# The acoustical design of the Christchurch town hall

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## Abstract

*The Christchurch Town Hall (New Zealand) was opened on September 30 1972. Disastrous earthquakes hit Christchurch in September 2010 and February 2011. Most of the CBD and the historic buildings were destroyed or damaged by the February event, including much of the Town Hall complex. The City Council in November 2012, resolved to restore the entire building but at the time of writing there remains uncertainty. The intention of this paper is to put on record the history of the Christchurch Town Hall design in case it does not survive the political after-shocks of the earthquakes. With the building's future now in jeopardy it seems appropriate to set out the process that led to this unique design, acknowledge the many contributors, outline its research base, the innovations in predictive technology employed, the evaluation of its acoustical properties and the learning that flowed from it.*

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## 1. Introduction

The design of the Christchurch Town Hall auditorium is inseparable from the discovery of the importance of lateral reflected sound in concert hall preference. Indeed the Christchurch project provided the problem statement, the hypothesis, testing and its initial application in a major symphony hall all in the space of five years between 1967 and 1972. In this paper I hope to give an account of this process.

## 2. Backround

Christchurch, the second largest city in New Zealand, pop c 250,000, (in 1965) had long needed a Town Hall. Such buildings in Australia and New Zealand were the principal cities' public auditoriums, rather than the seat of the city administration though some combined that function as well. There had been such a venue in the previous century but it was destroyed by fire in April 1873.

Prosperity had come to Dunedin and Auckland initially through the gold rushes of Central Otago and Coromandel respectively and their prosperity allowed them to build Town Halls, seating about 2000-3000 patrons in the classical tradition, and including a large pipe-organ. The prosperity of Wellington arose from its standing as Capital city with the commerce that attracted, and its Town hall was of a similar model. Seldom has a region, its Councils and its citizens been so united in desiring a public building, as Christchurch was in desiring a Town Hall.

### 2.1. The competition

An architectural competition was announced under the auspices of the NZ Institute of Architects [1], in July 1965. Only architects registered in NZ were permitted to enter. The first stage was to close on 31st January 1966. My role was as acoustical advisor to the competition Chairman, Mr. Ron Muston, then President of the NZIA. At the same time I was preparing to go to the UK to the newly formed Institute of Sound and Vibration Research at Southampton University, on Sabbatical leave from the University of Auckland, to complete my PhD. This was no small undertaking with a young family of 4 boys, with ages from almost one year to 7 so perhaps it is not surprising that I agreed without much discussion to provide an acoustical report on the 5 or 6 shortlisted designs at the end of Stage 1, prior to the second stage. That was to close on May 31st. In December we boarded the Shaw Saville liner "Southern Cross" and sailed to Southampton. Fifty eight entries were submitted in Stage 1.

### 2.2. At Southampton University

My project at Southampton had little to do with concert hall design [2]. I had long been intrigued by the enhanced annoyance that reverberation causes for the same level of intruding noise. My project was to find an objective measure using pupil dilation as a measure of CNS load. I was barely settled into the ISVR when a large role of drawings for the five short-listed schemes arrived by air from NZ, with the request that I furnish my acoustical reports by cable within two weeks.

As I looked through the competing designs I realized that there was nothing to guide me about preference for the sound these plans and sections would produce. When I undertook to write about each six months earlier I had in mind to draw heavily on Dr. Beranek's masterly work "Music Acoustics and Architecture" [3] which had seemed

to me to tie up all the uncertainties around the design of music rooms. It is a matter of history that by 1966 the conclusions in this book–apparently represented in the design of the NY Philharmonic Hall–were subject to serious questions. At that time the conventional wisdom was that only a narrow "shoe-box" could produce the excellence the competition sought and there was no narrow shoebox amongst the short-listed room shapes (Figure 1).

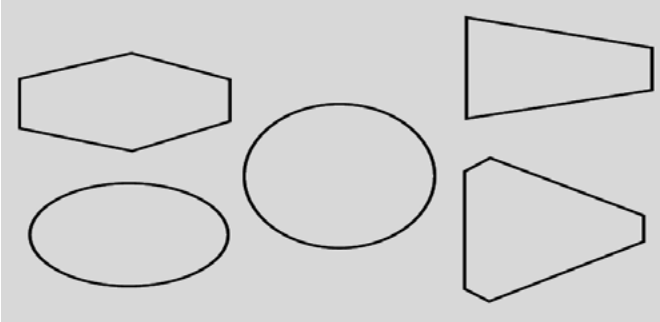

**Figure 1. Short-listed room shapes**

**2.3. A visit to the Royal Festival Hall**

While pondering this problem and feeling the truth of Dr Johnson's "If a man knows he is to be hanged in a fortnight, it concentrates his mind wonderfully," we went up to London for a concert in the Royal Festival Hall. As I listened I realised that there was only frontal sound–the lateral reverberation was inaudible. That started me on the hunt for a reason for this experience and led to a draft of my paper "A note on the importance of Room Cross-section in concert halls" [4].

**2.4. Work in Germany**

My supervisor and editor of the new and prestigious Journal of Sound and Vibration, Philip Doak, directed me to recent work in Germany which reflected the 60's change in emphasis from the Physics of sound in rooms to measurements in the psychophysics of what people hear.

Measurements at that time were primarily on the absolute threshold of perceptibility–*die Absolute Wahrnehmbarkeitschwelle*, abbreviated to AWS–of reflections in a variety of circumstances. Initially these were of speech signals [5] and showed the dependence of audibility of reflections on the relative direction of the direct sound and the reflection(s). That suggested to me a mechanism for the masking of lateral reflections. At that time I could find only one measurement for the threshold of a music reflection. That was in a BBC research report by Somerville, Gilford, Spring and Negus6 and was for a single reflection of music at 10ms delay. (That paper was subsequently published in the Journal of Sound and Vibration [6]).

**2.5. Miles Warren visit to the UK and Europe**

I wrote my reports on the five designs, including the new hypothesis, and sent them off. Entry Number 16 an elliptical room, was selected, and shortly thereafter, Miles Warren, the successful architect arrived to visit halls in Europe with me and to discuss the implications of the lateral reflection idea for his design. I was able to convince him of the reality of the effect, assisted by hearing Haydn's "Creation" on successive nights in both the Royal Festival Hall and in the Concertgebouw in Amsterdam. His visit turned into a design workshop with W. A. Allen (Bill) and his partners Engineering Design Consultants (EDC) London (see the next paragraph and Figure 2). In this the idea for the arrangement of reflectors in Christchurch TH was proposed. The architects were receptive because their design had already foreseen such large reflectors.

Meanwhile I had been appointed to a teaching position in the new School of Architecture, which opened in the University of Western Australia in 1967. I felt unable to continue as consultant for the Christchurch TH while settling into a new country and a new job. I asked Bill Allen to take it over for me and he agreed except that EDC would be the executive consultants. I agreed to retain only a "watching brief" for the project and set about writing up my PhD.

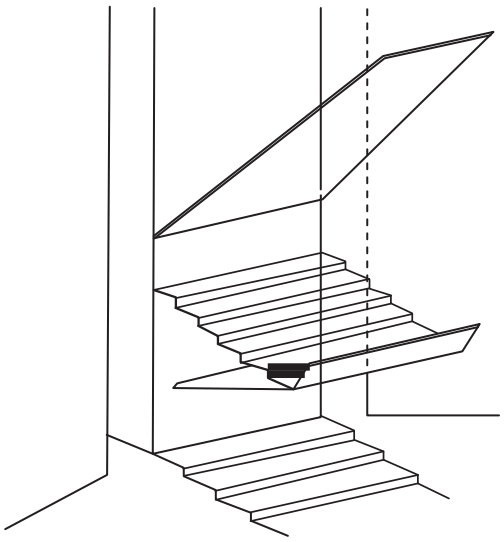

**Figure 2. Sketch of reflector system**

Meanwhile at Prof. Doak's suggestion I sent the draft of my paper to Professor Erwin Meyer, Director of the Third Physics Institute in Goettingen. He promptly invited me to Goettingen to discuss it. There, in addition to Prof. Meyer, I met Drs. Burgtorf, Kuttruff, Dieter Gottlob and several others. They referred me to a paper by Dr. Peter Schubert in the DDR which would not appear in the West for another two years [7]. It showed the AWS for reflections of a variety of music types, out to delays of 200ms. I want to acknowledge here the collegiality I encountered amongst the colleagues at Goettingen, their enthusiasm for the fresh idea I had proposed and

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the practical assistance they gave; even to making the first physical model of the Christchurch design, to demonstrate the reality of focusing in the ellipse. With the encouragement of Professor Doak, I submitted my paper, completed my experimental work and submitted my thesis now including the lateral reflection hypothesis. Late in 1967 this was examined and accepted, and I moved with my family to Western Australia in time for the start of the Autumn term in February 1968.

## 3. Confirmations

It may be worthwhile here to recall my description of the "premium quality of sound" reproduced from the "Note" [4].

### 3.1 Identification of the quality

To aid in the identification of the quality sought, it is observed that: (a), as a property of the *sound*, it is related to the loudness attributes; (b), as a property of the *hall*, it carries the idea of special responsiveness to the music; (c), for the *listener*, it generates a sense of envelopment in the sound and of direct involvement with it [5] in much the same way that an observed is aware of his involvement with a room he is in.

There has followed some 40 years of on-going research, refining the measures: separating aspects of global terms such as "Spatial responsiveness" (Marshall) [8], "Spatial Impression" (Barron) [9] and "Räumlichkeit" (Kuhl) [10] into "Apparent Source Width (AWS) (Morimoto and Maekawa) [11] Envelopment (Bradley and Soulodre) [12] and the introduction of a raft of Inter-aural Cross Correlation (IACC) measures as an alternative to the lateral energy fraction, Lf, Barron and I proposed (Schroeder, Gottlob and Siebrasse [13], Ando [14], and Beranek [15]). These are a small but representative selection of the relevant research.

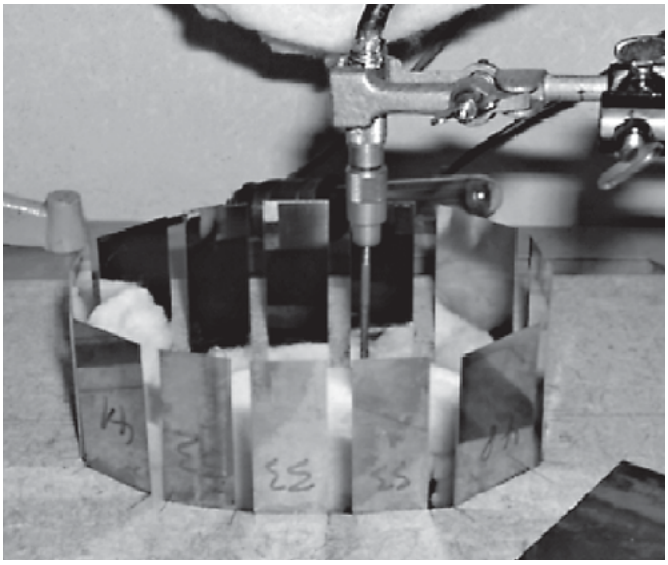

**Figure 3. First model of the auditorium**

## 4. In Western Australia

In WA, I received an establishment grant from the University and another from the Australian Research Grants committee which enabled me to set up a laboratory to pursue this question. The importance of these grants is gratefully acknowledged. In 1970 I was joined by Mike Barron who was completing his PhD, and we worked together on the research, until the opening of the Town Hall in October 1972 where he made the acoustic commissioning measurements.

### 4.1. Re-engagement with the Town Hall project

With research and teaching well established in WA (and because of the reluctance of Engineering Design Consultants to travel), the architects asked me to take up the executive role in the acoustical design. The principal result of EDC's work had been an increase in volume of the main auditorium following the predictions of the classical RT formulae, noise control, and optical reflection distribution studies for the main reflectors.

I reviewed the shape of the reflectors, found them ineffective and suggested the dihedral form for surfaces opposite the stage. The audible effect of this change (contrasting a single overhead reflection with a pair of lateral reflections oriented as if from adjacent dihedral surfaces) was demonstrated to the architects in a simulation recorded in the anechoic room. They were convinced sufficiently to make this change. The architects had produced their own 1:48 (1/4"=1') scale model which they sent to WA for me to study.

### 4.2. Testing for the audibility of lateral reflections

It had been argued that the mechanism by which lateral reflections could be masked depended on the reduction in intensity of the direct sound and reflections which grazed the audience; (after Schultz and Watters [16]). That resulted in the potential inaudibility of lateral reflections if these were preceded by an energetic ceiling or frontal reflection, on a path remote from the seating planes. This analysis was described in detail in a paper in the Architectural Science Review [17], and subsequently was included by Dr. Tom. Northwood in Volume 10 of Benchmark papers in acoustics, (Dowden, Hutchinson - Ross Inc. New York).

That approach was the basis for the testing of the model; estimating the strength of the respective reflections from the attenuations found in [16], and measuring the arrival times in the physical model using a spark source and a storage oscilloscope. It proved to be impossibly difficult. T.B Ardagh, already a graduate in both science and architecture, undertook Master of Building Science program in 1970.

For his thesis he chose to write the software for a digital study of echo and audibility of the lateral reflections in concert halls. Of course the subject hall was the Christchurch Town Hall design [18].

With computer power at everyone's fingertips these days we forget what a feat this was in 1970. The program was run on a PDP6 ex NASA computer and took all night for a single source position. It was certainly the first such application in our hemisphere and possibly in the world. T. B. Ardagh deserves special mention for his ground-breaking work.

Echoes were located and treated.

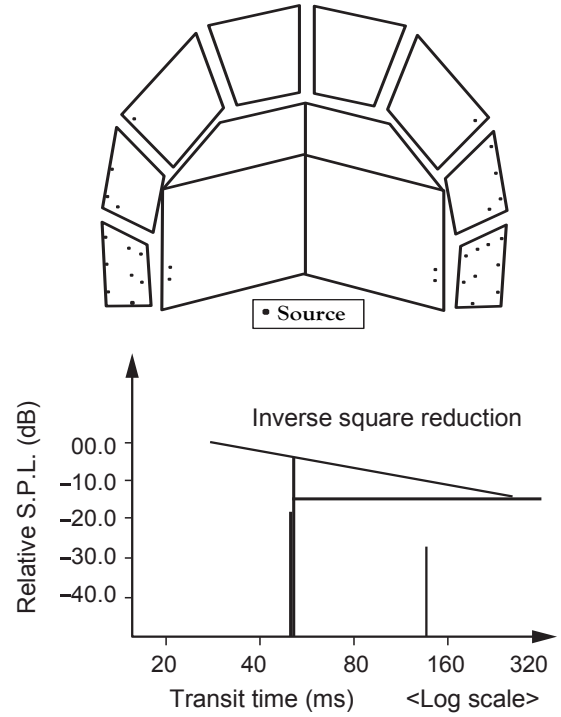


**Figure 4. Two illustrations from [19]. On top is a plot of seats failing the lateral reflection audibility, on the bottom is the computed echogram for the chosen seat (marked interactively with a X). Only every third seat was tested and the hall side walls were adjusted to correct these seats.**

### 4.3. Occam's Razor

While there is no doubt that in some cases the precedence of the ceiling reflection masked the side reflections, in the general case the precedence was not an issue. Barron showed conclusively that the ratio of lateral to frontal reflected sound energy was sufficient to describe all the subjective results. On this basis Barron devised the "lateral fraction" Lf as an objective measure for the spatial impression. This he measured with the "Gated Integrating Energy Meter" he designed and a Neumann SM69 studio microphone [19][20].

## 5. Commissioning

There was no opportunity for "tuning" the Hall as later became fashionable for concert halls. The official opening was on September 30 1972. For two or three days earlier we had access to make measurements - sometimes at night, as cleaning and finishing work was still in progress. On one of these days an invited audience arrived for occupied RT measurements (about 2000 people). The acoustic source was to be a 45 calibre pistol ex WW1, and I needed to warn the patrons to cover their ears. I found I could address this large audience without the sound system - which was still being installed. With an RT in excess of 2 seconds, speech clarity should have been poor. Subsequently this effect was quantified as described in [18].

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At the time of making these measurements, Dr George Dodd [21], University of Auckland, Acoustics Testing Service, pointed out that in effect we had clearly separated the early reflected sound field from the reverberant field. This separation both accounted for the high clarity, and I realized that it opened the possibility for large uncompromised multiple use spaces – arguably the most significant result to come from this design. Indeed the Programme Acoustique for the new Philharmonie de Paris [22] contains several essential passages, which might well have been a description of the Christchurch Town Hall acoustics [23].

Prior to the opening concert, balance between choir and orchestra was corrected with concealed reflecting panels which remained in place until the installation of the Rieger organ in 1997. Thereafter they were not needed. There were sundry other minor changes over the years.

At the opening concert the orchestra reported some difficulty with ensemble and that led to ongoing research [24] and measurement of the necessary and sufficient acoustical conditions for orchestral ensemble. A direct result was that the over-stage reflector and stage lighting framework (which had been omitted for cost and time reasons prior to the opening), was designed modeled, and installed by 1977.

## 6. Conclusions

Over some 38 years the Town Hall building had become a loved architectural treasure in Christchurch. It barely showed its age because of the architectural skills devoted to its creation. It received both the NZIA Gold Medal in 1973 and an Enduring Architecture award in 2000. Its acoustics have been acclaimed by such luminaries as Leonard Bernstein, Dame Kiri Te Kanawa, Yehudi Menhuin and Bryn Terfyl. I have outlined the process by which its acoustic design arose from the initial imperative to ensure the audibility of lateral reflected sound. I have recounted some unforeseen consequences of its unique form, which led in the subsequent decades to so much excellent research and learning. It may well be that the comparative isolation from the cultural inertia of both Europe and North America enabled the bold steps the architects were willing to embrace in the form of this room. Be that as it may, the intimacy, clarity yet full reverberance that the room produces remains one of the most exciting symphonic sounds in the world.

All that changed on February 22, 2011. The second earthquake destroyed the heart of Christchurch. The Town Hall building was damaged but is reparable; indeed the City Council has unanimously agreed to restore it in its entirety.

There is a counter-imperative however not unlike that that informed Rotterdam after WWII – the chance to have a brave new city [25], for which a concept plan now exists. The Town Hall could easily be included in this concept plan, given the will to do so. It would indeed be ironic if, when the *Philharmonie de Paris* opens next year, the Christchurch Town Hall has gone.

## Acknowledgements

My presence at ISRA 2013 is supported by a grant from the organisers and a further grant from Marshall Day Acoustics Ltd. and this support is gratefully acknowledged. My wife Shirley has, as always, supported my efforts; there is another story underlying this one in which she is the principal.

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25. Should you wish to write in support of this restoration, as many did to the City Council with such effect, please address your letter to: *gerry.brownlee@parliament.govt.nz*

rma net

It has been a quiet couple of months in the Courts for acoustic and vibration issues. The following is a brief summary of a recent Environment Court decision relating to the validity of a gun club's Certificate of Compliance in light of subsequent subdivision nearby, together with some details on a significant case which will soon be going to a further hearing in the Environment Court involving Palmerston North City Council and New Zealand Windfarms Limited. Full decisions and further information can be found on the RMA Net website at www.rma.net

## In the Enviromental Court

WAIMAKARIRI DISTRICT COUNCIL - Applicant

NORTH CANTERBURY CLAY TARGET ASSOCIATION - Respondent

[2014] NZEnvC 114, 24p, [88] paras, 23 May 2014

**Summary of Facts**

In 1995 the North Canterbury Clay Target Association (the Association) was granted resource consent for 13 shoot meetings and 13 practices per annum at a shooting facility at 269 Boundary Road, Cust. In 2007 the Association requested a Certificate of Compliance to increase its activity to 52 meetings and practices per annum. The application was accompanied by a noise assessment report which maintained that the noise at the then nearest dwelling complied with the permitted activity noise limits of the Waimakariri District Plan and as such the activity was a permitted activity under the Rural Zone rules. The Council granted the certificate in 2008, but subsequent lifestyle block subdivision closer to the facility resulted in complaints and the Council applied for declarations that the shooting activities were not permitted under the Plan and the Certificate of Compliance should not have been granted.

The Council held that the sound levels of gunfire associated with the activities were unable to be measured under Rule 31.11.1.1 in accordance with the provisions of NZS 6801:1991 and NZS 6802.1991. As such by reason