ACOUSTICAL HISTORY AND DESIGN OF THE BRISTOL BEACON

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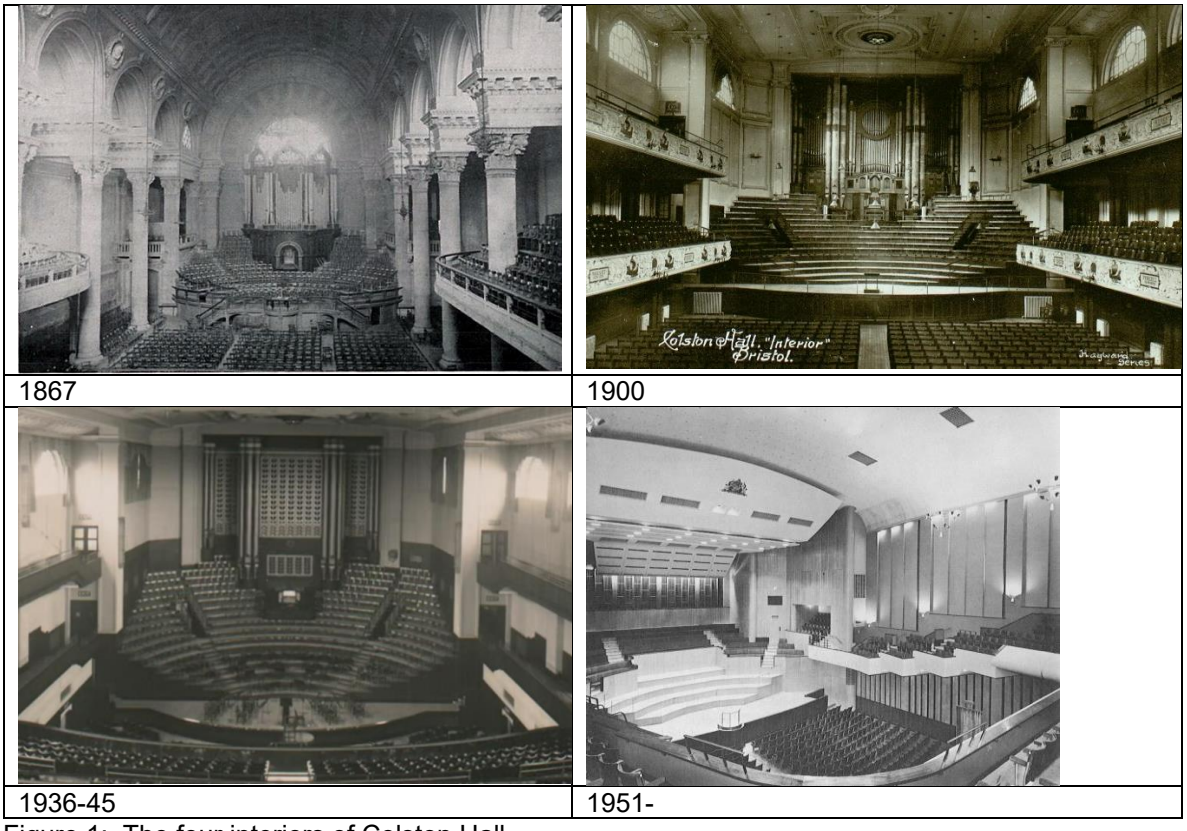
1 HISTORICAL BACKGROUND

Colston Hall has been an important concert venue in Southwest England since it was first constructed in 1867- 73 by the Colston Company. Owing to fires and changes in programming priorities, there have been three other versions of the main hall interior within the original masonry structure since then – 1899, 1936 (by then owned by Bristol City Council) and the 1951 hall known to many of us[1]. By the end of the 20th century this Grade II listed building had emerged as one of the most important music venues in the UK in terms of the quality of the performers on stage, but it was in dire need of refurbishment and acoustical improvement to keep up with the quality of other recent concert venues. The venue has welcomed a great many of the biggest names in the music over the years.



1867 | 1900

1936-45 | 1951-

Figure 1: The four interiors of Colston Hall

After being destroyed by fire in 1945, Colston Hall reopened with a new interior in 1951. For the reconstruction of the hall, acoustics advice was provided by Hope Bagenal and others at the Building Research Station. Bagenal's work to Colston Hall was in parallel with his work on the new Royal Festival Hall. The more prominent project at the time, it is likely that developments in the RFH project informed Bagenal's approach at Colston Hall.

While the 1936 incarnation of Colston Hall had been influenced by priorities for cinema, the conception for Colston 1951 was intended more for orchestra and choral music, but by this time it

had been influenced by the technical innovations in audio recording studios. It was decided that the hall would remain within 1860s rectangular room boundaries, however the balcony was deeper than the acousticians would have liked in order to meet the capacity goal. The acousticians' advice was to raise the roof, but that was rejected owing to structural limitations. They also recommended that the roof be built of massive concrete, but that too was rejected on practicality (cost) grounds. [2,3,4]

The deep main balcony provided every seat with an unobstructed view of the stage – an important consideration for cinema, but with serious acoustical disadvantages for classical music. In the last 5 seating rows under the 10-row balcony overhang, sound was received from only a very small window directly in front. The result was a sound that is quiet and uninvolving. In addition to this the balcony divided the room into a number of quite separate spaces – in front, above and below. This also contributed to the low overall reverberation and an overall quieter, less resonant and less immersive sound. In separating the audience this way, the overall connection to, and appreciation of, the rest of the audience was constrained to the detriment of all, including the performers, who received little helpful response back from the room. Still, the musicians liked the clarity onstage.

In Colston Hall, as well as at RFH and Fairfield Halls, Bagenal included a canopy over the stage, angled to project sound from the stage to the furthest audience members. (While a canopy provides helpful sound reflections back down to the orchestra and is a common feature of more recent halls, the particular canopy shape used in these halls drives more sound into the sound absorbent audience and reduces beneficial reverberation.)

Here Bagenal started with an existing tall, narrow room geometry which is a naturally reverberant shape. So by virtue of the 1860s proportions the acoustical changes to Colston Hall didn't create as dry an acoustic as at the completely new, and larger, RFH.

Finishes such as wood panelling were intended to control bass reverberation – a concern borne out of the muddiness of Victorian town halls and clarity of broadcast studio design experience. In the early 20th Century audio recording was new, but it was already understood that in order to achieve a good recorded sound, a room was needed that provided an even balance of bass and treble sound. In the era of the Colston Hall reconstruction, thin wood and plaster wall and ceiling panels were used to reduce bass reverberation time. Somewhat ironically, this turned out to be beneficial as rock and pop took off in the successive decades. However, the smooth timber finishes tended to encourage harshness at loud dynamics, as did later painting over porous finishes.

By the late 1990s the hall was in need of significant repairs and/or renovation., but the City Council could only afford to do part of a project, resulting in creation of the front-of-house building – now the "Bridgehouse" -- designed by architects Levitt Bernstein (LBA). Variable acoustic banners had been installed at balcony level in 2006 to reduce the reverberation time for amplified events, but they had limited effect for those in the stalls.

When we came on board in 2012 the operations and programming had recently been turned over to the newly constituted Bristol Music Trust (BMT). We first helped the Client and LBA to explore design and cost options ranging from fixing what's worn out, to renovation with worthwhile improvements, to knocking it down and creating a new building. The decision was to work with the existing building and transform it into a music centre for the 21st century, building on its history and its architectural assets.

2 CLIENT BRIEF/ PRIORITIES

The BMT's mission to enhance and expand the making and learning of music in Southwest England was joined with the intent to raise the acoustical quality to the level of the world's best concert halls. In the decades since 1951 Britain had gained several new concert halls with better acoustics and greater flexibility, and rock and pop had been born and grown to take over the mainstream. This

part of the brief was to maximise audience capacity with potential for standing audiences in the stalls; a high-quality sound system coupled with excellent acoustics for amplified performers; and increased capacity for production lighting, rigging and other production systems. Our challenge was to do so while respecting the musical heritage of the building.

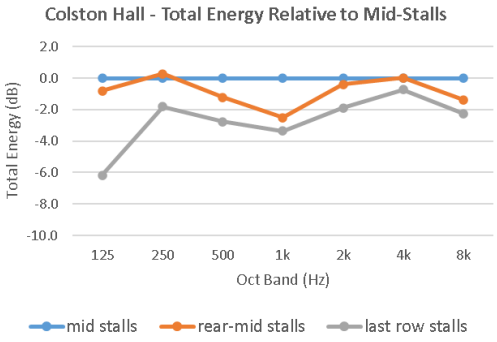
Coston Hall has been the large classical music venue in the Southwest since it first opened. While there is currently no resident symphony orchestra in Bristol, the Bournemouth Symphony Orchestra has for many years played a regular series of concerts in Colston Hall, and now Beacon Hall, and the Paraorchestra has found a home to explore a variety of different musical and physical formats. Orchestras and choirs needed a larger stage than for pop music; stage flexibility and efficiency of changeover without compromising the acoustical goals were required.

The acoustic of the existing hall was tonally warm, and considered somewhat too dry for orchestra; that may have helped its reputation for pop music. Onstage and in the audience, balance between strings and brass had been challenging. Increased strength and presence for strings and woodwinds was a goal. Tonal quality and resonance for the hundreds of audience covered by the balcony were poor. The classical music community appreciated the hall for its clarity, so we didn't want to lose that asset.

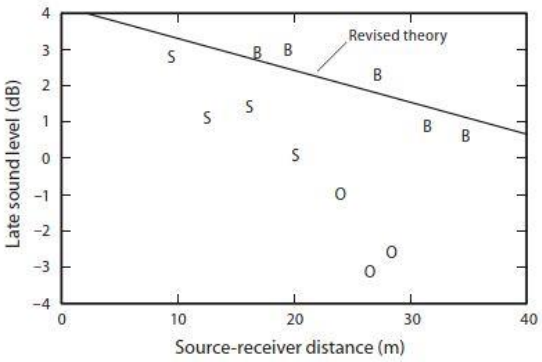
3 COLSTON HALL LISTENING AND MEASUREMENTS 2016

Our measurements in the empty hall corroborated measurements published by others, such as Mike Barron, in the past. We made only unoccupied measurements, but it was clear from listening to performances and rehearsals that there was quite a difference between the occupied and unoccupied states. Unoccupied mid-frequency Early Decay Time at 1kHz ranged from 1.8s mid-stalls to 1.3s under the balcony, and down to 1.2s at 2kHz.

The sound level dropped considerably under the overhang. Barron has illustrated this as well for Late sound level.



Total Energy decreased from mid-stalls to under deep balcony overhang, unoccupied, downstage source.



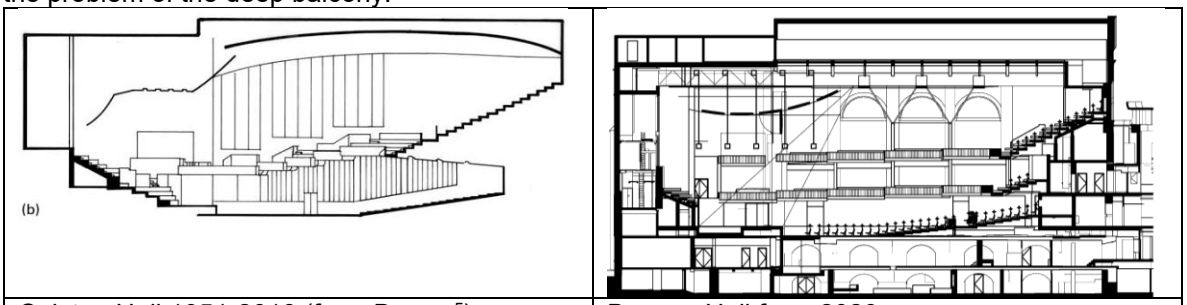
Late sound level. S=stalls, O=overhung, B=Balcony. From Barron[5].

Figure 2: Total and Late Sound level decrease under balcony.

Sound insulation performance of the existing envelope was quantified by playing loud rock music tracks on the PA and measuring the sound on the roof, at selected locations on the site perimeter. Background noise was measured at the nearest residences in the traditional way for the planning application, although we knew the traffic pattern would be changed by the time the building work was completed. Background MEP noise in the main hall was generally NR25.

4 KEY ELEMENTS OF ACOUSTICAL / ARCHITECTURAL DESIGN

The most fundamental change was geometric: to replace the single deep balcony with two shallower balconies, working to contemporary sightlines and without raising the roof. The rectangular perimeter of the hall had been used and reused since 1857, and we felt it would be a good basis for the transformation and the new brief. Mapping of the reverberation time illustrated the problem of the deep balcony.



Colston Hall 1951-2018 (from Barron[5])	Beacon Hall from 2023

Figure 3: Colson/Beacon Hall long section comparison

The audience capacity for classical music would be slightly reduced, and we were increasing the solidity of the room boundaries; given the planning limitations and the high cost of raising the roof, it was decided not to raise the ceiling and roof substantially. The curvature of the ceiling was flattened to reduce the effects of focussing in the balcony.

We intended to increase reverberation time slightly for classical music, and decrease RT for amplified events, increasing bass strength for orchestra, while not increasing bass reverberation for amplified music. The design included replacing the thin acoustic panelling on the walls with more solid, sound reflecting, and slightly scattering surfaces – largely brick with carefully chosen texture and carefully negotiated 3-timensional patterns, and several battened and shaped timber wall areas. The balcony fronts and acoustic canopy are comprised of warped triangular timber panels.

The stage area was increased for orchestra, with a riser system to optimise orchestra visual and aural communication onstage, and audience seeing and hearing from a relatively flat stalls floor, at the same time improving the loudness balance in the audience between brass and strings. The presence of the absorbing audience (or choir) behind the platform and the large organ were considered beneficial to limiting loudness and retaining clarity of communication between performers.

Two large platform elevators extend the stage 2 or 4m to accommodate symphony orchestra, and are set at stalls level with a smaller stage to maximise audience capacity for pop music and other smaller ensembles. These same elevators carry the stalls seating wagons to the basement store to created a flat stalls floor, which accommodates an additional 500 standing audience. Along with the extended stage a new overhead canopy was designed to improve projection of the performers. One element of the canopy flips down to allow deploy the loudspeaker clusters that are otherwise stored above.

New double-layer acoustic banners were incorporated at the side walls and curtains at the rear walls. As these have a low absorption performance at low frequencies, and given the rock and pop priorities, we included some variable bass absorbers: aQtube inflatable tubes from Flex Acoustics and Gerriets. Motorised controls make it easy to change the room from reverberant to dry.

Background noise in the old hall was NR25. The new criteria was NR15 or lower for unamplified events; NR25 for amplified events, with more air through the same ducts to cool the larger standing audience. As a start, the mechanical and electrical plant and the loading dock and lift are in a new,

separate structure. The supply air for Beacon Hall is delivered under floor, at the sides of the stalls, which, for seated events, feeds into the sides of the seating wagons and then up through openings under the seats. Extract is via a lined labyrinth above the stage.

5 LANTERN HALL

The Lantern Hall had spent several decades as the “Little Theatre”; our task was to re-make it as a music-oriented “second space” in the Beacon. The programming was to be for all genres of music that could fit in this smaller space, plus conferences, comedy and social occasions, while restoring the historic character. It had to work for both small and large occupancy and have sufficient resonance for string quartet or chamber choir on one hand, and clarity for amplified and unamplified speech and music as well as sufficient sound insulation to avoid impacting use of the Beacon Hall or any residential neighbours. The room is relatively tall, which allows sufficient reverberance for chamber music when the hard walls are exposed. Ceiling absorption controls the reverberation sufficiently for flat floor, sparsely occupied occasions. Simple variable acoustic curtains were developed with artist involvement in design of the custom fabric.

Lantern Hall w acoustic curtains deployed

Lantern Hall daylit w acoustic curtains retracted

Figure 4: Lantern Hall

6 ARCHITECTURAL DESIGN DEVELOPMENT

Improving sound insulation to/from the outside was achieved within the constrained site and footprint of the massive Victorian structure with doors and corridors as buffers and careful routing of services. The acoustical intent for increased isolation performance and uprated rigging loads ultimately led to replacing the roof structure (but not raising the height). The roof design was optimised for sound isolation performance without concrete. Addition of heavy secondary glazing in the Lantern Hall was straightforward within the thick walls, both to control traffic noise ingress and loud music sound egress.

Removing the single balcony and replacing it with 2 new balconies led to working out the sightlines and circulation. The architects developed a language of brick, timber and steel. Collaborative design of the curved timber balcony fronts and acoustic canopy and the 3-dimensional brick patterning was driven from a basic intent for mild mid and high frequency scattering.

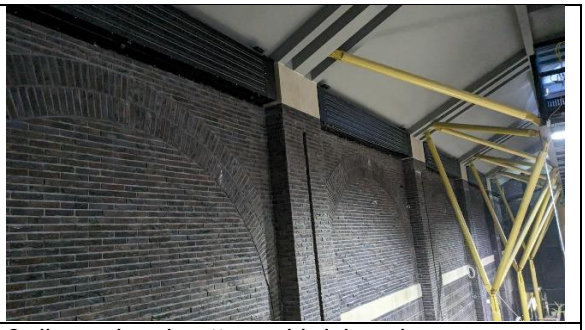
Respect for the historic character led to exposing much of the historic fabric and adaptive reuse of other elements. The linenfold chestnut wall panelling in Beacon Hall was refurbished, thickened and reused in roughly the same place in the stalls, but as a more dense and stiff material. Other reused elements are visible in other areas of the building.

7 CONSTRUCTION CHALLENGES

Demolition and construction began in 2019, and the building opened in November 2023. Covid was challenging, but it did not stop the project. However, the poor state of the underlying construction presented a large number of challenges -- for time, for cost and for redesign, and the team addressed the challenges without losing the focus on quality, and especially acoustical quality.

One of the most challenging aspects in terms of acoustics was how to construct the new patterned brick side walls inside the very rough existing masonry structure. The bricks had been purchased early, and the design intent was to fill the void between the inner and outer skin with lean mortar to take advantage of the composite stiffness. Once the 1951 interior was stripped out it was determined that the existing walls were not strong enough to support the volume of mortar, and too rough to leave exposed. After exploring many alternatives it was agreed to use wire ties, stiffer than normal and in greater than standard numbers to connect the finish brick course as stiffly as possible to the heavy wall behind. The specific brick was chosen for modest roughness and low porosity

Recycled linenfold chestnut panelling



3-dimensional patterned brickwork

Figure 5: Traditional finishes - timber on solid backing and patterned brick with stiff supports

This was just one of several situations where limited capabilities of the contractor and supply chain were challenged in the context of the old building and Covid. Another was how the newer requirements for fire rating doors and services penetrations severely limited the ability to optimise acoustical performance, because the supply chain had not yet caught up to serve the high-quality bespoke design market.

The builders uncovered surprises upon opening up the fabric: among them a hidden Elizabethan well and other basement water problems, and masonry columns that were assumed to be solid, but were actually empty.

For sound insulation and strength the timber floor of the Lantern Hall was upgraded with a concrete slab on steel structure with a heavy floating timber floor; and it had to support a depression for the recessed stage platforms and the imposed load of the retractable seating system. This all had to be done from above the fragile existing historic ceiling that would become part of the new restaurant.

While most of the heritage and low-carbon issues had been resolved during design, others proved difficult in implementation. The new acoustic canopy panels and the reused chestnut wall panelling were to meet stiffness and mass criteria that were clear in the contract but difficult to implement.

While the ventilation system and orchestra lighting are extremely quiet, well under NR15, commissioning measurements identified a few electrical noise makers that were contractor designed and had never been in the design and tender documents – small transformers in door security control boxes, an aspirant smoke alarm control cabinet with small fan above the grid, solar panel inverters, and the controller for the in-house radio communication system. Such elements creep into specialist electrical designs that become integral to building projects but are not quiet enough for a performance space with natural acoustics. There were various other non-optimised

decisions driven by the design-build procurement process, for example some timber elements that are thicker than needed for acoustics.

8 SOME QUANTITATIVE RESULTS

In reconfiguring the balconies and changing materials the sound is now clearer and more present for the last rows, and indeed for everyone.

Early Decay Time under balcony has not increased at high frequencies, but has decreased at low frequencies.

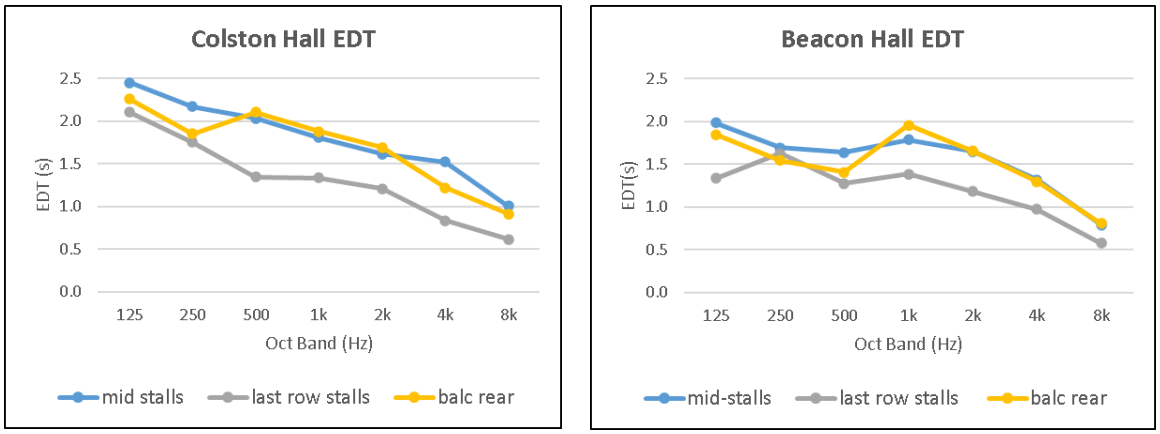
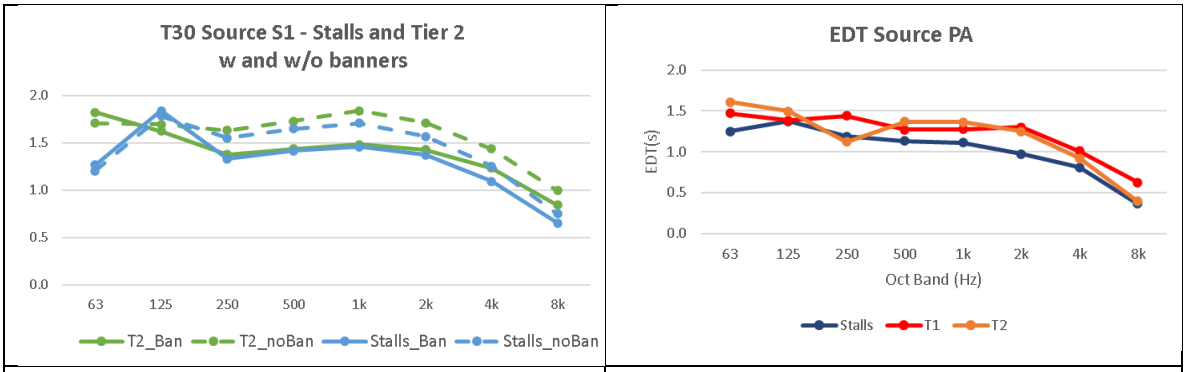


Figure 6: Comparison of EDT before and after renovation.

Similarly, the T30 Reverberation time at mid-frequencies is not much different in Beacon Hall than it was in Colston Hall, but the T30 at low frequencies has been reduced. By extending the acoustic banners and inflating the bass absorbers the mid-frequency T30 drops from 1.7s to 1.5s in the mid-stalls and 1.8s to 1.5s in the 2nd tier rear balcony.

As the greater portion of the programming is amplified music, it was important achieve a clear sound with the PA system and with the banners and bass absorbers extended. Figure 7(b) shows the EDT is lower using PA source than the dodec. The audio technicians and audiences have been pleased with the amplified sound quality generally and the tightness of the bass specifically.



(a) EDT in area averages for Dodec source mid-stage, banners and bass absorbers in and out

(b) EDT in area averages with PA source, banners and bass absorbers.

Figure 7: Effect on Reverberation Time by variable sound absorbing system and source type.

9 MUSICAL IMPRESSIONS

The clarity of the bass is significantly greater, and therefore improved. But it hasn't come with a reduction in warmth. To the contrary, it seems there is an increase in bass strength without being "loose".

Overall impact is strong. The 2-balcony geometry delivers multiple early lateral reflections, and the solidity of the materials plays a part in this, as does the quiet noise floor.

The sound character is probably nothing like any of the earlier manifestations, but is clear, tight, strong, immersive and warm. The combination of excellent acoustics and operational efficiency are considered excellent for current musical taste and priorities befitting a 21st Century music centre of international quality and vision in the heart of Bristol.

The programming and business model have been greatly enhanced by the fact that the stalls seats can be removed quickly for standing audiences, the stage risers can be configured in a variety of ways, the seating behind the platform is used for audience, and the marriage of PA system and variable absorption cleans up the sound for the loud amplified shows. Beyond the regular visits from the orchestral partners BSO and Paraorchestra, the quality has attracted other major UK and international orchestras.

Thanks to Emily McGeehin and Evan Green, who did much of the work on the project.

10 REFERENCES

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