

# Building Acoustic Design of the Queensland University of Technology Creative Industries Precinct Phase 2 (CIP2)

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## ABSTRACT

The QUT Creative Industries Precinct Phase 2 (CIP2) co-locates the music, dance, performance and visual arts portfolios of the Creative Industries Faculty in a mixture of new-build and adaptive re-use of heritage structures. The acoustic design of CIP2 was of primary importance to the overall building performance and posed significant design challenges. Building acoustic design included high sound-insulation separation requirements between music studios, particularly the two professional-quality recording studios and small/medium rehearsal rooms, as well as the design of open-plan office spaces connected by a full-height atrium and secondary voids in order to provide sufficient acoustic privacy between floors and reduce disturbance to office areas from student common areas on floors below. As part of the briefing study, auralisation was used to negotiate project-specific design criteria for the studio spaces based on the requirements of the end-users, resulting in significant cost savings to the building façade for dance and drama studios which did not require high levels of external noise control. A key design challenge was the low-noise mechanical services system for the recording studios, which used a non-traditional system including flexible ductwork which provided significant challenges in achieving the required services noise levels and in controlling crosstalk and duct-breakout between adjacent studios.

## 1. INTRODUCTION

Queensland University of Technology (QUT) has recently moved into the new Creative Industries Precinct Phase 2 (CIP2) building at the Kelvin Grove campus. CIP2 is a new-build facility co-locating the music, dance, performance and visual arts portfolios of the Creative Industries Faculty into a single site, replacing several buildings split across QUT's Kelvin Grove and Gardens Point campuses as well as an external recording studio facility in Newstead.

The CIP2 building is split into a "western bar" of three double-height floors, containing multiple studio spaces plus an "eastern bar" of six single-height floors. The western bar contains studios including a large ensemble rehearsal/performance room, small rehearsal/practice rooms, two recording studio complexes ("Studio A" and "Studio B", each consisting of multiple control, live and isolation rooms), three large interdisciplinary "black box" studios, three dance studios with sprung dance floors and four drama rehearsal spaces. The eastern bar contains office accommodation, meeting and seminar rooms and student common areas. Visual arts studios and gallery spaces are accommodated in an adjacent mixture of new-build and reused heritage structures which were formerly part of the Kelvin Grove barracks.

The acoustic performance of CIP2 was key to the success of the entire project and required careful acoustic design to achieve the desired performance outcomes.

This paper focusses on the building acoustic design of the CIP2 facility, with special emphasis on the high acoustic separation requirements between studios and unusual low-noise system design for recording studio spaces.

## 2. ACOUSTIC PERFORMANCE REQUIREMENTS

Acoustic design targets for CIP2 were developed in consultation with the end users via an auralisation workshop, which established the degree of acoustic performance required for each space. In several instances, the design targets adopted differed from the AS2107 (Standards Australia 2000) guidance – e.g. for music studios the end users required more-stringent control of background/external noise than AS2107, whereas for Dance/Performance studios less-stringent noise control was required. A credit interpretation request was negotiated with the Green Building Council of Australia in order to use the project-specific criteria from the end-user workshop in place of the AS2107 criteria.

### 3. BUILDING ACOUSTIC DESIGN

#### 3.1 Façade Sound Insulation

The CIP2 site is located adjacent to Kelvin Grove Road, a major arterial road north of the Brisbane CBD. External noise level control was particularly important for the music spaces. End-user consultation with the Dance and Performance portfolio staff concluded that external noise control was less-important for dedicated Dance or Performance spaces with the adopted targets of 45 dB(A)  $L_{Aeq}$  during peak hour being less-stringent than AS2107; however for music spaces the requirement for external noise control was significantly more-stringent than AS2107, with noise intrusion targets of 30 dB(A)  $L_{Aeq}$  (large rehearsal room) and 15 dB(A)  $L_{Aeq}$  (recording studios) during peak hour.



Figure 1 View from Rehearsal/Performance Room along Kelvin Grove Road

This constrained the space planning of music studios, in particular meaning that studio live rooms could not practically be located on the façade; however it was considered practical to have façade-located control rooms, because control rooms are slightly less-sensitive to external noise intrusion than live rooms.

The base building façade of the CIP2 studios was 10mm float glass | 12 mm airgap | 10.76 mm acoustic laminate glazing ( $R_w$  37), however for the Level 5 spaces structurally-isolated secondary glazing (supported from the isolated slabs of the music spaces) was required: 12.38 mm laminated glazing for the large rehearsal/performance room at the northern end of CIP2, and 18.38 mm laminated glazing for the recording studio control rooms at the southern end. To provide access to clean the secondary glazing, the airgap between the façade and the secondary glazing was wide enough to be trafficable (~900 mm), which also improved the acoustic separation.

Noise breakin levels in peak hour within the music spaces met the design targets, with a measured noise level (background-corrected, i.e. the measured break-in level during peak hour with the measured background noise outside of peak hour logarithmically subtracted) of 9 dB(A) in the Studio A control rooms, and 26 dB(A) in the large rehearsal/performance room.

#### 3.2 Internal Sound Insulation

The multidisciplinary nature of CIP2 means the internal sound insulation of the building needed to avoid disturbance between adjacent spaces, which could potentially be used simultaneously for noise-generating and

noise-sensitive activities. A relatively-high sound separation target of  $D_w$  60 between adjacent studios was set in order to allow for independent use of spaces.

The sound insulation strategy was defined separately for the music floor (Level 5) and other floors of the building. On other floors, the sound insulation between adjacent studios was generally achieved by space planning by incorporating buffer zone spaces such as storerooms between adjacent studios where possible; the main exception was the performance studios, which are paired within the structural building “box” and have an increased-performance wall construction.

For the music floor, all spaces except the large rehearsal room are fully-structurally isolated via a jack-up slab and a “box-in-box” construction, with a trafficable timber “lid” above the box that provides an accessible zone for services reticulation. The large rehearsal room has a floating floor for isolation from the dance studio below, but does not have fully-isolated internal walls as it (plus its associated control room and store room) occupies an entire structural “box” and hence has no directly-adjacent spaces on the same floor.

Partitions around live rooms within the studios and some rehearsal rooms were constructed of masonry blockwork, while other partitions were lightweight.

All measured studio spaces achieved the  $D_w$  60 performance requirement, with the best-performing separation between studios a measured performance of  $D_w$  73 for masonry partitions and  $D_w$  69 for lightweight partitions.

### 3.3 Acoustic Separation of Floors Via Atrium and Voids

Levels 2-6 of the eastern bar of CIP2 are linked by a central atrium and stair, while each pair of floors (1-2, 3-4 and 5-6) are further linked by double-height “voids” between floors. On studio floors (Level 3 and Level 5) the office accommodation in the eastern bar of CIP2 is separated from the voids by glazed partitions, however the intermediate floors (Level 2, Level 4 and Level 6) have glazed balustrades and open onto the voids.



Figure 2: Typical Void Connecting Office Floors

Locations of acoustic absorption were added onto the soffit of the voids and the soffit adjacent to the slab edge to control noise transfer between office floors via the voids/atriums and to reduce noise break-in to office areas from student activities in the foyers outside the studios (particularly the Level 5 foyer outside the music studios which is likely to have instruments warming up etc). An Odeon model of the atrium and voids was used to design the absorption layout and predict the extent of noise transfer between floors.



### 3.4 Services Noise Control

Somewhat unusually for a building with low-noise systems, the project procurement model for CIP2 had responsibility for services noise control with the mechanical engineer (Aurecon) with the acoustic consultant providing guidance and high level reviews of the mechanical design, but not conducting detailed calculations.

The system design for the low-noise (NR20 and NR25 systems) for the recording studios and music studios was undertaken using a Variable Air Volume (VAV)-based system with distribution via flexible ductwork – an unusual approach for a low noise system, but dictated by the reduced space which ruled out a more-traditional low-noise system. This was considered to be a high-risk approach since aerodynamic noise is typically the dominant noise source for low-noise systems and the aerodynamic noise generation of flexible ductwork is highly dependent on the installation conditions (ASHRAE 2015).

This required particular attention to detail during the construction phase as several instances of “convoluted” flexible duct routing were identified, either by visual inspection, or from audible aerodynamic noise once the air handling units (AHUs) were operational. This required some adjustment to the duct layouts (rerouting some flexible duct and strapping/sliding of flexible duct to ensure straight routing of the duct. An example is the ductwork layout shown in Figure 3.



Figure 3: Poorly-aligned flexible ductwork caused high aerodynamic noise levels and required modification

In order to keep the ductwork in place, the flexible ductwork runs required multiple support points to keep the ductwork as straight as possible and avoid uneven flow conditions (which could in turn result in aerodynamic noise). Figure 4 shows a typical flexible duct installation after adjustment.



Figure 4 Flexible ductwork required additional support from straps to keep the required duct routing

### 3.4.1 Measured Noise Levels

During the acoustic commissioning of CIP2, the initial tested range of noise levels in the recording studios was from approximately the N1 background noise curve (Essert 2013) – i.e. approximately the human threshold of hearing – through to NR36, a variation of 22 dB between systems with the same nominal noise criterion of NR20! The quietest spaces were the studio control rooms, with noise levels measured at just over N1, as shown in Figure 5:

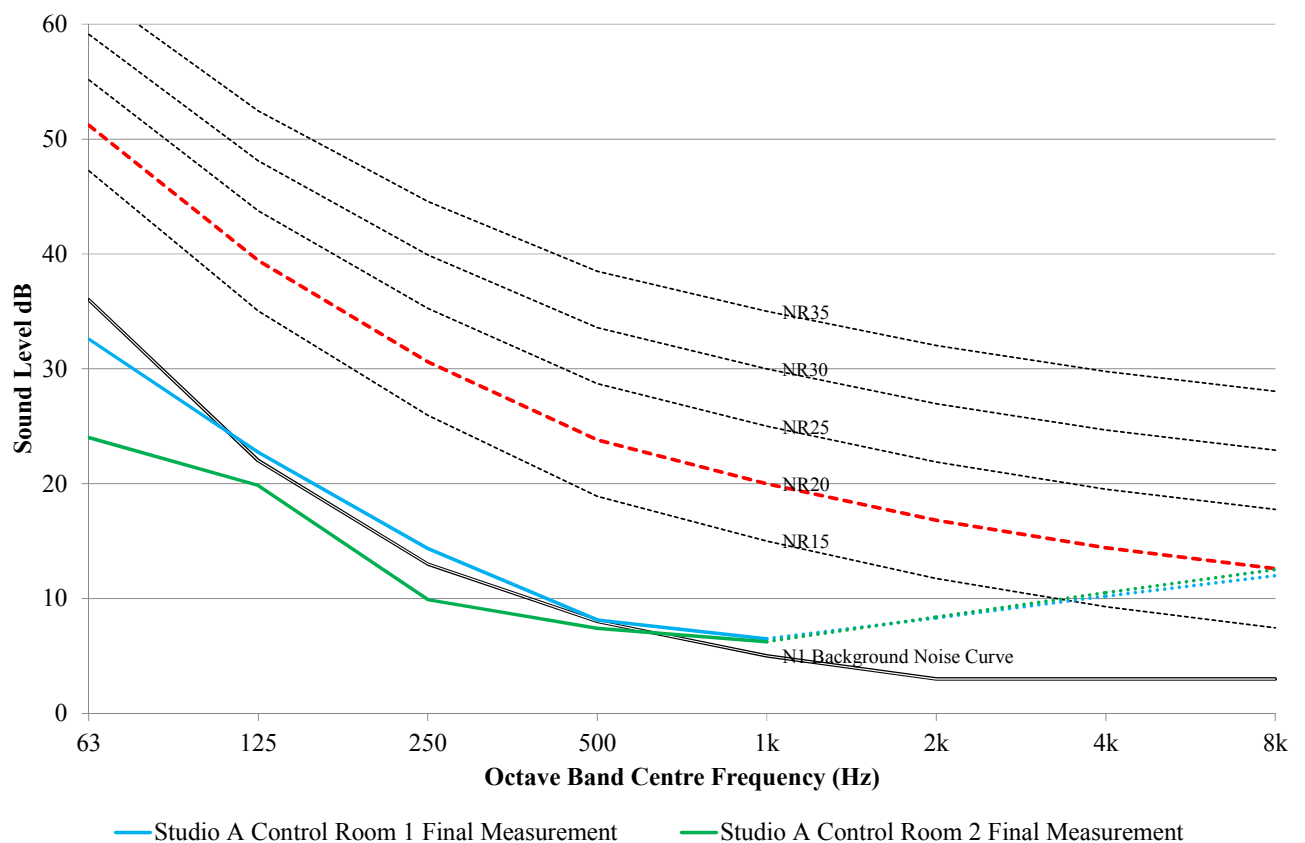


Figure 5: Background Noise Measurements ( $L_{90}$ ) in Studio A Control Rooms

(data from 1kHz upwards is at noise floor of meter and is shown dotted)

After subsequent adjustment of the flexible duct and adjustment to system balance, all spaces complied with the NR20 noise limit with the exception of one live room, where the AHU fan setting was set too high and the noise limit was marginally exceeded at NR22. It is expected that this room will meet criteria once the AHU fan speed is adjusted down to the design speed, although retesting of this space had not occurred at the time of writing of this paper. Figure 6 shows the results of background noise testing in this room with the contribution from each noise source (supply air, return air and house lights).

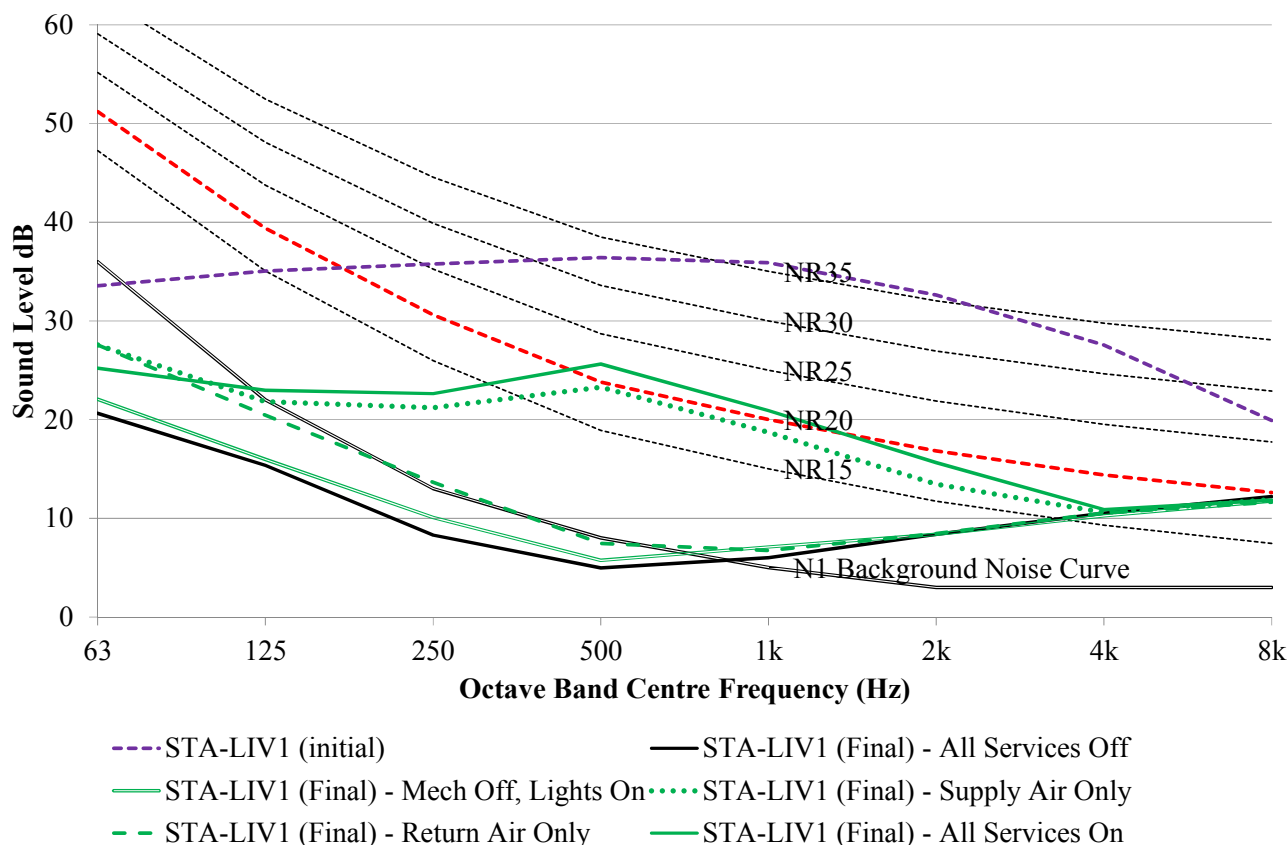


Figure 6 Studio A Live Room 1 Measured Background Noise (L<sub>90</sub>), showing effect of adjusting flexible ductwork

The experience at CIP2 suggests that low noise levels can be achieved even with a system design that would normally be considered “unsuitable” using duct elements such as VAV boxes and flexible ductwork. However, the experience at CIP2 also shows that such as an approach is inherently “risky” and that significant adjustment to the ductwork is likely to be required to meet the noise limits. Nevertheless, in cases where the spatial requirements rule out the use of a traditional low-noise system, it may be possible to meet low-noise targets even with an “unfavourable” design if extreme care is taken in the system design and in site supervision.

In particular, the following factors are expected to have contributed to the success of the system at CIP2:

- The ability to access the technical loft above the studios to make adjustments to the routing of flexible ductwork during construction and commissioning
- The presence of a length of lined sheet metal ductwork and a lined mitred bend as the final connection to the room for each isolated “box”. This was originally introduced to control crosstalk between rooms via the common technical loft (refer Section 3.4.2), but would also have an additional benefit in providing some “guaranteed” attenuation downstream of the flexible ductwork to address aerodynamic noise generated by the flexible ductwork.

### 3.4.2 Control of Duct Crosstalk

A major concern with the adopted mechanical services design was the risk of duct crosstalk between adjacent spaces. Although multiple AHUs were used so that adjacent spaces would not be served off the same AHU (with the large live room of each space being served by a dedicated AHU), there was still a risk of duct breakout from the flexible ductwork in the technical loft above the studios, since flexible duct has very low breakout/breakin TL.

To control crosstalk, the final 1.5m of ductwork was required to be internally-lined solid sheet metal ductwork incorporating at least one lined mitred bend. The ductwork was sized to be as small as practicable without exceeding the maximum velocity requirements for controlling aerodynamic noise in order to maximise the attenuation provided by the duct lining. This provided sufficient down-duct attenuation to control the crosstalk path



via the shared void. Measured acoustic separation between two non-adjacent rooms (i.e. transfer via the shared technical loft above) was in the range  $D_w$  73-78 for three pairs of rooms tested.

### 3.4.3 Structural Isolation of Services

All services connections to the isolated “boxes” were made using flexible connections (flexible ductwork, flexible pipe connections, and by cutting cable tray and providing slack in cable connections) to avoid bridging the structural isolation. Figure 7 shows the design concept for the structural isolation, where a flexible connection was included wherever services crossed a structural isolation joint. Figure 9 shows an example isolation joint. This allowed connections to the studio “box” itself to be made rigidly while avoiding bridging between adjacent studios by services.

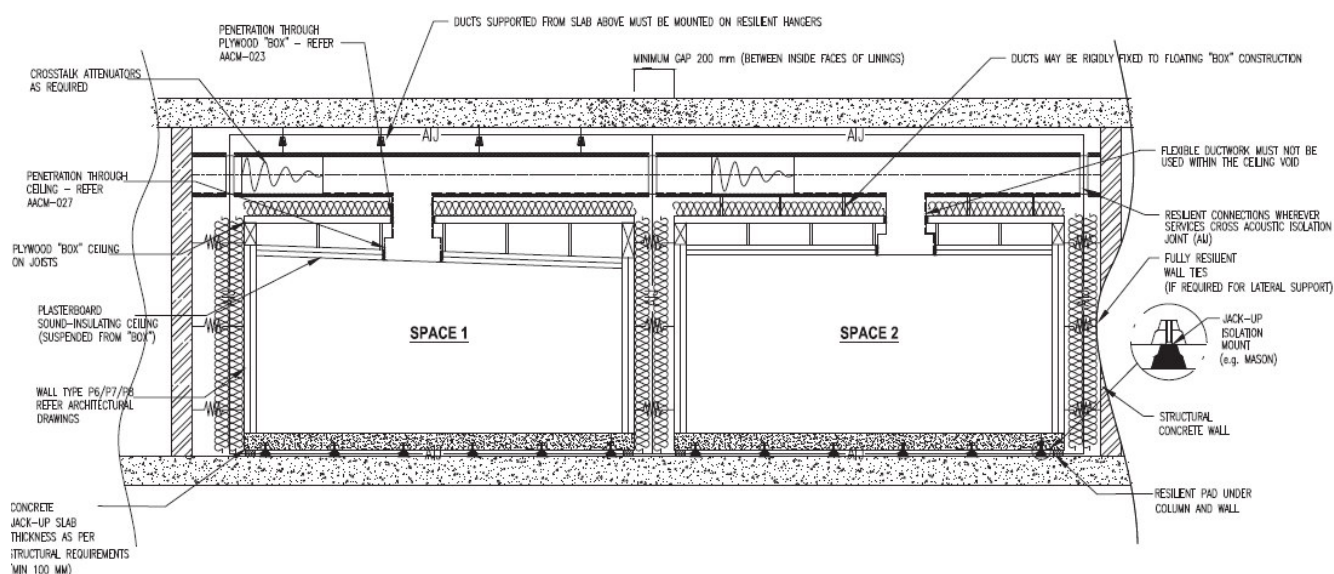


Figure 7: Structural and services isolation concept for recording studios

Coordination with the contractor and a series of “acoustic briefings” was critical in getting the contractor and subcontractors to understand the concepts of structural isolation and the importance of maintaining the integrity of the structural isolation breaks. Figure 8 shows a sketch developed with the architect and contractors which was displayed in the site office for the duration of the construction program to remind contractor and subcontractor staff of the requirements for preserving the acoustic isolation.



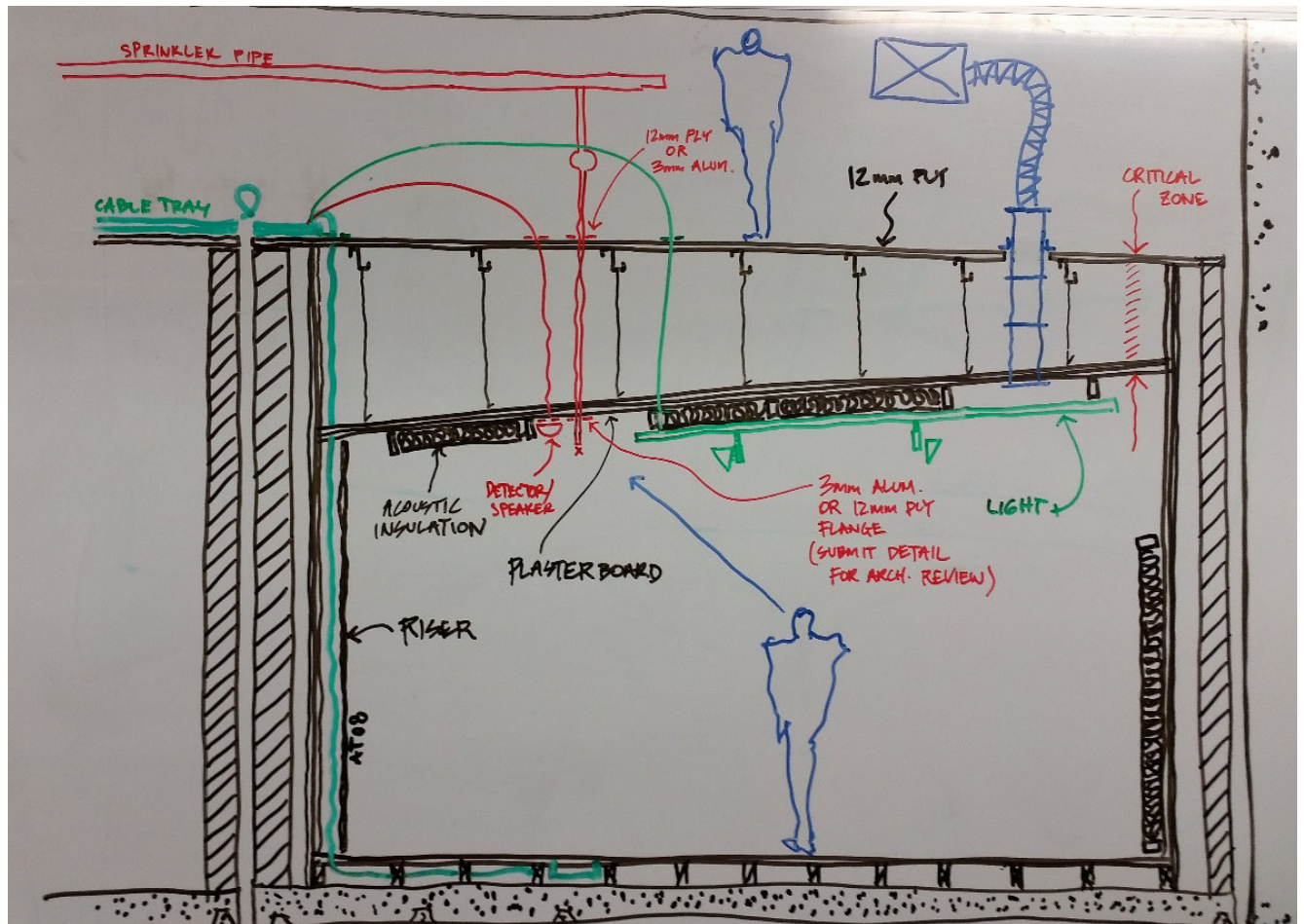


Figure 8: Site sketch used to convey structural isolation concepts to subcontractors.

During the construction stage, ongoing site inspections were required to preserve the integrity of the structural isolation, requiring some on-site modifications where solid ductwork had been incorrectly installed across an isolation joint.

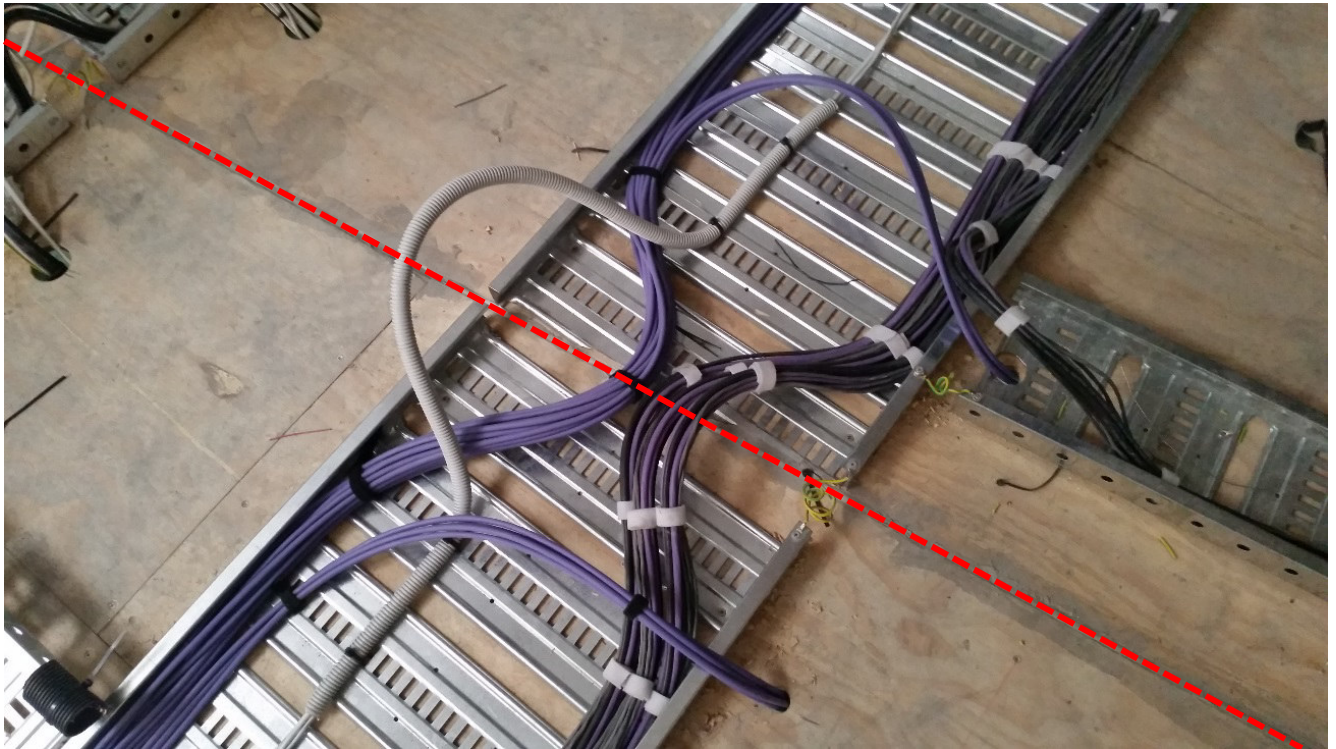


Figure 9: Example of Services Isolation at joint between isolated “box” constructions

## CONCLUSIONS

The Queensland University of Technology Creative Industries Precinct Phase 2 project has provided end users with a highly-flexible creative arts building, with initial feedback from end users being positive.

The co-location of multiple functional spaces in close proximity required careful acoustic design to achieve the high sound insulation requirements. Control of duct crosstalk and flanking paths allowed acoustic separation of  $D_w$  60 or higher to be achieved even with spaces sharing a common technical void above.

A particular highlight of the CIP2 project is the use of a non-traditional mechanical services system design for a low-noise application (especially the use of flexible duct), with the implemented system being closer to a typical office approach than a traditional low-noise system. The experience of CIP2 has shown that low noise levels (as low as N1) can be achieved even with a non-traditional system, but at the cost of a high degree of construction-stage supervision and additional tuning and commissioning of the system. While the approach of CIP2 would not be recommended as a “normal” approach to low-noise system design, it does demonstrate that in space-constrained environments low-noise levels can be achieved even with an “unfavourable” system design.

## REFERENCES

- American Society of Heating, Refrigeration and Air-conditioning Engineers, 2015 “ASHRAE Applications Handbook – Chapter 48 Noise and Vibration Control”
- Essert, R, 2003 “Why Silence?” Proc. International Symposium of Room Acoustics, Toronto, Canada, June 2013