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New Zealand is actively improving school acoustics with government-led initiatives

James Whitlock[1]
Marshall Day Acoustics
84 Symonds St, Grafton, Auckland 1051, New Zealand

ABSTRACT

New Zealand's Ministry of Education is taking active steps to ensure that the country's 35,000+ classrooms are fit for purpose. Acoustics is a primary factor in central government's School Property Strategy 2030, which has informed three major initiatives to establish and implement sensible acoustic regulations. All three initiatives are underway.

First is the Designing Quality Learning Spaces (DQLS) – Acoustics v3.0 document, launched in December 2020. It sets out mandatory requirements for reverberation time (RT), background noise and sound insulation in new and refurbished learning spaces.

Second is the Ngā Iti Kahurangi 'small and remote schools' programme. We are measuring RTs in 630 schools, assessing compliance with DQLS and adding absorption where necessary. The plan is to scale this programme up to include many more schools across the country.

Third is the Internal Environmental Monitoring (IEM) programme. Sound levels (and other environmental factors like temperature, humidity and CO_2) are continuously measured in a range of schools, and reviewed to inform improvements.

These initiatives aim to provide quality learning environments for New Zealand children, and this paper sets out how they have been designed and implemented. Similar initiatives could be adopted by other countries to improve acoustic quality in their classrooms.

1. INTRODUCTION

Good acoustic design supports all students and creates a better place in which to learn and teach. The New Zealand Ministry of Education (the MoE) owns more than 30,000 learning spaces in over 2,100 schools, and as part of their School Property Strategy [1] it aims to ensure that they are all quality and fit for purpose.

The MoE has initiated three major pieces of work that will establish acoustic design requirements for new and refurbished learning spaces, and field tests to ensure they work.

- Designing Quality Learning Spaces – Acoustics v3.0 [2]
- Ngā Iti Kahurangi 'small and remote schools' RT testing and improvement programme
- Internal Environmental Monitoring (IEM) programme

2. DQLS – ACOUSTICS V3.0

This is the third generation of the Designing Quality Learning Spaces – Acoustics document. The first was released in 2007 [3] and was simply a design guide for classrooms, written for the

[1] james.whitlock@marshallday.co.nz

benefit of teachers, principals and school boards to help them understand the importance of acoustics. It addressed small cellular and prefabricated classrooms only and, while well founded, did little to improve the classroom stock because it was only a guideline.

The second version in 2016 [4] made a big step forward by targeting an audience of architects, designers and engineers involved in the design and specification of schools. It also set mandatory requirements for reverberation time (RT), sound insulation between learning spaces, rain noise and ambient noise. It also addressed Innovative Learning Environments (ILE) – the name given to large open-plan learning spaces at the time. The mandatory requirements meant that architects had to design classrooms to an acoustic standard, which was enforced by the MoE who convened a design review panel to review the details of each school project.

DQLS v3.0 is an evolution of the second version, improving on its readability, layout, definitions, and changing some of the mandatory guidelines following feedback on version 2.0. A summary of its content is provided in the following sections.

2.1. Important acoustic concepts are up front and easy to understand

The important concepts page sets out five key acoustic concepts are used in DQLS – see Figure 1. This is largely targeted at architects and other lay readers, who often get confused between sound absorption and sound insulation (for example).

Each concept has its own font colour so when readers see that colour throughout the document, they are clear on its meaning and can easily refer back to the diagram.

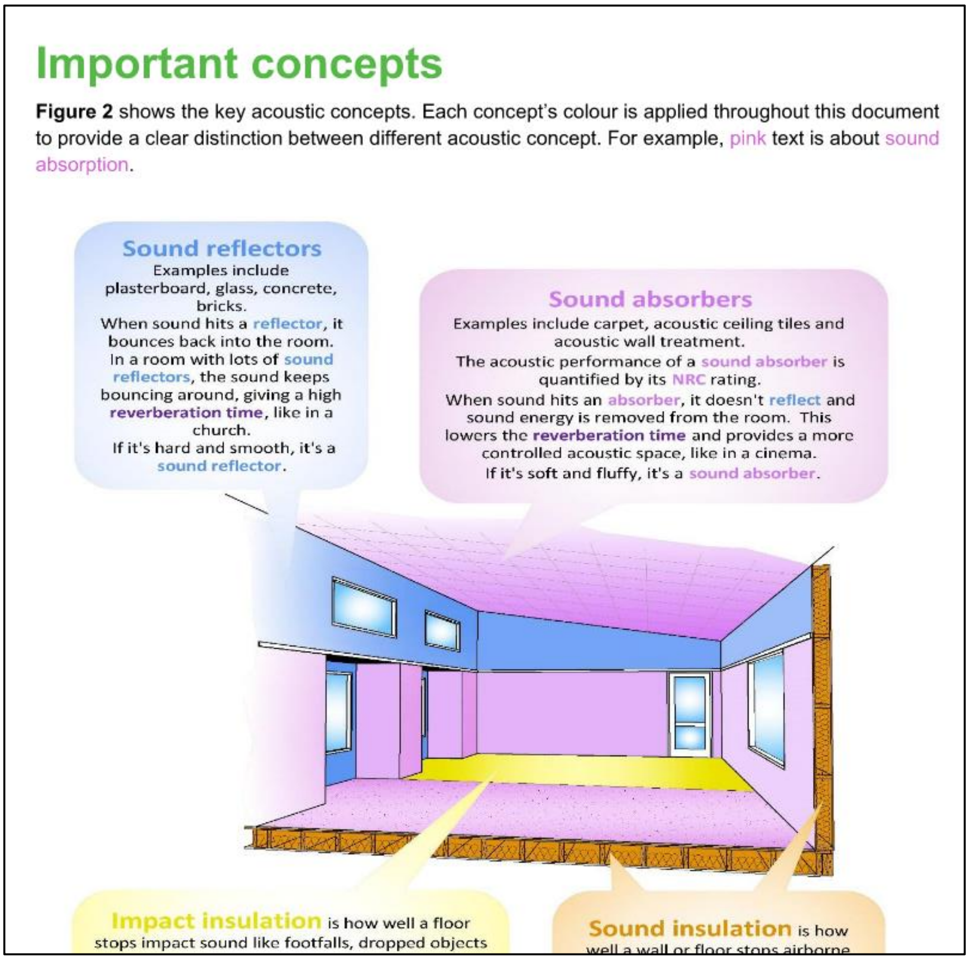

Figure 1: An excerpt from the important concepts page in DQLS v3.0

We also made a point of defining 'connected spaces'. Connected spaces are adjacent learning spaces physically connected by a door, corridor or opening (i.e. you can walk between them without going outside), and are part of the same general space in which learning activities are coordinated. Sound travels more easily between connected spaces, but this is okay provided activities are acoustically compatible, e.g. all quiet or all noisy at the same time. The MoE expect teachers to manage connected spaces so concurrent activities are acoustically compatible. Walls between connected spaces are permitted to have lower STC ratings – refer Section 2.2.2.

2.2. Mandatory requirements are the cornerstone of DQLS

The mandatory requirements have had a massive positive impact on classrooms because acoustic design (and the associated cost) can no longer be sidelined. Acoustic requirements are now itemised in checklist documents submitted to MoE as part of the design review process, and commissioning can be required by the MoE once the building is complete to confirm its acoustic performance.

The mandatory requirements address four key design aspects:

- Reverberation Time (RT)
- Sound transmission between learning spaces (STC)
- Impact insulation between floors (IIC)
- Indoor ambient noise levels, including HVAC noise and rain noise

2.2.1 RT and ambient noise level requirements

The mandatory requirements for RTs and ambient noise levels are based on AS/NZS 2107:2106 [5] and apply to rooms when they are unoccupied. Key values are 0.4 – 0.5s for small[2] primary school learning spaces and breakout rooms, 0.5 – 0.6s for small secondary school learning spaces, staff rooms and libraries and 0.5 – 0.8s for technology spaces including music rooms and science laboratories. These are mid-frequency T_{60s} – the arithmetic average of 500Hz and 1kHz octave bands.

Large learning spaces (>300m^3), assembly halls, auditoria and gymnasia have volume-based requirements, shown in Figure 2.

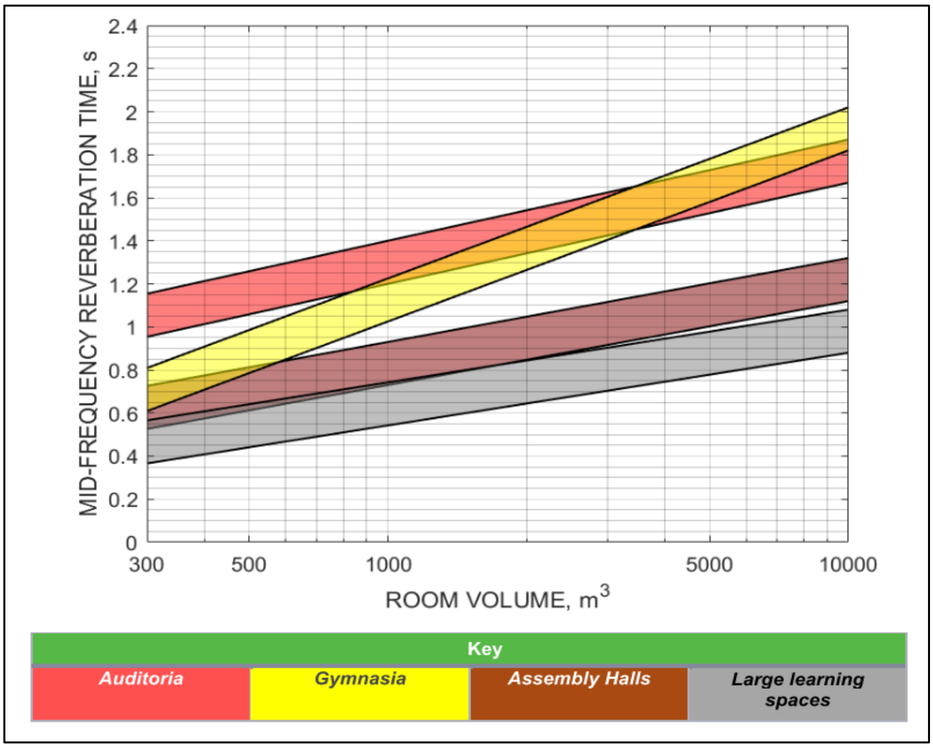

Figure 2: Mandatory RT criteria for large spaces

Learning spaces must also have a balanced RT spectrum. This means that the RT in the 125Hz, 250Hz and 2kHz octave bands must be ± 30% or ± 0.2 seconds of the mid-frequency RT, whichever is the greater.

[2] Small learning spaces are defined in DQLS as less than 300m^3 – the approximate size of conventional cellular classrooms

Requirements for ambient noise levels include 50 dB L_{Aeq} for gymnasia and circulation spaces, 45 dB L_{Aeq} for large learning spaces, technology rooms and libraries, 40 dB L_{Aeq} for all other learning spaces, breakout rooms and teacher workspaces and 35 dB L_{Aeq} for auditoria and assembly halls.

HVAC systems must be designed to 5 dB below these ambient levels. But a provision has been made for heat pump systems with high wall or cassette units, which are very common in NZ. For heat pumps, if the teacher has the ability to control the system themselves (as opposed to it being automated by a building management system (BMS)), their design criteria are the same as the ambient levels i.e. a 5 dB relaxation compared with other HVAC systems.

2.2.2 Sound and impact insulation requirements

Some examples of mandatory requirements for sound insulation are:

- STC 45 for walls between 'connected' learning spaces (as per the definition in Section 2.1), breakout spaces, libraries, meeting rooms and offices
- STC 50 for walls between learning spaces that aren't connected, low noise technology spaces and toilet blocks
- STC 55 for walls between learning spaces and moderate noise technology spaces, laboratories and plantrooms
- STC 60 for walls between learning spaces and high noise technology spaces, gymnasia, halls and music spaces
- IIC 55 for floors

Doors and windows have their own STC requirements, and following feedback from the NZ acoustics community about DQLS v2.0, we made provision for downrating partitions with openings in them, as per Table 1.

Table 1: Requirements for doors, glazing and openings in acoustic walls and floors

Opening type	**Requirement**
Fixed windows between separate spaces	Windows must have an STC rating within 5 points of the wall.
Fixed windows between 'connected' spaces	Windows must have an STC rating within 10 points of the wall.
Hinged doors/openable windows	Door/windows must have STC rating within 15 points of the wall. If the combined door/openable window area > 15% of the entire partition area (to ceiling height), the wall STC may then be reduced by 5 points. The door/window STC remains within 15 points of the original wall STC.
Sliding doors	Sliding doors must not be used in > STC 45 walls. This means that they can only be used between connected spaces. All sliding doors between learning spaces must be minimum STC 25. If the combined door/window area > 15% of the entire partition area (to ceiling height), the wall STC may be reduced by 5 points. The door/window STC remains within 15 points of the original wall STC

2.2.3 Rain noise requirements

DQLS version 2.0 mandated a rain noise level in learning spaces of NC 45 or less at a nominal rainfall rate of 20 mm/hr (average for New Zealand).

Since DQLS v 2.0 was published, rain noise became a lively topic in the NZ acoustics community with several papers questioning the validity and repeatability of testing roof-ceiling systems in accordance with the applicable standard (ISO 10140-1:2016) [6],[7] and the accuracy of prediction methods for rain noise [8].

Because of these uncertainties, DQLS v3.0 contains three approved design solutions. We split the country into three categories based on regional rainfall rate (high, medium and low) and set out an approved roof-ceiling design for each category. Other roof-ceiling designs can be accepted by the MoE, but they must be confirmed as acoustically equivalent by an acoustic engineer.

I note that the MoE has a preference for warm-roof systems, which provide thermal and water-tightness benefits but can be acoustically tricky because of their rigid insulation layer.

3. NGĀ ITI KAHURANGI – CLASSROOM IMPROVEMENT PROGRAMME

Ngā Iti Kahurangi is Māori phrase that means ‘small and precious things’. The programme involves measuring RTs in the learning spaces of 630 small and remote schools (i.e. those in rural areas, far from an urban centre). The measured results are compared against the DQLS RT criteria (refer Section 2.2.1), and any rooms that do not comply have acoustic treatment added to them.

If Ngā Iti Kahurangi is deemed successful, the MoE could scale the programme up to national level, and assess the RT of many more schools – potentially every learning space in their 30,000+ portfolio.

Other than the administration burden of running a programme like this (which has been well managed by MoE) the primary challenge was developing a viable RT testing method. The MoE has a network of facility managers that look after schools around the country and the goal was to upskill them and provide them with a robust testing rig so they could do the RT tests themselves.

We settled on using a modified version of IRIS – an impulse response software/hardware package developed by Marshall Day Acoustics (www.iris.co.nz). IRIS typically uses a dodecahedron loudspeaker, dedicated analogue to digital conversion hardware and a pro-audio grade ambisonic microphone. This equipment and cumbersome, and doesn’t lend itself to time-limited classroom measurements by non-acousticians. So we developed a ‘mini IRIS’ kit.

3.1. Mini IRIS and the traffic light compliance system

Our mini IRIS kit uses affordable consumer electronics for the sound source and microphone, is practically wireless, and fits into a standard Pelican case for easy transportation. The whole kit costs around $2,000 NZD (excluding the laptop and IRIS software licence) and includes the items listed below (and shown in Figure 3):

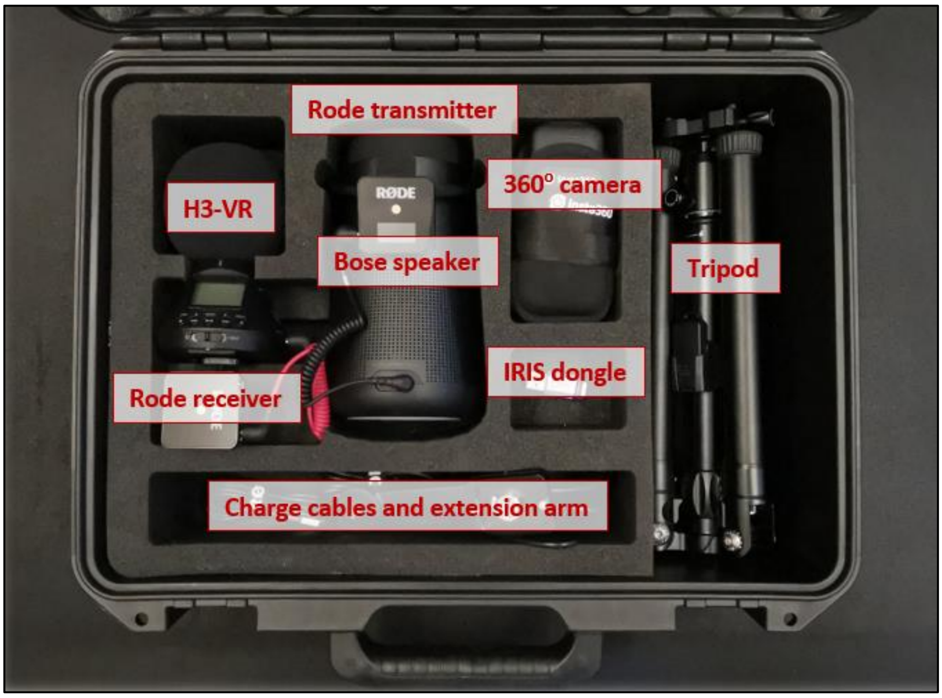

Figure 3: Mini IRIS kit in its case (laptop not shown)

- Zoom H3-VR ambisonic microphone (which has A/D conversion to B-Format onboard)
- Bose Soundlink Revolve+ bluetooth speaker
- Rode Wireless Go wireless connection system
- Insta 360° camera
- MeFoto backpacker compact tripod
- A laptop with IRIS software hardlock

Details of the components, and the acoustic verifications we performed on them to make sure they were fit for purpose, are set out in M. Dunn's 2021 paper [9].

We modified the IRIS software to incorporate the DQLS RT criteria. Each measurement takes a 10 second exponential sine sweep at a minimum of four test positions in the room and IRIS calculates a 3D impulse response for each position. RTs in octave bands are calculated from the impulse responses and the software shows a traffic light colour based on its compliance status. An image from a MoE IRIS measurement is shown in Figure 4.

Red means non-compliant, orange means borderline (i.e. very slightly over the criteria, or compliant in some assessment room locations and not others) and green means it complies. The room ratings are reviewed by the MoE, and the orange and red rooms are scheduled for acoustic improvements.

Figure 4: Example output from an IRIS classroom measurement

An added benefit of using IRIS (and the reason for using an ambisonic microphone) is its 'hedgehog pattern', which shows the direction and intensity of reflections in an interactive 3D plot [10] – see Figure 5. This allows us to identify which room surfaces are causing problematic reflections. This analysis is not done as part of the Ngā Iti Kahurangi programme, but the data is stored if the MoE or the school wants to investigate further.

The prospect of having this detailed acoustic data of more than 3000 learning spaces (and many more if the programme is scaled to a national level) is very exciting to us and will be an invaluable resource for future research projects.

3.2. Acoustic ceilings are installed in those learning spaces that don't comply

We needed to limit the range of acoustic improvements due to the scale of the programme, and the most pragmatic and effective place for treatment is usually the ceiling. Asona - a New Zealand acoustic panel manufacturer won the supply contract and installs one of two panel types, depending on the ceiling arrangement:

1) For rooms with a ceiling grid, replacing the existing tiles with Asona Triton 50mm (38 kg/m^3) glass fibre ceiling tiles (typically 1200x600mm)

2) For rooms with hard ceilings or skillion roofs, direct fixing Asona Triton 50mm glass fibre panels to the soffit, to a minimum coverage of 50% (to account for lights and other ceiling mounted hardware)

After the ceilings have been installed, the classrooms are tested again to confirm that compliance with the DQLS RT criteria has been achieved.

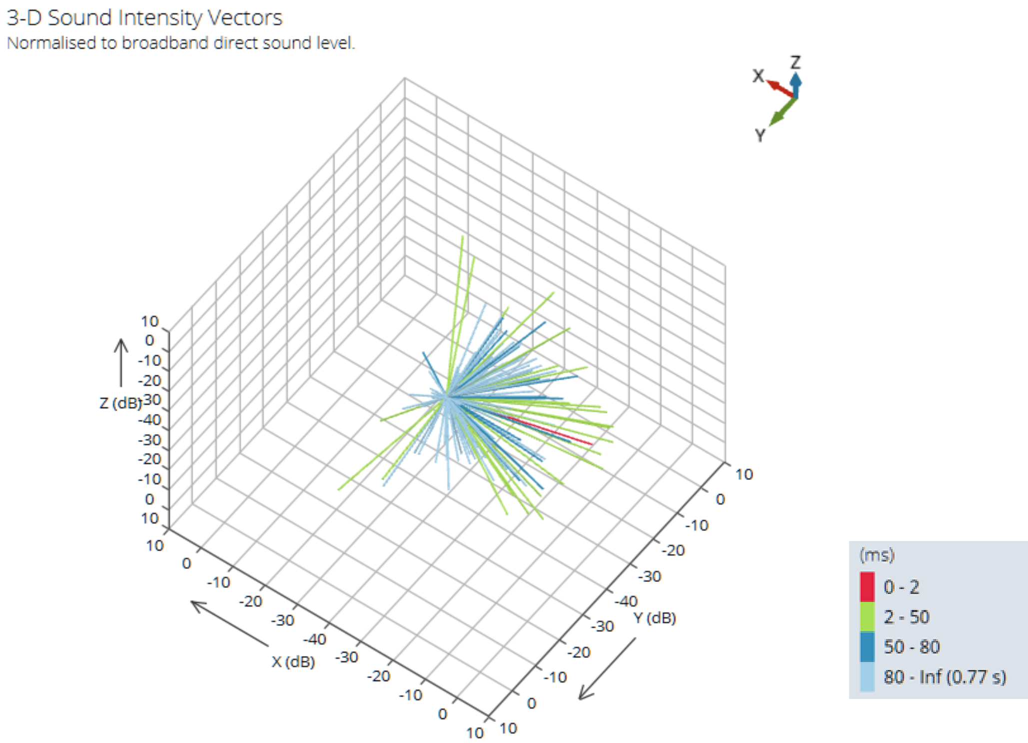

Figure 5: Example of an IRIS ‘hedgehog’ 3D sound intensity plot

4. INTERNAL ENVIRONMENTAL MONITORING (IEM) PROGRAMME

This MoE programme is on a smaller scale than Ngā Iti Kahurangi but its scope is wider. It involves deploying smart monitoring devices (IEMs) into classrooms that measure sound level, CO_2, temperature, humidity, air pressure, light level, VOCs and particulate matter. The IEMs communicate with the school’s network via Wi-Fi and send data to a cloud server for MoE to review.

The IEMs are not precision sound level meters. They use MEMS microphones (printed directly on circuit boards, like a cellphone) that cannot be acoustically calibrated by conventional means.

The MoE has engaged us to test the accuracy and repeatability of the IEM sound monitoring systems. To date, we have tested two different brands of IEM – Smooth Sensors and MonkeyTronics as shown in Figure 6. In our tests, we measured:

- Accuracy – Comparing IEM measured noise levels against a Class 1 reference device (Brüel & Kjær 2250 sound level meter)
- Averaging – Measuring a fluctuating pink noise level and confirming the IEMs are averaging the sound energy correctly
- Noise floor – Testing the quietest sound levels the IEMs can measure

I have communicated our findings to the MoE and IEM manufacturers, who can deliver over-the-air firmware updates to their devices to ensure they are measuring accurate and relevant sound level data.

(source: www.smoothsensors.io) *(source: www.monkeytronics.co.nz)*

Figure 6: Two examples of internal environmental monitors (IEMs) used in the programme

The collected IEM data provides an opportunity to assess activity noise levels, ambient noise and rain noise levels in learning spaces. This work has not yet been commissioned by the MoE, but when combined with the RT data from Ngā Iti Kahurangi it will cover all the important room acoustic aspects addressed in the DQLS.

4. CONCLUSIONS

These three programmes initiated by the New Zealand Ministry of Education set out clear acoustic performance requirements for classrooms, and test to see if they are being met. They will provide valuable insights into the state of New Zealand classrooms, and help direct funding where it is needed to ensure all New Zealand learning spaces are quality, and fit for purpose.

I have presented this paper to share some initiatives that are providing positive change on a large scale (by New Zealand standards at least). My colleagues and I are excited by the opportunities that the collected dataset will present for understanding classroom acoustics in a hands-on and tangible way, bridging the gap between theory and practice.

Perhaps by setting out the methods and innovations we have created for these programmes, we can inspire experts, researchers and education authorities in other countries to initiate similar plans. We would welcome open collaboration and data sharing, with a view to improving the learning spaces and educational outcomes of all students.

5. ACKNOWLEDGEMENTS

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