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Exploring the Multichannel Pop Record:

A series of compositions entitled ‘Iron and Ivory’ produced for 5.1 surround sound accompanied by an analytical research paper

Thomas Buckley

A thesis submitted to the University of Huddersfield for the degree of MA in Music by Research

University of Huddersfield

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Abstract

This paper focuses on the application of multichannel stereophonic sound capture and reproduction from a variety of practical and theoretical approaches. As a product of the research conducted, the author has prepared a series of original compositions as a vehicle to investigate recording and mixing techniques that are encapsulated in both two channel stereophony as well as the surround sound studio. The author has also dealt with the notion of human reactions to reproduced sound considering the practice of psychoacoustics as a tool in moulding specific spatial aesthetics during the stages of production and composition.

KEYWORDS: Surround Sound, 5.1, Stereophonic, Psychoacoustics, Envelopment.

Acknowledgements

Every element of the production and research process involved in compiling this project would not have been possible without the help of my good friends Sam Dyson, Dan Page and Oliver Perry for surrendering their time to provide valuable instrumental contributions. Secondly, to my partner Hannah for her never ending support. Finally, and most importantly, a heartfelt thank you to my supervisor, Stewart Worthy, whose valuable assistance throughout my time in higher education has been a memorable influence.

Table of Contents

Abstract 2

Acknowledgements 3

List of Acronyms 6

1. Introduction 7

1.1 Context 7

1.2 Rationale 8

2.1 Research Aims 9

2.2 Key Works 11

2.3 Research Chronology 13

2.4 Research Methods 14

3. Analysis of Recording Techniques for Surround Sound 16

3.1 5-Channel Stereophonic Recording Techniques for Drum Kit 16

3.1.1 Conclusions 27

3.2 Appropriate Mono and Stereo Microphone Techniques for Instrument Recording 28

3.2.1 Bass Guitar 28

3.2.2 – Electric Guitar 29

3.2.3 – Acoustic Guitar 30

4. Analysis of Surround Sound Mixing Techniques 33

4.1 Achieving Separation of Mix Components 33

4.2 Maintaining the Integrity of the 5.1 Stereo Image 37

5. Conclusions 40

6. Composition Programme Notes 43

6.1 Journey Through Time 43

6.2 My Religion 43

6.3 Dandelion's Lament 43

6.4 Black Buck 44

6.5 Locomotive Jazz 44

6.7 Devil's Striptease 45
6.8 You Won't Escape Me 45
7. References 46

List of Acronyms

AES – Audio Engineering Society

DAW – Digital Audio Workstation

DVD – Digital Versatile Disc

DVD-A – Digital Versatile Disc - Audio

LCR – Left, Centre, Right (Channels)

LFE – Low Frequency Effects

LS – Left Surround

RS – Right Surround

1. Introduction

This section intends to explain the background surrounding the research process including the departures involved in instigating the initial ideas for a thorough investigation of surround sound within the popular music field. Included is the context of the research, with a brief history and justification for the chosen output format; the rationale for carrying out the project; and the key literature that has been utilised whilst preparing the associated research paper.

1.1 Context

The notion of producing surround sound audio is by no means new. Since the 1920s audio engineers have been researching and testing the possibility of enveloping the listener in the sounds that they hear in a similar way to the natural environment in which we all exist.[1] As resources have progressed with time, and with the advent of digital storage of audio material, it has become easier to deliver large numbers of audio channels to a similarly large number of outputs. Within this, musicians and audio engineers have established new ways in which to record and process sounds for these output parameters and the creative process involved has even encouraged material that has existed for decades to be reproduced for an enhanced sound field.

The social context of surround sound is very much in parallel to all technological advancement in that in practice it is often appropriate to achieve a compromise that is both practical but is still fit for a high quality purpose in a wide range of environments. It is for this reason that the author has decided to

[1] Birkner, C. *Surround Sound (Practical Recording).* (London, 2004)

focus exclusively on the 5.1 surround sound field as the playback environment for the accompanying recording project.

1.2 Rationale

The main argument for a detailed analysis of Surround Sound production techniques when applied to the Popular Music genre is that a great deal of shared information exists in both the realms of 'traditional' two channel stereo music production and surround sound. At this point, for clarity, the author will adopt the perspective of the likes of Birkner and Holman and treat the concept of stereophonic sound as being in the format of two or more channels. This deviates from the definition expressed in the English dictionary which expresses the socially ingrained notion that stereo refers to only two channels. Where necessary, the author will precede the word 'stereo' with the appropriate number of channels for the purpose of differentiation.

It has been argued by the likes of Mason that there are no incorrect solutions when one comes to consider microphone placement.[2] The justification for Mason's theory argues that very little objective investigation has been carried out into surround and most tests use one's listening perceptions in order to reach a final decision.[3] However, despite the proposition of Mason to use a stringent testing process with a research sample, Corey and Martin suggest that the recording and mixing engineer often finds himself use subjectivity in order to achieve the most detailed aesthetics from the sound source during

[2] Mason, R. 'Microphone Techniques for Multichannel Surround Sound', *Audio: the Second Century – AES UK Conference* (June, 1999), 1.
[3] Mason, R. 'Microphone Techniques for Multichannel Surround Sound', *Audio: the Second Century – AES UK Conference* (June, 1999), 1.

recording.[4] In turn, it is hoped, that these selections will ultimately develop congruence between mix components.

With this wide range of influences impressed upon the amateur and professional sound engineer alike, it can be argued that through a series of structured tests, coupled with the subjective influence derived from qualitative listening, further ground can be covered in order to establish how effective bespoke recording and mixing methods for surround sound record production are in comparison to techniques established in two channel stereophony.

A further key rationale lies in the playback format. The fact that there is a rich back catalogue of recorded material that has either been primarily produced for such output, or, more prominently, has been remixed for surround sound from the original master tapes, allows strong comparisons to be sought between the various schools of thought employed during the creative processes.

2. Research Methodology

2.1 Research Aims

The research process intends to address a variety of goals:

- To complete a full musical production process encompassing the composition, performance, recording and mixing of an album (in excess of 40 minutes) to be compiled for the 5.1 surround sound field.

[4] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 42.

- To consider, test and critically appraise the use of a wide range of both existing mono and stereo recording techniques, comparing them to microphone techniques deliberately developed for surround sound recording.
- To examine the processing of recorded channels at the mixing stage and establish the most effective methods of separating each element of the composition.
- Critically appraise existing pieces of work by commercially successful popular music artists with particular reference to the production techniques used, in turn applying them to the author's own compositions.

These aims intend to answer the following research questions:

- Does using standard stereo microphone techniques during recording have a practical advantage over surround sound recording techniques when production reaches the mixing stage?
- What methods of capturing audio in surround sound are effective in creating cohesion between the output channels during playback?
- Is it possible to employ measures that will prevent the collapse of the stereo image when output loudspeakers are placed in non-ideal locations, or when the listener is not situated in the sweet spot?

2.2 Key Works

As with many areas of music production literature, the resources relating to the realisation of surround sound recording are plentiful. Seminal books from the likes of Holman and Rumsey offer one an introduction to the approaches that can be utilised in surround sound capture, but there are drawbacks.[5, 6.] For instance, there is little mention of the investigation into individual instruments and this theme is obvious in a variety of works that seem to concentrate on the topic of playback or general approaches to location recording. With this in mind, a key influence on some of the approaches used has been work such as Corey and Mason's paper on surround sound techniques. This paper has some weight in that it critically analyses how one can achieve the optimum balance of direct and reverberant sound in a recording.[7] Additionally, Lee Hyunkook's research paper on perspective control during surround sound recording has certainly influenced the author in his own approach to developing one's own surround sound recording techniques.[8]

With regard to the notion of achieving effective stereo imaging without risking collapse to individual loudspeakers, a key piece of literature used in the research process was Pulkki and Karjalainen's investigation into amplitude panning. The value of this particular article is substantial because of the prominent points expressed regarding the aesthetic nature of sounds in the

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[5] Holman, T. *5.1 Surround Sound Up and Running.* (Boston, MA. 2000)
[6] Rumsey. F, *Spatial Audio.* (Oxford, 2001)
[7] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.
[8] Lee, Hyunkook. 'A New Multichannel Microphone Technique for Effective Perspective Control', *130th Audio Engineering Society Convention*, (May, 2011), 2.

surround sound field, the critical analysis of altering various parameters at the source and their respective outcomes. Additionally, Moore and Wakefield's Audio Engineering Society (AES) convention paper on surround sound playback in 'constrained listening spaces' was useful in considering the feasibility of future innovation in the surround sound field with specific focus on effective 5.1 stereo imaging in the home.[9] This paper has a particular standing in this research, as it is indeed effective playback in the home that has made success for the surround sound record so elusive.

Of course, in addition to written documentation of several pieces of research, the nature of the author's research warrants some of the background research material to be existing audio work. Therefore, the author has selected a repertoire extending over several decades and covering the two main approaches to surround sound production. The works critically analysed are:

1. The Beach Boys - Pet Sounds (1966, 2003)
2. Pink Floyd – Dark Side of the Moon (1973, 2003)
3. Dire Straits – Brothers in Arms (1985, 2005)
4. Metallica – The Black Album (1991, 2001)
5. The Flaming Lips – The Soft Bulletin (1999, 2006)

N.B. Dates are in the format (Original Mono/Two-Channel Stereo Release, 5.1 Release).

[9] Moore, D. Wakefield, J. 'Designing Ambisonic Decoders for Improved Surround Sound Playback in Constrained Listening Spaces', *130th Audio Engineering Society AES Convention,* (May, 2011), 2-5.

2.3 Research Chronology

The production element of the project was completed in a chronological manner as detailed in the subsequent flowchart:

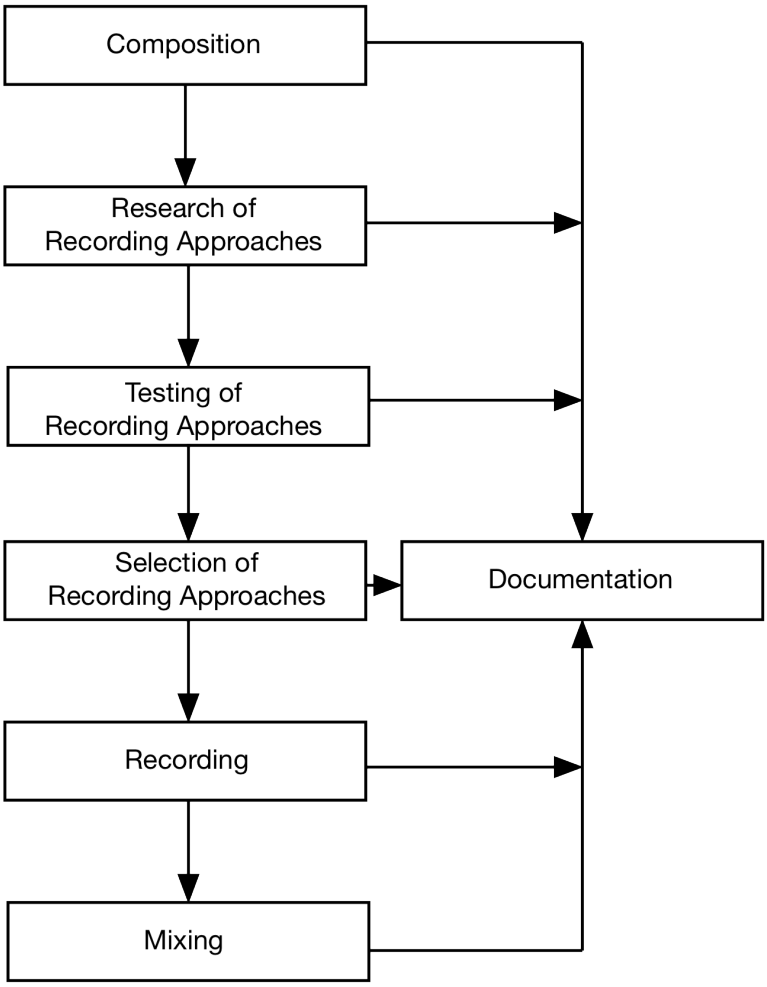

Fig. 1 - The Production and Information Gathering Process

Within the chronology of the production approach it was felt necessary to compose the majority of the material before the decisions regarding the recording process were considered. This allowed a greater degree of control over the overall sound of the final product rather than being speculative by

recording existing material by other artists or indeed by simply using improvisation as a tool during the research process.

2.4 Research Methods

In order to ensure a more regimented approach than the widely acknowledged practices of engineers, suggested by Corey et al, much thought was invested into the exact practices to be attributed to the research process. In agreement with Mason's recommendations, one could suggest that the most effective way of creating a strong qualitative test into the analysis of a recording environment is the replication of the space in spite of any change in the microphone array. Equally, it can be argued that one would strive to replicate the natural space and reverberation conveyed by the room in which recordings have taken place during the mixing process. With this in mind, the author's research methods have concentrated on the following main principles in respect of both creative processes:

- Utilising the same recording space for the capture of any given instrument(s). i.e. approaches for each instrument were exhausted in the same room as opposed to recording every instrument in the same room.
- Ensuring that mixing processes were undertaken in a room of similar proportions with a loudspeaker array appropriately calibrated for the chosen output format.

One of the most obvious ways in which the research into recording methods can be conducted is in a chronological order. Had the series of tests employed by the author been exclusive of the end product, the recorded

compositions in this instance, an ad hoc method could have been used which could have focused on a wider range of instruments; perhaps even probing a semi classical field, as has been used in some prominent up-to-date popular recordings. However, an approach more akin to bottom up design was used to develop the recordings as more components were added. As with a traditional multi-track recording process the recording created a collage beginning with the rhythm section moving through to the melodic elements.

In parallel with the testing of recording techniques, selections were made when necessary and material was recorded when an approach had conjured sufficient evidence to prove optimum effectiveness. In turn, more research led evidence was collected to influence the mixing decisions. This culminated in a well informed and justified mixing stage that produced a balanced 5.1 stereo image, the evasion of excess sonic colour and the obvious separation and localisation of mix components within the recordings.

3. Analysis of Recording Techniques for Surround Sound

This section intends to give an indication of the approaches explored by the author during the recording element of the project and will critically appraise both mono and two channel microphone placements as well as surround sound arrays tested by the author. In some cases, these approaches have been adapted from those proposed by the likes of Corey and Martin and Hyunkook depending on the nature of the source to be captured.[10]

3.1 5-Channel Stereophonic Recording Techniques for Drum Kit

Given the bottom-up nature of the recording process, the most intensive testing by the author was on the recording of the drum kit. The main justification behind this was a pre-conceived idea that in all cases the drum kit would be reproduced across the whole of the 5.1 sound field. Furthermore, as fundamentally suggested by Pulkki and Karjalainen, the author agrees that balancing 'direction, distance, width of sound sources and room envelopment' is vital to establish early on in the recording process.[11]

Corey and Martin's suggestion of using the two rear microphones in the array as a method of capturing reverberation was an initial departure for the author and had a key influence in the selection of microphones and their positions.[12] The directionality of captured sound is something that Corey et al suggest should be applied to the Left, Centre, and Right (LCR) channels with non-direct audio recorded with the surround microphone and applied to the Left

[10] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.
[11] Pulkki, V. Karjalainen, M. 'Multichannel Audio Rendering Using Amplitude Panning', *Signal Processing Magazine,* 25/3, (May, 2008), 118-119.
[12] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.

Surround (LS) and Right Surround (RS) channels. However, the author feels that in this instance the fact that the drum kit encompasses multiple instruments, maintaining a sense of direction is a facet best retained and the bias of character can be adjusted at the point of mixing. There are a series of reasons for this. Firstly, a subjective argument is that the room reverberation may not be flattering to the overall sound of the drum kit, particularly in larger spaces such as Phipps Hall, with an RT60 time of around three quarters of a second.[13] In this situation, with Corey and Martin's proposition as a model, the surround microphones may be liable to capturing excessive room reflection and this may colour the ambient sound of the drum kit. This was evident in Centre surround microphone channel which was capable of acting as a controllable reverb effect during initial monitoring.

With the early research-fed investigation into microphone set-ups for drum kit capture modifications were made to the propositions outlined by the aforementioned research papers. This resulted in several permutations which were then tested over two days in order to establish an effective bedrock on which further instrumental recordings would sit. The following microphone arrays were used alongside a series of close microphones outlined in the subsequent table:

[13] Gallagher, M. 'RT60 Time' *The Music Tech Dictionary.* (Boston, Massachusetts. 2009) *181*

Table One

Component	Microphone	Description
Kick Drum	Audix D6	Placed in Soundhole.
Kick Drum	Audio Technica AE2500 (Dynamic Capsule)	Inside Shell, three inches from batter head.
Kick Drum	Audio Technica AE2500 (Condenser Capsule)	Inside Shell, three inches from batter head.
Snare Drum (Top)	Neumann KM184	Directed at centre of drum, off- axis four inches distance.
Snare Drum (Bottom)	Shure SM57	Directed at snare, on axis, one inch distance.
Snare (Overhead)	Schoeps CMIT-5U	Directly above drum, on axis, four feet distance.
High Rack Tom	Sennheiser MD421	Centre of drum, off-axis, three inches distance.
Low Rack Tom	Sennheiser MD421	Centre of drum, off-axis, three inches distance.
Floor Tom	Sennheiser MD421	Centre of drum, off-axis, three inches distance.
Hi Hat	Neumann KM184	Directed close to top cymbal bell, away from kit, one inch distance.

Scenario One

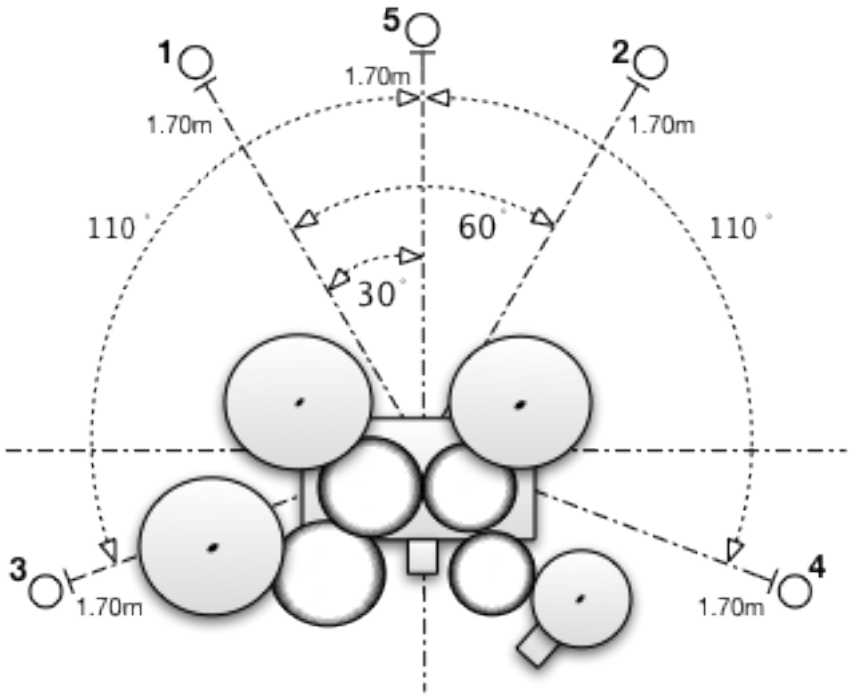

Fig 2.1 – Surround Microphones Positioned as a Direct Replication of 5.0 Speaker Locations

Reference Point – Kick Drum

1. Left 2. Right 3. Left Surround 4. Right Surround 5. Centre

The first approach to the drum recording process replicates the playback format, with the microphones positioned at the same angles as stipulated by the likes of Holman as Rumsey in their own publications. The reference point allows the kick drum to stay at the centre of the 5.1 stereo image because it is equidistant from each overhead microphone. Coupled with it's own close microphones, the kick drum channels become less difficult to phase align ensuring a solid low-end rhythm.[14] However, the drawbacks in this technique can begin in the overlapping of polar patterns on each side of the microphone array. This is Corey and Martin's main argument for using rear or ceiling

[14] White, P. *Creative Recording.* (London, 1999)

facing microphones to reduce the amount of direct sound captured in the surround channels.[15] Another issue with this idea is that the snare drum drifts away from the centre of the 5.1 image and this can distract the listener from the implied visual reference point, the centre loudspeaker.[16] The convention maintained by most modern popular music recording engineers is to hold the core elements of the drum kit in the centre of the two-channel stereo image and for the purposes of this project the author has embraced this notion.[17] This idea additionally permits the overhead channels to support the overall aesthetic intended by the author which attempts to envelope the listener within the sound of the drum kit.

[15] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.
[16] Howard, D. M. Angus, J. *Acoustics and Psychoacoustics* (Oxford, 1996)
[17] White, P. *Creative Recording.* (London, 1999)

Scenario Two

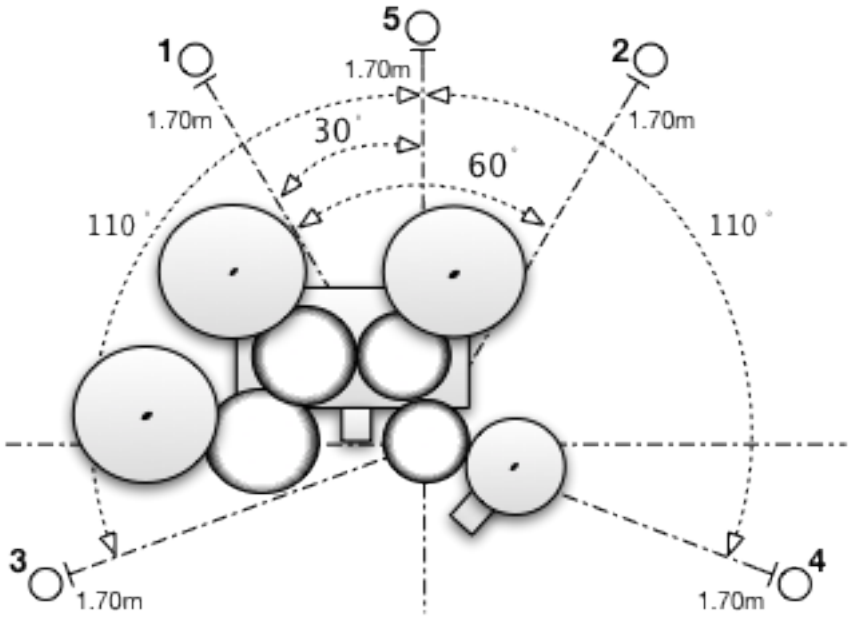

Fig 2 2 – Surround Microphones Positioned as a Direct Replication of 5 0 Speaker Locations

Reference Point – Snare Drum

1 Left 2 Right 3 Left Surround 4 Right Surround 5 Centre

With regards to the second theory tested, artefacts that quickly became clear in recorded material were that the 5.1 stereo image had shifted substantially to the left of the listener due to the modification of the reference point to the snare drum. With discrete mixing, which will be considered in detail later in the paper, this resulted in a lack of width across the toms, something which is a trait in Chuck Ainley's 5.1 surround sound mix of Dire Straits' *Money for Nothing.*[18] Furthermore, the cymbals suffer movement across the 5.1 stereo image because of the layout of the kit in this instance. The physics behind this result is the excessive delay caused by the difference in source arrival time at each microphone and in this case the 'lop-sided' feeling is expressed through

[18] Dire Straits, 'Money for Nothing', *Brothers in Arms,* Universal/Mercury 9871498 (2005)

direct sound to the listeners left and ambience on the other side of the 5.1 stereo image.[19]

Scenario Three

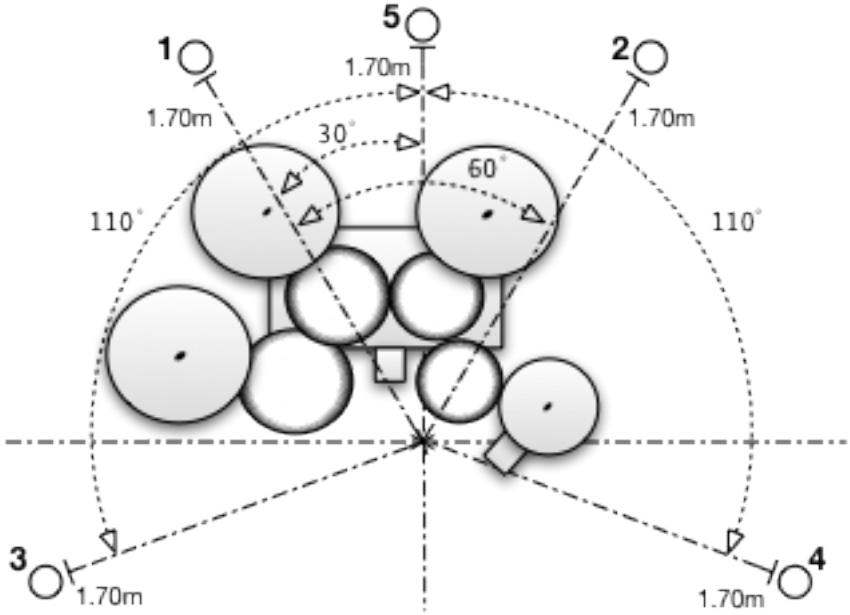

Fig 2.3 – Surround Microphones Positioned as a Direct Replication of 5.0 Speaker Locations
Reference Point – Drummer
1. Left 2. Right 3. Left Surround
4. Right Surround 5. Centre

Thirdly, the author investigated using the drummer as a reference point in an attempt to allow the listener to be in the centre of the ensemble, in turn experiencing an array of sounds surrounding them from other elements of the composition. While this brings the 5.1 stereo image more to the centre, and also brings the location of the kick and snare drums to a compromise in a future mix, the cymbals once again stray away from balance and create unnecessary confusion in the sound field. At this point the author felt it

[19] Rumsey. F, *Spatial Audio.* (Oxford, 2001)

appropriate to embellish these ideas with a direct suggestion of Corey and Martin's, but also to adjust that idea further in an attempt to achieve cohesion in all 360˚ of the kit.

Scenario Four

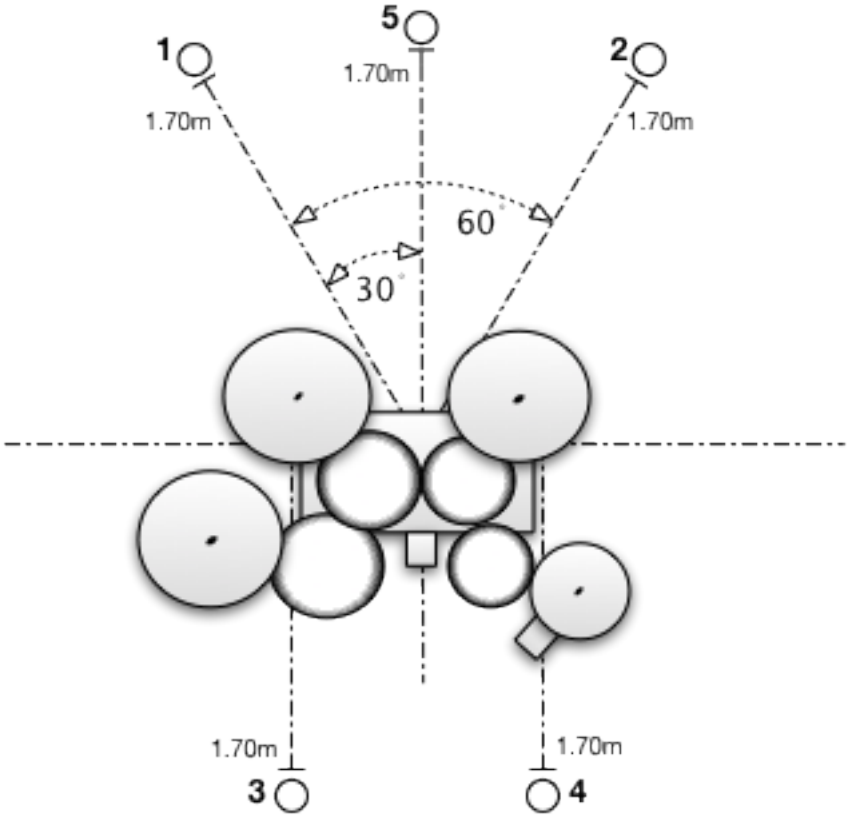

Fig 2.4 – Microphones Positioned with a Rear AB Cardioid Stereo Pair
Reference Point – Kick Drum
1. Left 2. Right 3. Left Surround
4. Right Surround 5. Centre

Scenario four includes the same LCR configuration as the previous approaches but considers an AB spaced pair as a replacement for the wide LS and RS microphones employed in earlier tests. The proposition of Corey and Martin suggests that cardioid microphones should be used directed at an

angle that will isolate a strong amount of direct sound.[20] As already described by the author, this was not a characteristic to be considered as an advantage to the end result and therefore the AB pair was employed in a similar manner to a stereo array used in the likes of theatre. One distinct advantage is the narrow placement of the pair in the array as it prevents the characteristic hole in the middle which can occur when spaced microphones are simply placed too far apart.[21]

[20] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.
[21] Savanyi, S. 'Stereo Mics', *Broadcast Engineering,* 52/2, (February, 2010), 28.

Scenario Five

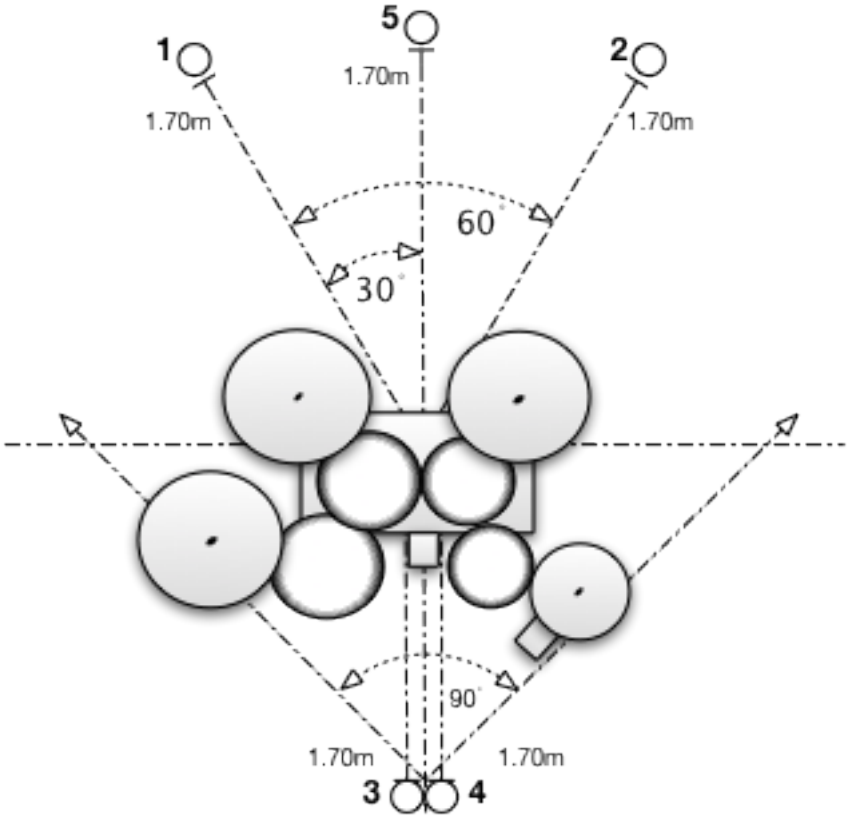

Fig 2.5 – Microphones Positioned with a Rear XY Cardioid Stereo Pair
Reference Point – Kick Drum
1. Left 2. Right 3. Left Surround
4. Right Surround 5. Centre

The final scenario employed in the drum recording process was to replace the previous AB spaced pair with an arguably stronger XY or coincident pair of cardioid pattern microphones placed at an angle of 90°. This enhances the pick up area of the array when compared to a spaced pair but the wider angle also prevents the polar pattern from overlapping with the front left and right microphones which can blur the different perspectives that each microphone

can give on what is essentially a complex instrument.[22] However, one disadvantage proposed by Rumsey, is that the phantom image designed to be created by the pair of microphones behind the listener is liable to provide a false image in front of the listener.[23] This is largely because of sound reaching one's ears simultaneously and in precisely the same way one localises a frontal sound source.[24] Therefore it can be argued that this problem can make the rear phantom image capable of interfering with its frontal counterpart and causing instability in the drum mix.[25]

The resulting approach from these tests maintained the use of an LCR array which involved the left and right front overheads creating a traditional two-channel stereo phantom image but also leaving room for the centre to channel to output the core elements of the kit such as the kick, snare and hi-hat. As described, the reverb time in the room was sufficient not to need bespoke capture of the sonic reflections in the space and a secondary motivation was the availability of convolution reverbs which can be applied to taste and relieve the risk of having an unwanted colour permanently captured on the original recordings. Therefore, the rear microphones were placed at around a 65° angle to take on different characteristics to the front in line with Corey et al's reasoning.[26] Moreover, a subjective reason behind this decision is that the author found that the rear microphones, when positioned equidistant from the kick drum, picked up a fuller sound from the individual drums in the kit. One

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[22] Savanyi, S. 'Stereo Mics', *Broadcast Engineering,* 52/2, (February, 2010), 28.
[23] Streicher, R. Everest, F.A. *The New Stereo Soundbook*. (Pasadena, 2006)
[24] Rumsey, F. *Spatial Audio* (Oxford, 2001)
[25] Streicher, R. Everest, F.A. *The New Stereo Soundbook*. (Pasadena, 2006)
[26] Corey, J. Martin, G. 'Surround Sound Micing Techniques', *World Broadcast Engineering,* 46/3 (March, 2004), 44.

explanation for this could be that the absence of cymbals in a direct line to the microphones was allowing the rear microphones to be a more accurate captor of the kit as opposed to behaving as a pair of cymbal microphones.[27]

3.1.1 Conclusions

Finally, in researching this element of the recording process as a case in point, what can be ascertained is that Lee's argument for better control of perspective when designing a multichannel microphone recording array can be carried out in practice, though the author argues that the array does not have to conform to Lee's suggestions. An example of this was the centre microphone used by the author which acted as an adjustable control of the space in the room. Combined with the close microphones in the array it was possible to create an overall sound which when balanced in one way could deliver the characteristics of the room in which it was recorded. Conversely, balancing a different way had the ability to make a very dry outcome but one which still retained the mark of it being recorded in 360 degrees. However, as is the case for much of the research presented on surround sound recording, instruments are rarely a theme that is exclusively explored and one again has to point to Mason's suggestion that much investigation is carried out subjectively – a trait which is often argued to be the focus of popular music production.[28]

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[27] White, P. *Creative Recording.* (London, 1999)
[28] Mason, R. 'Microphone Techniques for Multichannel Surround Sound', *Audio: the Second Century – AES UK Conference* (June, 1999), 1.

3.2 Appropriate Mono and Stereo Microphone Techniques for Instrument Recording

3.2.1 Bass Guitar

Conversely, to the drum kit, many of the instruments recorded subsequently required more basic efforts during the recording process despite the output format. Sharing its place in the low end of the mix of a record with the drum kit, the bass guitar is arguably a simple instrument to capture even in a multichannel format. Once again, relying on the convention of popular music producers almost all commercial recordings will employ the bass guitar in the centre of the stereo image and there are several justifications for why the instrument does not lend itself to being over-complicated during the recording process. Unlike on stage in small live music venues where bass amplifiers will usually be found on one side of the stage and thus be localised to there, a listener finds a visual reference with recorded music which states that the core timekeeping elements i.e. the rhythm section will be equally balanced in the centre of the stereo image. As with the decision to ensure the kick and snare drum were most apparent in the centre of the 5.1 stereo image at the stage of recording, the nature of the bass guitar is another component to require this treatment. Justification for this decision can be related to the common decision during composition for the bass guitar to 'lock in' with the drum kit and indeed the author wished to pre-empt this fundamental idea of pop music rather than concentrate on an over complex sound within an instrument that is rarely given much ambience within a recording.[30]

[30] Senior, M. 'Mixing Bass', *Sound on Sound,* 27/11 (September 2012), *68-81*

3.2.2 – Electric Guitar

With the compositions lending themselves to guitar playing, with a broad range of genres influences such as Reggae, Latin American rhythms and Progressive Rock styles, complex parts were written for the guitars and several solos are taken in the work as a whole.

The approach was varied and several different guitars, amplifiers, effects and microphone configurations were used largely due to the variety of the material with reference to genre, dynamics and the visualisation of achieving different aesthetics both for the compositions and ultimately for the finished recordings. Lengthy investigation was conducted into capturing the instrument in a sterile way with close microphones but additional microphones were tested in each different room used in order to capture reverberation, room ambience and additional character which could be applied at the mixing stage. This approach attempted to ensure that the guitar is present in the mix but also has natural, musical character that has the ability to act as an adhesive quality to the music, fusing each instrument into a coherent single entity whilst preserving the subtleties of each component in the composition.

The standard close microphone technique employed was a Shure SM57 cardioid pattern dynamic microphone positioned at an angle of approximately 45 degrees to the loudspeaker and around two inches from the loudspeaker cone. Experimentation was used in relation to the position of the microphone in order to capture the optimum mode within the loudspeaker.[31] Augmentation of the character of the overall sound was achieved with the warmer overtones

[31] Greeves, D. 'Understanding and Recording Guitar Speakers', *Sound on Sound,* Unknown, (February 2002)

of a valve microphone in this particular configuration and this was mixed with the close signal to achieve greater depth and detail.

The second microphone array used was a variation of the mid-side or sum and difference pair and this is a particular example of a recording approach that lends itself well to application in a surround sound setting. As with the bass guitar, the mid microphone provides the punch necessary to have definition in the mix but meanwhile the side components can be attributed to the left and right loudspeakers in order to widen the reproduced sound. A second option is to apply the side channels to the surround loudspeakers which can be used as a means of enveloping the listener. Once again this is a possibility when there is the desire to bring the guitar forward in the mix as a creative decision. This would be defined as using the technique like an equaliser as opposed to simply increasing volume or gain. These techniques will be further discussed during the section devoted to the mixing process.

3.2.3 – Acoustic Guitar

In the series of compositions prepared in conjunction with this paper, the acoustic guitar in most cases was used as a textural tool as part of the rhythm section in the ensemble. In turn, the instruments standing in each piece dictated how it would be recorded. Despite the desire to make this guitar unobtrusive, simultaneously there was also a need for it to be a strong component of the final mix that if removed would be dearly missed.

The first approach that was investigated was a 5.0 configuration that had been used on a larger scale with classical music. The Österreichischer Rundfunk (ORF) in Vienna conducted a study into recording in the format with

high-end professional microphone arrays and there were some intriguing outcomes particularly with regard to the colour and character of different manufacturers products throughout the surround sound stereo image.[32] In the instance of recording the acoustic guitar a DPA set was used comprising three omnidirectional capsules and two cardioid capsules as surround microphones. Whilst the results were of reasonable quality, the surround microphones provided a thin sound lacking a degree of warmth. This may have been due to their positioning behind the musician though another contributing factor will have been that they were not directional towards the sound. This captured reflections more akin to a reverb effect and this damaged the overall sound. One solution was to discard the surround channels and retain the left, centre and right channels. A second approach was also used. A direct injection channel was recorded that possessed a bright characteristic useful for achieving presence in a mix. Coupled with an XY pair of matched condenser microphones the mellow timbre from the neck of the guitar was captured along with the brighter, more abrasive sound from the bridge that in turn provides one with a series of options when one arrives at the point of mixing.

3.2.4 – Vocals

With the ability to artificially double track vocals many popular music records stand fast with a single microphone in order to obtain a vocal that will sit comfortably within a mix. However, with surround sound techniques, the

[32] Hauptmikrofon, 'ORF Sound Techniques', Hauptmikrofon.de, http://www.hauptmikrofon.de/index.php?option=com_content&view=article&id=68&Itemid=58 (12th March 2012)

subtle variations in phase that occur when a series of microphones are used results in the comb filtering effect that has been used on many occasions with instruments such as the electric guitar.[33]

Although single microphones were used on some vocal tracks, particularly harmonies or on lead vocals where proximity effect was to be used creatively, three microphones were used as an array that, like the guitars and drum recording, could be used effectively when routed discretely to the centre channel, and either the left and right or surround channels, or indeed all four corners of the loudspeaker array. One main advantage of the approach is that channels can be mixed discretely with others. For instance, the centre vocal can stand alone whilst the left and right recorded channels can be mixed with harmonies or double tracks within an individual speaker channel. This achieves greater separation of the component parts of recorded tracks be disallowing crosstalk, something that is a widely talked about issue within dual channel stereo.

One other main advantage of using several vocal microphones is that less directional microphones also have the ability to be used as effects. Conversely to the recording of the acoustic guitar, when the left and right microphones in the three channel vocal array are used their slight lack of directionality adds a feeling of space that is natural and also avoids the colouring nature of using effects and plug-ins as a means of achieving depth to a recording.[34]

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[33] Gallagher, G. 'Discrete', *The Music Tech Dictionary* (Boston, MA. 2009) *35*
[34] Howard, D. M. Angus, J. *Acoustics and Psychoacoustics* (Oxford, 1996) *364-368*

4. Analysis of Surround Sound Mixing Techniques

This element of the paper devotes itself to the discussion of the research question relating to the processing of compositional elements when one reaches the point of mixing a record. Whilst the recordings captured for this series of compositions have included techniques that have deliberately considered the mixing process, delivering a mix that has a feeling of spaciousness can be complicated when introducing another layer of recorded channels, in this instance the Centre and LS and RS channels.

4.1 Achieving Separation of Mix Components

In parallel with mono and two-channel stereo, the ability to distinguish individual components of a mix are integral to the cohesion that many academics believe is the essence of a strong surround sound recording. However, as with past and current formats, the number of tracks available within DAW software is so vast that it is easy build up numerous takes of the same part to achieve a multitracked characteristic. As is widely acknowledged in two-channel stereo production, the use of more than one microphone has often been to create a sound derived from separating and/or processing the individual channels. Examples of this are the mid-side technique and the coincident pair.[35] On the other hand, the professional sound engineer has regarded it to be easier to mix for two-channel stereo rather than 5.1 stereo despite the increased number of channels.[36] One possible explanation could lie in the argument set out in Moore and Wakefield's paper on constrained

[35] Savanyi, S. 'Stereo Mics', *Broadcast Engineering,* 52/2, (February, 2010), 28.
[36] Jackson, B. '*Pet Sounds* in Surround', *The Mix,* 26/13, (December, 2002), 154.

playback spaces, making it difficult for the listener to become enveloped by the composition.[37] In some of the works listened to by the author, particularly Metallica's *Black Album,* it can be argued that the mixing engineer has taken similar simple decisions such as placing more ambient components in the surround speakers. This is obvious on the recording of *Nothing Else Matters* where the only significant mix component to be shifted to the rear of the 5.1 stereo image is the guitar solo.[38] On the other hand, in the case of the album *Pet Sounds* by the Beach Boys, appraisals by audio enthusiasts accuse the mix of being too biased towards the rear speakers.[39] This suggestion when coupled with the visual reference of the LCR speakers in the front of the listener could arguably make the mix difficult to absorb because of the expectation that the front loudspeakers will deliver the same elements as in a two-channel stereo production, or in the case of the Pet Sounds, an example of monaural record production.[40]

With these potentially pre-conceived conventions in mind, the author's approach acknowledges the techniques used by the compositions previously mentioned. However, one feels that key parts of the recordings can be permitted to explore the 5.1 stereo image further than being sent to the front or rear of the loudspeaker array. One example of how this has been achieved in the accompanying works is with 'up-front' elements such as the guitar solos and the vocals. Siding with Lee's suggestion of achieving perspective, the

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[37] Moore, D. Wakefield, J. 'Designing Ambisonic Decoders for Improved Surround Sound Playback in Constrained Listening Spaces', *130th Audio Engineering Society AES Convention,* (May, 2011), 2.
[38] Metallica, 'Nothing Else Matters', *The Black Album (5.1),* Elektra (2001)
[39] Jackson, B. '*Pet Sounds* in Surround', *The Mix,* 26/13, (December, 2002), 154.
[40] Howard, D. M. Angus, J. *Acoustics and Psychoacoustics* (Oxford, 1996)

component has often been discretely panned to the centre channel to retain the visual reference point associated with the listening position.[41] The control of perspective has then been achieved by using the rear channels. This approach involved using one of the recorded channels, often a less present channel, and using the amplitude of the signal to deliver a control of depth. By balancing the three channels in use this allows the mix component to move back and forth but also allows the presence achieved by close miking or lack of it by more ambient microphones to discover the optimum way of enveloping the listener.[42]

One problematic area during the mixing process was the clear separation of the low-end parts such as the bass guitar and kick drum. However, there is little difference in the approach employed to overcome this issue when in the 5.1 stereo format when compared to two-channel stereo mixing. This is because of the decision to pan the kick drum, snare drum and bass guitar all to the centre speaker in the array; a decision that could be argued as a translation of panning centrally in a two-channel stereo format.

The most obvious remedy to this issue in the mix is to use corrective equalisation (EQ).[43] After using subjective analysis on the channels, mainly through isolating the relevant components of the mix; and EQ analysis software, it was found that the most effective equalisation for the kick drum was a low pass filter to approximately 80 Hertz (Hz). This was a subjective

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[41] Lee, Hyunkook. 'A New Multichannel Microphone Technique for Effective Perspective Control', *130th Audio Engineering Society Convention*, (May, 2011), 2-3.
[42] Pulkki, V. Karjalainen, M. 'Multichannel Audio Rendering Using Amplitude Panning', *Signal Processing Magazine,* 25/3, (May, 2008), 118-119.
[43] White, P. *Creative Recording.* (London, 1999)

decision as it allowed the sub-harmonics of the bass to fit into the mix, a characteristic that the author feels important because of the additional Low Frequency Effects (LFE) channel. This reinforcement of the low frequencies is something that lends itself well to the final section of *Devil's Striptease*, composed by the author, where a synthetic kick drum has had the sub frequencies deliberately boosted to achieve a heavy sound. Equally this has been employed to the tam-tam in the same composition to increase the fullness of the instrument and to create a harder hitting sound beneath the opening riff. However, the presence of the LFE channel within a 5.1 loudspeaker array and the fact that it processes the frequencies below approximately 100Hz, means that all the sub frequencies are output through a single transducer. This is a potential drawback for separation of mix components

Like with the drum kit, the tam-tam was also recorded using five surround microphones and was panned discretely in order to impress the dimensions of the room upon the listener. Equally the panning of the toms is intended to stretch the 5.1 stereo image so that the listener is influenced in believing that they are enveloped by the drum kit, percussion and the backing vocals which are panned to surround the listener from all angles. This is something that engineers developing both the Beach Boys and the Flaming Lips' mixes have done on their respective works.[44] By processing the elements of the mix to create distinguishable components, and in turn surrounding the listener with

[44] Jackson, B. '*Pet Sounds* in Surround', *The Mix,* 26/13, (December, 2002), 154.

them, the idea of enveloping the listener is fully explored.[45,46] An additional way in which this has been achieved in the Flaming Lips' *The Soft Bulletin* is by extremely sparse parts in particular sections of songs. This deliberately makes localisation easy for the listener as the direction of sounds panned to discrete channels are easily recognisable. This is something the author has attempted to achieve when dynamics have been softer in songs such as *Black Buck*, with it's extensive use of speech samples, and also in *You Won't Escape Me,* where the string quartet becomes isolated at the end of the composition to bring the collection of works to a close.

4.2 Maintaining the Integrity of the 5.1 Stereo Image

During the course of the mixing process several things became evident to the author as track counts were pushed high and methods of separation in the mix were further exhausted. Firstly, the perception of width outlined by Pulkki and Karjalainen's paper is an aesthetic quality that attempts to give a sense of depth to a mix and becomes part of a natural environment rather than from a one-dimensional source.[47] Both this and Lee's idea of achieving different levels of perspective have similar results, but the key difference is that Lee's suggestions are almost entirely based on microphone technique whereas Pulkki and Karjalainen are very focused on the processing of audio to bring out the aesthetic qualities they mention being key to true envelopment.[48] The idea of using amplitude is also fundamental in the application of computer

[45] Beach Boys, *Pet Sounds (5.1),* Capitol 72434-77937-9-0 AA01 (2003)
[46] Flaming Lips, *The Soft Bulletin (5.1),* Warner Brothers (1999)
[47] Pulkki, V. Karjalainen, M. 'Multichannel Audio Rendering Using Amplitude Panning', *Signal Processing Magazine,* 25/3, (May, 2008), 119-120.
[48] Pulkki, V. Karjalainen, M. 'Multichannel Audio Rendering Using Amplitude Panning', *Signal Processing Magazine,* 25/3, (May, 2008), 119-120.

software panning plug-ins, as it is in audio hardware systems, but in any case it is these interactions that give the surround sound mix a feeling of the space the sound field occupies and the localisation of mix components. One problem, however, is managing to keep these attributes accurate when one is not located in a fixed, optimum listening space. Such calibration devices exist for even the modest home cinema system but these rely on a strong original mix to be successful.[49] An inherent problem during mixing is the fact that the angles of the speakers in a 5.1 array encourage sound to be directed at sounds from opposing speakers, arguably resulting in a comb-filtering effect when similar sounds either collide or reach the ears at very slightly different times.[50]

Issues with difference in arrival time to the ears from irregular loudspeaker placement, and also the listener's position in relation to the loudspeaker array, can result in a collapse of the 5.1 stereo image and this is a trait of the author's own work at the initial mixing stage. Several measures were undertaken to discover the exact root of this problem. It first may have been thought that not enough corrective EQ had been conducted at the mixing stage creating a 'boxy' characteristic. This was found in the low frequencies comprising the electric guitar, bass guitar and snare drum and resulted in poor separation particular when the guitars were panned to the left and right channels, similar to a two-channel stereo approach, and were battling for supremacy with the bass guitar and snare drum discretely sent to the centre channel. The solution that was used to overcome this issue was using more

[49] Holman, T. *5.1 Surround Sound Up and Running.* (Boston, MA. 2000)
[50] Streicher, R. Everest, F.A. *The New Stereo Soundbook*. (Pasadena, 2006)

extreme high pass filters on the guitars and this was reasonably successful. However, one area in which the mix resulted in being unsuccessful was the difficulty in mixing tracks that were directly panned to the centre speaker. This was evident in both the case where software panning was used and also where discrete panning was used. In hindsight, a criticism of the approach used to mix the rhythm section was the choice to involve all of the drum kit whilst finding an area for the bass guitar channels to sit in the mix. A potential solution could be to mix the centre speaker in a similar manner to a monaural recording in order to develop a strong balance of parts and in turn to build around this with elements such as the surround overheads.

A final case in point in relation to achieve a 5.1 stereo image which maintains it's integrity throughout a series of recorded compositions lies in the attitude towards compression. For many years engineers have used audio compressors to characterise sounds rather than just to smooth out their dynamics and arguably this is a creative tool that should logically be applied to 5.1 stereo recordings. One issue encountered by the author was a harsh sound particularly in sibilant areas of the mix such as the cymbals and also because of the nature of the vocals. As well as this, there was collapsing of mix components that had been spread using software panning that was initially intended to provide the listener with a virtual image between loudspeakers.

The problems with the final mixes outlined by the author were found to be a result of the mastering style compression applied to the master bus of the DAW projects and this had also enhanced the 'boxiness' previously mentioned in the low-middle frequencies. This excessive dynamic processing

seemed to cloud the mixes and prevented the colour of higher-order harmonics standing out and giving overall clarity to the recordings.

The nature of the compressor used, in this case a multi-mono software compressor within the DAW, proved also to be an issue when making remedial changes to the final mixes presented by the author. The characteristics of the compression appeared to be ducking other elements of the composition when the threshold was reach and gain reduction applied. In turn, this had a seriously detrimental effect to the integrity of the 5.1 stereo image due to the sound field appearing to shift backwards and forwards. This was particularly evident in *My Religion,* where the off-beat guitars and snare drum are supposed to interact. However, the result was the guitars pulling the mix backwards before the snare drum battled with stereo image on the second and fourth beats and succeeded in pulling it excessively towards the front of the soundfield.

Despite this myriad of problems, the solution was reasonably simple and involved removing the master bus compression from the recordings and making subtle changes to the mixes to balance it appropriately for the final bounces. Having done this, a lot more low-level dynamic detail was retrieved from within the mixes which unarguably is a much better aesthetic decision than excessive processing to achieve loudness.

5. Conclusions

Upon reflection, and considering the research aims and questions outlined during the conduction of this project and subsequent thesis, there are some

important areas that have been explored and influenced the author's conclusions.

Firstly, an overriding concept in much of the research carried out by the author has been influenced by taste, in a directly opposite way to Mason's propositions at the start of the paper. Whilst there is indeed a rich amount of research on the subject of surround sound recording, the extent of it is mainly regarding the capture of large spaces or classical ensembles. This leaves very little to rely on other than the information that has been collected and recorded by the two-channel stereo sound engineer or producer. Equally, the relevant works cited by the author as being in an influential vein for the composition of the material have all been derived from two-channel stereo albums and indeed this format has been what has led to them being commercially prominent. Therefore, a potential recommendation is that arguably records must be deliberately developed for the surround sound format for the consumer to move on from two-channel stereo products. Of course, this is a complicated notion and the popularity of combining audio and visual production is perhaps the only way in which this can be explored in an age when listening in an analytical way is so out of fashion. One way this certainly can be done is already being explored and is through recording concerts in 5.1 surround sound along with video material.

Secondly, and more closely linked with the audio material created by the author, and in research conducted by others, is the level of sonic superiority that can be achieved when producing surround sound recordings. Moore and Wakefield's research is highly prominent in this light and if technology can be made more accessible in the home then high-resolution surround sound audio

will become more commonplace, and could possibly edge out the processing that takes place to create virtual surround sound in home theatre. Furthermore, the notion of playing a surround sound recording when on the move rather than in a fixed listening position may become as accepted as putting on a two-channel stereo record.

Finally, and relating to the effective capture of surround sound audio, is the fact that whilst two-channel stereo media and recording techniques are still deeply embedded in the recording studio they are also a prominent part of developing recordings with additional channels. This has been proven through the work done by the likes of Chuck Ainley for Dire Straits and Alan Parsons for Pink Floyd, but to an extent it has been also shown through the compositions created by the author. This is likely to be because of using less channels and therefore less space in the mixes, but also because of the bedrock of surround sound created by researching the techniques involved in recording the drums and then adding layers of sound in an attempt to create a sense of envelopment for the listener, something which from the outset has been cited in both formal, and informal research, as paramount when producing recordings for a multichannel environment.

6. Composition Programme Notes

6.1 Journey Through Time

The opening song on this project was composed as a piece in which the subject evolves as a long car journey unfolds. The author has written lyrics that describe what is seen as town becomes countryside and farmland becomes industry. Coupled with this is melody from clean guitars and the sampled waves and seagulls which intend to set the scene of the composition as being elsewhere than the listening position.

6.2 My Religion

Dealing with the controversial subject of the satire that has been applied to Christianity in several comedies such as Father Ted and The Vicar of Dibley, *My Religion,* in some ways refers to the negative perception by other religions when this applied to their own faith. The marrying of the two genres of Reggae and Latin American styles creates some interesting interplay between the guitars and the bass in the breakdown sections before coming together to transform into a lilting rhythm that carries the chorus.

6.3 Dandelion's Lament

As the name suggests, *Dandelion's Lament* is a recording in which the dynamic range has been made to cover the very soft spoken way in which dandelion clocks drift through the air, come to rest and germinate. Conversely, the heavy section in the middle that introduces a tutti band deals with the situation of how the dandelion is a flowering plant that becomes rampant when the seeds are dispersed.

6.4 Black Buck

This composition was wholly composed with the Falklands War as a theme and relates specifically to the Argentinian invasion and the mounting of Operation 'Black Buck', which is the longest distant air mounted military operation ever to take place.[51] The introduction focuses on news reports from the period and was inspired by a desire to 'set the scene' as it were. The reversed guitars that interplay with melodic rhythm guitar line were intended to emulate a feeling of flight and this is reinforced with the sampled Vulcan aircraft that introduces the rhythm section. Of course, the main influence on composing this song was the fact that it is a little over 30 years since the Falklands conflict ended and this seemed an apt motivation for a themed composition. The use of a military style single snare drum at the bridge section is intended to be a sobering moment and offers time to briefly consider that while the events of Operation 'Black Buck' were a widely acknowledged success for the Royal Air Force though the campaign could perhaps have ben avoided and the loss of life prevented.

6.5 Locomotive Jazz

As an incidental piece, which links two of the compositions in the project, the recording is a semi-improvised jazz style piece that features a minimalistic arrangement and allows for the use of samples of both steam trains and the more modern, heavy industrial sound created by diesel locomotives which for which the name 'Locomotive Jazz' is inspired. Perhaps the initial impression is that the piece is inspired by Pierre Schaeffer's *Les Etudes aux Chemin de*

[51] Royal Air Force, 'Operation Black Buck', RAF – Operation Black Buck, http://www.raf.mod.uk/history/OperationBlackBuck.cfm (10th September 2012)

Fer. Whilst this is true in the sense that similar material has been utilised to create the Musique Concrete sound at the beginning, it is in fact the author's interest in the subject of trains and railways that has prompted the recording of the samples.[52]

6.7 Devil's Striptease

Devil's Striptease is a composition that considers one's ability to be corrupted and likens this to being influenced by a metaphorical devil. Once again a wide range of dynamics are used between the introduction, which includes a tam-tam, before relaxing into a gentle rhythm and sparse instrumentation. The dynamics are then toughened in the finale where the climax of the subject matter is reached, at which point the decision to include an almost hard cut signifies the inevitable downhill spiral that occurs when the control of such an influence as corruption reaches it's peak.

6.8 You Won't Escape Me

The theme in some of the other songs in this project has been to create some memorable choruses as an element of the compositional process and this has been the case in the final track on the record. The orchestral arrangement of brass and strings attempts to emulate a fanfare like feel as a vehicle to demonstrate that this composition is the last piece to feature on the project. The theme deals with childhood and the memories of those who are no longer a part of your life. Despite the lyrics 'Youth Won't Escape Me', the decision was chosen to call the song *You Won't Escape Me* in the respect of the subject matter as opposed to the content of the composition.

[52] Schaeffer, P. 'Les Etudes aux Chemin de Fer.' (1948)

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