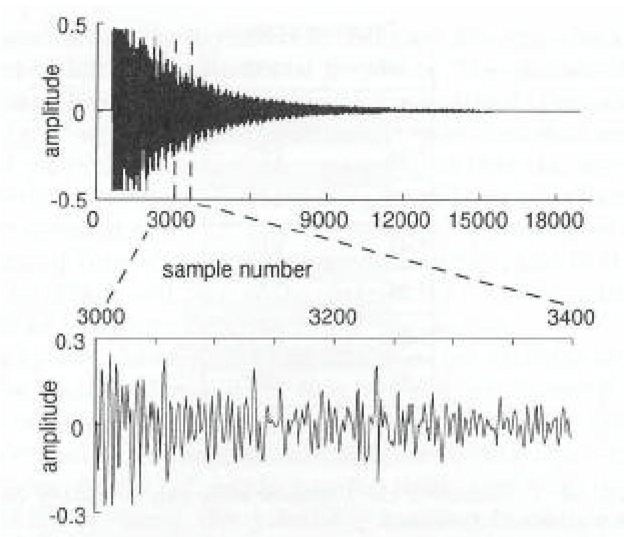


Figure 7.1.1: Typical waveform of the Chaco Rock when struck with by a hard mallet. A small portion is expanded to make the irregularity of the waveform more apparent[40].

[37] Owen. D, Interview with Ned Boulassa, University of Derby, 2002, p.2
[38] Sound On Sound, Media House, Trafalgar Way, Bar Hill, Cambridge, CB3 8SQ, United Kingdom
[39] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.131
[40] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.132

Using a pitch shift on the digital sampler to spread this sample across the keys, Sethares noticed some fundamental problems with the sound. Primarily, it degenerates in the high and low registers. Furthermore, whilst the instrument is fine for percussive playing, for denser pieces with sustained notes it becomes increasingly dissonant. It seems to him that the traditional twelve note scale on the keyboard is not suited for the sonorous quality of the rock[41]. In order to create a lithophone that is concordant, he returns to some basic Pythagorean principles - to discover the rocks' natural modes, and bases the scale that the lithophone is tuned to around them.

The first step is to take some samples that indicate the range of sounds that occur from striking the rock. This is a common practice when sampling sounds, and it is often important as you are not able to alter the way the sound expresses itself outside of the computer - in the natural world - after you have sampled it. Sethares settled on twelve different samples and took the Fast Fourier Transform (FFT) of them. Three examples are shown below:

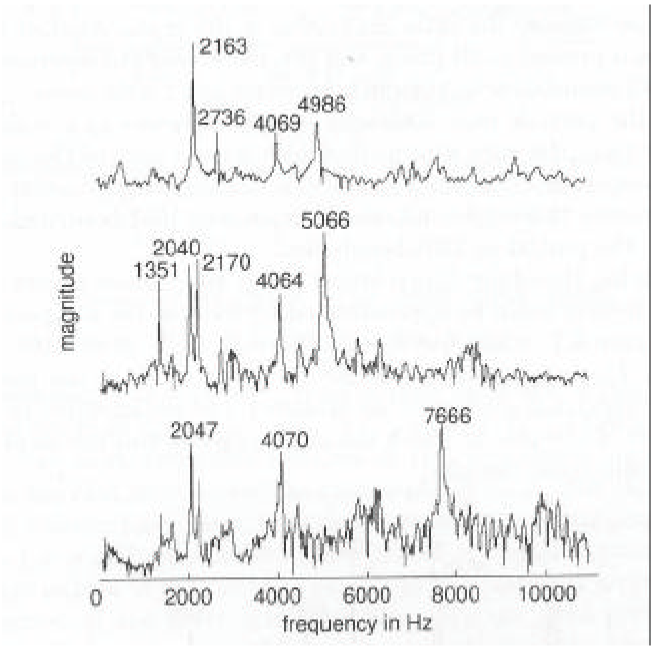


Figure 7.1.2: The harmonic spectra caused by three different strikes of the Chaco rock.[42]

These results are compared to one another in an attempt to identify the modes that are common in the rock. From the above examples, we can see some correlations: the mode at 4070Hz; and the loudest portion of the sound is between 2040 - 2200Hz40. We also see some differences: a strong partial at 7666Hz; and a partial at 1351Hz. Combining his observations from the twelve FFT's, he was able to draw up the following chart illustrating the full spectral envelope of the rock:

[41] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.131-133
[42] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.133

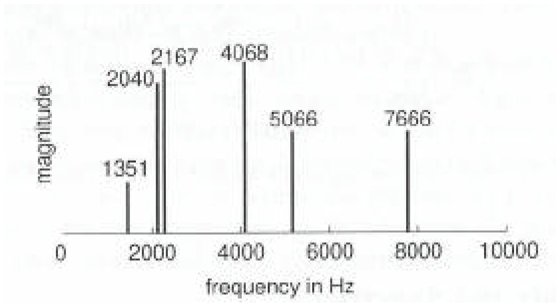


Figure 7.1.3: A composite line spectrum illustrating the acoustic behaviour of the samples. The inharmonicity of the rock, which was evident to his ear, is also apparent to the eye.[43]

The next stage is to draw the Dissonance curve. Instructions on how to build the dissonance curve are given in Sethares [4].[44] The Curve should be calculated over two octaves. An illustration of the curve is shown below:

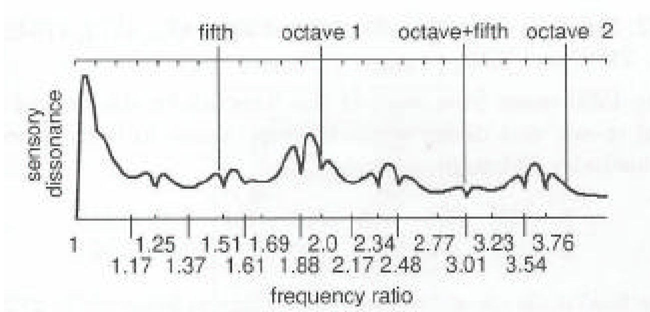


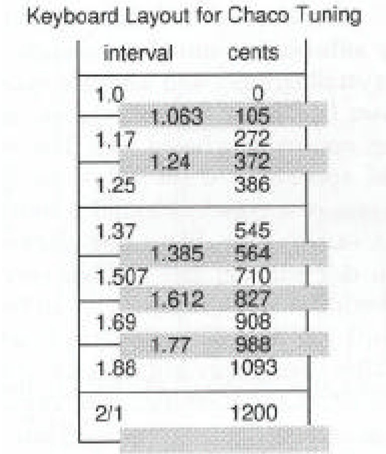
Figure 7.1.4: The Dissonance curve for the composite Chaco rock spectrum has 17 minima over two octaves. These are indicated on the lower horizontal axis. The upper axis illustrates the conventional 12 note octave scale.

The intervals are shown by the dips in the dissonance curves, and are the following values; 0, 273, 386, 545, 713, 824, 908, 1093, 1200, 1472, 1572, 1764, 1908, 2030, 2188 and 2293. Subtracting 1200 cents from the upper octave allows us to compare which intervals are common across both octaves and which are not.[45]

0	272	386	545	713	824	908	1093
0	272	372	564	708	830	988	1093

With some deductive manipulation it is possible to build a scale from these results that would suit the natural sonorous qualities of the rock. Shown below is the sample spread across the keys of the keyboard. We can see that Sethares added an extra note at 105 cents to bridge the gap between 0 and 272.

[43] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.134
[44] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, pp.299-302
[45] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.135



Keyboard Layout for Chaco Tuning

interval	cents
1.0	0
1.063	105
1.17	272
1.24	372
1.25	386
1.37	545
1.385	564
1.507	710
1.612	827
1.69	908
1.77	988
1.88	1093
2/1	1200

Figure 7.1.5: One possible layout for the Chaco rock over a keyboard. The value cents represents the tuning of each key, respective to a fundamental frequency f.[46]

Using the methods shown above, Sethares has constructed an instrument in the digital domain which is true to the natural harmonic spectrum of the rock. This instrument he would never have been able to build otherwise, as the Chaco Canyon is a nature reserve, and it would not be legal to take ten or so rocks and carve them into notes. The sampling method he used is known as 'Format Connected Sampling'.[47]

7.2 Representing the Acoustic Properties of Traditional Instruments with Digital Techniques

It is common for a composer to represent traditional instruments using electronic methods. These techniques involve both sampling and synthesis and will be done primarily for economic purposes. Accurate electronic representations of traditional instruments have allow composers to write music and ‘perform’ music that would otherwise be costly as it is often cheaper to use electronically manipulated sound files than hiring an orchestra and the space to record them in. An example where electronic methods have been used to represent traditional instruments for reasons other than cost is Giorgio Morodor score for 'Midnight Express'. His soundtrack won popular acclaim: his synthesised sounds seem to carry the emotion and tension of the film. It was recognised as one of the first solely electronic scores for a film; despite being put together in two weeks.[48] Electronic methods are therefore more suitable to media formats that might demand last minute alterations to the arrangement.[49]

[46] Sethares. W.A, Tuning, Timbre, Spectrum, Scale, Springer, 1998, p.137
[47] Sound on Sound, January 1999
[48] Music for Films, Heroism, Film Four Documentary, episode 1, 2002
[49] White. P, Interview with Nathan McCree and Mat Kemp ‘Music for Computer Games, *Sound on Sound*, May 2000, p.102

7.3 Principles of Accurate Representation

Whatever the reason for using electronic techniques, the composer must pay close attention to what is humanly possible when playing the real instruments. No matter how convincing the synthesised sound, the listener will be less able to picture the imaginary performer, if the performance of that sound is not modelled with the physical characteristics of the real instruments in mind. For example:

"...a flute player needs to breathe, so it is no good writing long passages with no breaks."[50]

The composer must recreate a sense of realness by accounting for the artefacts that would be present in the true performance. In the previous example of the flute player this might be done, by sampling a breath and placing that sample in the gaps. If the composition consists of a full orchestra, then it may help to position the 'instruments' in a virtual sound-space that is representative of the traditional seating arrangements in a performance[51], or in the case of a solo violin:

"…you have to know how the bowing works. For example, if you do a scale on one long bow stroke; it sounds quite different to playing the same line with alternating strokes. You can add life and dynamics by incorporating both types so the music progresses at different places… If you are writing a very agitated piece, you may want the bow action to be a lot quicker, whereas if it is a smooth, calming piece, you have to take into account your choice of string sound. It is not as simple as writing a string part, then moving the phrases into tracks assigned to the right kind of string sounds - you also need to play the sounds differently."[52]

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[50] White. P, Interview with Nathan McCree and Mat Kemp 'Music for Computer Games, *Sound on Sound*, May 2000, p.104
[51] White. P, Interview with Nathan McCree and Mat Kemp 'Music for Computer Games, *Sound on Sound*, May 2000, p.104
[52] White. P, Interview with Nathan McCree and Mat Kemp 'Music for Computer Games, *Sound on Sound*, May 2000, p.104

8. Composition in Sound

The practice of composing music with sounds that have been sonically manipulated by the composer is unique to the past 100 years. It has proliferated alongside the technology that is used to carry out the tasks[53] As Steve Knee states:

"Rather than being note based, or rhythmically based its just gone full circle and is based on sounds. Sounds that we can create. Soundscapes, where we can create anything. A lot of music, Future Sound of London is based on sound, rather than traditional music principles, and that has come full circle."[54]

The extent which composers can manipulate sound in their songs has been made possible by the recording medium. It only by capturing a sound on tape or Hard-disk that the composer is able to alter the sound in any way she pleases. Working with created sound has allowed artists such as the Future Sound of London, Aphex Twin, Brian Eno to design, not only new instruments, but new locations for them as well.

As Delia Derbyshire states:

"…my passion is to make original, abstract electronic sounds and organise them in an appealing, acceptable way, to any intelligent person."[55]

The influence of sound occurs on many levels within electronic music. Simply by recording a sound, you will create a difference between the original sound and the play back from the recording. This is called production, and the decisions made by the producer/engineer will affect the overall sound of the recording. For example, placing microphone (a) in a different place to microphone (b) will capture a different inflection from the instrument on the record:

[53] Sarig. R, Early Electronic Music Comes of Age, 2000, web R. [3]
[54] Interview by Owen. D, 'Steve Knee', Derby University, 2002, p.6
[55] Interview with Delia Derbyshire, 'Delian Mode', pansiecola, 2000, web R. [5]

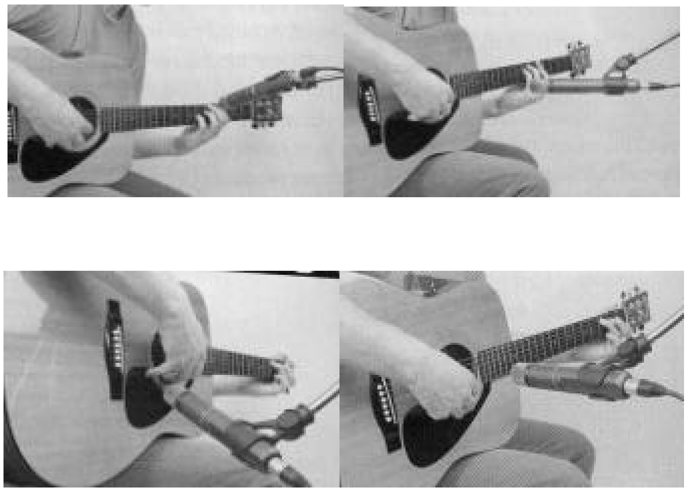

Figure 8.1: The capturing of sound from an acoustic guitar. From left to right: a) Microphone will pick up the treble areas of the guitar, and will accentuate the movement of the hand on the frets; b) will detect a mixture from the hole and the fret board; c) will accentuate the bass regions of the guitar sound hole; d) will detect the bass region from the guitar and the deeper resonances from the sound hole.[56]

Historically we see different styles of music from jazz to dance techno; from folk to grunge; each with their own engineers who have manufactured different sounds within these genres. Butch Vig and George Martin are among two examples. Their quintessential sounds have stemmed from the technology they used and the ways in which they used it. In today's music scene it is widely held that the difference between one record and another has as much to do with the technology and the production techniques used as it has with the content of the music.

"A fact of almost any successful pop record is that the sound is more of a characteristic than its melody or its chord structure or anything else. The sound is the thing that you recognise."[57]

8.1 The Sound Space

Sound occupies an abstract space; different sounds will 'fit' in, different places on a record:

"Electroacoustic sounds can and should be any sound really, so the question is not so much what to combine, but rather what to leave out. Often, the problems are more technical than poetic. If you have a really heavy, in-your-face techno beat, chances are there's not much room in the frequency spectrum for anything else, certainly not

[56] Sound on Sound, August 2001, p146
[57] Quoted in Stevenson. B, Paintings in Sound [1], Dissertation Victoria University of Manchester, 1997, p.26

something subtle. So then it's a question of filtering the beat to make room for other sounds."[58]

The following diagrams illustrate the spaces that different instruments might fill, I have returned to conventional instruments to illustrate this because very little work has been carried out on the spaces that electronic sounds occupy. Figure 8.1.1, illustrates the 3 dimensional spaces that different instruments occupy dependent on their timbre and pitches. Figure8.1.2 shows the dimensional space that traditional instruments occupy in the frequency domain:

[58] Interview with Ned Boulassa, M-Station, 2002, web R. [6]

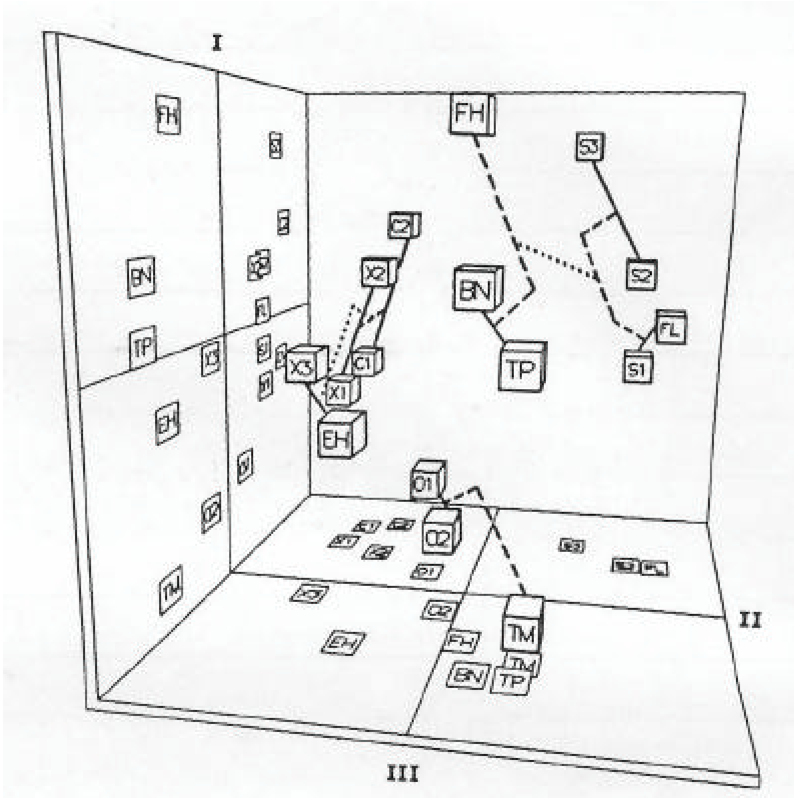

Figure 8.1.1: Greys timbre space. Musical instruments are laid out by similarity in three dimensions. Instruments: O, oboes; C clarinets; X, saxes; EH, English horn; FH, French horn; S, strings; TP, trumpet; TM, trombone; FL, flute; BN, bassoon. The purpose of this graph is to illustrate the manner in which an Oboe is related to a trumpet in three dimensional space.[59]

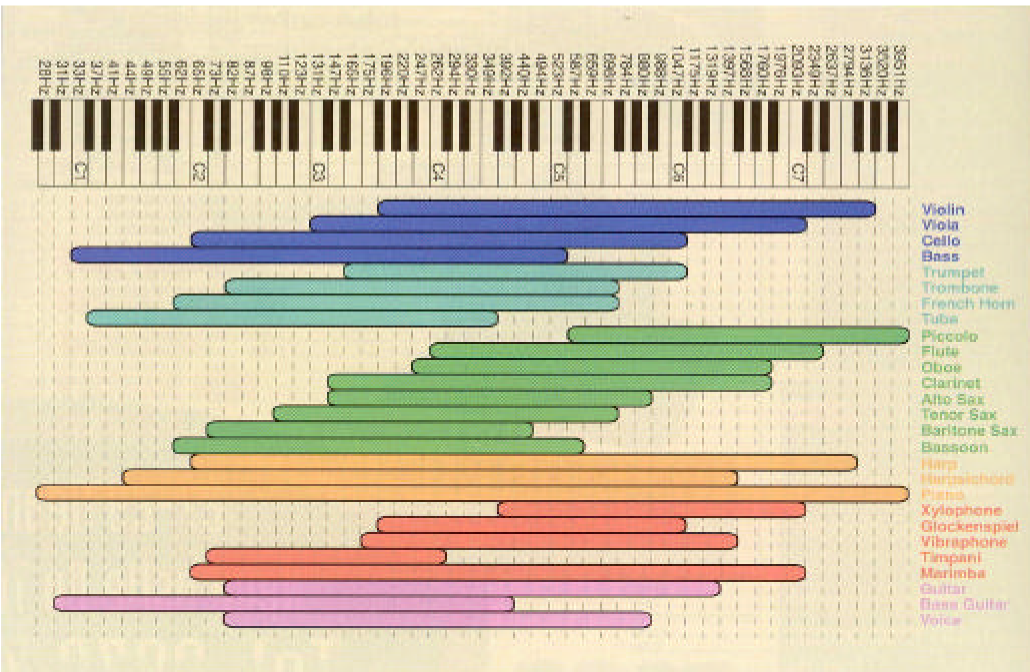

Figure 8.1.2: An illustration of the frequency that traditional instruments occupy.[60]

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[59] Mathews. M, Introduction to Timbre, Music, Cognition, and Computerized Sound, MIT Press, 1999, p.86

[60] Sound on Sound, May 1998, p146

Equalisation is a tool that can be used in a variety of ways to mould Soundscapes. The following example is taken from Sound on Sound magazine and illustrates the manner in which E.Q is utilized to bring out varying sonic characteristics from a single sound source:

Instrument	**Frequency Boost**	**Results**
Bass Drum	80 - 100Hz	Brings out a meaty characteristic of AC/DC's 'Black in Black' and Britney Spears 'Baby One More Time'
	200 – 300Hz	A warmer sound, such as those in James Brown 'I Got You (I Feel Good)'
	2.5 – 6kHz	Emphasises the click of the beater. An aggressive sound like in Madness 'My Girl'
Snare	120 – 400Hz	The fatness of the drum. See AC/DC and Britney Spears examples
	800Hz – 1.2 kHz	A boxy sound like in Guns & Roses song 'Sweet Child of Mine'
	2 – 4kHz	The resonance of the drums 'ringing' is found here, example is Bob Marley's 'Get Up Stand Up' and other Reggae tracks
Tom - Toms	100 – 300Hz	A fuller sound
	1 – 3kHz	The 'ringing' and 'rattling' of the skins, as evidenced in Iggy pop's 'Lust For Life'
	4 - 8kHz	The attack of the drum is emphasised also evident in Iggy Pop 'Lust For Life'
Cymbals	100 – 300Hz	Can help to emphasise the clunk of the stick against the ride or high-hat, noticeable in Donavan's 'Mellow Yellow'
	1 – 6kHz	Emphasised ringing overtones of crash and ride cymbals, example: Led Zeppelin's 'Rock & Roll'
	8 – 12kHz	Emphasised sizzle character, example: Metallica's 'Enter Sandman

Table 8.1.1: Equalisation can be used to bring out different sonic characteristics from the individual drums of a drum kit. Adapted from Sound on Sound[61]

The ability to alter the characteristics of a sound in this manner allows the possibilities of intertextuality in music: Records can be produced that sound like they are from different eras this is demonstrated in Robbie William's album *'Swing when you are winning'*, where the entire album is reminiscent of 'Big Band' from the 1950's.

[61] Sound on Sound, January, 1998, p156

Brian Eno has attempted to use electronic techniques in an attempt to find a new space for music in our lives. Music for Airports [1978] is an album 'designed' for the airport - the music is supposed to soften the hard edges of the environment - to allow people the space to think whilst fitting into the functionality of the airport:

"I started to think what kind of music would work. It was clear that the music would need to be able to withstand interruption...and it would have to be something that didn't need to be loud...I realised that I'd have to work in frequency ranges that did not conflict with conversation...The idea was to try to suggest that there were new places to put music, new kinds of niches where music could belong."[62]

This type of ambient music was designed to be a part of the environment, to soften the clanging of knives and forks, to neutralise the noise from the streets, and fill in the pauses in conversation. It had to therefore, withstand attention, i.e. not to be boring, yet at the same time not distract one's attention from the tasks at hand. Electronic production/composition techniques were used by Eno to mould and make his music fit into these situations and contexts.

8.2 Emotive Sound

In addition to occupying a space, sound also has an emotional dimension. Consider a fly buzzing around the room, and a car passing outside your window. Auditory scene analysis enables you to enables you to successfully decode the location of each sound source, but the effects of audio stimuli do not stop there. The sound of the fly buzzing around your room is likely to conjure a different emotional response to the car passing. These responses to sound are intrinsic to our nature and are personified by a mother's response to her baby's cry. When I asked Jeff Rona whether he found himself working with sound shapes and (emotional) textures, his reply was:

"Absolutely, I always look for sounds that will evoke emotion and response from the audience."

To comprehend the differences that sound has made to music, one should consider the difference between musical sounds, such as a trombone, a violin, and natural sounds such as a dog's bark and a door slamming closed. The former we are used to hearing for their musical value, the latter we hear by 'reference to their instrumental causes'.[63] Thus a loud bang could be a gun sounding, a tyre bursting or a teenager kicking a ball against a wall made from corrugated iron. Our response to different sounds is likely to depend on a range of variations such as our emotional state and the atmosphere of

[62] Interview with Korner. A, 'Aurora Musicalis', Artforum xxiv: x, 1986, quoted in Stevenson. B, 'Paintings in Sound' [1], p.18
[63] Hodgkinson. T, Pierre Schaeffer, Recommended Records Quarterly Magazine Volume 2 number 1, 1987, web R. [2]

the music. However the range of emotions that are carried forth by music has been heightened by the availability of manipulated sound.

Presently, our responses to sounds remain a scientific mystery, the research in this field is found in two formats "music aesthetics" which deals with emotive/affective responses to music from a theoretical perspective and "experimental aesthetics", which deals with emotion and cognition.

8.3 Influence of Sound Recording and Manipulation of Sound on Composition

The differences between music and our natural sound world have become less distinct. This is shown in Lars Von Trier's musical Dancer in the Dark. The main character in this film is suffering from an eye disorder and is slowly going blind, but she is enveloped in a world of sound and music. The soundtrack itself draws on the sounds from the film and transposes them into rhythms: the music occurs in the factory and the rhythm section you hear is based around the noise of the machines. Another example of this being done is by Penguin Cafe where the sound of a dialling tone is intersected by an engaged tone, and this forms the melodic and rhythmic structure of the song. The song is called 'Telephone and Rubber Band', *(C.D. track (4))*.

Both the previous examples use sounds that have been manipulated in order to make them more pleasing to the ear although they still retain enough of their original source to give impressions of what they are. It is also common for electronic composers to build sound worlds that have elements of fantasy, where the sounds are based on something outside of our natural world:

"One (philosophy) that interests me is the use of electronics to transform sounds that we're used to. I think of Luc Ferrari's "Presque Rien" in which a day at the beach becomes a surreal collage. I think there's a lot of room for creating a new fantasy world out of the elements we already know"[64]

The range of music styles we encounter has been increased to include influences from all over the world because we can record their sounds and their songs. The influence of this on western music can be seen on an instrumental level, where samples from ethnic instruments are used in composition; or on a holistic level where the structures and ambience of exotic music influence our own structures:

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[64] Gross. J, ‘Kyle Gann Interview’, Furious Green Thoughts, 2002, web R. [7]

"Nonlinearity [in music] prevails to a much greater extent in the repertoire of the twentieth-century. This sudden increase was nurtured by two significant factors: the influence of non-Western Music and the impact of sound recording technology."[65]

The composer, who writes music using electronic methods, does not necessarily need to play a conventional instrument, as songs can be composed in small steps where the composer fits sounds into where they should be played. The medium has therefore opened the gates of music to a larger variety of people. Furthermore electronic technology has given the composer total control over the sounds in her songs, and has provided the composer with a means to create music which is unplayable:

"Until we can play the kind of pitch distinctions on acoustic instruments that I can do on synthesizers, I'm going to have to always generate my music electronically...There's also rhythms that I'm extremely interested in hearing that I can't do any other way." [66]

Recorded sound is therefore a major tool in modern day composition and can be an inspiration for the composer to write different material:

"I often begin a project by creating a sonic palette for the film. It will grow over the course of the project but it gets me started."[67]

"New synthesizers are often a major influence for new tracks, because it's new sounds which cause you to fire of in different directions."[68]

8.4 New Methods of Composition

The range of formats that music is incorporated and the range of styles that are associated with these formats have caused a variety of unique compositional methods to emerge. Nathan McCree composer for Tomb Raider explains what it is like to compose for a computer game:

"We are actually given very little at the start of a job. Most of the time I have to work from a single word. They might say they want something to go with the jungle level of a game and you have to go away and write something that might fit in with a jungle scene. Or they might tell me she goes on a ship at some point, and off you go again...I tend to concentrate on a section a few bars long, then I'll add the different instruments

[65] Stevenson. B, Paintings in Sound : Vertical Time in the Ambient Music of Brian Eno, Dis. Victoria University of Manchester, 1997, p.30
[66] Gross. J, 'Kyle Gann Interview', Furious Green Thoughts, 2002, web R. [7]
[67] Interview by Owen. D, 'Jeff Rona', University of Derby, 2002, p.2
[68] Interview by Owen. D, 'Steve Knee', University of Derby, 2002, p.2

until that section is complete. When I've got that, I'll work around the edges by adding sections before or after what I've just written and grow the piece like that." [69]

The methods used to build a sound are often labour intensive and a great deal of attention can be paid to the details. Delia Derbyshire describes that she often had the feeling of music growing quite slowly whilst putting it together.[70] Endeavouring to understand the way that composers might work with technology, I asked Ned Boulassa about some of the techniques he used in composition:

"I don't think that I 'create' sounds really. I'm not interested in synthesizing materials using things like CSound or MSP. I like to take sounds that already exist and manipulate them using real-time plug-ins and other dsp software. I often generate textures by playing with parameters of effect plug-ins in real-time and then editing the 'best' parts afterwards. That's also the way I work with musicians. I like to record them improvising over a basic track that I've written, and then I'll build the 'melodies' using bits and chunks that I like."[71]

Track 2/1, on Music for Airports by Eno *(CD track (8))* uses Looping for a slightly different purpose. The song consists of human voices singing 'Ah' which have been electronically treated and seven tape loops of lengths ranging from 17 to 31 seconds. Each loop is recorded with a different five second pitch and given separate positions in the stereophonic sound-field. The tape loops are left to repeat and they play at various moments in time - sometimes they are clustered together leaving periods of silence, other times they meet to form melodic patterns - but in the eight minuets and twenty-five seconds of music they never repeat the same phrase. The notation of this track is included in the appendix B.

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[69] White. P, Interview with Nathan McCree and Mat Kemp 'Music for Computer Games, *Sound on Sound*, May 2000, p.101
[70] Interview with Delia Derbyshire, 'Delian Mode', pansiecola, 2000, web R. [5]
[71] Interview by Owen. D, 'Ned Boulassa', Derby University, 2002, pp.1-2

9. Notating Electronic Music

9.1 Should We Notate Electronic Music

Most composers who use a high concentration of electronic methods in their compositions do not notate their music. Of 40 responses not one claimed to notate the noises or sounds that have been created. The results of the Questionnaire are presented below, the questions asked can be found in the Appendix.

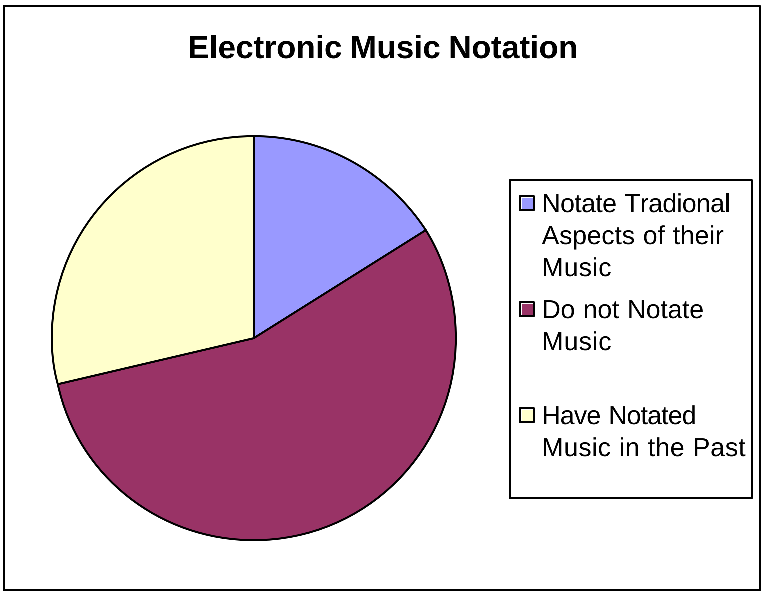

Figure 9.1: Pie chart indicating the percentage of those questioned who notated their music. In total, forty composers where asked[72]. See Appendix C

A common reason why composers do not notate electronic music is because they have alternative methods to store their music - on computers and storage C.D.'s. The argument that conventional notation is unsuitable for notating electronic music is prevalent and it would therefore not be used as a means to compose a song. When asked why he does not notate his music Brian Siskind of 'Fognode:::', stated the following:

"The music is too improvisational and atonal -- plus with field recordings and other elements it makes notation impossible..."[73]

There also exists among some composers a rejection of the notation form:

"I write music for speakers, not for paper..."[74]

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[72] Owen. D, 'Questionnaire on notation', see Appendix C
[73] Owen. D, 'Quantative Questionnaires', University of Derby, 2002, example 023

Jeff Rona summarizes the general trend, when he writes:

"No composers I know, myself included, are creating written documents of our electronic scores. There is no need for it, and more or less no interest."[75]

However, the composer might notate his music if it is necessary to communicate it to a performer. In such cases the noise elements are not notated:

"…it is done when it is needed. And the parts of the score that are not played by humans are not transcribed in any way. So odd, strange noise elements are not looked at."[76] "If I do have a soloist in the studio with me, I've even just put the music on-screen and have them look over my shoulder."[77]

9.2 Examples of Electronic Notation

Despite the prevailing rejection of notation methods there are still some interested in this field. Brian Eno often notated his music; some examples are included in the Appendix B for the reader's reference. Example 1 is of track 2/1 on Music for Airports, the methods used to create this track are described in section 8.4 and should be compared to the notation which represents the manner in which the song is constructed. This song is included on the C.D. for your reference *(C.D. track (8))*. However in more complex songs the composer would need to choose a method of notation that could represent the finer points (timbre, un-scaled pitches) in the music. The preferred method among many composers is of graphical notation, an example of track 2/1 is shown in Appendix B example 2.

Graphical notation must represent three things that conventional notation cannot:

1. Timbre
2. Timbral Changes
3. Enharmonic Pitches

1. The composer who wishes to transcribe his music graphically, must first identify and define the timbres used in the song. This is often done with descriptive words which are associated with the sounds, for example Andrew Lewis [7] finds 9 different sound groups in Francias Dhomonts Novars these include Door Creaks and Slams, Filter-Swept Chords/Resonances, Granular noise bands. These groups can then be

[74] Correspondence with Ned Boulassa, University of Derby, 2002
[75] Interview by Owen. D, 'Jeff Rona', University of Derby, 2002, p.2
[76] Interview by Owen. D, 'Jeff Rona', University of Derby, 2002, p.1
[77] Interview by Owen. D, 'Jeff Rona', University of Derby, 2002, p.1

represented using a specific colour and shade, which enables the timbre to be identified when it is transcribed. Please refer to Appendix B, Example 5.

2. It is very important to note that timbre is not static and may change overtime. This is illustrated on conventional notation using lines to represent crescendo, piccolo etc Wendy Carlos has adapted these methods into her own electronic notation. She often uses symbols or words to show how the timbre is affected at that point in the music, for example by filter-sweeps see Appendix B, Example 6. Andrew Lewis adopts a different method. By analyzing the music and identifying the timbral changes that are present in the piece, he groups them according to their characteristic. He calls these groups 'behavioural types', some examples [78] are discussed below, the reader should refer to Andrew Lewis's Notation of Novars for further details:

1. Rapid judder - rapid rhythmic modulation of otherwise continuous sounds (example 10), see Andrew Lewis Notation of *Novars* in Appendix B.

2. Stable pitches – the opening sounds in the piece exhibit this behaviour

3. Phased pitches – the introduction of moving bands of phase shift with varied degrees of resonance turns otherwise stable structures into mobile and flexible entities, and relatively simple profiles to complex ones.

4. Resonant filter – a spectral modification, this behaviour can be applied to entire musical phrases without disturbing the essential features by which the original material can be recognised (Ex. 11), see Andrew Lewis Notation of *Novars* in Appendix B.

Finally to overcome the notation of un-scaled pitches that can not be separated into discrete steps (as note are on conventional notation), Lewis makes use of the vertical axis with the higher pitches shown at the highest point and the lowest pitches shown at the lowest point. Whilst this does not give information about the specific pitches of the sounds, it presents the reader with an idea of the overall soundcape.[79] The methods of Andrew Lewis and his final result is intended as a tool for the visual study of music, not for its performance[80].

[78] Lewis. A, Francis Dhomont's Novars, *Journal of New Music Research*, Vol. 27, No. 1-2, 1998 pp.75-77

[79] Lewis. A, Francis Dhomont's Novars, *Journal of New Music Research*, Vol. 27, No. 1-2, 1998 pp.77-80

[80] Lewis. A, Francis Dhomont's Novars, *Journal of New Music Research*, Vol. 27, No. 1-2, 1998 p 80

9.3 The Timbral Approach

In the following I suggest an improvement to the method discussed in section 9.2. The following method is pioneered by K. Jensen [5] and is in the very early stages of development, however has it yielded some promising results. In his Thesis, Jensen identifies the following attributes of sound as being imperative to timbre recognition, classification and synthesis. They are as follows:

***The spectral envelope attributes*:** brightness, tristimulus, odd, and irregularity;

***The temporal envelope attributes*:** attack and release relative amplitude, duration and curve form, the sustain frequency

***The irregularity attributes*:** amplitude irregularity standard deviation, bandwidth and correlation and the inharmonicity.

Although he studied others, these twelve are imperative to differentiating[81], classifying[82] and re-synthesizing timbre. Each timbre attribute can be analysed using summation equations, these are derived in [5]. For example the estimated Brightness is found by:

$$? \, k a_k / ? \, a_k$$

k = the partial
a_k = maximum amplitude of the partial

Figure 9.3.1: Summation equation used to find the estimated brightness of a harmonic waveform.[83]

The formula returns a value known as the estimated brightness; likewise values can be determined for all of the other Timbre attributes, and once collected the data can be used to re-build the original sound or classify the sound. Jensen has tested his 'Timbre Model' on acoustic instruments with some rewarding results[84]. Figure 9.3.2 shows how the collected data is used to re-synthesize the sounds:

[81] Jensen. K, *Timbre Models of Musical Sounds*, PhD. Dissertation, DIKU Report 99/7, 1999, pp.1-247, web R. [11]
[82] Jensen. K, Arnspang. J, Binary Decision Tree Classification of Musical Instruments, Proceedings of the ICMC, Beijing, China, 1999, web R. [9]
[83] Jensen. K, *Timbre Models of Musical Sounds*, PhD. Dissertation, DIKU Report 99/7, 1999, pp.127, web R. [11]
[84] Jensen. K, Timbre Models of Musical sounds. Ph.D. dissertation, Department of Computer Science, University of Copenhagen, 1999, pp.185-199, web R. [11]

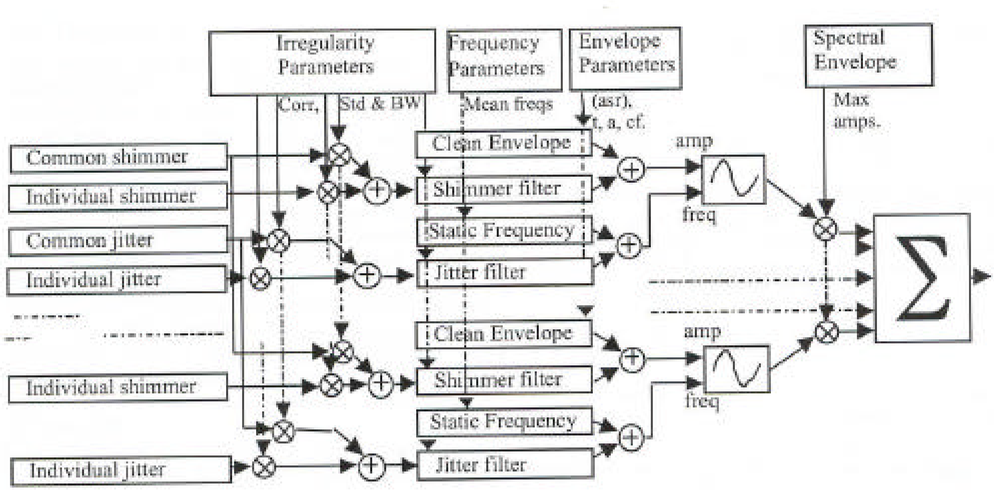

Figure 9.3.2: Timbre model diagram. "The model consists of a number of sinusoidals, with amplitude as a sum of the clean envelope, and the frequency as a sum of the static frequency and the jitter. The shimmer and filter are a sum of common (correlated) and individual Gaussian white noise filtered and scaled by the standard deviation." [85]

As of yet the Timbre Model requires some further development before it is able to recognise percussive, and inharmonious sounds[86], but potentially the techniques used by Jensen could be applied the sound types of electronic compositions. The information collected could form a legend for notation, whereby the sounds could be re-synthesized by the aspiring composer.

[85] Jensen. K, *The Timbre Model*, Music Informatics Laboratory University of Copenhagen, 1999, web R. [8]

[86] Jensen. K, *The Timbre Model*, Music Informatics Laboratory University of Copenhagen, 1999, web R. [8]

10. Live Performance

The use of electronic technology in the studio has meant that composers have a new set of considerations concerning the performance of that music on stage. The following is a quote from Air; it typifies some of the concerns of a live performer who uses a high concentration of electronic methods to make their albums:

"…we don't want to use programming on stage when we play. It means we have to play everything ourselves. This has created technical problems, and with so many different sounds and experimental pieces it also meant we've spent the last couple of mouths solid in rehearsals for the tour."[87]

Technology has also been used to enhance the performance. Damon Albans Gorilaz has utilised video syncing techniques to the extent where the audience do not know the identity of the performers, as the musicians play behind a screen which has images of cartoon characters projected on them. These characters are completely synced with the live performance. Steve Knee, uses similar syncing methods to create a wholly different live performance, he describes his motivations:

"The thing was to try and break down the standard formats for performance. So we've got, standard stage to audience relationship in almost everything we see, I did not like that - I wanted to give people a choice...a different experience for everyone depending on where they are within modules...We've got six screens of visual, four stages with musicians on, lighting lasers, depending on which reincarnation you see, there is sound going here there and everywhere..."[88]

His dissatisfaction at the way audio and visuals are erroneously bolted together in live performance led him to come up with a new solution to audio/visual synchronisation using midi triggers.

[87] Rea. J, France Clamour, *City Lights October*, 2001, pp.12-14
[88] Interview by Owen. D, 'Steve Knee, University of Derby, 2002, p.4

11. The Technology

11.1 Cyber-scripts

A Cyber-script is a presence in most technological systems; it is a language that is to some degree universal and allows the user to navigate different systems. A user who is familiar with technology, will be able to learn new equipment simply by navigating the device and coming to terms with its function; whereas the unfamiliar user may need to refer to the instructions. Furthermore, should a problem arise with the equipment, providing the user is familiar with technology she will be more likely to understand the root cause and the solution for the problem despite having never experienced technical difficulties on that specific device.

"Cyber-scripts are presences that more or less inhabit technological systems depending on the consciousness levels of the original creators of the technology and the attitudes of the users of the technology."[89]

I was interested to find out more about the relationship between the composer and his technology, and asked Steve whether he felt he was overwhelmed by his technology:

"Not at all; never. Because of the way I have built up my own set-up...I built it up from first principles."

This benefit of knowing your kit well is insinuated by Jean Benoit of air:

"You have to love your machines to know how to use them properly[90]"

11.2 Negative Effects of Technology

Eduardo R. Miranda [3] describes how music made with technology can overtake our evolutionary status. Thus if composers begin making music at the microscopic level our ears will not be fully able to appreciate it. Therefore some composers may introduce more random elements into their work to maintain a human element:

"I think emotion is best expressed by doing minimal composition…[we] try to keep each track as close to one-take as possible, eschewing demos and remixes…"[91]

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[89] Pellegrino. R, Compositional Algorithms as Cyberspirit Attractors, The Electronic Arts of Sound and Light, 1998, web R. [11]
[90] Rea. J, France Clamour, *City Lights October*, 2001, pp.12-14
[91] Rea. J, France Clamour, *City Lights October*, 2001, pp.12-14

There must also be limits that the composer places on herself with the technology in her studio:

I'm dead keen on limiting my resources...You need to have discipline in order to be truly creative. If you're just given total freedom to do anything you like...then you become confused because you want to do everything all at once...You've got to impose some discipline on either the form you're going to use or he sounds you're going to use."[92]

Aphex Twin even went so far as selling a lot of his equipment, because it was presenting him with too many options at once. I noticed a disappointing and potentially harming effect that is directly the result of having too much equipment in my interview with Steve Knee when asked 'how far do you move away from the factory presets, on your hardware?'

"Less, now that I have got more kit."[93]

11.3 The Future of Technology

This report has accounted for the history of electronic technology up to the present day, but about the future we can only look at new developments such as 'Format Corrected Sampling' and second guess the emergence of new technology within the next five years. Further into the future we can not see, although Ned Boulassa highlights one possible development:

"I want to manipulate sound in 3D with my hands, like a sculptor manipulating clay. I want to stretch a sound in time by stretching it in space. I want my wall to be my score. I want to compose a beat by bouncing a drum loop up and down, like a basketball. I want to filter a flute sound by cupping my hands together. I want to chew a string loop in my mouth and spit out the resulting mangled file."[94]

[92] Interview with Delia Derbyshire, 'Delian Mode', pansiecola, 2000, web R. [5]
[93] Interview by Owen. D, 'Steve Knee, University of Derby, 2002, p.3
[94] Interview by Owen. D, 'Ned Boulassa', University of Derby, 2002, p.3

12. Analysis and Discussion

The true extent that electronic technology has affected the music of the 20^{th} Century has been illustrated throughout this report. Beginning with the early investigations into the ‘Science of Sound’ in Ancient Greece, the report has shown the key developments that have led to the requisition of music by electronic technology. The report then focussed on the influences that electronic technology has over our music composition and production, relating to the reader some examples (such as the music by Brian Eno), that are indicative of the changes that electronic technology has caused. In order to demonstrate some of these changes, the report describes how electronic techniques have caused a metamorphosis of music that has meant it is no longer possible to notate music using traditional formats. Finally, the report investigates some methods that the composer and the producer may use to create audio stimuli, within their electronic compositions. The avenues opened to the composer from the use of electronic technology are explored within each section.

The topic areas of this report are multi-dimensional, and many of these dimensions are investigated in surface detail, to do otherwise would involve using many more words and require an increased time limit from those declared as standard by the University of Derby. Such topics that would be open to further investigation include the subtleties of timbre and the different responses of the brain to different natural sounds; possible methods of notation for Electronic Music and detailed technical accounts of selected devices from the music studio. The report aimed at giving substantial information to the reader who has previous experience in this field, simultaneously, it should be comprehensible to the novice who has had no prior experience of electronic technology. In order to satisfy this arrangement references to further information are included throughout.

13. Conclusion

Electronic Composition Techniques have diagrammatically altered the range of sounds available to the composer to make music with, this has been made possible by especially dedicated electronic technology. Including the existing instruments, composers can mould sound files into any shape and any texture using Digital Signals Processing. Digital Signal Processing methods are available in a variety of carnations on both Hardware and Software formats, offering the composer greater choice than ever before. Furthermore, the composition techniques a composer can use to organise the sounds she makes with these techniques, are varied and the electronic technology has been built around their needs.

The extent of the changes, can be seen when we compare music notation of old, to today's situation where music can sometimes be too complex to notate on the stave. Thus the use of traditional notation in composition has been superseded by electronic methods which allow the composer total control over every aspect of their music. This in itself has led to a different set of concerns. Today's composer must ensure their music retains some sense of the 'human element', and that live performances are essentially, as 'live' as any performance with acoustic instruments. Furthermore, should the composer wish to represent traditional acoustic instruments in their songs they must return to the actual characteristics of those instruments and model the synthesised performance on the real artefacts.

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Appendix A

HISTORY OF ELECTRONIC AND COMPUTER MUSIC INCLUDING AUTOMATIC INSTRUMENTS AND COMPOSITION MACHINES

2nd century, BC. The Hydraulis was invented by Ktesibios sometime in the second century B.C. Ktesibios, the son of a Greek barber, was fascinated by pneumatics and wrote an early treatise on the use of hydraulic systems for powering mechanical devices. His most famous invention, the Hydraulis, used water to regulate the air pressure inside an organ. A small cistern called the pnigeus was turned upside down and placed inside a barrel of water. A set of pumps forced air into the pnigeus, forming an air reservoir, and that air was channeled up into the organ's action.

Greek Aeolian harp. This may be considered the first automatic instrument. It was named for Aeolus, the Greek god of the wind. The instrument had two bridges over which the strings passed. The instrument was placed in a window where air current would pass, and the strings were activated by the wind current. Rather than being of different lengths, the strings were all the same length and tuned to the same pitch, but because of different string thicknesses, varying pitches could be produced.

5th-6th centuries BC, Pythagorus discovered numerical ratios corresponding to intervals of the musical scale. He associated these ratios with what he called "harmony of the spheres."

890 AD Banu Musa was an organ-building treatise; this was the first written documentation of an automatic instrument.

ca. 995-1050, Guido of Arezzo, a composer, developed an early form of solmization that used a system of mnemonics to learn "unknown songs." The method involved the assignment of alphabetic representations, syllables, to varying joints of the human hand. This system of mnemonics was apparently adapted from a technique used by almanac makers of the time.

1400s The hurdy-gurdy, an organ-grinder-like instrument, was developed.

Isorhythmic motets were developed. These songs made use of patterns of rhythms and pitches to define the composition. Composers like Machaut (14th century), Dufay and Dunstable, (15th century) composed isorhythmic motets. Duration and melody patterns, the talea and the color respectively, were not of identical length. Music was developed by the different permutations of pitch and rhythmic values. So if there were 5 durations and 7 pitches, the pitches were lined up with the durations. Whatever pitches were 'leftover,' got moved to the first duration values. The composer would permute through all pitches and durations before the original pattern would begin again.

Soggetto cavato, a technique of mapping letters of the alphabet into pitches, was developed. This technique was used Josquin's Mass based on the name of Hercules, the Duke of Ferrara. One application of soggetto cavato would involve be to take the vowels in Hercules as follows: e=re=D; u=ut=C (in the solfege system of do, re, mi, fa, etc., ut was the original do syllable); e=re=D. This pattern of vowel-mapping could continue for first and last names, as well as towns and cities.

1500s The first mechanically driven organs were built; water organs called hydraulis were in existence.

Don Nicola Vicentino (1511-1572), Italian composer and theorist, invented Archicembalo, a harpsichord-like instrument with six keyboards and thirty-one steps to an octave.

1600s Athanasius Kircher, described in his book, Musurgia Universalis (1600), a mechanical device that composed music. He used number and arithmetic-number relationships to represent scale, rhythm, and tempo relations, called the Arca Musarithmica.

1624 English philosopher and essayist, Francis Bacon wrote about a scientific utopia in the New Atlantis. He stated "we have sound-houses, where we practice and demonstrate all sounds, and their generation. We have harmonies which you have not, of quarter-sounds, and less slides of sounds."

1641 Blaise Pascal develops the first calculating machine.

1644 The Nouvelle invention de lever, an hydraulic engine produced musical sounds.

1738 Mechanical singing birds and barrel organs were in existence.

The Industrial Revolution flourished. There were attempts to harness steam power to mechanical computation machines

1761 Abbe Delaborde constructed a Clavecin Electrique, Paris, France.

Benjamin Franklin perfected the Glass Harmonica.

Maelzel, inventor of the metronome, and friend of Beethoven invented the Panharmonicon, a keyboard instrument.

1787 Mozart composed the Musikalisches Wurfelspiel (Musical Dice Game). This composition was a series of precomposed measures arranged in random eight-bar phrases to build the composition. Each throw of a pair of dice represented an individual measure, so after eight throws the first phrase was determined.

1796 Carillons, "a sliver of steel, shaped, polished, tempered and then screwed into position so that the projections on a rotating cylinder could pluck at its free extremity," were invented.

1830 Robert Schumann composer the Abegg Variations, op. 1. This composition was named for one of his girlfriends. The principal theme is based on the letters of her name: A-B-E-G-G--this was a later application of a soggetto cavato technique.

1832 Samuel Morse invented the telegraph.

1833-34 Charles Babbage, a British scientist builds the Difference Enginer, a large mechanical computer. In 1834, he imagines the Analytical Engine, a machine that was never realized. Ada Lovelace, daughter of Lord Byron, assisted in the documentation of these fantastic devices.

1835 Schumann composed the Carnaval pieces, op. 9 , twenty-one short pieces for piano. Each piece is based on a different character.

1850 D.D. Parmelee patented the first key-driven adding machine.

1859 David E. Hughes invented a typewriting telegraph utilizing a piano-like keyboard to activate the mechanism.

1863 Hermann Helmholtz wrote the book, On the Sensations of Tone as a Physiological Basis for the Theory of Music. Historically this book was one of the foundations of modern acoustics (this book completed the earlier work of Joseph Sauveur).

1867 Hipps invented the Electromechanical Piano in Neuchatel, Switzerland. He was the director of the telegraph factory there.

1876 Elisha Gray (an inventor of a telephone, along with Bell) invented the Electroharmonic or Electromusical Piano; this instrument transmitted musical tones over wires.

Koenig's Tonametric was invented. This instrument divided four octaves into 670 equal parts--this was an early instrument that made use of microtuning.

1877 Thomas Edison (1847-1931) invented the phonograph. To record, an indentation on a moving strip of paraffin coated paper tape was made by means of a diaphragm with an attached needle. This mechanism eventually lead to a continuously grooved, revolving metal cylinder wrapped in tin foil.

Emile Berliner (1851-1929) developed and patented the cylindrical and disc phonograph system, simultaneously with Edison.

Dorr E. Felti, perfected a calculator with key-driven ratchet wheels which could be moved by one or more teeth at a time.

1880 Alexander Graham Bell (1847-1922) financed his own laboratory in Washington, D.C. Together with Charles S. Tainter, Bell devised and patented several means for transmitting and recording sound.

1895 Julian Carillo's theories of microtones, 96 tone scale, constructed instruments to reproduce divisions as small as a sixteenth tone. He demonstrated his instruments in New York, 1926. The instruments included an Octavina for eighth tones and an Arpa Citera for sixteenth tones. There are several recordings of Carillo's music, especially the string quartets.

1897 E.S. Votey invented the Pianola, an instrument that used a pre-punched, perforated paper roll moved over a capillary bridge. The holes in the paper corresponded to 88 openings in the board.

1898 Valdemar Poulson (1869-1942) patented his "Telegraphone," the first magnetic recording machine.

1906 Thaddeus Cahill invented the Dynamophone, a machine that produced music by an alternating current running dynamos. This was the first additive synthesis device. The Dynamophone was also known as the Telharmonium. The instrument weighed over 200 tons and was designed to transmit sound over telephone wires; however, the wires were too delicate for all the signals. You can sort of consider him the 'Father of Muzak.' The generators produced pure tones of various frequencies and intensity; volume control supplied dynamics. Articles appeared in McClure's Magazine that stated "democracy in music...the musician uses keys and stops to build up voices of flute or clarinet, as the artist uses his brushes for mixing color to obtain a certain hue...it may revolutionize our musical art..."

Lee De Forest (1873-1961) invented the Triode or Audion tube, the first vacuum tube.

1907 Ferruccio Busoni (1866-1924) believed that the current musical system was severely limited, so he stated that instrumental music was dead. His treatise on aesthetics, Sketch of a New Music, discussed the future of music.

1910 The first radio broadcast in NYC (first radio station was built in 1920, also in NYC).

1912 The Italian Futurist movement was founded by Luigi Russolo (1885-1947), a painter, and Filippo Marinetti, a poet. Marinetti wrote the manifesto, Musica Futurista; the Futurist Movement's creed was "To present the musical soul of the masses, of the great factories, of the railways, of the transatlantic liners, of the battleships, of the automobiles and airplanes. To add to the great central themes of the musical poem the domain of the machines and the victorious kingdom of Electricity."

Henry Cowell (1897-1965) introduced tone clusters in piano music. The Banshee and Aeolian Harp are good examples.

1914 The first concert of Futurist music took place. The "art of noises" concert was presented by Marinetti and Russolo in Milan, Italy.

1920 Lev (Leon) Theremin, Russia, invented the Aetherophone (later called the Theremin or Thereminovox). The instrument used 2 vacuum tube oscillators to produce beat notes. Musical sounds were created by "heterodyning" from oscillators which varied pitch. A circuit was altered by changing the distance between 2 elements. The instrument had a radio antenna to control dynamics and a rod sticking out the side that controlled pitch. The performer would move his/her hand along the rod to change pitch, while simultaneously moving his/her other hand in proximity to the antenna. Many composers used this instrument including Varese.

1922 Darius Milhaud (b. 1892) experimented with vocal transformation by phonograph speed changes.

Ottorino Respighi (1879-1936) called for a phonograph recording of nightingales in his Pini di Roma (Pines of Rome).

1926 Jorg Mager built an electronic instrument, the Spharophon. The instrument was first presented at the Donaueschingen Festival (Rimsky-Korsakov composed some experimental works for this instrument). Mager later developed a Partiturophon and a Kaleidophon, both used in theatrical productions. All of these instruments were destroyed in W.W.II.

George Antheil (1900-1959) composed Ballet Mechanique. Antheil was an expatriate American living in France. The work was scored for pianos, xylophones, pianola, doorbells, and an airplane propeller.

1928 Maurice Martenot (b. 1928, France) built the Ondes Martenot (first called the Ondes Musicales). The instrument used the same basic idea as the Theremin, but instead of a radio antenna, it utilized a moveable electrode was used to produce capacitance variants. Performers wore a ring that passed over the keyboard. The instrument used subtractive synthesis. Composers such as Honegger, Messiaen, Milhaud, Dutilleux, and Varese all composed for the instrument.

Friedrich Trautwein (1888-1956, Germany) built the Trautonium. Composers such as Hindemith, Richard Strauss, and Varese wrote for it, although no recordings can be found.

1929 Laurens Hammond (b. 1895, USA), built instruments such as the Hammond Organ, Novachord, Solovox, and reverb devices in the United States. The Hammond Organ used 91 rotary electromagnetic disk generators driven by a synchronous motor with associated gears and tone wheels. It used additive synthesis.

1931 Ruth Crawford Seeger's String Quartet 1931 was composed. This is one of the first works to employ extended serialism, a systematic organization of pitch, rhythm, dynamics, and articulation.

Henry Cowell worked with Leon Theremin to build the Rhythmicon, an instrument which could play metrical combinations of virtually unlimited complexity. With this instrument Cowell composed the Rhythmicana Concerto.

Jorg Mager (Germany) was commissioned to create electronic bell sounds for the Bayreuth production of Parsifal

1935 Allegemeine Elektrizitats Gesellschaft (AEG), built and demonstrated the first Magnetophon (tape recorder).

1937 "War of the Worlds" was directed by Orson Welles. Welles was the first director to use the fade and dissolve technique, first seen in "Citizen Kane." To date, most film directors used blunt splices instead.

Electrochord (the electroacoustic piano) was built.

1938 Novachord built.

1939 Stream of consciousness films came about.

John Cage (1912-1992) began experimenting with indeterminacy. In his composition, Imaginary Landscape No. 1, multiple performers are asked to perform on multiple record players, changing the variable speed settings.

1930s Plastic audio tape was developed.

The Sonorous Cross (an instrument like a Theremin) was built.

1941 Joseph Schillinger wrote the The Schillinger System of Musical Composition. This book offered prescriptions for composition--rhythms, pitches, harmonies, etc. Schilllinger's principal students was George Gershwin and Glenn Miller.

The Ondioline was built.

1944 Percy Grainger and Burnett Cross patented a machine that "freed" music from the constraints of conventional tuning systems and rhythmic inadequacies of human performers. Mechanical invention for composing "Free Music" used eight oscillators and synchronizing equipment in conjunction with photo-sensitive graph paper with the intention that the projected notation could be converted into sound.

1947 Bell Labs developed and produced the solid state transistor.

Milton Babbitt's Three Compositions for Piano serialized all aspects of pitch, rhythm, dynamics, and articulation.

The Solovox and the Clavioline were built.

1948 John Scott Trotter built a composition machine for popular music.

Hugh LeCaine (Canada) built the Electronic Sakbutt, an instrument that actually sounded like a cello.

Pierre Schaeffer (b. 1910), a sound technician working at Radio-diffusion-Television Francaise (RTF) in Paris, produced several short studies in what he called Musique concrete. October, 1948, Schaeffer's early studies were broadcast in a "concert of noises."

Joseph Schillinger wrote The Mathematical Basis of the Arts.

1949 Pierre Schaeffer and engineer Jacques Poullin worked on experiments in sound which they titled "Musique concrete." 1949-50 Schaeffer and Henry (1927-96), along with Poullin composed Symphonie pour un homme seul (Symphony for a Man Alone); the work actually premiered March 18, 1950.

Olivier Messiaen composed his Mode de valeurs et d'intensities (Mode of Durations and Intensities), a piano composition that "established 'scales' not only of pitch but also of duration, loudness, and attack."

The Melochord was invented by H. Bode.

1940s The following instruments were built: the Electronium Pi (actually used by a few German composers, including: Brehme, Degen, and Jacobi), the Multimonica, the Polychord organ, the Tuttivox, the Marshall organ, and other small electric organs.

1950 The Milan Studio was established by Luciano Berio (b. 1925, Italy).

1951 Clara Rockmore performed on the Theremin in worldwide concerts.

Variations on a Door and a Sigh was composed by Pierre Henry.

The RTF studio was formally established as the Groupe de Musique Concrete, the group opened itself to other composers, including Messiaen and his pupils Pierre Boulez, Karlheinz Stockhausen, and George Barraque. Boulez and Stockhausen left soon after because Schaeffer was not interested in using electronically-generated sounds, but rather wanted to do everything based on recordings.

John Cage's use of indeterminacy culminated with Music of Changes, a work based on the charts from the I Ching, the Chinese book of Oracles.

Structures, Book Ia was one of Pierre Boulez' earliest attempts at employing a small amount of musical material, called cells (whether for use as pitches, durations, dynamics, or attack points), in a highly serialized structure.

1951-53 Eimert and Beyer (b. 1901) produced the first compositions using electronically-generated pitches. The pieces used a mechanized device that produced melodies based on Markov analysis of Stephen Foster tunes.

1952 The Cologne station of Nordwestdeutscher Rundfunk (later Westdeutscher Rundfunk) was founded by Herbert Eimert. He was soon joined by Stockhausen, and they set out to create what they called Elektronische Musik.

John Cage's 4'33" was composed. The composer was trying to liberate the performer and the composer from having to make any conscious decisions, therefore, the only sounds in this piece are those produce by the audience.

1953 Robert Beyer, Werner Meyer-Eppler (b. 1913) and Eimert began experimenting with electronically-generated sounds. Eimert and Meyer-Eppler taught at Darmstadt Summer School (Germany), and gave presentations in Paris as well.

Louis and Bebe Baron set up a private studio in New York, and provided soundtracks for sci-fi films like Forbidden Planet (1956) and Atlantis that used electronic sound scores.

Otto Luening (b. 1900, USA; d. 1996, USA) and Vladimir Ussachevsky (b. 1911, Manchuria; d. 1990, USA) present first concert at the Museum of Modern Art in New York, October 28. The program included Ussachevsky's Sonic Contours (created from piano recordings), and Luening's Fantasy in Space (using flute recordings). Following the concert, they were asked to be on the Today Show with Dave Garroway. Musicians Local 802 raised a fuss because Luening and Ussachevsky were not members of the musicians' union.

1953-4 Karlheinz Stockhausen (b. 1928) used Helmholtz' research as the basis of his Studie I and Studie II. He tried to build increasingly complex synthesized sounds from simple pure frequencies (sine waves).

1954 The Cologne Radio Series "Music of Our Time" (October 19) used only electronically-generated sounds by Stockhausen, Eimert, Pousseur, etc. The pieces used strict serial techniques.

Dripsody was composed by Hugh LeCaine. The single sound source for this concrete piece is a drip of water.

1955 Harry Olson and Belar, both working for RCA, invent the Electronic Music Synthesizer, aka the Olson-Belar Sound Synthesizer. This synth used sawtooth waves that were filtered for other types of timbres. The user programmed the synthesizer with a typewriter-like keyboard that punched commands into a 40-channel paper tape using binary code.

The Columbia-Princeton Studio started, with its beginnings mostly in the living room of Ussachevsky and then the apartment of Luening.

Lejaren Hiller (1924-92) and Leonard Isaacson, from the University of Illinois composed the Illiac String Quartet, the first piece of computer-generated music. The piece was so named because it used a Univac computer and was composed at the University of Illinois.

1955-56 Karlheinz Stockhausen composed Gesang der Junglinge. This work used both concrete recordings of boys' voices and synthesized sounds. The original version was composed for five loudspeakers, but was eventually reduced to four. The text from the Benedicite (O all ye works of the Lord, bless ye the Lord), which appears in Daniel as the canticle sung by the three young Jews consigned to the fiery furnace by Nebuchadnezzar.

1956 Martin Klein and Douglas Bolitho used a Datatron computer called Push-Button Bertha to compose music. This computer was used to compose popular tunes; the tunes were derived from random numerical data that was sieved, or mapped, into a preset tonal scheme.

Tokyo at Japanese Radio, an electronic studio established.

Luening and Ussachevsky wrote incidental music for Orson Welles' King Lear , City Center, New York.

1957 Of Wood and Brass was composed by Luening. Sound sources included trumpets, trombones and marimbas.

Scambi, composed by Henri Pousseur, was created at the Milan Studio, Italy.

Warsaw at Polish Radio, an electronic studio established.

Munich, the Siemens Company, an electronic studio established.

Eindhoven, the Philips Company, an electronic studio established.

David Seville created the Chipmunks, by playing recordings of human voices at double speed. Electronic manipulation was never really used again in rock for about ten years.

1958 Edgard Varese (1883-1965) composed Poeme Electronique for the World's Fair, Brussels. The work was composed for the Philips Pavilion, a building designed by the famous architect, Le Corbusier who was assisted by Iannis Xenakis (who later became well-known as a composer rather than an architect). The work was performed on ca. 425 loudspeakers, and was accompanied by projected images. This was truly one of the first large-scale multimedia productions.

Iannis Xenakis (b.1922) composed Concret PH. This work was also composed for the Brussels World's Fair. It made use of a single sound source: amplified burning charcoal.

Max Mathews, of Bell Laboratories, generated music by computers.

John Cage composed Fontana Mix at the Milan Studio.

London, BBC Radiophonic Workshop, an electronic studio established.

Stockholm, Swedish Radio, an electronic studio established.

The Studio for Experimental Music at the University of Illinois established, directed by Lejaren Hiller.

Pierre Henry leaves the Group de Musique Concrete; they reorganize as the Groupe de Recherches Musicales (GRM)

Gordon Mumma and Robert Ashley founded the Cooperative Studio for Electronic Music, Ann Arbor , MI (University of Michigan).

Luciano Berio composedThema-omaggio a Joyce. The sound source is woman reading from Joyce's Ulysses.

1958-60 Stockhausen composed Kontakte (Contacts) for four-channel tape. There was a second version for piano, percussion and tape.

1958-9 Mauricio Kagel, an Argentinian composer, composed Transicion II, the first piece to call for live tape recorder as part of performance. The work was realized in Cologne. Two musicians perform on a piano, one in the traditional manner, the other playing on the strings and wood. Two other performers use tape recorders so that the work can unites its present of live sounds with its future of pre-recorded materials from later on and its past of recordings made earlier in the performance.

Max Mathews, at Bell Labs, began experimenting with computer programs to create sound material. Mathews and Joan Miller also at Bell Labs, write MUSIC4, the first wide-spread computer sound synthesis program. Versions I through III were experimental versions written in assemble language. Music IV and Music V were written in FORTRAN. MUSIC4 did not allow reentrant instruments (same instrument becoming active again when it is already active), MUSIC5 added this. MUSIC4 required as many different instruments as the thickest chord, while MUSIC5 allowed a score to refer to an instrument as a template, which could then be called upon as many times as was necessary.

The Columbia-Princeton Electronic Music Center was formally established. The group had applied through the Rockefeller Foundation, and suggested the creation of a University Council for Electronic Music. They asked for technical assistants, electronic equipment, space and materials available to other composers free of charge. A grant of $175,000 over five years was made to Columbia and Princeton Universities. In January, 1959, under the direction of Luening and Ussachevsky of Columbia, and Milton Babbitt and Roger Sessions of Princeton, the Center was formally established.

The RCA Mark II synthesizer was built at Columbia-Princeton Electronic Music Center (the original version was built for the artificial creation of human speech). The Mark II contained oscillators and noise generators. The operator had to give the synthesizer instructions on a punched paper roll to control pitch, volume, duration and timbre. The synth used a conventional equal-tempered twelve-note scale.

1960 Composers of more traditional orchestral music began to rebel. Many composers tried to get quasi-electronic sounds out of traditional instruments. Bruno Bartelozzi, wrote new book on extended instrumental techniques.

Morton Subotnick, Pauline Oliveros, and Ramon Sender established the San Francisco Tape Music Center.

John Cage composed Cartridge Music, an indeterminate score for several performers applying gramophone cartridges and contact mics to various objects.

1961 The first electronic music concerts at the Columbia-Princeton Studio were held; the music was received with much hostility from other faculty members.

Varese finally completed Deserts at the Columbia-Princeton Studio.

Fortran-based Music IV was used in the generation of "Bicycle Built for Two" (Mathews).

The production of integrated circuits and specifically VLSI-very large scale integration.

Robert Moog met Herbert Deutsch, and together they created a voltage-controlled synthesizer.

Luciano Berio composed Visage. This radio composition is based on the idea of non-verbal communication. There are many word-like passages, but only one word is spoken during the entire composition (actually heard twice), parole (Italian for 'word'). Cathy Berberian, the composer's wife, was the performer.

The theoretical work, Meta+Hodos, written in 1961 by James Tenney (META Meta+Hodos, 1975 followed).

1962 Bell Labs mass produces transistors, professional amplifiers and suppliers.

PLF 2 was developed by James Tenney. This computer program was used to write Four Stochastic Studies, Ergodos and others.

Iannis Xenakis composed Bohor for eight tracks of sound.

Milton Babbitt composed Ensembles for Synthesizer (1962-64) at the Columbia-Princeton Studio.

At the University of Illinois, Kenneth Gaburo composed Antiphony III, for chorus and tape.

Paul Ketoff built the synket. This synthesizer was built for composer John Eaton and was designed specifically as a live performance instrument.

1963 Lejaren Hiller and Robert Baker composed the Computer Cantata.

Babbitt composed Philomel at the Columbia-Princeton Studio. The story is about Philomel, a woman without a tongue, who is transformed into a nightingale (based on a story by Ovid).

Mario Davidovsky composed Synchronism I for flute and tape. Davidovsky has since written many "synchronism" pieces. These works are all written for live instrument(s) and tape. They explore the synchronizing of events between the live and tape.

1964 The fully developed Moog was released. The modular idea came from the miniaturization of electronics.

Gottfried Michael Koenig used PR-1 (Project 1), a computer program that was written in Fortran and implemented on an IBM 7090 computer. The purpose of the program was to provide data to calculate structure in musical composition; written to perform algorithmic serial operations on incoming data. The second version of PR-1 completed, 1965.

Karlheinz Stockhausen composed Mikrophonie I, a piece that required six musicians to generate. Two performers play a large tam-tam, while two others move microphones around the instrument to pick up different timbres, and the final two performers are controlling electronic processing.

Ilhan Mimaroglu, a Turkish-American composer, wrote Bowery Bum. This is a concrete composition, and used rubber band as single source. It was based on a painting by Dubuffet.

1965 Hi-fi gear is commercially produced.

The first commercially-available Moog.

Varese died.

Karlheinz Stockhausen composed Solo. The composition used a tape recorder with moveable heads to redefine variations in delay between recording and playback, live manipulation during performance.

Karlheinz Stockhausen composed Mikrophonie II for choir, Hammond organ, electronics and tape.

Steve Reich composed It's gonna rain. This is one of the first phase pieces.

1966 The Moog Quartet offered world-wide concerts of (mainly) parlor music.

Herbert Brun composed Non Sequitur VI

Steve Reich composed Come out, another phase piece.

1967 Walter Carlos (later Wendy) composed Switched on Bach using a Moog synthesizer.

Iannis Xenakis wrote Musiques Formelles (Formalized Music). The first discussion of granular synthesis and the clouds and grains of sound is presented in this book.

Leon Kirschner composed String Quartet No. 3, the first piece with electronics to win the Pulitzer Prize.

Kenneth Gaburo composed Antiphony IV, a work for trombone, piccolo, choir and tape.

Morton Subotnick composed Silver Apples of the Moon (title from Yeats), the first work commissioned specifically for the recorded medium.

The Grateful Dead released Anthem of the Sun and Frank Zappa and the Mothers of Invention released Uncle Meat. Both albums made extensive use of electronic manipulation.

1968 Lejaren Hiller and John Cage composed HPSCHD.

Morton Subotnick composed The Wild Bull

Hugh Davies compiled an international catalogue of electronic music.

1969 Terry Riley composed Rainbow in Curved Air

late 1960s The Sal-Mar Construction was built. The instrument was named for composer Salvatore Martirano and designed by him. The Sal-Mar Construction weighed over fifteen hundred pounds and consisted of "analog circuits controlled by internal digital circuits controlled by the composer/performer via a touch-control keyboard with 291 touch-sensitive keys."

Godfrey Winham and Hubert Howe adapted MUSIC IV for the IBM 7094 as MUSIC4B was written in assembly language; MUSIC4BF (a Fortran-language adaptation of MUSIC4B, one version was written by Winham, another was written by Howe).

Music V variants include MUSIC360 and MUSIC11 for the IBM360 and the PDP11 computers, these were written by Barry Vercoe, Roger Hale, and Carl Howe at MIT, respectively.

GROOVE was developed by Mathews and F. Richard Moore at Bell Labs, and was used to control analog synthesizers.

1970 Charles Wuorinen composed "Times Encomium," the first Pulitzer Prize winner for entirely electronic composition.

Charles Dodge composed Earth's Magnetic Field. This is a great example of mapping numerical statistics into musical data.

Steve Reich composed Four Organs.

1972 Pink Floyd's album The Dark Side of the Moon was released; it used ensembles of synthesizers, also used concrete tracks as interludes between tunes.

1973 SAWDUST, a language by Herbert Brun, used functions including: ELEMENT, LINK, MINGLE, MERGER, VARY, and TURN.

1974 The Mellotron was built. The instrument was an early sample player that used tape loops. There were versions that played string sounds or flute sounds, and the instrument was used in movie soundtracks and on recordings.

Clara Rockmore releases Theremin recordings.

1976 Composer Philip Glass collaborated with librettist Robert Wilson on Einstein on the Beach. This was a large-scale multimedia 'opera' in the minimalist style.

1977 The Institut de Recherche et Coordination Acoustique/Musique (IRCAM), Paris, under direction of Pierre Boulez.

Systems Concepts Digital Synthesizer (SCDS), built by Peter Samson for CCRMA, signal generating and processing elements all executing in parallel, and capable of running in real time. There are 256 digital oscillators, 128 signal modifiers (filters, reverb, amplitude scalers), a scratch-pad memory for communicating values between processing elements, and a large memory for reverberation and table storage.

1980 Philip Glass composed Satyagraha, another full scale opera in the minimalist style.

1981 Larry Austin composed Canadian Coastlines, a composition that used a land map of Canada in order to determine textural, rhythmic, and melodic content.

Music V variants: newer developments include Cmusic (by F.R. Moore), so named because it is written entirely in C programming language.

1985 HMSL, Hierarchical Music Specification Language was released. The basic organization of HMSL is a series of data structures called "morphs" (named for the flexible or morphological design of the software). Within the superstructure of these morphs there exist other data substructures named shapes, collections, structures, structures, productions, jobs, players, and actions. These secondary types of morphs are used to control aspects of higher level scheduling and routines.

Interactor, by Morton Subotnick and Mark Coniglio, was designed specifically for live performance and score-following capabilities.

1986 Another Music V variant was release--CSound, by Barry Vercoe of MIT.

Jam Factory written by programmer David Zicarelli. He was trying to create a program that would listen to MIDI input and 'improvise' immediately at some level of proficiency, while allowing (Zicarelli) to improve its ability.

Joel Chadabe, Offenhartz, Widoff, and Zicarelli began work on an algorithmic program that could be used as an improvisation environment. The performer could be seated at the computer and shape data in real time by "a set of scroll bars that changed the parameters of this algorithm, such as the size of the jump from one note to another, the lowest and highest note, etc." The original version was to be named "Maestro," then "RMan" (Random Manager), and finally, "M."

Music Mouse, written by Laurie Speigel, was designed to be a stand-alone performance system. It may be used as a MIDI controller or as a performance station using the Macintosh internal sound. Unlike other programs for the Macintosh environment, Music Mouse was not intended to be used as a recorder/player program. Instead, the program enables the programmer to "play" the computer. Check out the software at: http://www.dorsai.org/~spiegel/ls_programs.html

The Max program was written in the C language and was developed at IRCAM by Miller Puckette. It was later scheduled for distribution by Intelligent Music (the company that also distributed M and Jam Factory), but it was the Opcode company that eventually released it. Miller Puckette's original intention was to build a language that could control IRCAM's 4X synthesizer, and there was no need for the graphical implementation. The graphics were added after a version of Max for Macintosh computer using MIDI was proposed. Since 1989, David Zicarelli has updated and expanded the program for the Macintosh environment.

Dolby SR introduced

R-DAT spec announced

Mackie Designs Inc. founded

Sonic Solutions founded

1987 Apple introduced MacII

first consumer DAT decks available

1988 Steve Reich composed Different Trains for string quartet and tape.

1989 Digidesign introduces Sound Tools

Mackie 1604 debuts

1990 Sony introduces writeable CD

1991 Sony develops MiniDisc

Alesis ADAT introduced

1992 Sony announces multimedia CD-ROM

Emagic founded

Macromedia founded

Spirit by Soundcraft introduced

1994 DVD introduced

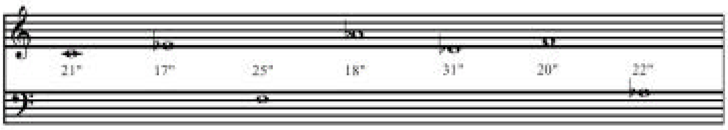
1996 first MiniDisc multitracks introduced

1997 DVD-Audio standard develops

Appendix B

Examples of Electronic Notation

1. Pitch Cycle Lengths in Music for Airports 2/1[95]

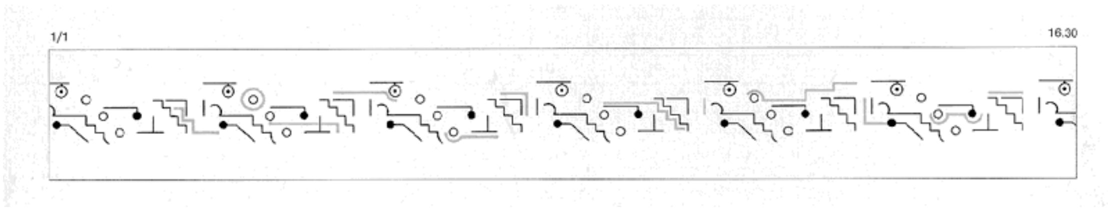


2. Graphical Representation of Music for Airports 2/1[96]

3. Music for Airports 1/1[97]

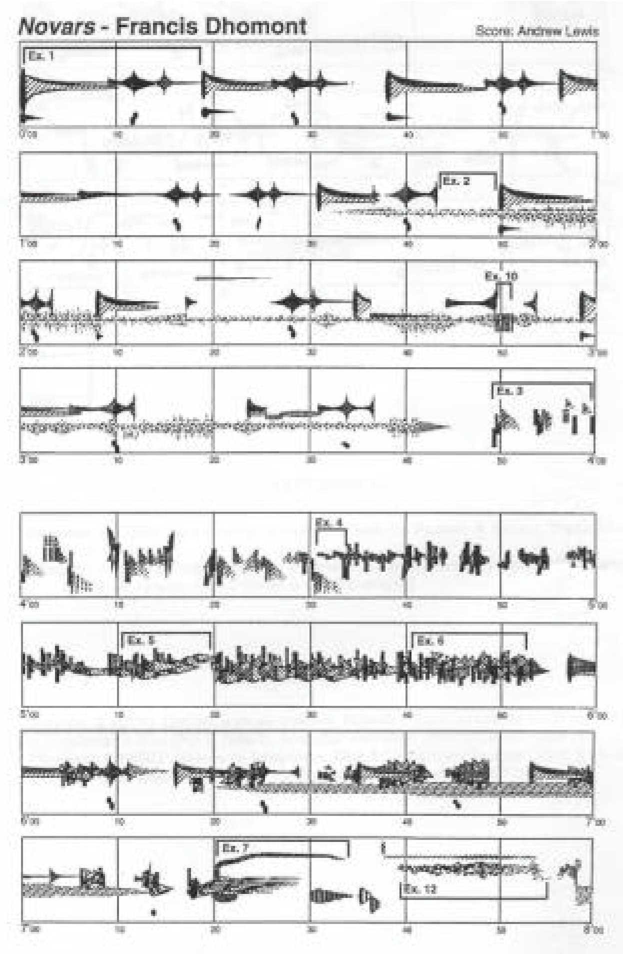
[95] Stevenson. B, Paintings in Sound : Vertical Time in the Ambient Music of Brian Eno, Dis. Victoria University of Manchester, 1997, p.63
[96] Taken from Album sleve, Brian Eno, Music for Airports, Discography [8]
[97] Stevenson. B, Paintings in Sound : Vertical Time in the Ambient Music of Brian Eno, Dis. Victoria University of Manchester, 1997, p.62

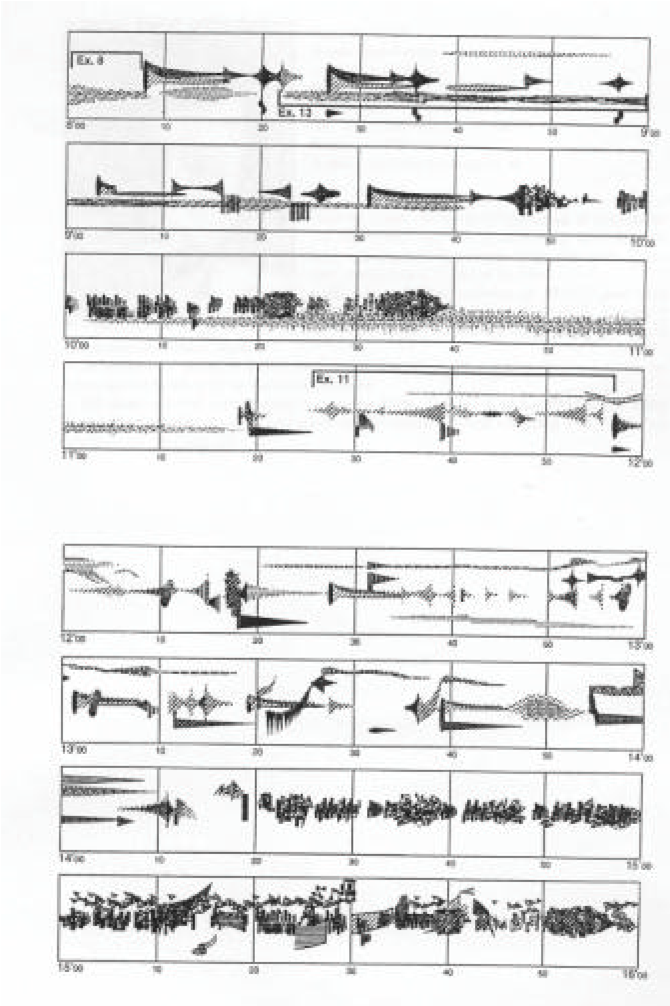
4. Graphical Repsentation of <u>Music for Airports 1/1</u>[98]

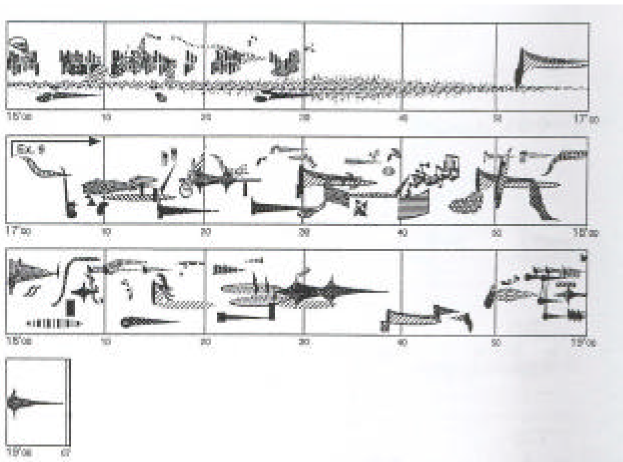


5. Graphical Representation of <u>Novars</u>[99]

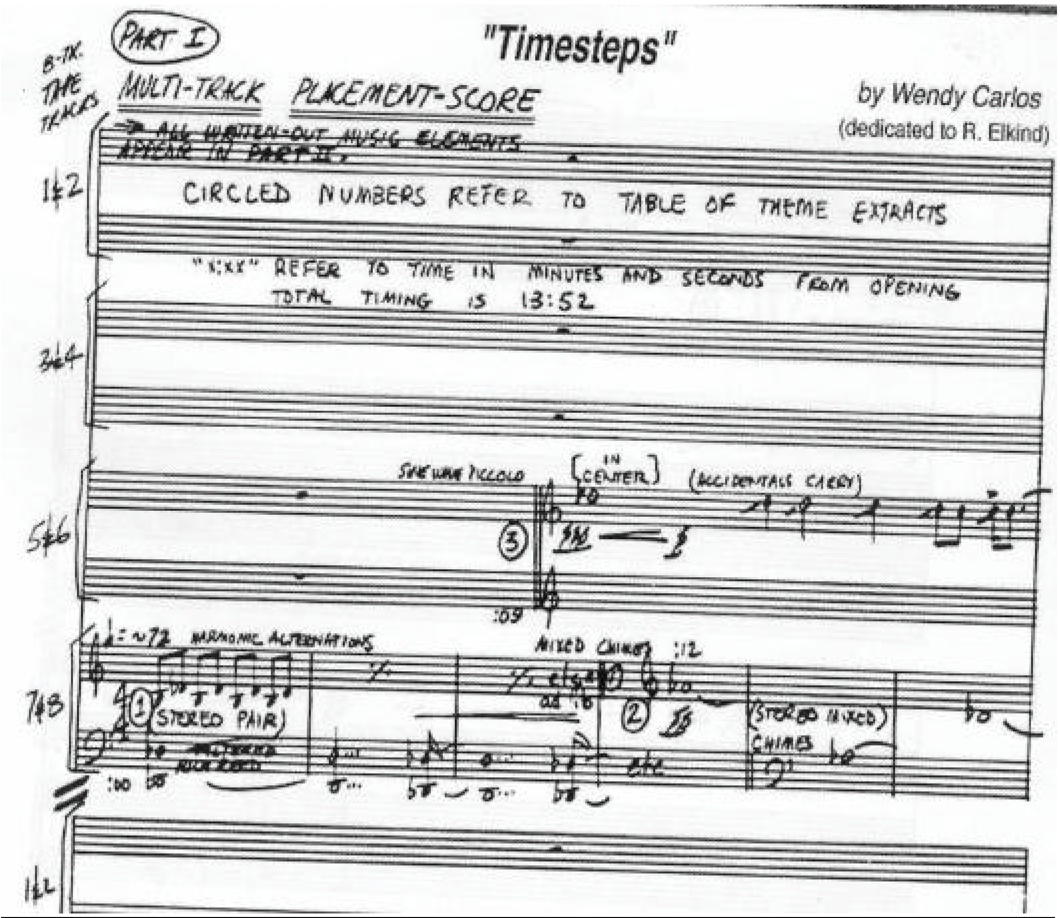
[98] Taken from Album sleve, Brian Eno, Music for Airports, Discography [8]
[99] Lewis. A, Francis Dhomont's Novars, *Journal of New Music Research*, Vol. 27, No. 1-2, 1998 pp.80-82


Novars - Francis Dhomont
Score: Andrew Lewis
Ex. 1
Ex. 2
Ex. 10
Ex. 3
Ex. 4
Ex. 5
Ex. 6
Ex. 7
Ex. 12


Ex. 8
Ex. 13
Ex. 11


Ex. 9

Example 6 Wendy Carlos[100]



[100] Wendy Carlos, 'Timesteps', Web R. [18]

Appendix C

Answer/Question Example of Questionnaire Distributed through E-mail

Sent: Wednesday, March 20, 2002 10:43 AM
To: info@infrasound.net
Subject: info sound

If Possible could you forward this to any electro - composers you know, I am trying to collect as many answers as possible, for my dissertation on music with technology. Any help you can give me will be really appreciated!?

Do you notate your music?
No

If Yes: Do you notate the noises, strange sound effects, filter-sweeps etc.

If No: How do you keep copies of your music?
On computers, cd-r's

Would you like to be able to keep notated (noises included) versions of your music if this was possible?
No

Please give reasons for your answer:
The music is too improvisational and atonal -- plus with field recordings and other elements it makes notation impossible...

Thank-you for your time, I am putting together a research paper on the history and current state of electronic music. I am trying to get as many responses to this question as possible, as it forms part of the essay.

David Owen
England

Appendix D

Interview with Steve Knee; Thursday 2pm the 28th of March2002.

First of all I am interested to know what types of music you are involved in.

Well two general types really, there's the work that I do with bands; and then the work that I do at home, the electronic music where I am the composer and producer. Either way, I am doing anything, if I am doing stuff with a band it is still very heavily produced; whether it's electronic or acoustic.

He points to vocals as his baby.

Okay, right! For this interview I would like to concentrate mainly on your electronic music. I am interested first, to know what type of kit you use, beginning with the hardware?

Everything is heavily centred now around logic. PC. running Korg 12/12 with 8 channels I/O; that's obviously my primary recording hardware. Even if you work with electronics and midi, everything always ends up as audio in a sequencer anyway. In terms of actual noise generation for additive synthesis, there's the JV1080, Roland G220, Yamaha TX81z, Kertworld k2000, probation bass station, micro modular, Korg station SR... and I use giga sampler on the P.C as well.

So how much has that set you back?

Thousands.

How about software, I understand that you use a lot?

Its logic audio primarily. I use other bits and bobs as and when; but everything is based around logic. Logic has its own plug ins, it has its own soft instruments, so if I want to use anything like that...I try to avoid soft instruments, I still prefer hardware. But when you get cheesed off with a piece of hardware, you wonder why you bother when its all just sitting there in the PC, but I still tend to use just hardware.

Do you feel that you are overwhelmed by the amount of technology you have got around you?

Not at all. Never. Because of the way I have built up my own set-up...I built it up from first principles - I started up with an Atari St (I had one anyway), and when I first got into composition I bought my first keyboard - I got a four note polyphonic Casio for Christmas, if you use it multitimbral mode then you could have four monophonic lines, that's what I started with. So I had learnt that piece of kit inside out. then I went of and got the Yamaha Txz81 module, and then you learn that piece of kit inside out. So because it's all built up bit by bit I know each bit of kit very well. So it does not overwhelm me at all, I'm not in anyway concerned about that.

So none of your kit has gone out of date?

No. I got a policy of not chucking away or selling anything; I'll always be able to go back to a particular sound, so even though a piece of kit might not be used that often, I'll always tend to keep it, just in case.

So, what are your musical influences?

I try and take influences...its always a horrible cliché when you talk to anyone, any interview or whatever and they always say I've got a range of influences, and these people try and justify there existence by saying they are influenced by a lot of people....

..ummm..my influences, well Jean Michelle Ja, have always been a big influence on me, especially as far as my electronic music is concerned. With that you get the usual raft of artists like Kraftwork, Mike Oldfeild, Enigma, all those kind of electronic artists. Not electronica, so much, but quite main stream artists. Then you've got other people who have influenced me, people like Burt Camfort, Asia, Foreigner, MeatLoaf. .... ELO! Jeff Lynn is a major, major production influence, the kind of acoustic/ electronic music that he does, was very subtle and still very big. Anything around me, even if I don't buy it, I still take something from it....Pete Waterman, in terms of song structure, keeping it catchy - but' my music is not quite as disposable as that.

Do you think you've got your own style, you own way of working?

Yes; very much so. It is something that I have developed over a period of time and it very important to me to have. One style, I have a much produced style, vocal style, perhaps in an instrument kind of way rather than a song kind of way.   Vocals are always a very big thing for me, so that's a big part of my style. I tend to like heavy well rounded tunes, with a good bottom end; but not dance, I don't like dance.

So how do your start your composition....where would you start?

It could start in any number of ways...it could start with a vocal line, it could start with a lyric; sometimes when I'm driving along I tend to think of lyrics, my phone can get filled with all sorts of ideas.

Do you sing it yourself?

Ummm no, I often come up with lyrics rather than vocal lines...sometimes when I might fit a melody around a lyrical idea, but often it will start with sounds, be it a drum loop, be it a new synth. New synths are often a major influence for new tracks, because it's new sounds which cause you to fire of in different directions. then you get a basic bed of stuff, say 8-16 bars of something that sounds quite interesting, and then maybe a vocal line will come of that; if not, maybe a melodic line.

But it can come from anyway really....and you learn to develop around that inspiration. and that's where you're working with 10% inspiration and the rest you are just building. Using the tools and techniques, you have developed yourself.

Do you use reference tracks, in terms of the sound of your tracks?

No. I do what I want to do.

How far do you move away from the factory presets, on your hardware?

Less, now that I have got more kit. I once read a very good quote, that said don't buy all your synths from one manufacture otherwise you'll end up sounding like a demo for that manufacture. I therefore try and mix and match.

Okay, but how can you tell that a particular effect is a good effect, say for example, when you are working with Reverb?

From an Engineering point of view, you would start to reference listening to different reverbs; you should be aware of what the reverb on commercial recordings sound like. But it comes with experience, you learn to judge what different reverbs sound like, you learn what budget reverb sound like. A good reverb will allow something to sit in the mix rather than get in the way itself. So its experience, that tells you that stuff!

Yep. Do you notate you music?

I have done. At college and at university, I found various methods of graphically representing sounds.

Would you use those regularly?

No

Why is that?

Because I don't need to communicate with other people. Okay, I might need a bit of notation if I need to communicate with a violinist, if I need them to play something for me. But certainly when I am dealing with anyone other than classical musician there is no need. For me the production is the composition, and there’s no point putting it on paper, I might as well put it on C.D.

Have you ever composed for film or for Graphics?

(Thinks back..) I once composed the soundtrack to a laser display, at the Equinox nightclub in Leicester Square! It was an 8 - 10 minute piece, and was very choreographed/story boarded, sounds set to images. Obviously I do work with images quite a lot, my whole bag is the multi media stuff, things like modules; where music is closely tied into images and movements around the space, lighting and all that stuff. So I have composed to visual cues very much, but nothing that’s got a style director or something like that.

I have always wondered, what’s the game with modules?

Modules is an event. Modules came out of my desire for two things...One was; the need to break away from standard multimedia techniques. Which is someone will compose some music or create some visuals, and then bolt on the other elements; so that everything is bolted together rather than creating an integrated whole. So the idea with modules, was something that was created from the ground up, working with graphic designers, video artists, lighting guys, and actually building the thing up from the ground; rather than just taking a piece of music and getting visuals put to it.

So it was an attempt to experiment and play with that. The second thing was to try and break down the standard formats for performance...so we've got, standard stage audience scenario in almost everything we see, I did not like that - I wanted to give people a choice - I didn't like the different quality of experience that people get in standard set ups. So I wanted to create the same quality of experience, but a different experience for everyone depending on where they are within modules. So everyone comes out and goes, 'oooo did you see that?' and someone goes 'no I did not see that, but I saw that, did you see it?'. There's too much going on for anyone person to take in anyone part. We have got six screens of visual, four stages with musicians on, lighting lasers, depending on which reincarnation you see, theirs sound going here there and everywhere.

The idea is that there's too much to see, but the audience have the choice as to what they watch and they can make the choice. It's kind of interactive in a passive way. I hate interactive things where the people actually govern what goes on; but they are being interactive in so far as the audience participation, so they are getting the chance to choose what they look at, choose what they listen to.

So a different sort of live experience then?

Its suppose to be a different sort of live experience. It started with a very basic prototyping with something called the cue point principle. Which is quite literally where you build a cube for one person, where the visuals are put up on the four walls, one person sat inside with Quadraphonic sound. But to get the whole idea of surround working, we moved it up to a bigger event with about 70 people, and eventually we developed through to modules with six screens and some various bits and bobs.

What are you most typical considerations when you are building something like this?

It's Syncing, its show control, it's bringing the whole thing together for a reasonable cross. There are ways of implementing show control for a lot of money, but we did not have that. Getting six videos to sync together for a period, getting lasers and lighting to chase; getting everything to sync together...we've done it! Syncing, syncing video, no-one knew how to sync some video without spending thousands, trying to find a way of doing that w2as a major consideration. But we done it, we found a way to do that, which involved getting a little program made by this guy in Sweden.

Okay, so what was that then?

This guy created some midi triggers, because it accoutred to me that if we could get the video to stay in sync; that is not it in itself; because depending on which video coding you choose governs whether or not it will actually stay in sync. But by choosing appropriate codec, and bit rate you can get a video to stay in sync. But we then needed to create a trigger that triggered them of at the same time. so we created a midi trigger, which triggered with a midi not on, which triggered the start of a media player within windows. This guy wrote a program to do that.

So we triggered them all of with logic, so logic will run, runs all the audio and is the master, but it will also send mtc to other devices, lasers and such like, and will send note ons to trigger the videos. We also chose to convert midi data into dmx, which is the lighting protocol, which allows us to create all the control files within logic rather than use a separate desk, so everything can be completely sync'd.

Okay, but where do the live performers fit in all this?

Well most of the backing tracks will come of logic. But then, we've got some vocalist, maybe some thermion stuff; but then we ended up with whole bands, drummers, bassists, depending on who is around.

And that’s all integrated with the visuals?

Yeah; so the drummer will play to a click track for example.

So technology has really helped you out?

Yeah, definitely, there is no way I would have been able to do that five years ago.

It sounds good when are you playing?

Errr, not in the near future modules kind of went in its box, after we took it to Earls Court.

Well that’s all me questions out, but I’m sure I can think of a few more. Like, when did you first start writing music?

After going to see Jean Michelle Ja in 1988, I then decided that was what I wanted to do.

Do you play any musical instruments?

Not apart from keyboard, and singing. I'm not a great player though, I could never be bothered to put time in to practice, and I would rather do it with a sequencer.

Yea, you don't need to play an instrument really well when you can compose with computers.

Nope. The studio is an instrument. Some times people don't really see it as one though, and think that the computer does all the work like magic; which I think is ridiculous.

Is there any reason why you use hardware, rather than software?

It was the only option around, when I started. I'm not scared of using software, it’s just for me hardware is easier and quicker than software, I don't trust software at times also.

Electronic music has opened up the range of music an artist can compose...

yep

...why do you think this is?

It’s widened the palette of sound we have got access to, plus its widened the access to music to people who want to be composers...you don't have to play an instrument anymore. The guy from the Tangerine Dream said in the 70's that within 10 years everyone will have a synthesiser on stage, and he was right. If you listen to any pop act, or any rock act and even if it’s not meant to sound like a synthesiser is playing, there will be electronics all over it. In the recording, in the production, or whatever. Electronics give people access to sounds that either they could not get access to before or did not even exist.

Can you think of anything that is not already being done by a computer, that you would like to see out there?

(long silence)

Let me know

I will do. I remember the time when sampling plus synthesis was the main synthesis method; people were just scratching their heads thinking what the next thing could possibly be, when suddenly ... came up.
But I think, just the complete thing!...rather than being note based, or rhythmic based its just gone full circle and is based on sounds. Sounds that we can create. Soundscapes, where we can create anything. A lot of music, future sound of London is based on sound, rather than traditional music principles, and that has come full circle.

Excellent thanks Steve