EXPLORING THE CINEMATIC HEMISPHERE FOR ORCHESTRA

A Collaborative Research Project on 3D Microphone Array Techniques for Orchestral Recording

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1. INTRODUCTION

Immersive audio represents a transformative evolution in sound recording and reproduction, enabling listeners to experience music with a heightened sense of spatial realism. In the context of orchestral recording, immersive microphone array techniques go beyond traditional stereo or surround formats by capturing the intricate spatial relationships within the ensemble and the acoustic character of the performance space. By leveraging advanced microphone arrays and latest spatial audio technologies, engineers and producers can create recordings that place the listener inside the soundstage - preserving the richness, nuance, and dynamic scale of the orchestra. This approach can not only enhance listener's emotional engagement but also open new creative possibilities for composers and producers, and audiences.

The ECHO Project was established with the aim of advancing immersive sound recording techniques for orchestral music and to bridging the gap between academia and the audio industry. In the spirit of the 3D-MARCo project, which championed the open sharing of high-quality immersive recording resources for education and research, we are publishing orchestral recordings made with eight microphone arrays—each designed by one of seven professional recording engineers—for open access under the CC BY-NC-ND 4.0 license.

The process of the project was as follows: first, we formed a focus group of recording engineers and researchers, comprising:

- Kellogg Boynton (PlayStation Studios)
- Anthony Caruso (PlayStation Studios)
- Hyunkook Lee (APL, University of Huddersfield)
- Morten Lindberg (2L)
- Simon Ratcliffe (Sound and Motion Studios)
- Katarzyna Sochaczewska (AGH University of Krakow)
- Mark Willsher (Pin3hot Ltd)
- Nick Wollage (AIR Studios)

The focus group held a series of online meetings to discuss the philosophies behind their recording approaches, theoretical principles, and best practices, as well as to plan the recording session. To explore different possibilities for musical immersion facilitated by microphone arrays, the group decided to record an orchestra in two physical layouts: traditional (180°) and circular (360°). A special composition for this project, *Train Journey*, was created by Oscar-winning composer Volker Bertelmann (a.k.a. Hauschka), with the aim of maximising the immersive potential of the musical arrangement. A public domain piece *Kammersinfonie für 23 Soloinstumente* by Franz Schreker was also chosen. The recording session took place at the Lyndhurst Hall, AIR Studios in London on 17 Dec 2024. The music was performed by London Contemporary Orchestra (LCO), conducted by Hugh Brunt. Following the recording session, the sensitivity of each microphone used was measured, and the track levels were calibrated. Each focus group engineer mixed the recordings captured by their own array in Dolby Atmos 7.1.4 and created the corresponding ADM BWF master files.

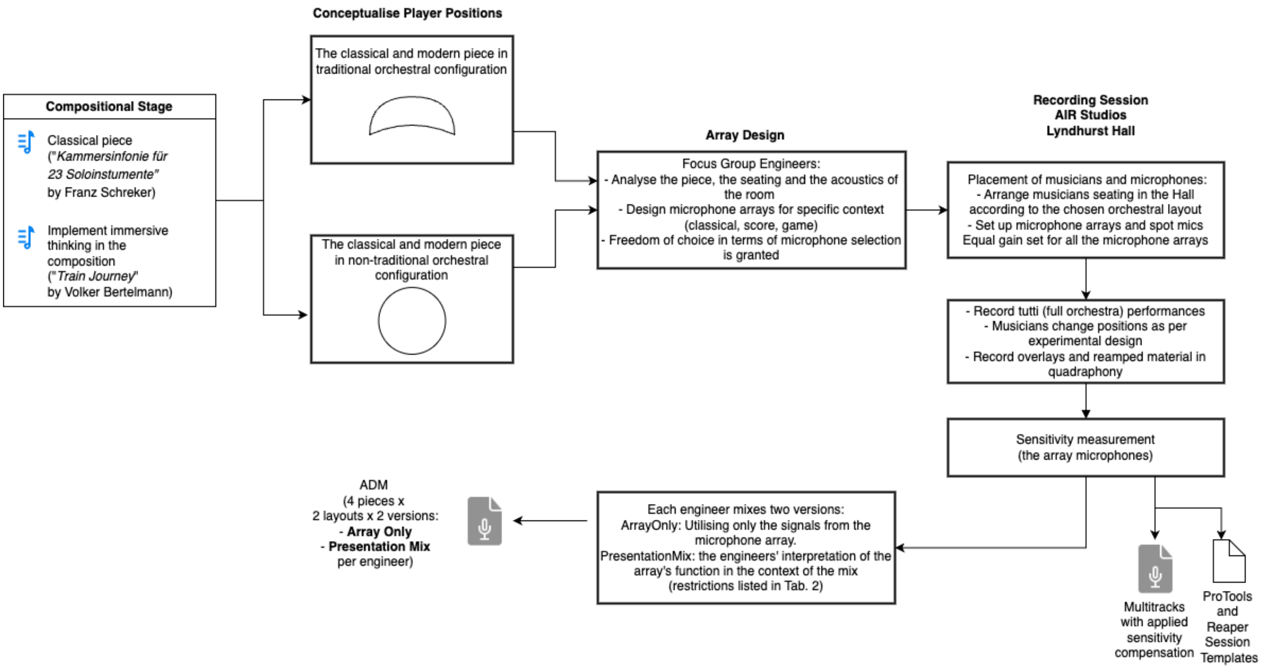


Fig. 1. ECHO Project – Process.

2. RECORDING SESSION

2.1. Physical setup

The recording session took place at Lyndhurst Hall, AIR Studios in London, UK. The hall, designed in the Romanesque style by Alfred Waterhouse in 1884, features two large and two small booths—each capable of functioning as an isolated room. The main area, hexagonal in shape, houses a movable canopy with double-sided panels: one side reflective and the other absorbent. For the ECHO recordings, the upward-facing side was absorbent, while the top remained reflective.

To ensure consistency and transparency at the microphone preamplifier stage, two Avid MTRX II units were used, configured with:

- 14 Avid Mic/Line Cards, providing up to 112 channels of analogue input
- 2 Avid 8-Channel Analogue Output Cards
- A Thunderbolt I/O option module in each MTRX II

An additional Avid MTRX Studio was employed to provide 16 more analogue output channels.

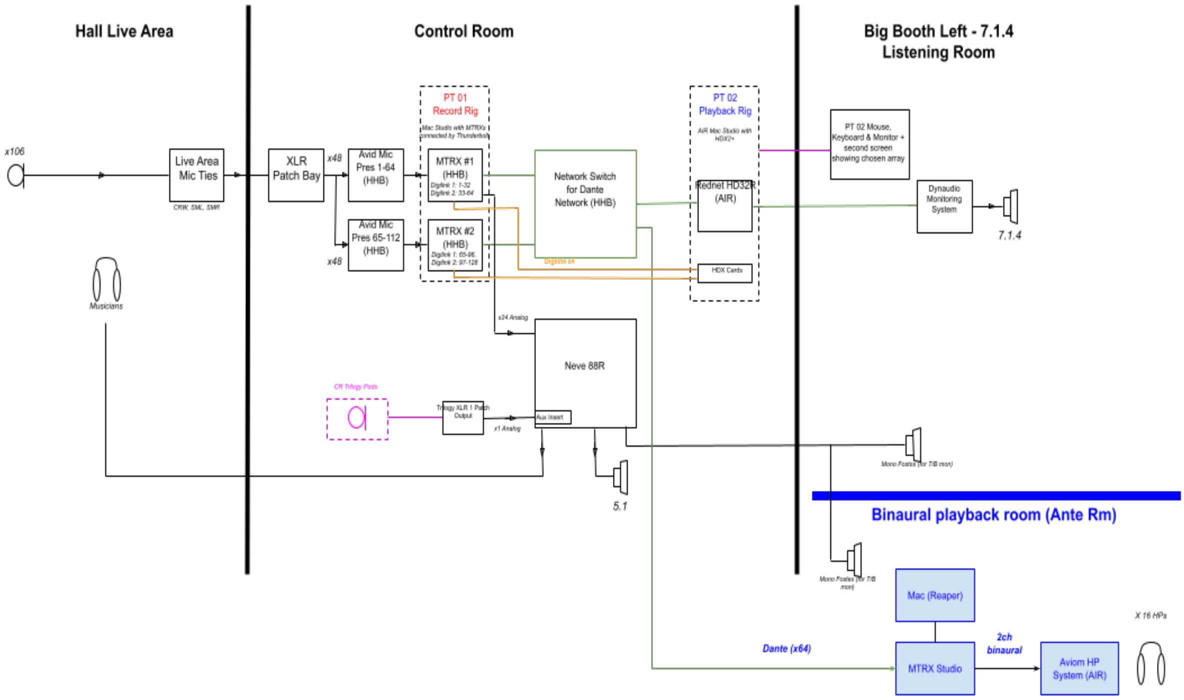


Fig. 2. Physical setup.

2.2. Orchestra Layouts

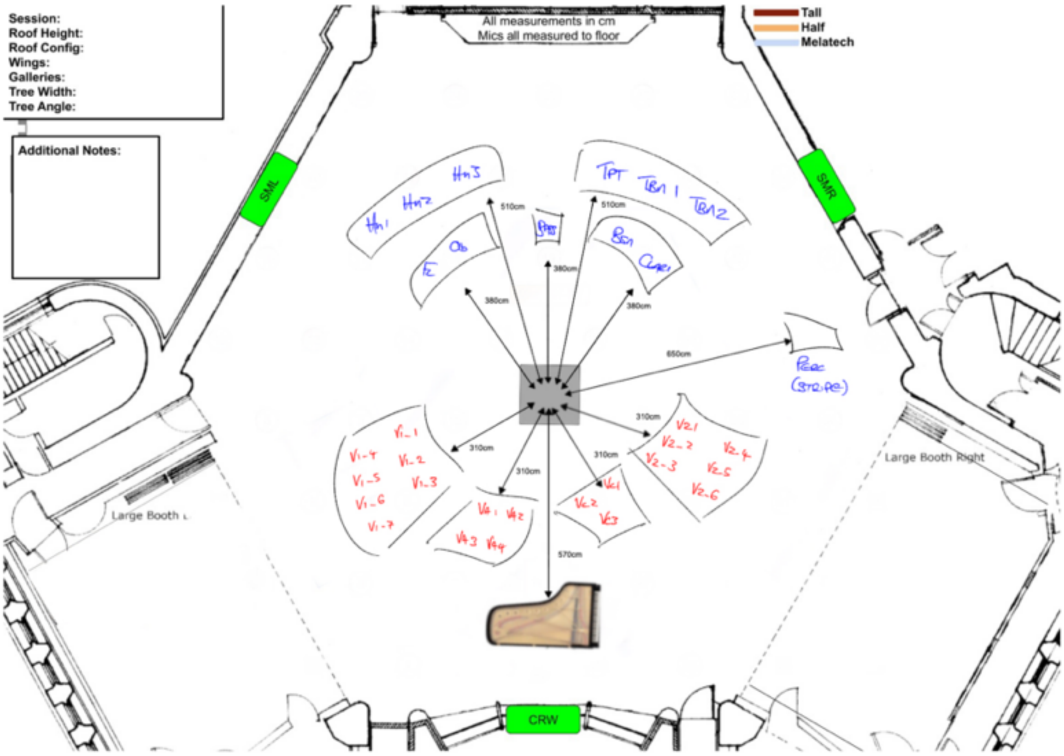
The orchestra consisted of 33 players from LCO as follows:

Table 1. Instrumentation.

Instrument	No of players
Violin 1	7
Voilin 2	6
Viola	4
Cello	3
Contra Bass	1
Flute	1
Oboe	1
Clarinet	1
Bassoon	1
French Horns	3
Trumpet	1
Trombone	1
Percussion	1
Piano	1

Two layouts were used: Circular (360°) and Traditional (180°).

Circular layout



Traditional layout

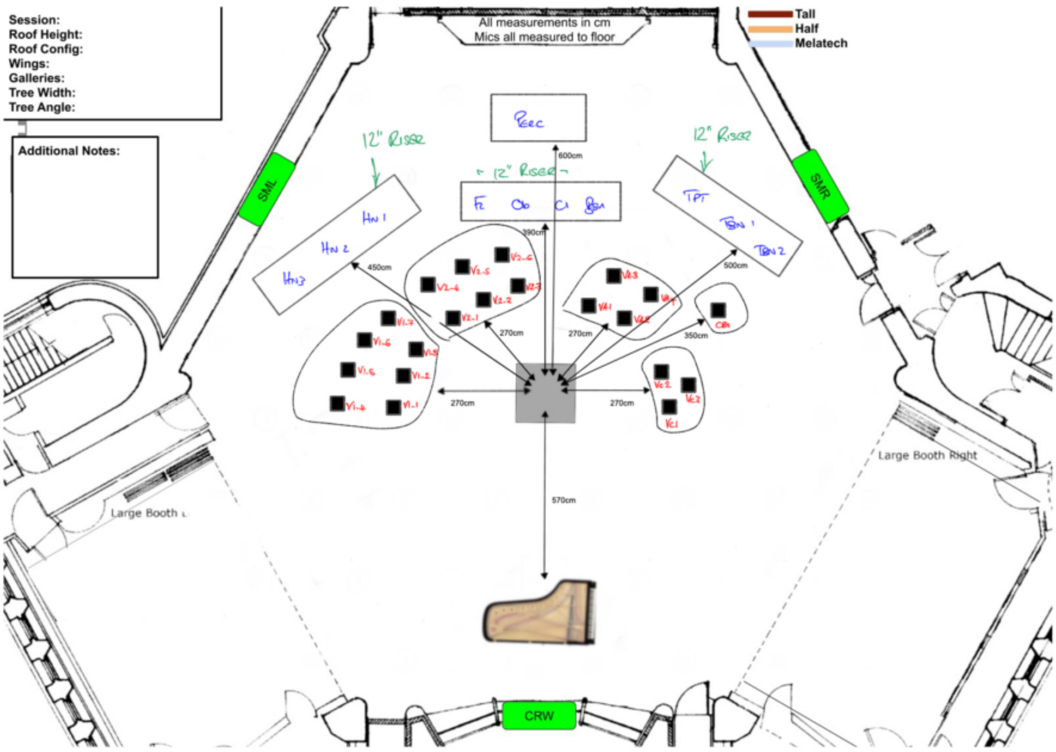


Fig. 3. Orchestral layouts.

2.3. Music

Train Journey (2024) – Volker Bertelmann

The full potential of immersive recording can only be realised when spatial thinking is incorporated into the compositional process. The ECHO Project recognises the importance of this crucial first stage in immersive music production. Therefore, we invited Volker Bertelmann (Hauschka)—a film music composer, pianist, and Academy Award winner known for his complex textural style and use of prepared piano—to collaborate with us. Volker composed a three-movement piece, Train Journey, specifically for the project, embracing the concept of immersive composition and crafting a captivating musical narrative inspired by a train ride from Bath to Cardiff.

Kammersinfonie für 23 Soloinstumente (1916) – Franz Schreker

This piece blends late Romantic lyricism and Impressionist colour with a rich texture. Written for the Vienna Academy, it features intricate counterpoint and expressive melodies, showcasing Schreker's orchestral mastery in an intimate chamber setting.

3. MICROPHONE ARRAYS

Microphone arrays play an important role in acoustic recording, capturing not only the sound sources but also the acoustics of a space. When properly designed, they enable accurate spatial and tonal reproduction of the sound field. An array's configuration can be adjusted through various factors, including microphone type, polar pattern, spacing and angles between capsules, and the placement of both the array and the musicians.

For this project, seven recording and mixing engineers contributed eight distinct microphone arrays, each developed over years of professional experience and tailored to capturing orchestras for film, games, and classical recordings. We supported the freedom of microphone choice, as microphones are an essential part of an engineer's sonic identity.

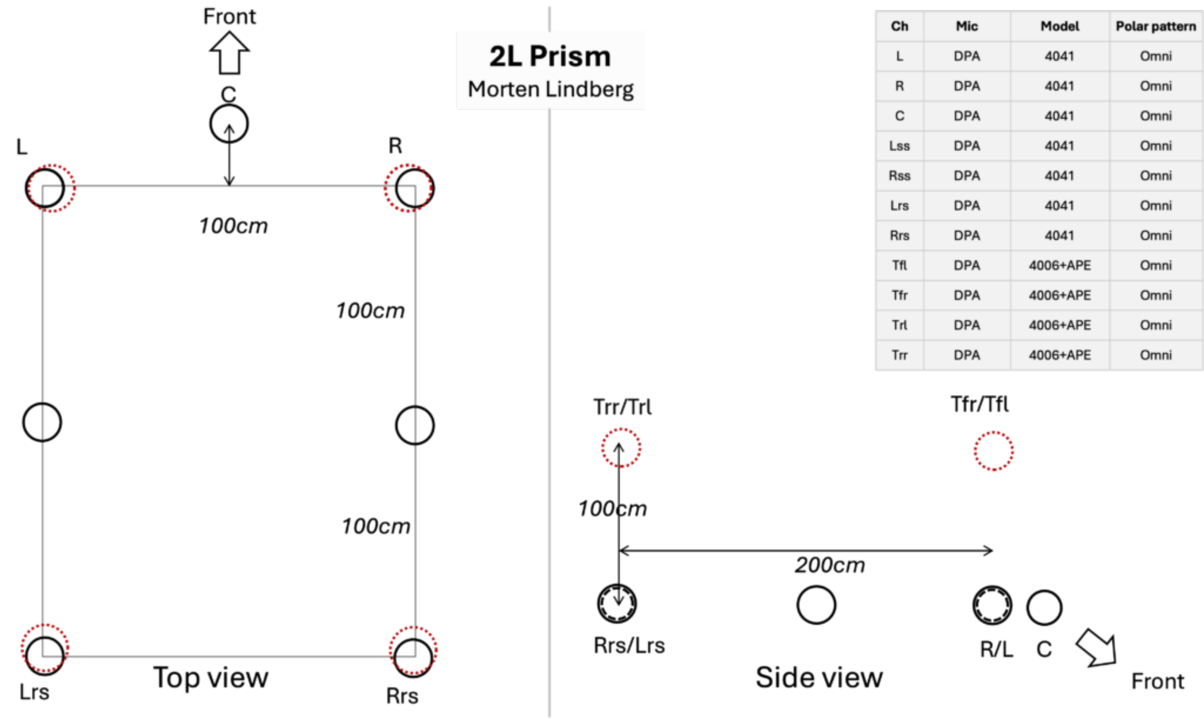
- **2L Prism** by Morten Lindberg
- **AirCage** by Nick Wollage
- **ESMA-3D** by Hyunkook Lee
- **P3H Anamorphic** by Mark Willsher
- **P3H Pyramid** by Mark Willsher
- **PAMA** by Simon Ratcliffe
- **PCMA-3D v2** by Hyunkook Lee
- **PentaSphere** by Anthony Caruso & Kellogg Boynton

3.1. 2L Prism – Morten Lindberg

Objective: Optimised level balance and transparent tonal reproduction, including low frequencies due to incorporating omnidirectional microphones, ideal for classical context especially in circular setup.

Configuration:

- Omni-directional microphones arranged in a cubic configuration that mainly relies on interchannel time difference (ICTD), mapped as discrete objects to 7.1.4 configuration.
- Acoustic pressure balls are used for height microphones to achieve higher directionality, thus introducing some interchannel level different at higher frequencies
- Ideally, all the correct balance is achieved through adjusting the positions of the musicians around the array.



Ch	Mic	Model	Polar pattern
L	DPA	4041	Omni
R	DPA	4041	Omni
C	DPA	4041	Omni
Lss	DPA	4041	Omni
Rss	DPA	4041	Omni
Lrs	DPA	4041	Omni
Rrs	DPA	4041	Omni
Tfl	DPA	4006+APE	Omni
Tfr	DPA	4006+APE	Omni
Trl	DPA	4006+APE	Omni
Trr	DPA	4006+APE	Omni

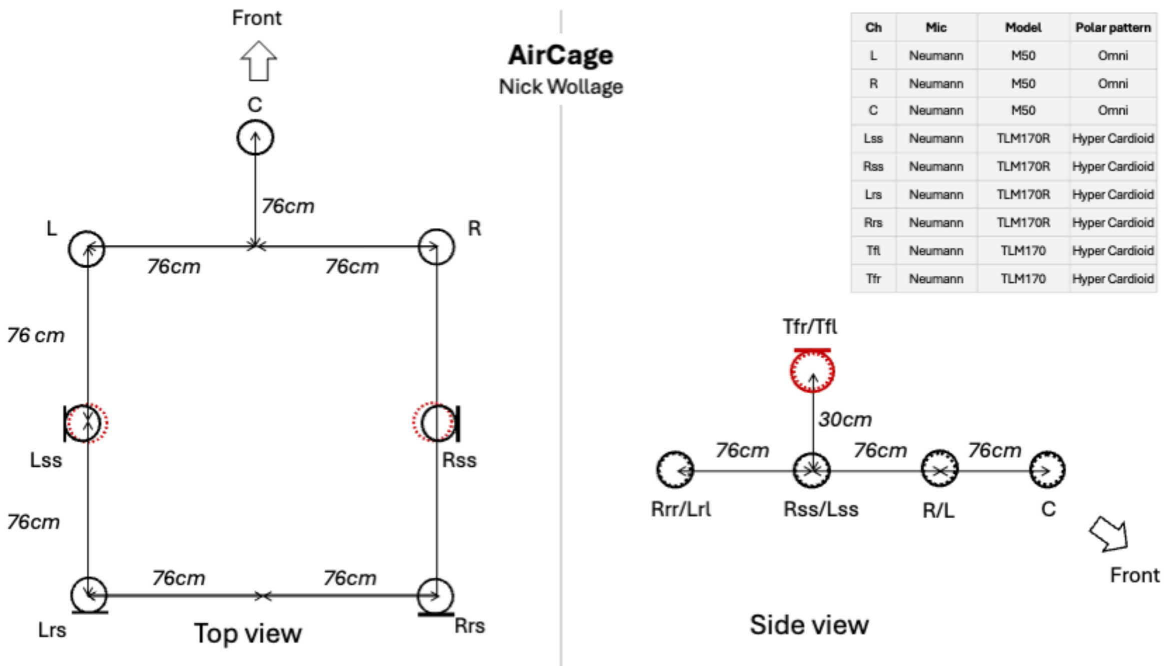
Fig. 4. Configuration of the 2L Prism.

3.2. AirCage – Nick Wollage

Objective: Spacious and enveloping sound for traditional cinematic orchestration, characterised by the unique timbral character of Neumann M50 microphones. Offers good translation in Dolby Atmos and fold-downs.

Configuration:

- Traditional Decca Tree with M50s for L/C/R, extended with TLM170s for sides, rears and height layer.
- The use of hyper-cardioids for the TLM170s offer a greater level of interchannel decorrelation and separation, resulting in enhanced envelopment.



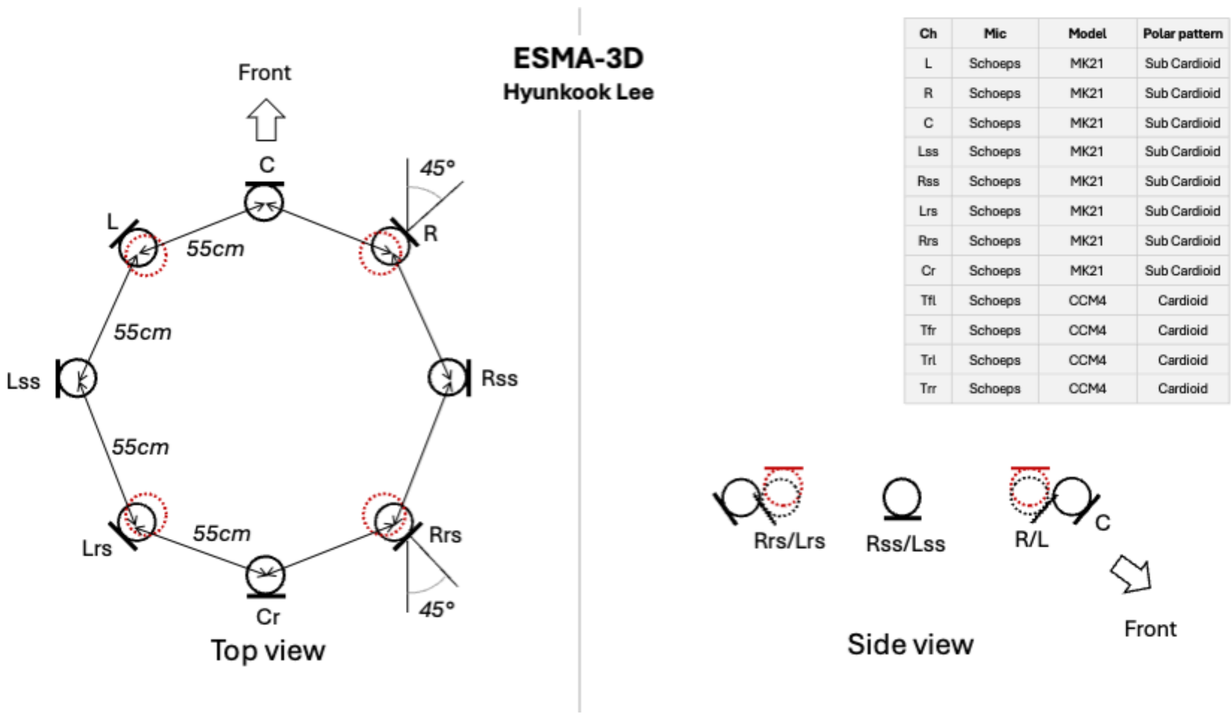
Ch	Mic	Model	Polar pattern
L	Neumann	M50	Omni
R	Neumann	M50	Omni
C	Neumann	M50	Omni
Lss	Neumann	TLM170R	Hyper Cardioid
Rss	Neumann	TLM170R	Hyper Cardioid
Lrs	Neumann	TLM170R	Hyper Cardioid
Rrs	Neumann	TLM170R	Hyper Cardioid
Tfl	Neumann	TLM170	Hyper Cardioid
Tfr	Neumann	TLM170	Hyper Cardioid

Fig. 5. Configuration of the AirCage.

3.3. ESMA-3D – Hyunkook Lee

Objectives: The Equal Segment Microphone Array 3D (ESMA-3D) is optimised for 360° sound field recordings, providing accurate and continuous imaging across all loudspeakers during reproduction and sound field rotation for head-tracked VR applications. The original ESMA concept was proposed by Michael Williams in the 1980s, and Hyunkook Lee optimised the configuration based on his MARRS ICTD/ICLD-based localisation model.

Configuration: The ESMA design concept requires: (i) the subtended angle between microphones in each stereophonic segment to match the base angle between the corresponding loudspeakers in reproduction, and (ii) the stereophonic recording angle (SRA) to match the base angle. For example, in an octagonal layout, the microphone subtended angle, loudspeaker base angle, and SRA are all 45°, while in a quadraphonic layout, they are 90°. However, the octagonal ESMA still provides good imaging across L, C, and R in a Dolby Atmos 7.1.4 loudspeaker layout. The 55 cm microphone spacing ensures sufficient decorrelation for spatial impression. The original octagonal ESMA employs cardioid microphones for the main layer, but in the ECHO project, sub-cardioids (Schoeps MK21) were used instead to enhance low-end response. ESMA-3D extends the original ESMA by adding four cardioid microphones (Schoeps CCM4) for the height layer, arranged in a vertically coincident fashion. These height microphones face directly upwards to ensure at least 7–10 dB of channel separation, which is sufficient to prevent vertical image shift and unpleasant colouration.



Ch	Mic	Model	Polar pattern
L	Schoeps	MK21	Sub Cardioid
R	Schoeps	MK21	Sub Cardioid
C	Schoeps	MK21	Sub Cardioid
Lss	Schoeps	MK21	Sub Cardioid
Rss	Schoeps	MK21	Sub Cardioid
Lrs	Schoeps	MK21	Sub Cardioid
Rrs	Schoeps	MK21	Sub Cardioid
Cr	Schoeps	MK21	Sub Cardioid
Tfl	Schoeps	CCM4	Cardioid
Tfr	Schoeps	CCM4	Cardioid
Trl	Schoeps	CCM4	Cardioid
Trr	Schoeps	CCM4	Cardioid

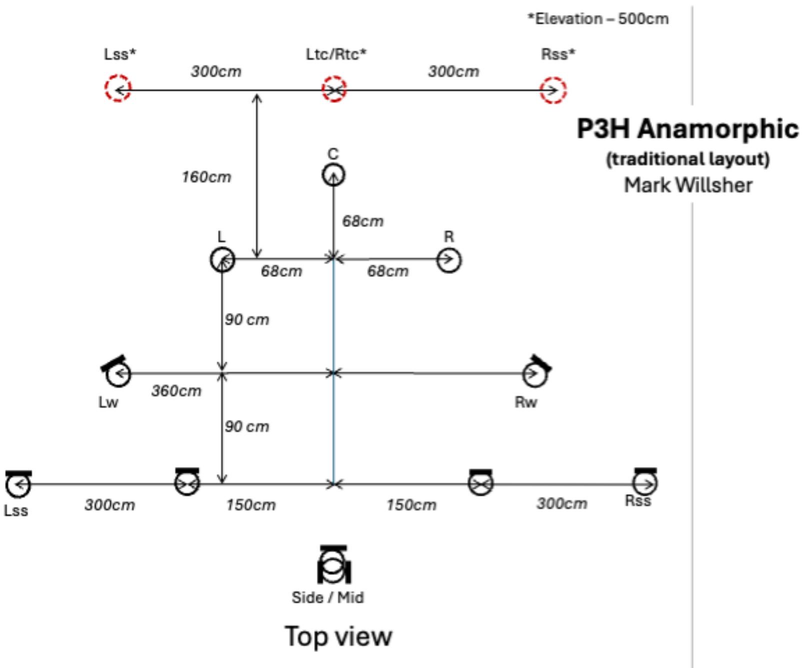
Fig. 6. Configuration of the ESMA-3D.

3.4. P3H Anamorphic – Mark Willsher

Objective: To distort the image of a traditional front-facing orchestra, and wrap it around the sides of the listener, providing greater width and envelopment, without losing forward focus. The setup is designed for theatre / film music. It offers good translation between different fold-down configurations: 7.1.4, 7.1.2, 5.1, etc.

Configuration: A Decca Tree of 680 mm from the centre to capsule (Schoeps M222 MK2H KA40, with corresponding outriggers) to provide precision and focus, combined with a set of seven extended frequency response Sanken microphones for added scale and dimension. An additional E/S setup is placed in a highly diffuse area of the recording space and decoded for the rear channels – providing further realism with no distraction from the front hemisphere's clarity (The ES may require time adjustment to achieve the desired result).

- Sankens' off-axis response enables wider spacing without compromising tonal integrity.
- Mono higher layer capture is aimed to provide a consistent listening experience throughout a larger cinema space, but also translates well to HE. This microphone's timbral and spatial correlation to the overhead Lss/Rss helps keep the overall image from narrowing in larger venues while still providing adequate height information.
- Audience focus remains on the central performance while they perceive good sense of envelopment and directional clarity.



Ch	Mic	Model	Polar pattern
L	Schoeps	MK2H+M222 + APE KA40	Omni
R	Schoeps	MK2H+M222 + APE KA40	Omni
C	Schoeps	MK2H+M222+ APE KA40	Omni
L	Sanken	CO-100K	Omni
R	Sanken	CO-100K	Omni
Lw	Schoeps	MK2H + APE KA40	Omni
Rw	Schoeps	MK2H + APE KA40	Omni
Lss	Sanken	CO-100K	Omni
Rss	Sanken	CO-100K	Omni
Lss	Sanken	CUX-100K	Far Cardioid
Rss	Sanken	CUX-100K	Far Cardioid
Ltc/Rtc	Sanken	CUX-100K	Far Cardioid
Side	Schoeps	MK2S	Omni
Mid	Schoeps	CCM8	Fig-8

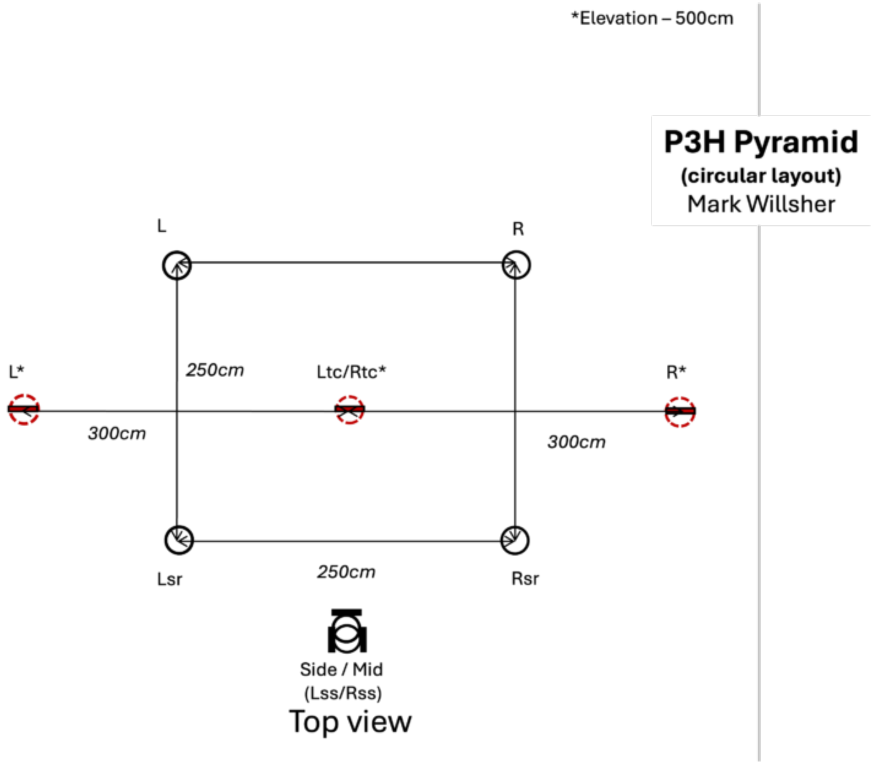
Fig. 7. Configuration of the P3H Anamorphic.

3.5. P3H Pyramid – Mark Willsher

Objective: This array is intended to be used in conjunction with coincident microphone arrays (or spot microphones) in order to expand scale and perceived dimension.

Configuration: A cube of Sanken CO-100K microphones with sides of 250cm positions L/R and Lsr/Rsr, and an overhead trio of CUX-100K positioned Lss/Ltc/Rss. The quad of CO-100K provides a foundation and the overhead CUX-100K act in a similar manner to the poles in a circus tent - spreading the sound stage wider and higher.

- CO-100K omni quad provides strong energy from front and rear loudspeakers regardless of placement of source - filling the listening room with sound.
- CUX-100K Far Cardioid provide clarity to sides and ceiling expanding perceived width and height.
- ES pair placed in a highly diffuse area of the room provides a cloud of diffuse sound that helps glue the overall space together - positioned Lss/Rss.



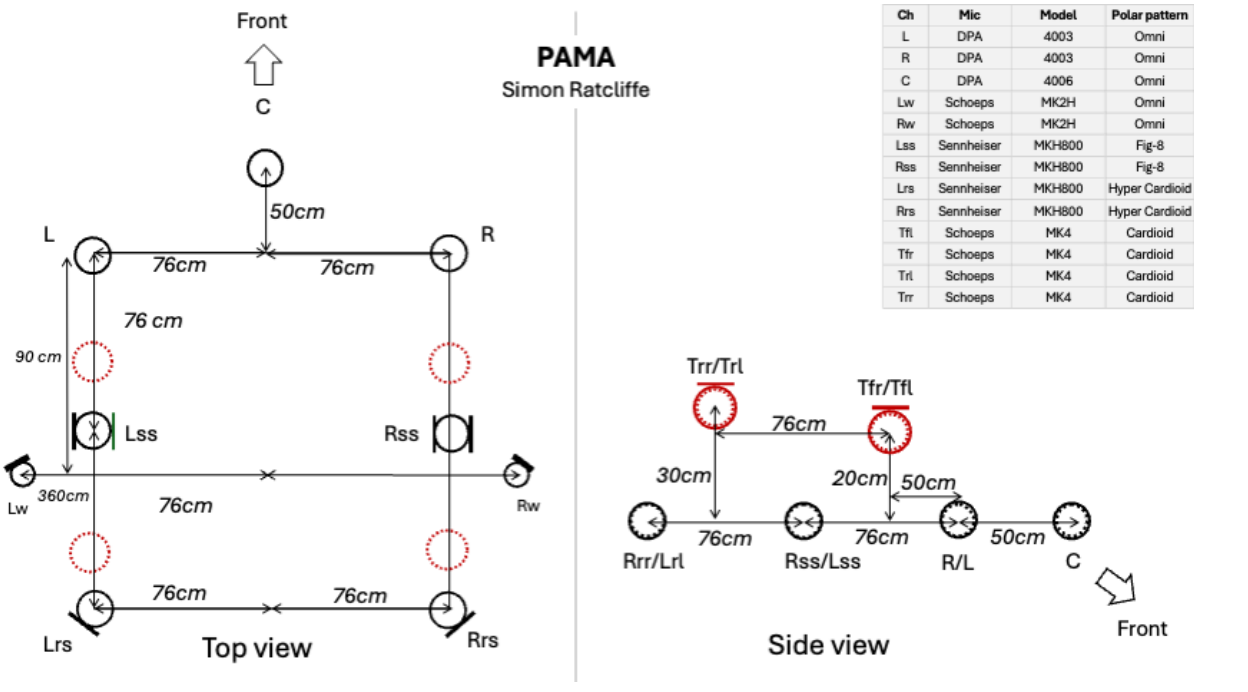
Ch	Mic	Model	Polar pattern
L	Sanken	CO-100K	Omni
R	Sanken	CO-100K	Omni
Lsr	Sanken	CO-100K	Omni
Rsr	Sanken	CO-100K	Omni
L	Sanken	CUX-100K	Far Cardioid
R	Sanken	CUX-100K	Far Cardioid
Ltc/Rtc	Sanken	CUX-100K	Far Cardioid
Side	Schoeps	MK2S	Omni
Mid	Schoeps	CCM8	Fig-8

Fig. 8. Configuration of the P3H Pyramid.

3.6. PAMA – Simon Ratcliffe

Objective: Stemming from orchestral film and game music, PAMA (Prototype Atmos Microphone Array) is an in-progress design that aims to extend traditional recording configurations into the immersive space, while ensuring Dolby Atmos compatibility across theatrical and home entertainment platforms, and consecutive fold-downs and workflows typical of media score delivery.

Configuration: Anchored on a modified Decca Tree + wide pair, and extended by sides, rears and height microphones, reflecting 7-0-4/9-0-4 speaker configurations. By addressing the beds, but preserving the heights as a quad-width object, a combination of speaker arrays and front-to-back height can be addressed to extend the soundstage. The array seeks to self-correct observed issues for theatrical and HE playback by a combination of polar patterns. 1) The use of bidirectional microphones help with the observed side-surround/surround array high load of information (especially in the lower mids) characteristic of omnidirectional microphones, we well as extending the natural ambience of the recordings through their non-directionality, and in combination with the rear super-cardioid microphones and wide channels, work well in decorrelation and provide good fold-down characteristics when delivering stereo or 5.1, as well as binaural Atmos. The height channels assigned as overhead objects, when panned 75% in from from and rear cardinal points, suitably address theatrical arrays and HE systems in facilitating overhead L/R and F/R, further addressed by the rear Height mics being 10 cm higher than the fronts.



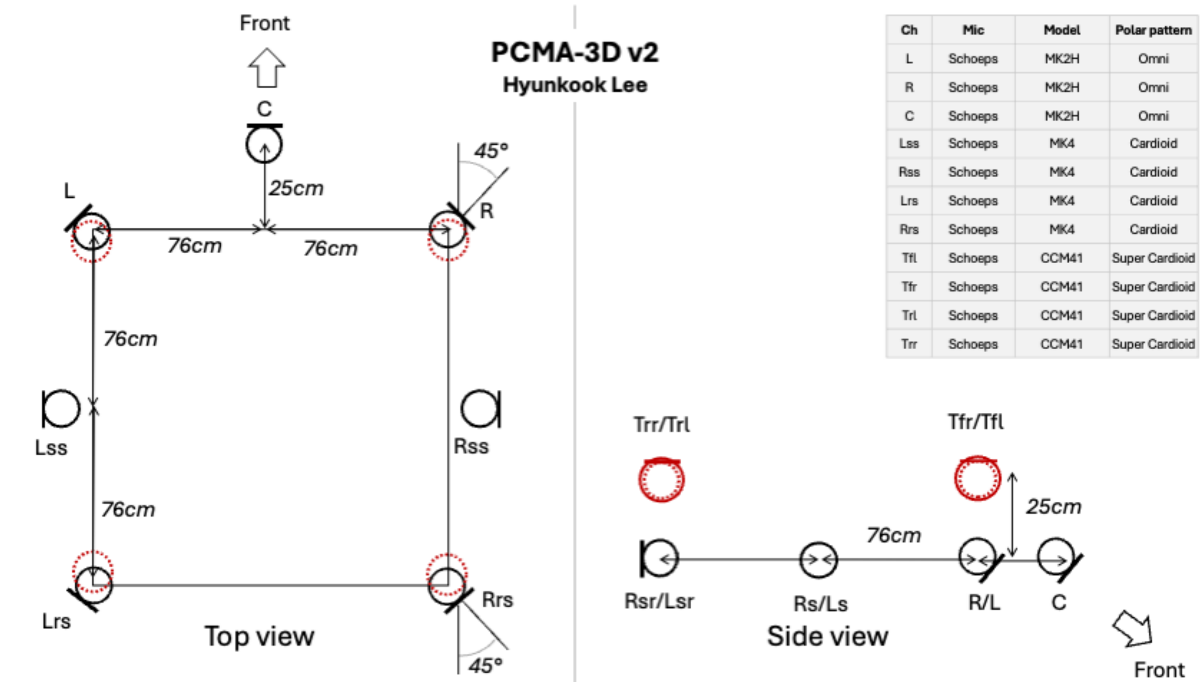
Ch	Mic	Model	Polar pattern
L	DPA	4003	Omni
R	DPA	4003	Omni
C	DPA	4006	Omni
Lw	Schoeps	MK2H	Omni
Rw	Schoeps	MK2H	Omni
Lss	Sennheiser	MKH800	Fig-8
Rss	Sennheiser	MKH800	Fig-8
Lrs	Sennheiser	MKH800	Hyper Cardioid
Rrs	Sennheiser	MKH800	Hyper Cardioid
Tfl	Schoeps	MK4	Cardioid
Tfr	Schoeps	MK4	Cardioid
Trl	Schoeps	MK4	Cardioid
Trr	Schoeps	MK4	Cardioid

Fig. 9. Configuration of the PAMA.

3.7. PCMA-3D v2 – Hyunkook Lee

Objectives: PCMA-3D, which stands for Perspective Control Microphone Array 3D, aims to provide a natural and realistic representation of the sound field, ensuring accurate localisation and a balanced spatial impression. This design is based on key psychoacoustic principles of vertical stereophony.

Configuration: The original PCMA was designed for effective direct-to-reverberation ratio control in the 5.1 format, utilising two coincidentally arranged directional microphones at each pick-up point of the array. This concept was later adapted for 3D recording, based on experimental findings suggesting that vertical microphone spacing or vertical decorrelation has little effect on overall spatial impression. PCMA-3D, therefore, employs a horizontally spaced, vertically coincident microphone arrangement. The vertical pair is angled so that there is at least 7-10 dB of channel separation as in ESMA-3D. A supercardioid microphone (Schoeps CCM41) facing directly upwards captures the height channel, while a cardioid microphone directed towards the source ensures optimal performance. For the ECHO project, PCMA-3D v2 was used instead, featuring omnidirectional microphones (Schoeps MK2H) for the main layer (L, C, and R) to extend low-frequency response. Additionally, the height layer was positioned approximately 25 cm above the main layer, providing sufficient channel separation through decorrelation above 1 kHz.



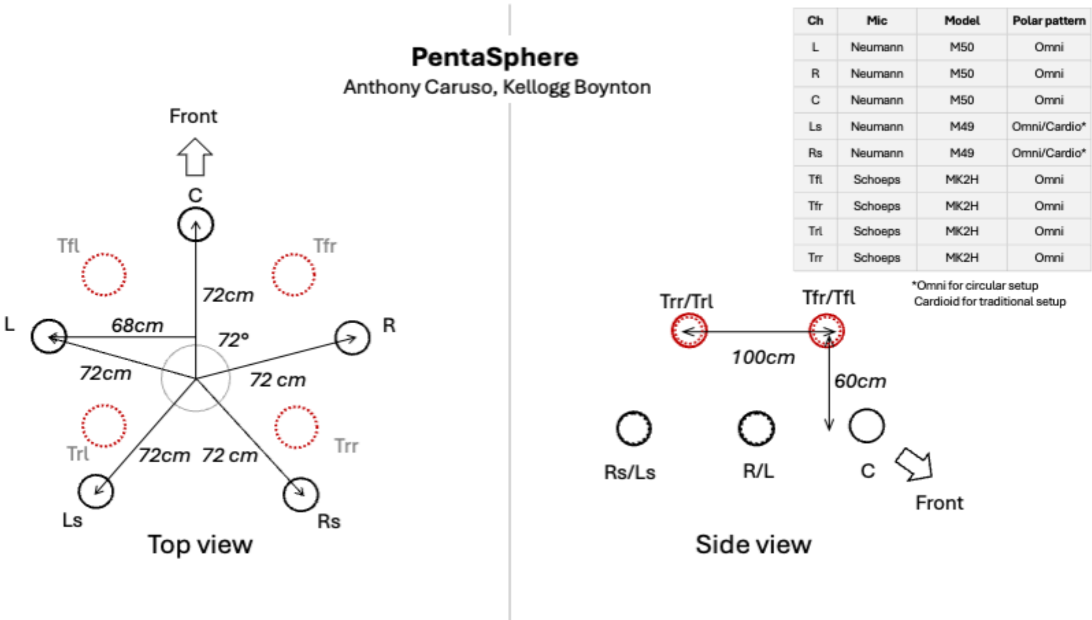
Ch	Mic	Model	Polar pattern
L	Schoeps	MK2H	Omni
R	Schoeps	MK2H	Omni
C	Schoeps	MK2H	Omni
Lss	Schoeps	MK4	Cardioid
Rss	Schoeps	MK4	Cardioid
Lrs	Schoeps	MK4	Cardioid
Rrs	Schoeps	MK4	Cardioid
Tfl	Schoeps	CCM41	Super Cardioid
Tfr	Schoeps	CCM41	Super Cardioid
Trl	Schoeps	CCM41	Super Cardioid
Trr	Schoeps	CCM41	Super Cardioid

Fig. 10. Configuration of the PCMA-3D v2.

3.8. PentaSphere – Anthony Caruso/Kellogg Boynton

Objective: The microphones forming the array are positioned on a surface of a sphere with a radius around 1.3m, aiming for maximum coherency with spherical HRTFs used by the PS5. Additionally, the use of Neumann M50's matches the sound of the Decca tree typically used in PlayStation's orchestral recordings, bringing a classic score sound to the immersive array.

Configuration: All the microphones are equidistant from each other. When capturing musicians in a circular layout, the focus of the array may be rotated so that any triplet of mics can become LCR for the image, with the option of using opposing top layer mics as a .2 for Atmos mixing. Ideally the bottom mics would be all M50's, but not having that available we chose M49's, set to Omni for the circular layout, and cardioid for the traditional layout.



Ch	Mic	Model	Polar pattern
L	Neumann	M50	Omni
R	Neumann	M50	Omni
C	Neumann	M50	Omni
Ls	Neumann	M49	Omni/Cardio*
Rs	Neumann	M49	Omni/Cardio*
Tfl	Schoeps	MK2H	Omni
Tfr	Schoeps	MK2H	Omni
Trl	Schoeps	MK2H	Omni
Trr	Schoeps	MK2H	Omni

Fig. 11. Configuration of the PentaSphere.

4. DATABASE

The ECHO database is freely available under the CC-BY-NC-ND 4.0 license from https://doi.org/10.5281/zenodo.15268471.

It includes the following:

- **Original multitracks** from the eight microphone arrays used by the focus group, along with additional ambience microphones, a KU100 dummy head, an EigenMike EM32, and spot microphones.
- **ADM/BWF** files of Dolby Atmos 7.1.4 mixes created by the engineers.
- **Binaural** versions of the mixes rendered with APL Virtuoso.

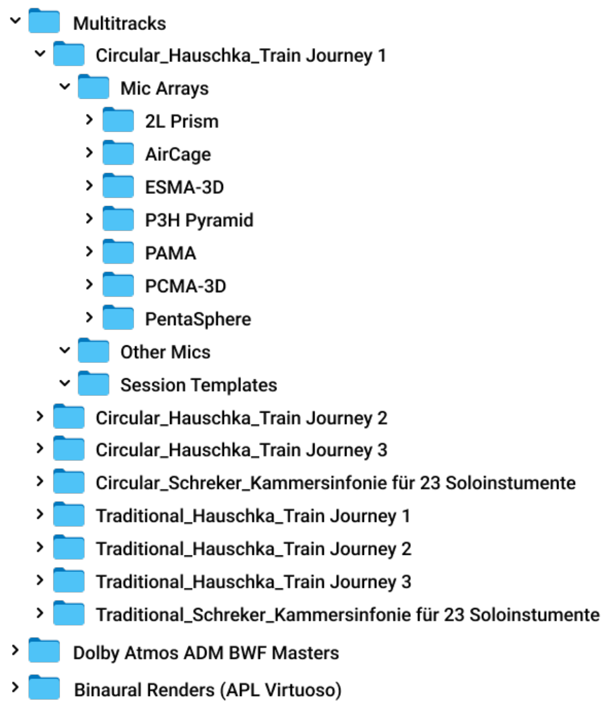


Fig. 12. Database folder structure.

4.1. Multitracks

The multitrack files consist of individual microphone signals for each of the arrays, and other microphones (additional ambience arrays, dummy head and spot microphones). Table 2 summarises the microphones used for the multitracks. All of them were recorded with an equal gain, however, since they had different sensitivities, level normalisation was performed so that track levels are aligned at the same sensitivity. For this, the impulse response of each microphone used for the arrays was captured and the recorded level was adjusted with a reference to the energy of the 1 kHz octave band of pink noise convolved with the direct sound portion of the impulse response.

The multitrack files consist of individual microphone signals for each of the arrays, as well as other microphones (including additional ambience arrays, a dummy head, and spot microphones). Table 1 summarises the microphones used in the multitracks. All signals were recorded with equal gain;

however, since the microphones had different sensitivities, level normalisation was performed to align the track levels to a consistent reference sensitivity. To achieve this, the impulse response of each array microphone was captured, and the track level was adjusted based on the energy of the 1 kHz octave band of pink noise convolved with the direct sound portion of the impulse response. The multitrack files of the arrays were exported with the normalisation applied.

Table 2. List of the microphones used for the recording session.

No	Source	Microphone Model	Manufacturer	Note	Polar Pattern
1	2L Prism L	4041	DPA		Omni
2	2L Prism R	4041	DPA		Omni
3	2L Prism C	4041	DPA		Omni
4	2L Prism Lss	4041	DPA		Omni
5	2L Prism Rss	4041	DPA		Omni
6	2L Prism Lrs	4041	DPA		Omni
7	2L Prism Rrs	4041	DPA		Omni
8	2L Prism Ltf	4006	DPA	+50mm APE	Omni
9	2L Prism Rtf	4006	DPA	+50mm APE	Omni
10	2L Prism Ltr	4006	DPA	+50mm APE	Omni
11	2L Prism Rtr	4006	DPA	+50mm APE	Omni
12	LFE 1	4006	DPA	GranCasa	Omni
13	LFE 2	4006	DPA	Basses	Omni
14	AirCage Lss	TLM170R	Neumann		Hyper Cardioid
15	AirCage Rss	TLM170R	Neumann		Hyper Cardioid
16	AirCage Lrs	TLM170R	Neumann		Hyper Cardioid
17	AirCage Rrs	TLM170R	Neumann		Hyper Cardioid
18	AirCage Ltf	TLM170	Neumann		Hyper Cardioid
19	AirCage Rtf	TLM170	Neumann		Hyper Cardioid
20	ESMA-3D L	MK21	Schoeps		Sub Cardioid
21	ESMA-3D R	MK21	Schoeps		Sub Cardioid
22	ESMA-3D C	MK21	Schoeps		Sub Cardioid
23	ESMA-3D Lss	MK21	Schoeps		Sub Cardioid
24	ESMA-3D Rss	MK21	Schoeps		Sub Cardioid
25	ESMA-3D Lrs	MK21	Schoeps		Sub Cardioid
26	ESMA-3D Rrs	MK21	Schoeps		Sub Cardioid
27	ESMA-3D Ltf	MK21	Schoeps		Sub Cardioid
28	ESMA-3D Rtf	CCM4	Schoeps		Cardioid
29	ESMA-3D Ltr	CCM4	Schoeps		Cardioid
30	ESMA-3D Rtr	CCM4	Schoeps		Cardioid
31	ESMA-3D BC	CCM4	Schoeps		Cardioid
32	P3H Anamorphic L	MK2H(M222)	Schoeps	+KA40 APE	Omni
33	P3H Anamorphic R	MK2H(M222)	Schoeps	+KA40 APE	Omni
34	Anamorphic C	MK2H(M222)	Schoeps	+KA40 APE	Omni
35	P3H Anamorphic / Pyramid L	CO-100K	Sanken		Omni
36	P3H Anamorphic / Pyramid R	CO-100K	Sanken		Omni

37	Anamorphic + PAMA Lw	MK2H	Schoeps	+KA40 APE	Omni
38	Anamorphic + PAMA Rw	MK2H	Schoeps	+KA40 APE	Omni
39	P3H Anamorphic Lss / Pyramid Lsr	CO-100K	Sanken		Omni
40	P3H Anamorphic / Pyramid Rss	CO-100K	Sanken		Omni
41	P3H Anamorphic Lss / Pyramid L	CUX-100K	Sanken	Canopy	Far Cardioid
42	P3H Anamorphic Rss / Pyramid R	CUX-100K	Sanken	Canopy	Far Cardioid
43	P3H Anamorphic / Pyramid Ltc/Rtc	CUX-100K	Sanken	Canopy	Far Cardioid
44	P3H Anamorphic / Pyramid Lrs	MK2S	Schoeps	ES Pair	Omni
45	P3H Anamorphic / Pyramid Rrs	CCM8	Schoeps	ES Pair	Fig-8
46	PAMA L	4003	DPA	+40mm APE	Omni
47	PAMA R	4003	DPA	+40mm APE	Omni
48	PAMA C	4006	DPA	+40mm APE	Omni
49	PAMA Lss	MKH800	Sennheiser		Fig-8
50	PAMA Rss	MKH800	Sennheiser		Fig-8
51	PAMA Lrs	MKH800	Sennheiser		Hyper Cardioid
52	PAMA Rrs	MKH800	Sennheiser		Hyper Cardioid
53	PAMA Ltf	MK4	Schoeps		Cardioid
54	PAMA Rtf	MK4	Schoeps		Cardioid
55	PAMA Ltr	MK4	Schoeps		Cardioid
56	PAMA Rtr	MK4	Schoeps		Cardioid
57	PCMA-3D L	MK2H	Schoeps		Omni
58	PCMA-3D R	MK2H	Schoeps		Omni
59	PCMA-3D C	MK2H	Schoeps		Omni
60	PCMA-3D Lss	MK4	Schoeps		Cardioid
61	PCMA-3D Rss	MK4	Schoeps		Cardioid
62	PCMA-3D Lrs	MK4	Schoeps		Cardioid
63	PCMA-3D Rrs	MK4	Schoeps		Cardioid
64	PCMA-3D Ltf	CCM41	Schoeps		Super Cardioid
65	PCMA-3D Rtf	CCM41	Schoeps		Super Cardioid
66	PCMA-3D Ltr	CCM41	Schoeps		Super Cardioid
67	PCMA-3D Rtr	CCM41	Schoeps		Super Cardioid
68	PentaSphere / AirCage L	M50	Neumann		Omni
69	PentaSphere / AirCage R	M50	Neumann		Omni
70	PentaSphere / AirCage C	M50	Neumann		Omni
71	PentaSphere Ls	M49	Neumann		Omni
72	PentaSphere Rs	M49	Neumann		Omni
73	PentaSphere Ltf	MK2H	Schoeps		Omni
74	PentaSphere Rtf	MK2H	Schoeps		Omni
75	PentaSphere Ltr	MK2H	Schoeps		Omni
76	PentaSphere Rtr	MK2H	Schoeps		Omni
77	Bottom Ch L	OM1	Line Audio		Omni
78	Bottom Ch R	OM1	Line Audio		Omni

79	Bottom Ch Ls	OM1	Line Audio		Omni
80	Bottom Ch Rs	OM1	Line Audio		Omni
81	Canopy Top AL	MKH800	Sennheiser		Fig-8
82	Canopy Top AR	MKH800	Sennheiser		Fig-8
83	Canopy Top BL	MKH20	Sennheiser		Omni
84	Canopy Top BR	MKH20	Sennheiser		Omni
85	Mid L	Blue Bottle	Blue		Omni
86	Mid C	Blue Bottle	Blue		Omni
87	Mid R	Blue Bottle	Blue		Omni
88	Solo A	MK22	Schoeps		Open Cardioid
89	Solo B	MK22	Schoeps		Open Cardioid
90	Solo C	MK22	Schoeps		Open Cardioid
91	Solo D	MK22	Schoeps		Open Cardioid
92	Violin 1	MK21	Schoeps		Sub Cardioid
93	Violin 2	MK21	Schoeps		Sub Cardioid
94	Viola	MK21	Schoeps		Sub Cardioid
95	Cello	MK21	Schoeps		Sub Cardioid
96	Contra Bass	MKH40	Sennheiser		Cardioid
97	Piano	C12	AKG		Omni
98	Percussion 1	C414 B-ULS	AKG		Cardioid
99	Percussion 2	C414 B-ULS	AKG		Cardioid
100	LFE	M150	Neumann		Omni
101	Woodwind L	C12VR	AKG		Cardioid
102	Woodwind R	C12VR	AKG		Cardioid
103	French Horns	C12	Telefunken		Cardioid
104	Trumpet / Trombone	C12	Telefunken		Cardioid
105	Dummy Head L	KU100	Neumann		
106	Dummy Head R	KU100	Neumann		
107	Spherical mic array	Eigenmike EM32	mh acoustics		

4.2. ADM BWF Dolby Atmos Masters

Each focus group engineer created two versions of Dolby Amtos 7.1.4 mixes, which are provided in ADM BWF files:

- **ArrayOnly Mix** with level balancing and EQ; no other processing and no spot microphones were allowed.
- **Presentation Mix** made based on each engineer's array; processing and the use of spot microphones were at the engineer's discretion.

To play the master files, you will need either the Dolby Atmos Renderer software, a DAW that supports Dolby Atmos/ADM playback (e.g., Pro Tools, Nuendo, Logic, or Studio One), or a binaural application capable of playing ADM files (e.g., APL Virtuoso standalone).

Table 3. Requirements for the Dolby Atmos mixes in the ADM BWF files.

Parameter	ArrayOnly Mix	Presentation Mix
Sample Rate / Bit Depth / Frame Rate	48kHz / 24bit, 24fps	48kHz / 24bit, 24fps
Channels/Objects	7.1 channels + objects 11-14 for the height channels	7.1 channels + objects 11-14 for the height channels + extra objects if needed.
Percussion Overlays + Electronic Reamp (only for circular layout)	Standardised values Pass B: -1.6 dB Pass C: -1.8 dB Pass D: -3.6 dB	No restrictions
Binaural Metadata	"Near"	No restrictions
Trim and Downmix Settings	Default	No restrictions
Loudness - Train Journey Movements	-23 Integrated +/-0.5dB, -1 dBTP	-23 Integrated +/-0.5dB, -1 dBTP
Loudness - Schreker	-23 Integrated +/-0.5dB, -1 dBTP	-23 Integrated +/-0.5dB, -1 dBTP
Loudness Range	No restrictions	Not restricted
EQ	Allowed	All processing allowed
Reverb	Not allowed	All processing allowed
Limiting	Not allowed	All processing allowed
Microphone Used	Only dedicated microphone array. No spot microphones allowed.	The dedicated microphone array is the foundation; spot microphones are allowed. No mixing microphones from other arrays is allowed.

4.3. Binaural Renders

To deliver a high-quality virtual loudspeaker listening experience over headphones, the original 7.1.4 mixes were binaurally rendered using the APL Virtuoso plugin. The APL Listening Room preset, which is based on the ITU-R BS.1116-compliant critical listening room at APL (RT 0.2s; dimensions: 6.2 m × 5.2 m × 3.5 m), was used. This preset provides a neutral tonal balance and effective externalisation for headphone listening.

4.4. Session Templates

Each of the multitracks folders include ProTools and Reaper session templates.

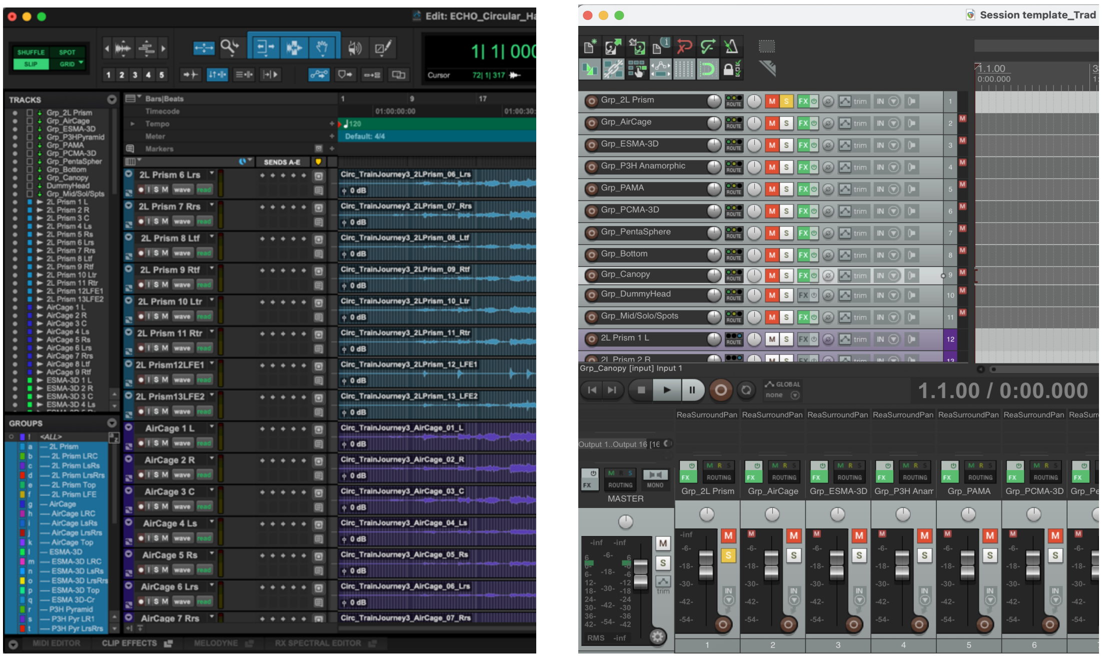


Fig. 12. ProTools and Reaper session templates.

ProTools

- Multitracks are grouped within Arrays, Bottom, Canopy and Spot Microphones. Additional subgroups (L-C-R, Ls-Rs, Lsr-Rsr, etc) are also included for the ease of use.
- Each main group is routed to an 7.1.4 AUX (Grp_...) with appropriate panning.
- Two separate Session Templates are provided for Circular and Traditional layouts.

Reaper

- Multitracks are grouped into Group Tracks (Grp_...) for Array, Bottom, Canopy and Spot Microphones.
- The ReaSurroundPan plugin with appropriate panning information is inserted on each group track.
- Two separate Session Templates are provided for Circular and Traditional layouts

5. ACKNOWLEDGEMENTS

We would like to express gratitude to the sponsors of the ECHO Project, who contributed financially and with in-kind support.

- AIR Studios
- HHB and Avid
- Dynaudio
- Dolby Labs
- Air Edel
- University of Huddersfield
- Spitfire Audio
- Audeze

- Applied Psychoacoustic Lab (APL)
- Audiomovers
- Production Expert
- Schoeps Mikrofone

Special thanks to:

- Focus group engineers: Kellogg Boynton, Anthony Caruso, Morten Lindberg, Simon Ratcliffe and Mark Willsher.
- AIR Studios staff: Simon Knee, Wil Jones, Rebecca Hordern, Eve Morris, Tom Walsh, Charlotte Matthews, Katy Jackson, Debbie Waldron, Rory Calvert
- University of Huddersfield staff/students: Mark Wendl, Sungyoon Choi and Juraj Fanor
- Legal support: Maggie Rodford and Henriette Amiel
- Composer: Volker Bertelmann
- Musicians: London Contemporary Orchestra
- Conductor: Hugh Brunt
- Technical and in-kind support:
  - John Johnson, Lexie Morgan, Jon Parkes, Oli Phillps, Lukas Simma – *HHB*
  - Stanley Yang – *Goerdyna*
  - Bryn Richards, Stephen Entwistle, Henrik Kastenskov – *Dynaudio*
  - Andrea Borgato, Richard Addis, Robert Karlsson, Scott Greiner, Mike Hall – *Dolby*
  - Eddie Pitman, Matt Soczywko – *Audiomovers*
  - Sankar Thiasgasamudram – *Audeze*
- Orchestration: Jan Andrees and Raffael Seyfried - *Ricochet Orchestration und Verlag*
- Copyist: Ananda Chatterjee
- Meg Monteith, Chris Parker