AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 49, September 2026

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

I am deeply saddened by the devastating floods that have struck communities across Nepal and Tibet in recent days. The loss of life, the destruction of homes and livelihoods, and the suffering endured by families and entire villages weigh heavily on our hearts. Actually, around the world, we continue to witness increasing human loss from both armed conflicts and natural disasters, reminding us of the fragility of life and the urgent need for resilience in our built environment. On behalf of ANSHM, we extend our deepest condolences to the affected communities and reaffirm our commitment to advancing technologies that protect lives and support recovery in the face of natural hazards.

Congratulations – AJIF Award Success

We warmly congratulate Dr Mehrisadat Makki Alamdari (UNSW) and her collaborators, Professor Chul-Woo Kim (Kyoto University) and KyoCenseo Inc, for securing support from the prestigious Australia–Japan Innovation Fund (AJIF) for an amount of A$100k. Their project, "A Vehicle-Integrated Approach to Digital Twin Deployment for Bridges," represents a major advancement in cross-border innovation and a significant milestone for the future of infrastructure monitoring. "Their project... represents a major advancement in cross border innovation and a significant milestone for the future of infrastructure monitoring."

The AJIF is a flagship bilateral program attracting a highly competitive field each year. This awarded project addresses a critical challenge shared by both nations: cost-effective monitoring of ageing bridge networks. By integrating sensing technologies directly into vehicles, routine trips can generate continuously updated digital twins—offering scalable, data-driven solutions for entire road networks.

This collaboration exemplifies the AJIF's mission to foster high-impact international partnerships. It also strengthens Australia–Japan research ties and advances the development of drive-by SHM, an area of growing importance for our community. On behalf of ANSHM, we extend our heartfelt congratulations to Dr Makki Alamdari and her team. Securing AJIF support not only deepens bilateral collaboration but also contributes meaningfully to the advancement of SHM technologies in both countries. This achievement marks an important first step toward combining Australia's and Japan's expertise in the development of next-generation drive-by SHM. We look forward to future research grants that will support further progress—particularly toward transforming drive-by scanning into a dynamic digital-twin ecosystem that integrates indirect sensing, signal processing, probabilistic modelling, and machine-learning surrogates. Such advances will help shift bridge management from labour-intensive inspections to predictive, cost-effective stewardship of ageing infrastructure.

We, as a SHM community, have significant work ahead as we support this important shift toward predictive, data-driven infrastructure management. Our last Advisory Board Mid-Year Meeting included valuable discussions to facilitate this transition, as reported in my June update. These conversations continued in the recent Executive Committee Meeting (4th in 2026), where we explored how these ideas could be consolidated; further details will be provided later in this monthly update. One key item concerned how we can better promote good SHM practice across our community.

Commercialisation Landscape in SHM

One key item raised at the Advisory Board meeting was the need to promote good SHM practice through the establishment of a Best SHM Award. This is a complex undertaking, and our discussions in the EC meeting focused on how best to structure the task. Developing meaningful criteria for ranking nominees is essential, and these should reflect practical applications, real-world implementations, and the adoption of SHM products. In Issue No. 48 of the ANSHM Newsletter, when discussing the SHM Person of the Year Award organised by Structural Health Monitoring: An International Journal, I highlighted the importance of evaluating nominations based on research developments, practical applications, and implementation. However, one crucial dimension was not emphasised strongly enough: commercialisation potential, which is increasingly central to both best practice and leading R&D in SHM.

Commercially, the SHM field is rapidly evolving—moving toward software platforms, integrated sensor packages, drone-based inspection services, cloud dashboards, and standards-based monitoring systems. As technical guidelines mature, agencies can adopt these tools more confidently, and companies can deliver them with greater assurance. This is creating a growing industry centred on safer structures, lower maintenance costs, and improved public service.

After revisiting the nomination documents, I examined their commercialisation potential more closely. This helps us understand the current state of the art in SHM and consider how these developments might be incorporated into SHM practice in Australia. The following table summarises the commercialisation pathways reflected in recent research and development outputs.

Commercial offering	Main technical capability	Typical structure type
Bridge monitoring platform	Sensor fusion, anomaly detection, modal tracking, reliability assessment	Long-span bridges, bridge networks

Commercial offering	Main technical capability	Typical structure type
UAV inspection service	Autonomous flight, vision-based defect detection, image acquisition	Bridge decks, towers, difficult-access structures
3D damage mapping software	Computer vision, reconstruction, digital-twin updating	Bridges, tunnels, large civil assets
AI data-cleaning module	Data anomaly detection, imputation, automatic screening	Sensor networks on bridges and dams
Cloud SHM dashboard	Trend analysis, reporting, decision support	Transport agencies, asset managers
Standards and certification package	Validation, specification, reporting templates	Procurement and compliance workflows
Monitoring-as-a-service	Continuous assessment, alerts, periodic reports	Bridges, dams, large infrastructure portfolios
Digital twin subscription	Live model updating, condition visualization, scenario analysis	Major bridges and complex networks

Below are the updates for the month.

18th ANSHM Workshop

Prof. Jun Li of Curtin University, the Workshop Chair, and the Organising Committee, chaired by Dr Zhen Peng of Curtin University, are working earnestly for the Workshop.

The theme of the 18th ANSHM Workshop is

Listening to Infrastructure: Transforming Data into Knowledge.

Up to now, seven keynote speakers of the 18th ANSHM Workshop have been confirmed, and the updated list of keynote speakers is available here:

https://anshm2026.github.io/ANSHM2026/keynote.html

Please note the following regarding registration and sponsorship opportunities for the 18th ANSHM Workshop, which are modified from the reminder sent by Dr Zeng Pang dated 14 Aug 2026:

1. Registration

- Registration link: https://anshm2026.github.io/ANSHM2026/registration.html
- The registration deadline is **15 September 2026**.

2. Flexible Presentation Options

- You may **register now and confirm your presentation title later** if your topic has not yet been finalised.
- You are also very welcome to **register for attendance only**. Giving a presentation is not required.

3. Registration Fee Waiver for Advisory Board and Executive Committee Members

- A new registration category, **"Advisory Board and Executive Committee Members (Registration Fee Waived),"** has been added to the registration page.
- Eligible members may select this option when completing their registration.

4. Sponsorship Opportunities

- The workshop is open to sponsorship, and we warmly welcome support from interested organisations and industry partners.
- The **Sponsorship Package** is available on the workshop website:
  https://anshm2026.github.io/ANSHM2026/index.html

For more details, please refer to the website https://anshm2026.github.io/ANSHM2026/index.html.

We are also planning to host two dedicated forums at the Workshop: an Industry Forum and an AI in SHM Forum. The Industry Forum has long been an highlight of our annual Workshops, providing a valuable platform for dialogue between practitioners and researchers. At last year's Workshop, it was raised in the Advisory Board Meeting and the Annual General Meeting: an important question regarding the role of AI in SHM. In response, a formal task was established, led by Prof Jianchun Li of UTS, and the AI in SHM Forum will serve as the main venue for advancing this work.

We warmly welcome both returning participants from previous ANSHM Workshops and colleagues joining us for the first time. Your engagement is vital to the continued growth of our community.
We would greatly appreciate your support in sharing the event within your networks and encouraging colleagues and students to participate. Promoting the 18th ANSHM Workshop 2026 will help us broaden our impact and strengthen collaboration across the SHM community. The Local Organising Committee looks forward to working with you and hopes to see you in Perth. For any enquiries, please contact the Local Organising Committee at zhen.peng1@curtin.edu.au.

Industry News

Please see below the industry updates provided by John Vazy of EngAnalysis, our Industry Liaison Officer.

Industry challenges

- Organisations focused on selling products or services rather than solving problems or quantifying risk.
- Academic projects can strengthen their impact by substantiating broad benefit claims with evidence, practical examples, and measurable outcomes.
- There is an opportunity to pair strong visuals and advanced analytics with clearer evidence of service performance, limitations, and practical value.
- The sector would benefit from clearer ways to distinguish novelty, meaning something new, from innovation, meaning something that delivers a genuine improvement, and from better methods to measure that difference.
- Stronger understanding of the underlying physics would help practitioners assess AI-enhanced informatics outputs and claims more confidently and critically.
- There is a valuable opportunity for the education sector to place greater emphasis on critical assessment, particularly as engineers are asked to evaluate increasingly evidence-poor AI-developed assessments.
- The relatively small market for high-end structural health monitoring currently seems constrained by the relatively small number of engineers who have experience in using data effectively.

Opportunities

- Please get in touch if any of you would like to help create a video series exploring key market challenges.

Delivery of SHM services

- Several projects are investigating how thermal effects influence structural capacity. If any academic teams have experience or interests in this area, please get in touch.
- We have completed the first-phase review of industrial adhesives for long-term monitoring, and it is encouraging to see academic teams continuing this work.
- Several emerging projects require better methods for long-term strain gauge application. Academic teams interested in collaborating on sensor-related work are encouraged to get in touch.
- There is strong potential in onboard telemetry systems for trucks and trailers. The data is valuable, and academic collaboration could help identify both its insights and its limitations for heavy vehicle regulation.
- As noted above, AI-generated content has greatly increased the volume of low-quality assessments, making critical thinking more important than ever. While it is difficult to predict what we will all be doing in three years, a strong grasp of the physics and the ability to critically examine decisions will likely remain invaluable.

Closure

- Spring is here again, so keep an eye out for snakes and wasps, and have a plan in place if you encounter them.

Task allocations of ABM (Mid-Year) on ANSHM Directions & Research Opportunities

Following the discussions on ANSHM Directions & Research Opportunities during the Mid-Year Advisory Board Meeting on 19 June 2026, eight key tasks were reviewed and discussed during the 4th Executive Committee (EC) Meeting on 7 August 2026. Each task was evaluated individually, with decisions rendered and Officers-in-Charge assigned as outlined below:

Task 1 — Risk-Based Decision-Making Frameworks

- **Decision:** Prepare guidance documents and frameworks linking SHM data to risk-based infrastructure management decisions (suggested by Prof. Mark Stewart of UTS). This initiative has been combined with Task 8. It will remain an ANSHM strategic direction, with substantive work deferred to the Research Hub pending a successful application. Prof. Mark Stewart is proposed by the EC to lead this initiative in his capacity as an Advisory Board member, with support provided by the EC.

Task 2 — Data Sharing and Standardisation Initiative

- **Decision:** Establish a mechanism for shared datasets and standardised environmental and operational data collection (suggested by Dr Govinda Pandey of Rockfield). Recognizing existing barriers—such as restrictive road authority policies and complex data ownership layers—Dr Andy Nguyen of USQ will take charge of identifying opportunities and consolidating data, rather than heavy execution, given the voluntary nature of the role. If successful, the ARC Research Hub for Infrastructure 4.0 will be leveraged, while relevant road authorities and research partners will be approached. Industry support will be provided by Dr Govinda Pandey and John Vazey (EngAnalysis).

Task 3 — Independent Technical Panel

- **Decision:** Form an independent panel to offer practical advice on SHM implementation, review technical specifications, and assist asset owners in selecting appropriate monitoring strategies (suggested by John Vazey of EngAnalysis). John Vazey and A/Prof. Ali Hadigheh (USyd) will lead the structural setup of the panel, with operational support from the ANSHM EC.

Task 4 — Educational and CPD Programs

- **Decision:** Develop educational and Continuing Professional Development (CPD) programs (suggested by Dr Desiree Nortje of Transurban). Building on ANSHM's ongoing efforts in organising Technical Workshops, Seminars, and Webinars, A/Prof. Xinqun Zhu of UTS will take the lead in coordination alongside Prof. Richard Yang of UWS and Lei Hou of RMIT.

Task 5 — Best Practice Award

- **Decision:** Establish an ANSHM Best Practice Award alongside the proposed Best Paper Award to address an unfulfilled niche in the sector (suggested by John Vazey of EngAnalysis). As immediate implementation is not yet feasible given ANSHM's current scale, full rollout is deferred until the organisation expands or the ARC Research Hub for Infrastructure 4.0 bid succeeds. Exploring joint awards with existing bodies will also be considered. Prof. Jianchun Li of UTS will present a plan featuring available options at the next Advisory Board meeting in November 2026.

Task 6 — Industry–Academia Collaboration

- **Decision:** Further strengthen active collaboration between industry and academic sectors (suggested by Prof. Ian Petersen of ANU). The EC noted that substantial collaboration is already actively driven through John Vazey (Industry Liaison Officer), A/Prof. Ali Hadigheh, and Dr Andy Nguyen (External Affairs Officer). The team will maintain and expand upon these current activities.

Task 7 — Business Case and Economic-Benefits Documentation

- **Decision:** Produce comprehensive documentation demonstrating the business case and economic benefits of SHM to accelerate adoption (suggested by Parvez Shah of TfNSW). Because full implementation requires currently unavailable resources, major work is deferred. However, initial financial-benefit analyses are currently progressing through supervised undergraduate projects (including a combined Business/Civil Engineering thesis), which can later feed into the Infrastructure 4.0 Hub. The task remains on record as a high priority.

Task 8 — Climate-Change Impacts on SHM Guidance

- **Decision:** Incorporate climate-change impact considerations into standard SHM guidance (suggested by Parvez Shah of TfNSW). This task has been merged with Task 1. It is identified as a suitable candidate for a future PhD project under the Infrastructure 4.0 Hub, and the EC will resume active development once dedicated resourcing is secured.

In summary, several tasks requiring dedicated resources have been strategically deferred to the proposed ARC Research Hub for Infrastructure 4.0. The officer assignments listed above establish clear leadership and accountability as these initiatives progress.

Proposed ARC Research Hub for Infrastructure 4.0

As mentioned at the start of this monthly updates, we witnessed the devastating floods in Nepal and Tibet—alongside the many natural disasters that have unfolded across the world in 2026—we are reminded of how vulnerable communities remain to climate-driven hazards. These events highlight the urgent need for stronger, smarter, and more resilient infrastructure systems. As President of ANSHM, I reaffirm our commitment to advancing structural health monitoring, digital sensing, and predictive technologies that safeguard lives and support rapid recovery when disasters strike via the objectives of ANSHM.

This global context also reinforces why Australia must accelerate its own infrastructure transformation. Our ageing assets, growing population, and exposure to increasingly severe weather demand a new generation of intelligent, cyber-secure, and adaptive infrastructure solutions. The proposed ARC Research Hub for Infrastructure 4.0 directly addresses this national need, driving the transition towards predictive, data-driven infrastructure management mentioned above. While grounded in Industry 4.0 principles—such as short-term resilience and predictive maintenance—the Hub also supports the transition toward Industry 5.0 by embedding human-centric strategies that enhance sustainability, adaptability, and resilience in infrastructure monitoring, operation, and management.

It can be seen from the above that many of the tasks identified at the recent Advisory Board Mid-Year Meeting require resources beyond the current capacity of ANSHM, yet they align closely with the aims and objectives of the proposed Hub. These have been incorporated into the Hub's proposal, which seeks to develop advanced sensors, AI-enabled diagnostics, and real-time predictive maintenance technologies to replace outdated scheduled inspections with proactive, data-driven decision systems.

The recent tragedies again remind us of the urgency of strengthening Australia's infrastructure resilience. Our nation faces mounting pressures from population growth, ageing networks, and climate-driven extremes. The ARC Research Hub for Infrastructure 4.0 aims to meet these challenges by delivering cyber-secure digital technologies and intelligent monitoring systems capable of transforming how critical infrastructure is managed. In partnership with industry, the Hub will provide real-time diagnostics and predictive maintenance, enabling a shift from reactive inspections to smarter, more efficient stewardship.

After submitting the proposal last November, we received assessor feedback in late January. The response was highly positive across all four assessment categories. Assessors commended the team's strong expertise, industry-aligned research program, cross-disciplinary innovation, value for money, and substantial partner commitment. A few queries arose from proposal oversights or criteria misaligned with ARC policy, all of which were addressed in a clear and well-supported Rejoinder submitted on 10 February 2026. Our Research Office described both the application and the Rejoinder as exceptionally strong.

The ARC has since revised the outcome announcement window from 9 July–8 October 2026 to 24 September–8 October 2026. This means the earliest possible outcome may arrive this month (September). Let us keep our fingers crossed.

ANSHM Website

We are pleased to share that the ANSHM website has been given a renewed look, with improved presentation and clearer navigation to better support our community. It has undergone a series of important enhancements. Regular updates have been implemented to ensure the site remains current, informative, and reflective of our ongoing activities. New projects have been added under Current Projects, and the details of our Advisory Board and Executive Committee members have been refreshed to maintain accuracy and transparency.

We gratefully acknowledge the dedicated efforts of Prof Hong Guan and her team, whose continued commitment and careful stewardship have been instrumental in maintaining and elevating the ANSHM website.

SHMII-14 (2027) Special Session 1 – Call for Contributions

As noted previously, the session organisers are pleased to invite submissions to Special Session 1, titled "SHM of Ageing Infrastructure in Australia and Beyond: A Focus on Practical Solutions," as part of the 14th International Conference on Structural Health Monitoring of Intelligent Infrastructure (SHMII-14), which will be held from 29 June to 2 July 2027 in Naples, Italy. As one of the flagship events for our global SHM community, SHMII-14 provides an important platform for Australian researchers and practitioners to showcase advances, strengthen collaborations, and engage with international leaders in intelligent infrastructure monitoring. Please click this link for details about the Special Session.

Abstract preparation guidelines and templates are available on the conference website https://shmii-14.com/abstract-submissions/, and submissions can be made through the Springer Meteor portal https://meteor.springer.com/shmii-14. The conference proceedings will be published by Springer and indexed in Scopus and Web of Science, ensuring strong visibility for accepted contributions.

The technical program is already shaping up with 43 special sessions and four plenary speakers. A unique highlight for 2027: Naples will also host the America's Cup (https://www.americascup.com/), offering attendees the chance to experience one of the world's premier sailing events alongside SHMII-14. As the city is expected to be exceptionally busy during this period, early arrangements for travel and accommodation are strongly recommended.

Please note that the first submission deadline is 30 September 2026 for abstracts. Other key dates can be found here.

The ANSHM Best Article Award

As mentioned previously, we have decided to establish an Annual Best Article Award for articles submitted to the ANSHM Newsletter. In the last EC meeting, the two-step selection process was confirmed for the ANSHM Best Paper Award. The editorial team will nominate papers based on agreed weighted criteria, after which an award selection committee will confirm the final recipient. To ensure fairness and manage conflicts of interest, an independent judging panel—including members of the Advisory Board from both academia and industry—will be formed. The award will be certificate-based, with eligibility limited to papers published from the September 2026 issue onward. The 1st Best Article Award will be announced at the 19th ANSHM Workshop in November 2027, following a judging meeting scheduled for October 2027. The selection criteria will be reviewed at the Advisory Board meeting during the 18th ANSHM Workshop.
In the next section, we will have three articles from our members. The first article, a collaboration between UNSW Sydney and UNSW Canberra, is titled “Single-Sensor Localization and Reconstruction of Unknown Excitation Forces Using a Randomized Resonant Metamaterial”. The second article is a collaboration involving UNSW Sydney, Kyoto University, the University of Hong Kong and KyoCenseo Inc (Japan), presenting the technical background and progress of the above-mentioned AJIF-awarded project on a Vehicle-Integrated Approach to Digital Twin Deployment for Bridges. Finally, we include an industry note from EngAnalysis entitled “How to run a site deployment”, offering practical insights from field experience.

With kind regards,

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Single-Sensor Localization and Reconstruction of Unknown Excitation Forces Using a Randomized Resonant Metamaterial

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Abstract

This article reports a numerical study on single-sensor force localization and time-domain reconstruction using a randomized resonant metamaterial, in which randomly distributed local resonators produce highly uncorrelated frequency response from six candidate excitation locations to a central output sensor. The metamaterial frequency response function (FRF) matrix is used to formulate localization as a group-sparse inverse problem, solved using the Group Fast Iterative Shrinkage and Thresholding Algorithm (G-FISTA) with automatic regularization parameter selection. Once the active location is identified, the force time history is recovered by Tikhonov-regularized least squares on the corresponding FRF column. Three types of excitation are evaluated: impact-type burst force, modulated wave packet, and burst random force, at 5 % and 10 % white Gaussian noise. G-FISTA correctly identifies the excitation location in all cases. Reconstruction accuracy is assessed using L_1, L_2, and relative sum-squared error metrics. Recovering both the excitation location and force waveform from a single sensor has potential utility in applications where placing force transducers is impractical, including impact detection on lightweight aerospace and civil structures, dynamic load characterization, and vibration source identification in mechanical systems.

Keywords: Randomized resonant metamaterial; Force localization; Force reconstruction; G-FISTA; Tikhonov regularization; Single-sensor identification

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1. Introduction

Vibration responses measured on a structure carry information about the sources that excite it. Recovering that information, specifically knowing where a force acts and what its time history looks like, is relevant to impact detection on aerospace composites and wind turbine blades [1–3], load characterization on civil and mechanical structures [4, 5], and fault diagnosis in rotating machinery [6–8]. Direct measurement with force transducers is often impractical because impact locations are not known in advance, sensors add mass that alters the local structural response, or the candidate surface is inaccessible [9–11]. Indirect identification from measured responses inverts the structural transfer matrix, but when the number of candidate locations exceeds the available sensing channels the problem is underdetermined, and direct inversion distributes force energy across all locations while amplifying noise [10]. Dense sensor arrays can reduce this underdetermination but increase instrumentation complexity and cost. An alternative is to design the wave transmission properties of the sensing path itself so that each candidate source location leaves a distinguishable imprint at a single output point, removing the need for a large sensor array from the outset. Locally resonant metamaterials can provide this property through their frequency-selective behaviour, which arises from internal resonators and can be tuned independently for each transmission path [12, 13]. This concept has been applied to vibration source localization in elastic and acoustic systems [14–18].

In these metamaterial sensing systems, candidate excitation locations are each connected to a central output node through a network of locally resonant units [6, 14]. By assigning distinct resonator frequencies to each connection path, each candidate location imprints a spectrally unique signature on the single-channel output, with signatures that are mutually uncorrelated across all candidate locations [14]. These uncorrelated signatures satisfy the incoherence conditions required for compressive recovery [19, 20], so the active source can be identified through sparse inversion of the single measured response. Jiang et al. [14] demonstrated recognition ratios of up to 96.7% for up to three simultaneous sources using the TwIST algorithm [21], with the measurement matrix assembled from 20 pre-measured training signals per candidate location. Subsequent work extended the potential of this encoding approach to artificial structures [15, 22] and to elastic wave sensing [16]. The compressed sensing-based methods require a pre-built library of known excitation signals obtained through calibration [6, 14, 22]. This limits their applicability when the applied force waveform is arbitrary and unknown. In contrast, Zhang et al. [16] overcome this limitation by using a deep learning decoder that can generalize to unknown signals without requiring a pre-built library. However, their system remains a classifier that provides only location information and does not reconstruct the force excitation itself. For a more complete characterization, the problem reduces to an underdetermined inverse problem in which both the source location and the force waveform must be inferred simultaneously from a single measured channel.

Solving this blind source problem without a training library requires additional constraints on the solution [10]. Tikhonov (L2) regularization suppresses noise amplification but does not distinguish between candidate locations; L1-sparse methods promote sparsity at the level of individual frequency bins but miss the natural group structure of a spatially localized force [1]. A force at one candidate location is spectrally extended, meaning its spectrum is non-zero across many frequency bins simultaneously, while every other candidate location contributes zero across those same bins. The $\ell_{2,1}$ group penalty captures this by penalizing the ℓ_2 norm of each candidate-location group and driving inactive groups to zero [23]. Rezayat et al. [23] developed G-FISTA for this purpose, solving the group-sparse frequency-domain problem through proximal gradient descent with block soft-thresholding. Identifying the source location is, however, only one part of the problem; in many applications the force waveform itself is also needed. For waveform reconstruction given a known source location, established methods include Tikhonov regularization [10], sparse impact recovery [1, 9], Bayesian system identification [24], and data-driven approaches [2]. Most assume the source location is already known or rely on multiple sensors. Qiao et al. demonstrate single-sensor localization using a pre-defined grid of candidate locations, but this approach still requires a known grid and a pre-measured transfer matrix [1]. To the best of our knowledge, using a metamaterial's FRF matrix as the dictionary for simultaneous blind source localization and force waveform reconstruction without requiring a pre-built training library or calibration has not been addressed in the literature.

This study uses the FRF matrix of the randomized resonant metamaterial from Jiang et al. [14] as the forward model. However, our framework differs fundamentally in its definition of the transfer quantity. Jiang et al. define transmission as the ratio of displacement at the output sensor to displacement at the input node, which requires pre-measured training signals for each candidate location. In contrast, our approach defines the FRF as the ratio of displacement at the output sensor to the applied force at the input node. This enables single-source localization and force waveform reconstruction without any training library. G-FISTA with BIC-based parameter selection identifies the active excitation location through group-sparse inversion. Tikhonov-regularized least squares on the corresponding FRF column then recovers the force time history. The framework is validated numerically at 5 % and 10 % white Gaussian noise for three excitation types: impact-type burst force, modulated wave packet, and burst random force. Section 2 describes the metamaterial model, Section 3 sets out the identification framework, Section 4 reports the numerical results, and Section 5 summarizes the findings.

2. Randomized Resonant Metamaterial (RRM)

The RRM of Jiang et al. [14] connects six candidate excitation locations to a single output node, each through a dedicated 19-node hexagonal coupling network of locally resonant unit cells, as illustrated in Fig. 1. Panel (a) shows the unit-cell geometry; panel (b) shows the hexagonal coupling network topology together with the equivalent lumped model used in the numerical simulation; panel (c) shows the complete six-path sensing system; and panel (d) gives the block-level connection diagram for the numerical implementation. Full geometric and material parameters are given in [14]. The operating band spans 200 to 800 Hz.

Within each unit cell, the resonator mass m_n is coupled to the host via spring stiffness k_n and damper c_n, as shown in the red box of Fig. 1(b). Following [14], the frequency-dependent effective mass of the n-th resonator unit is given in Eq. (1).

$$m_{eff,n}(\omega) = M + \frac{k_n^d\, m_n}{k_n^d - \omega^2 m_n}\ ; \qquad k_n^d = k_n + i\omega c_n \qquad (1)$$

where M is the host mass, m_n is the resonator mass, k_n and c_n are the resonator stiffness and damping, and $\omega_n = \sqrt{(k_n/m_n)}$ is the natural frequency of the n-th resonator. Near ω_n, the real part of $m_{eff,n}$ becomes negative, producing a local attenuation band in which wave transmission through the network is suppressed [6, 12, 13].

When all resonators within a coupling network share the same natural frequency, the network is referred to as an ordinary coupling network (OCN). An OCN produces six identical FRF columns at the output node (Fig. 2(b)), so the measured response carries no information about which of the six candidate locations was excited.

The randomized coupling network (RCN) resolves this by assigning each resonator a distinct, randomly selected natural frequency. The disordered effective masses produce complex and location-specific propagation paths, so the six FRF columns differ substantially across the operating band (Fig. 2(a)). The cross-correlation map in Fig. 2(c) gives an average cross-correlation coefficient of $\mu_{Ave} = 0.492$ among the six FRF columns. This is higher than the transmission-based $\mu_{Ave} \approx 0.145$ reported in [14], as the two transfer quantities are defined differently. Despite the higher pairwise correlation, the six FRF columns retain sufficient spectral diversity for G-FISTA to correctly identify the active excitation location in all test cases, as reported in Section 4.

The present study reproduces the RRM numerically as a coupled mass-spring system solved in the frequency domain. Assembling the equations of motion for each RCN yields the FRF matrix $H(f) \in \mathbb{C}^{1\times N_c}$, where $N_c = 6$ is the number of candidate locations and each

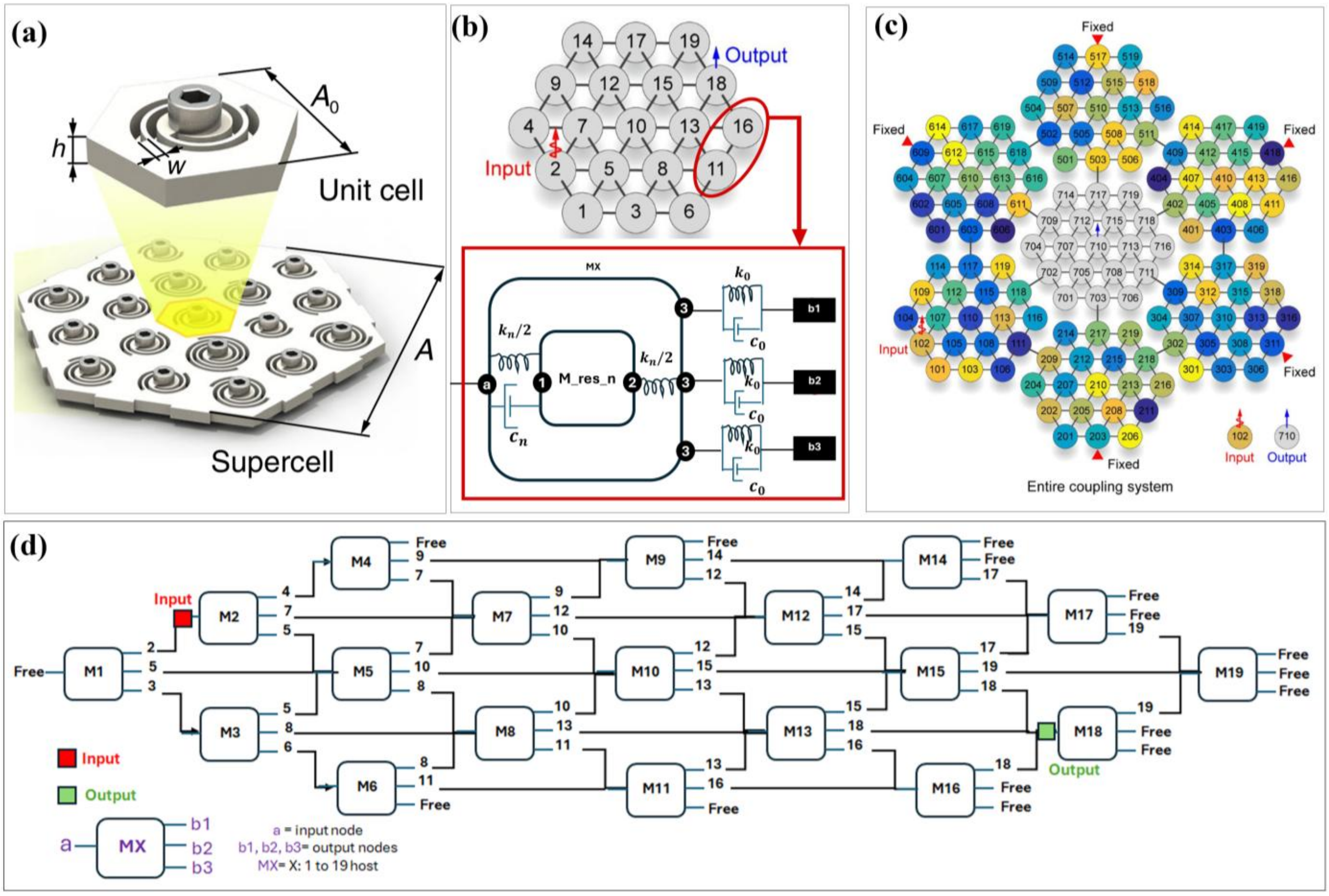

Fig. 1: Randomized resonant metamaterial (adapted from [14]). (a) Physical unit cell: a bolt-and-nut centre mass connected to the hexagonal host plate via two Archimedean spiral beams, with unit-cell lattice constant A_0, height h, and spiral-beam gap parameter w; multiple cells assemble into a hexagonal supercell of overall size A. (b) Top: hexagonal coupling network of 19 host nodes representing one source-to-output transmission path, with input and output ports marked. Red box: numerical model of a single unit cell, showing resonator mass $M_{res,n}$ coupled to the host via stiffness k_n and damper c_n; neighbouring nodes are connected via coupling stiffness k_0 and damper c_0. (c) Complete coupling network connecting six candidate input locations (red arrows) to one output node (blue arrow); peripheral nodes carry fixed boundary conditions. (d) Block-level connection diagram for the numerical implementation showing the 19 host nodes (M1–M19) with input at M2 and output at M18.

column $H_j(f)$ is the transfer function from candidate location j to the output node at frequency f. This matrix replaces the calibrated measurement matrix of the original approach and forms the basis for the inverse identification framework described in Section 3.

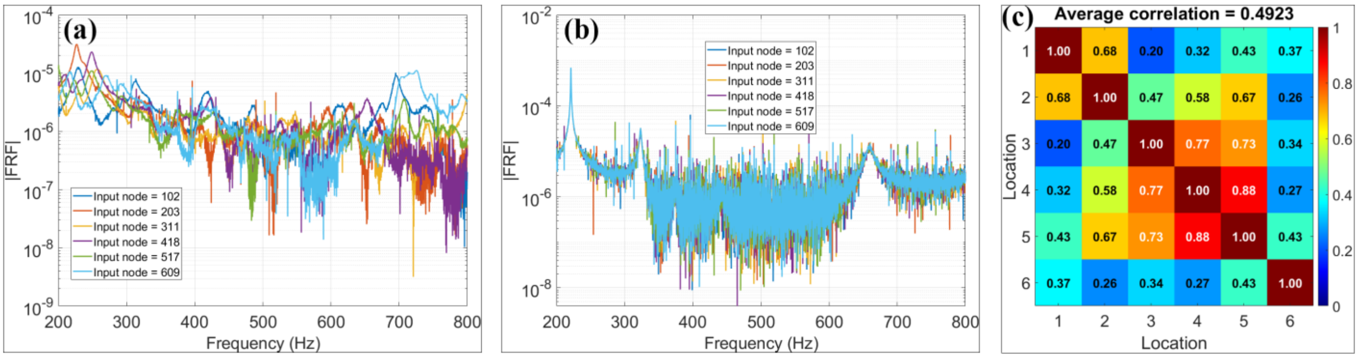

Fig. 2: FRF properties of the numerically reproduced RRM system (5 % WGN). (a) FRF amplitude from each of the six candidate excitation locations to the output node for the randomized coupling network (RCN); the six columns of *H*(f) are spectrally distinct across the 200 to 800 Hz operating band. (b) FRF amplitude for the ordinary coupling network (OCN), in which all resonators share the same natural frequency 475 Hz; all six FRF columns are identical, making source discrimination impossible. (c) Pairwise cross-correlation map of the six RCN FRF columns; the average correlation coefficient μAve is shown above the map.

3. Force Localization and Reconstruction

The FRF matrix $H(f) \in \mathbb{C}^{1\times N_c}$ (one output node; $N_c = 6$ candidate inputs; entry $H_j(f)$ = output displacement / force at location *j*) is assembled by applying burst random force (60% activity, 10 s window) at each candidate location, integrating the ODE, and computing the FFT ratio of displacement to force. Two sets are built, for 5 % and 10 % WGN respectively. Independent WGN is added to both the excitation signal and the displacement response during both FRF construction and observation, because in practice neither the applied force nor the measured response is free from noise. The complete identification pipeline, comprising G-FISTA localization with BIC-selected regularization [23] and Tikhonov force reconstruction [25], is summarized in Fig. 3; full formulation details are given in [23, 25]. Reconstruction accuracy over the active excitation window (5 % threshold) is reported as relative e_{L1} [25], e_{L2} [26], and e_{RSSE} [23] errors.

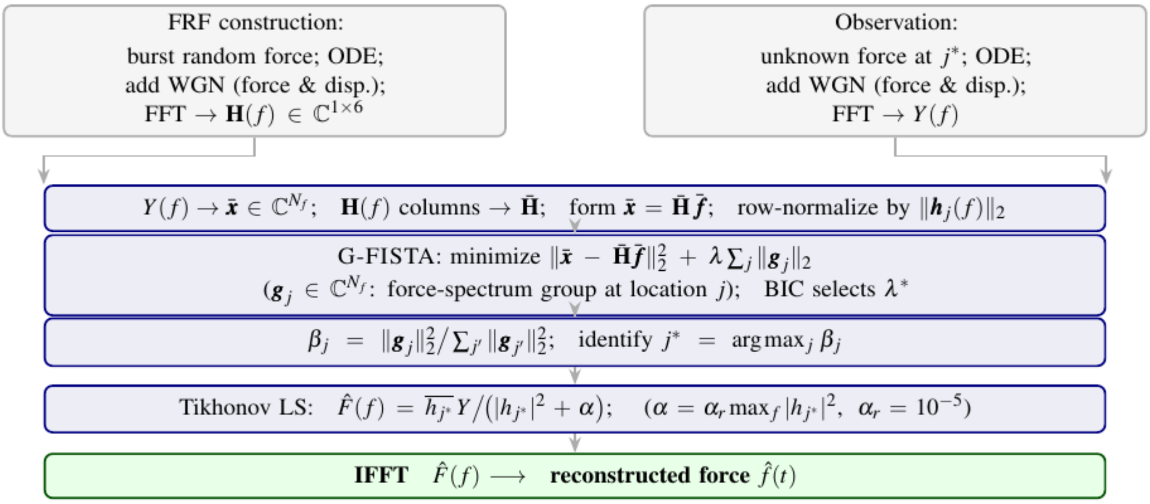

Fig. 3: Force localization and reconstruction pipeline. Left track: FRF construction from burst random force with time-domain ODE integration and WGN injection on both force and displacement. Right track: test observation with the same noise protocol. The two tracks converge into a block-diagonal inverse problem; G-FISTA with BIC-selected regularization identifies the active location, and Tikhonov-regularized inversion of the identified FRF column yields the force time history.

4. Numerical Results

The RRM model is solved numerically over the 200 to 800 Hz operating band using the parameters of Jiang et al. [14]. Three excitation types are evaluated at six candidate locations: impact-type burst force, modulated wave packet, and burst random force. Results for three representative locations (1, 3, and 5) are presented in Fig. 4: row (a) shows the applied excitation signals, rows (b) and (c) show the localization and reconstruction results at 5 % and 10 % WGN, respectively.

Force localization: G-FISTA correctly identifies the excitation location in all cases tested, covering all three excitation types, all six candidate locations, and both noise levels. The β-λ maps in rows (b) and (c) of Fig. 4 show a dominant β ridge at the true location at both noise levels, with BIC-based regularization parameter selection requiring no manual adjustment.

Force reconstruction: To isolate the effect of noise on reconstruction accuracy, the same candidate location is used for each excitation type at both noise levels. For the impact-type burst at Location 1, e_{L1} increases from 2.04 % at 5 % WGN to 5.98 % at 10 % WGN; for the modulated wave packet at Location 3, from 6.79 % to 11.86 %; and for the burst random force at Location 5, from

6.64 % to 12.18 %. This consistent trend confirms that higher noise leads to larger reconstruction error across all excitation types, while the waveform shape is qualitatively preserved in all cases shown. It is worth noting that while localization is always correct at all six candidate locations, reconstruction accuracy varies across locations for the same excitation type; only these representative cases are presented here. Full error metrics are given in Table 1.

Table 1: Localization and reconstruction results for representative cases. Noise applied to both FRF estimation and observation. All excitation locations are correctly identified. Errors computed over the active excitation window.

WG-Noise	Excitation type	True→ID	e_{L1} (%)	e_{L2} (%)	e_{RSSE} (%)
5 %	Impact burst	1→1	2.04	1.71	0.03
	Wave packet	3→3	6.79	6.88	0.47
	Burst random	5→5	6.64	7.13	0.51
10 %	Impact burst	1→1	5.98	4.95	0.24
	Wave packet	3→3	11.86	11.99	1.44
	Burst random	5→5	12.18	13.08	1.71

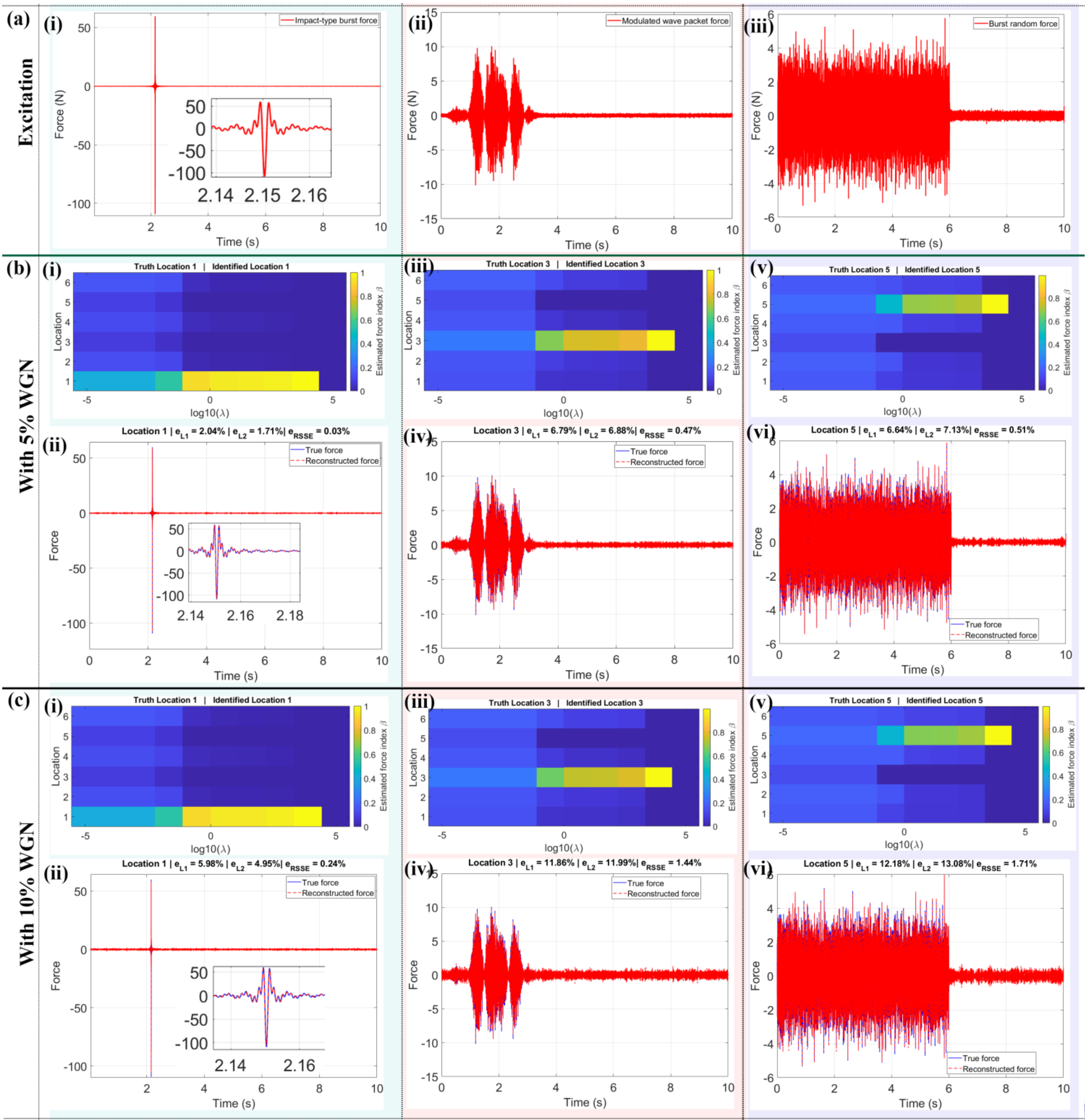
(a)
Excitation
(i)
Impact-type burst force
Force (N)
Time (s)
(ii)
Modulated wave packet force
Force (N)
Time (s)
(iii)
Burst random force
Force (N)
Time (s)
(b)
With 5% WGN
(i)
Truth Location 1 | Identified Location 1
Location
log10(λ)
Estimated force index β
(iii)
Truth Location 3 | Identified Location 3
(v)
Truth Location 5 | Identified Location 5
(ii)
Location 1 | e_L1 = 2.04% | e_L2 = 1.71%| e_RSSE = 0.03%
True force
Reconstructed force
Force
Time (s)
(iv)
Location 3 | e_L1 = 6.79% | e_L2 = 6.88%| e_RSSE = 0.47%
(vi)
Location 5 | e_L1 = 6.64% | e_L2 = 7.13%| e_RSSE = 0.51%
(c)
With 10% WGN
(i)
Truth Location 1 | Identified Location 1
(iii)
Truth Location 3 | Identified Location 3
(v)
Truth Location 5 | Identified Location 5
(ii)
Location 1 | e_L1 = 5.98% | e_L2 = 4.95%| e_RSSE = 0.24%
(iv)
Location 3 | e_L1 = 11.86% | e_L2 = 11.99%| e_RSSE = 1.44%
(vi)
Location 5 | e_L1 = 12.18% | e_L2 = 13.08%| e_RSSE = 1.71%

Fig. 4: Numerical results for three excitation types at representative candidate locations. Row (a): applied excitation signals; (i) impact-type burst force, (ii) modulated wave packet, (iii) burst random force. Row (b): results at 5 % WGN; row (c): results at 10 % WGN. Within rows (b) and (c), panels (i,iii,v) show the β–λ localization map at Locations 1, 3, and 5, respectively, with true and identified locations in the title; panels (ii,iv,vi) show the corresponding force reconstruction (blue: true force; red dashed: reconstructed) with e_{L1}, e_{L2}, and e_{RSSE} errors.

5. Conclusions

This article demonstrated force localization and time-domain reconstruction using the randomized resonant metamaterial of Jiang et al. [14], with the FRF matrix used directly in place of the original training library. The results show that the metamaterial's spatially encoded response functions are sufficient for identifying both the excitation location and the force waveform when neither is known in advance.

G-FISTA correctly identified the excitation location in all cases, covering all three excitation types across all six candidate locations at both noise levels, with BIC-based regularization requiring no manual tuning. Reconstruction accuracy decreased with noise level: at 5 % WGN, e_{L1} remained below 7 % for all three excitation types shown; at 10 % WGN, the same cases gave e_{L1} up to 12.18 %, with the impact-type burst yielding the lowest error (e_{L1} = 5.98 %) owing to its broad spectral support.

All validation here is numerical, experimental confirmation and the effect of FRF measurement uncertainty under real sensor noise remain as future work. Extension to multiple simultaneous sources is also not addressed and would require additional formulation work.

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A Vehicle-Integrated Approach to Digital Twin Deployment for Bridges

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Ageing bridge infrastructure is a growing concern in Australia and Japan. Conventional assessment relies on periodic visual inspection, which is subjective and may miss early-stage deterioration, and on permanently installed monitoring systems, which are costly and difficult to scale across large inventories, particularly in regional networks.

Drive-by, or indirect, monitoring offers a route around both. A sensorised vehicle records vibration as it crosses, and condition is inferred from the vehicle-bridge and vehicle-road interaction contained in that measurement. The difficulty is that the bridge contributes only a small part of what the vehicle records: the signal is dominated by vehicle dynamics and the road profile, so the damage signature is weak, and detecting damage under operational traffic in a way that transfers between structures remains open.

The project addresses this through five objectives: neural-operator surrogates of the interaction, trained on simulated and field data; optimisation of the inspection vehicle, its sensor layout and signal processing; an estimator that reconstructs responses at unmeasured locations and identifies parameters that cannot be measured directly; an anomaly-detection framework for vehicle-mounted data; and validation on a large-scale bridge in Japan.

1. Case study: the Old Ada Bridge and its numerical twin

The Old Ada Bridge, a simply supported single-lane steel Warren truss spanning about 59 m, was selected as the principal case study. It served roughly five decades before decommissioning in 2012, and its field campaign suits the project unusually well: it combines bridge-mounted and vehicle-based measurements, and includes several experimentally introduced damage states, produced by cutting a vertical member at mid-span and later at around five-eighths of the span [1]. Figure 1 shows the bridge, these damage states and the inspection vehicle used to collect the dataset. Datasets with real, physically introduced damage are rare, and they allow the framework to be validated rather than only demonstrated.

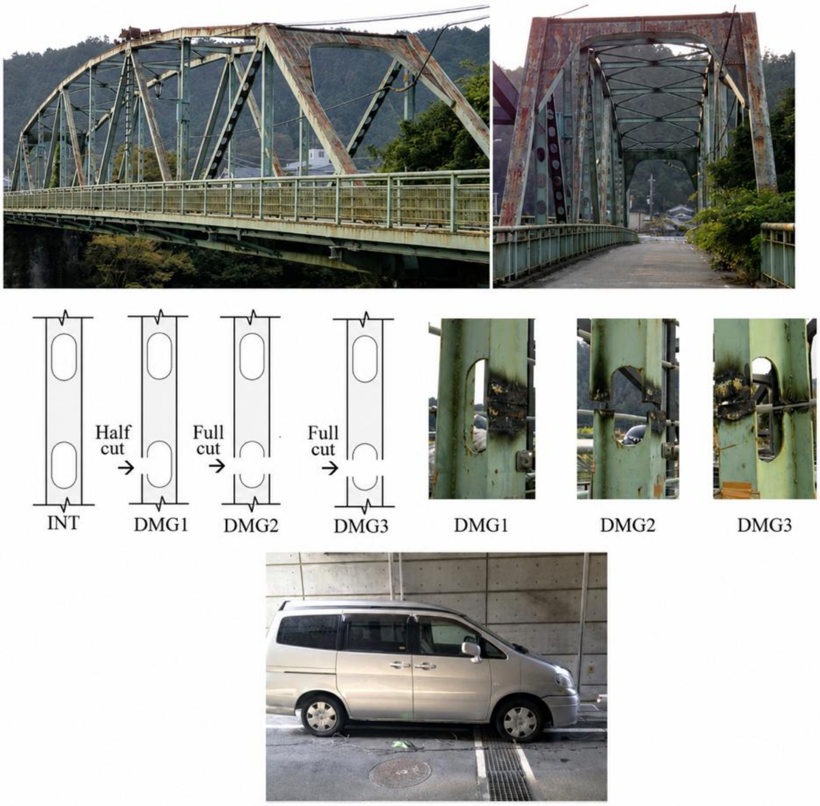

Figure. 1 the Old Ada Bridge, the damage scenarios introduced during field testing, and the inspection vehicle used to collect the dataset.

A detailed three-dimensional model exists [2], but repeated evaluation for interaction simulation, damage screening, uncertainty quantification and dataset generation would be prohibitive. A reduced two-dimensional finite-element model was therefore built from Euler-Bernoulli frame elements, representing the principal longitudinal truss plane with the floor system and deck mass, preserving the global bending behaviour that matters for drive-by monitoring.

The initial model reproduced the fundamental mode reasonably well but diverged for the higher bending modes, reflecting uncertainty in material properties, corrosion-induced section loss, connection behaviour and non-ideal supports. Bayesian updating by transitional Markov chain Monte Carlo [3] was applied, with a likelihood combining natural-frequency discrepancy and the modal assurance criterion, and with the elastic modulus, member cross-sectional areas and support condition identified as dominant. Updating against the intact and damaged states together improved transferability beyond the intact case. The calibrated model now serves as the numerical digital twin for the work described below.

2. Neural-operator surrogate modelling

Simulating vehicle-bridge interaction is central to drive-by monitoring and is also its bottleneck. Every crossing requires a full time-domain finite-element solve of the coupled system, with contact forces migrating along the span, and screening damage scenarios, quantifying uncertainty and optimising the vehicle each require that solve to be repeated many thousands of times.

A Fourier neural operator, whose architecture is shown in Figure 2, was adopted to stand in for the simulator. A conventional network maps a fixed-length vector to another and is tied to one discretisation; a neural operator learns a mapping between functions. The quantities of interest here, the damage distribution along a span and the response time history, are functions, so the operator formulation is a natural fit and the trained model is largely independent of the sampling rate or mesh.

The framework comprises two complementary models. The forward surrogate predicts the response for a given damage condition, providing the rapid prediction engine a continuously updated twin requires. The inverse model recovers the damage field from the response, so detection, localisation and quantification are obtained in a single step rather than as separate stages of a conventional identification procedure.

A benchmark problem retains the essential physics: a simply supported Euler-Bernoulli beam traversed by a two-axle half-car, integrated by the Newmark-beta scheme with the coupled matrices reassembled as the contact points move. Damage was idealised as a localised reduction in flexural stiffness parameterised by location and severity, with the dataset partitioned so that performance is assessed on unseen scenarios. The forward surrogate reproduced the response closely, capturing not only the deflection under the passing vehicle but the far smaller perturbations introduced by damage. The inverse model identified the damaged segment at the correct position and approximately the correct severity, consistently along the span rather than only near the sensing location.

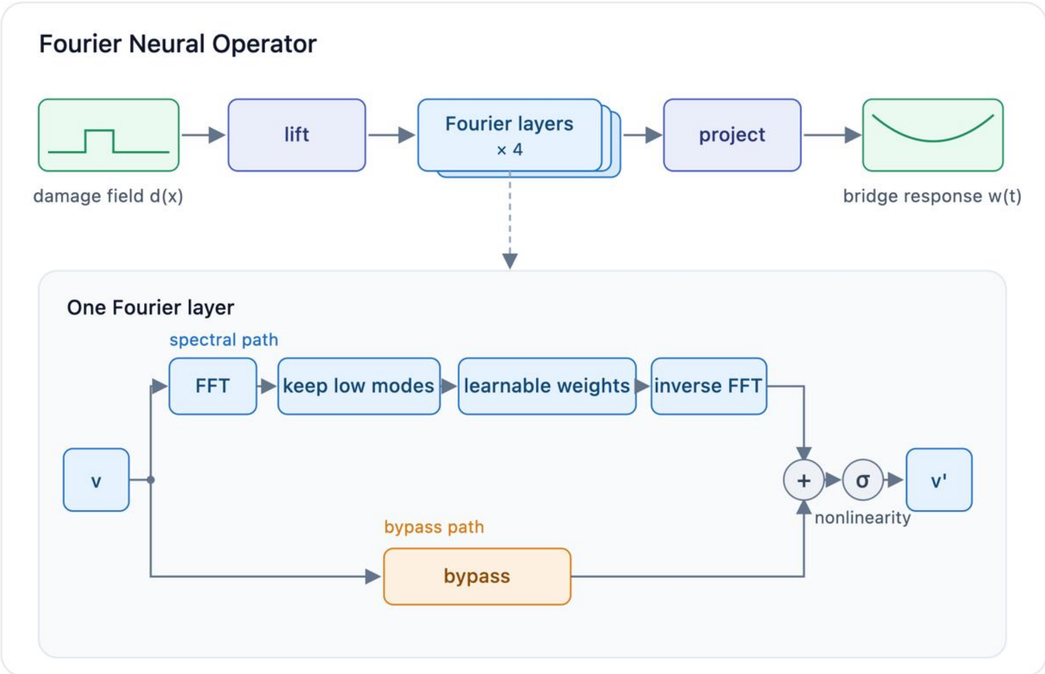

Figure 2: architecture of the Fourier neural operator used for the forward and inverse models.

Two gaps separate this demonstration from drive-by deployment. The first is the move from the bridge response used here to a vehicle-borne measurement, a change of output rather than of physics but one carrying a much weaker damage signature. The second is the move from the benchmark beam to the Old Ada model, where damage is discrete and member-based rather than a continuous field, and then to field data. Collaborators at Kyoto University and the University of Hong Kong are developing complementary formulations: a multiple-input Transformer-operator hybrid [4] and a physics-informed operator that embeds the governing equations to improve robustness and reduce data requirements [5].

3. Inspection-vehicle optimisation

Drive-by performance is governed by the coupled interaction, so the measured response is not determined by bridge condition alone. Vehicle mass, tyre-suspension stiffness, damping, natural frequency and speed all shape both the excitation imparted to the bridge and the transmission of bridge vibration to the sensors, and an unsuitable configuration can suppress damage-sensitive information altogether.

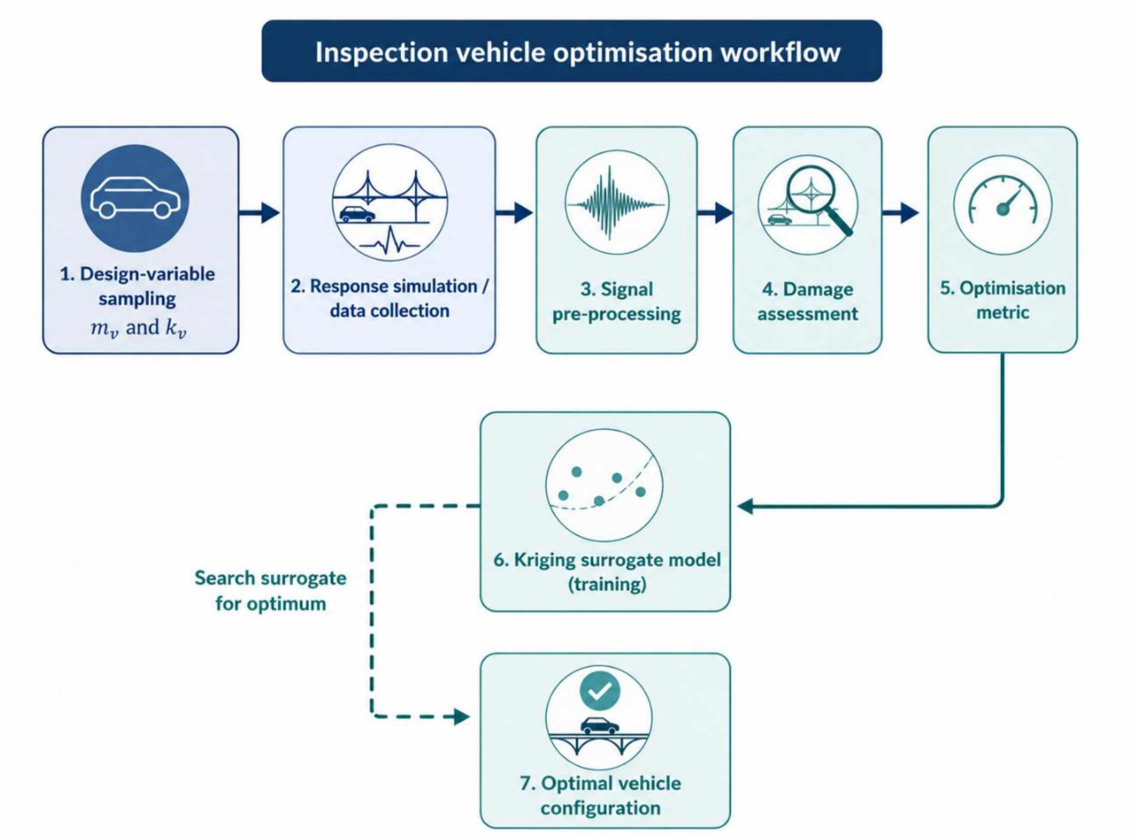

Figure 3: the inspection-vehicle optimisation workflow, from design-space sampling and interaction simulation through contact-point reconstruction and signal processing to damage assessment and surrogate-based optimisation.

Selecting the mass and tyre-suspension stiffness of a two-axle vehicle is posed as an optimisation problem, and the resulting workflow is shown in Figure 3. The vehicle is represented by a half-car model with vertical translation and pitch, carrying sensors at both axles [6]. The contact-point response contains contributions from both bridge and road and cannot be measured directly, so it is reconstructed from the axle response; existing formulations are largely restricted to single-degree-of-freedom sensing and neglect vehicle damping, and a half-car formulation that retains damping is used instead. Because the two axles traverse approximately the same profile with a time delay, subtracting the front and rear contact-point spectra cancels much of the common road content while retaining interaction-related differences. The residual spectrum is then band-limited around the bridge-sensitive range, averaged over repeated crossings, and normalised against the healthy baseline.

Damage assessment is unsupervised: an adversarial autoencoder trained on baseline spectra yields a damage index from its reconstruction error, and the separability of the healthy and damaged distributions, measured by the Wasserstein distance, becomes the optimisation objective [7]. A Kriging surrogate approximates that objective across the sampled design space and particle swarm optimisation locates the best configuration, with results expressed through vehicle-bridge mass and frequency ratios so they generalise between structures.

4. Virtual sensing and joint input-state estimation

Drive-by monitoring inherits a hard constraint from the field: the structural response is known at only a few points, and displacement, the quantity most directly related to deformation and load effect, is typically not recorded at all. This limits what can be inferred from a crossing and constrains the data available to train and validate the surrogates.

Virtual sensing combines the validated model with the available measurements to estimate responses where no sensors exist and recover quantities never measured. The approach is joint input-state estimation using an augmented Kalman filter. The bridge is driven by moving axle loads whose magnitude is unknown but whose distribution is not, since the contact position follows from the vehicle speed and the load is apportioned to adjacent nodes by the element shape functions, so the load-distribution matrix is time-varying yet known. Augmenting the state with the unknown input allows force and state to be estimated together, returning displacement and velocity at every degree of freedom, including panel points carrying no instrumentation.

The vehicle is deliberately excluded and the interaction absorbed into the process noise; retaining it would require the coupled system to be reassembled and solved at every contact position and time step, which is prohibitive inside a recursion running over a whole crossing. The simplification keeps the filter linear and fast, and identifies precisely where a fast surrogate becomes valuable. Figure 4 shows the sensor layout adopted. On the numerical twin, at a crossing speed and sampling rate matching the field campaign, with noise added and only a small number of channels supplied, the filter reconstructs the response accurately at un-instrumented panel points.

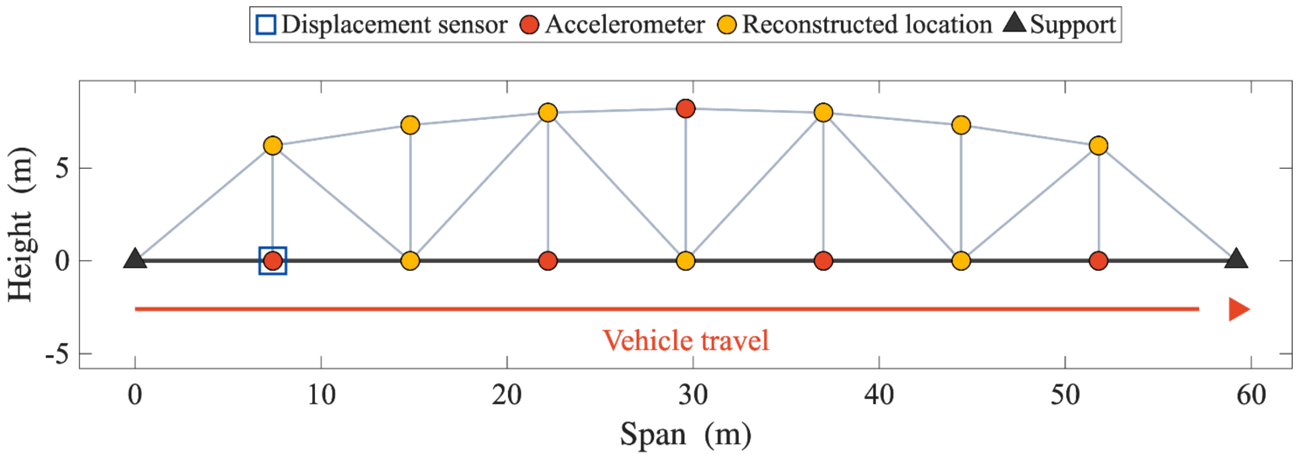

Figure 4: sensor layout used in the numerical demonstration, showing the measured channels and the locations at which the response is reconstructed.

Extending to field measurements exposes the next problem. There the response is largely governed by the road profile, which excites the vehicle and reaches the bridge as a broadband, continuously varying contact force, and neither the road roughness nor the vehicle parameters are known, so the modelling error absorbed into the process noise becomes large. The coupled problem is addressed directly through a nonlinear extension of the Universal Filter [8], a minimum-variance unbiased estimator in which vehicle and bridge are modelled together and the structural state, the road roughness and the vehicle parameters are estimated jointly. Because the vehicle is included in the estimation, no prior characterisation of it is required, which is essential for deployment in routine traffic.

5. Integration

The three developments are complementary. The optimised vehicle improves the bridge information carried in the measurement; virtual sensing reconstructs unmeasured responses and enriches a scarce field dataset into one suitable for operator learning; and the neural operator supplies rapid forward and inverse prediction without repeatedly solving the coupled model, offering a route to embedding the interaction inside the estimator rather than relegating it to process noise.

Acknowledgements

The authors would like to thank Australia Japan Innovation Fund (AJIF) for making this research possible.

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Technical Note

Subject	**How to run a site deployment**		
EngAnalysis Reference	EN-229-0732-TEC-001.A	Date	16/04/2026
Author	John Vazey	Checked	Ali Hadigheh

Document Scope

This technical note is intended as a guide for running a successful and safe sensor array on a live asset. While many of the general principles apply to any machine or structure, there is a strong emphasis on bridges.

As a "guide", this document is full of intent and motherhood statements that require some care and adaptation and implementation into any specific project.

Executive Aims

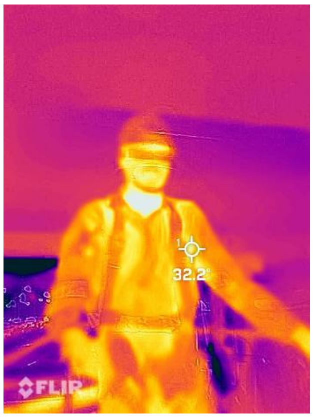
- We are generally deploying sensing systems to provide the evidence for an asset owner to make more informed decisions. These systems pivot around risks both known and unknown. Our society is benefited by these systems being based in science and engineering, effective, reliable and actionable.
- Where this is going is that it is good for society to do a good job of this and present limitations and capabilities honestly and openly. Help make these projects better by looking for improvements and remaining curious about the structural behaviours and deterioration.
- From a business perspective, we are there to profitably achieve the contractual aims safely and efficiently.
- From a team perspective, if people don't find each stage in the experience of doing this work to be enriching, fun and interesting, you may find it difficult to get people born after 1980 to help next time.

Planning Phase

Most of our projects have a 1 - 2 week period between receiving a purchase order and being on site with tools.

The consequence of this is that "planning" seems mostly like a great concept. In reality, we are generally scrambling to get all of the necessary gear, documentation, people and material on site.

Achieving tight timelines requires a team of people and coordination. I recommend against recurring meetings as this wastes time and negates the point of delegation. My preference is to have a kick-off meeting "volunteer people" into the coordination subsets, then facilitate and support individuals to make decisions.



My aim is to get involved only when a viable decision is possible or when people are struggling to find one. When all of the constraints are considered, there are generally only a few options (and decisions) that are viable.

The main point here is to elect others to sweat the small stuff and support this to make sure everyone turns up, has what they need to get on site (and do the work) and gets home safely once the project is complete.

Keep It Simple

Plans should be as simple as possible, well communicated, compliant with local safety rules and confirmed with the client. See the safety section below.

Simple plans are generally easy to pivot and adapt to the near-constant changing landscape of restrictions that occur or become evident during deployment.

It is important to expect and adapt to unforeseen restrictions on large infrastructure. Ideally, this is well articulated in the proposal stage and the variation caused is obvious and changeable.

In the planning stage, have contingencies for weather; including high winds, lightning, rain or other site services interrupting your team's program.

Emergencies

The term "emergency" is often over-used and generally inappropriate. In any physical reality, unexpected stuff happens almost continuously. Last week I was stuck in a EWP machine for around 2 hours before a curfew to cross a road. This was inconvenient, but not an emergency and we called a mechanic and were let down and packed up the site (eventually).

The point here is, don't use the term "emergency" unless people are hurt and rushing will help.

That said; have a plan and a robust chain of command within the team such that everyone knows who to turn to if things start going wrong. Emergencies do happen more frequently when people make bad decisions with real or perceived time pressure.

Don't Panic: keep it cool and build a moment into any new problem to review how you might react and then talk it through with someone you trust.

Fatigue

Of the things we do in these projects, I suspect fatigue and diving dominate our risks.

Wherever possible, limit driving to less than 8 hrs and have 2 people in a vehicle.

Change something if you are planning to work for more than 12 hrs and drive anywhere.

We try to book last-minute accommodation for staff to avoid late night drives back from the site. I am often thwarted by people wanting to get home and offering a number of lame excuses like "I don't have an overnight bag". Require people to travel to the site with an overnight bag as a minimum requirement.

Be aware of people getting depleted and try to help them make better choices and build slack into their personal systems.

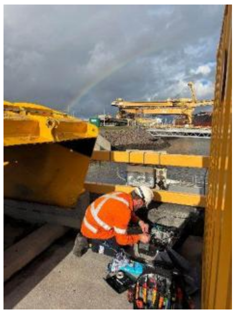
Like all other aspects of leadership, it's best to demonstrate how not to take risks by practicing rests and not driving after 6 pm.

Planning Documents

We generally take two documents to site:

A simplified sensor map and a naming convention for all sensors (including axes) with wiring diagrams down to cable wires for each sensor type.

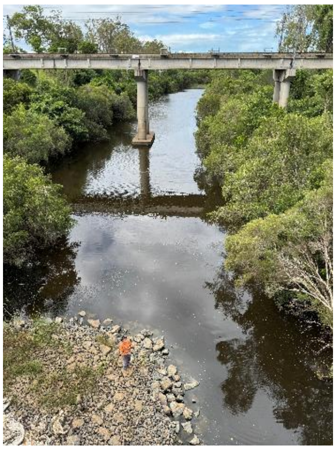
The Safe Work Method Statement (SWMS). This document presents the risks and how these risks are managed. We generally embed contact details, MSDS sheets, maps and accommodation information, contact details for everyone and travel times in this document.



The Sensor Map

The simplified map must be detailed to the extent of orientation and distances to relevant components that exist. Where possible keep this simple (e.g., “Central to Lower flange in the mid span as measured from the abutments” is a useful and realistic aim, but getting this will require a laser distance sensor and a square). It is a good idea to include a photograph with the explicit detail and dimensions and ideally a tolerance in the map. For simple structures, we laminate the map or print it on water-proof paper.

These maps often find their way into the installation reports (a document that defines what was done including serial numbers and calibration details on all sensors)



The Safe Work Method Statement (SWMS)

Safety planning usually hinges around the intended instrumentation and the inherent site restrictions.

Some risks are obvious such as “falling off the bridge” but others get tricky such as lead based paint or silicates in grinding or drilling.

We generally use forced air respirators for paints and silicates grinding and drills with vacuums for all masonry drilling. The modern SDS drills with an integrated vacuum are cheap, simple and effective.

The SWMS aims to provide a thorough strategy for dealing with risk and if you set it in the SWMS you need to action this in the deployment.

It is wise to use words like “gloves to be used where practical” to avoid the need to use gloves at all times. This comes into play when dealing with fiddly strain gauge tape, typing or electronics where dexterity is a requirement. The introduction of rules that can’t be followed undermines the entire safety system process and while you can't generally change site-given restrictions you can write well thought through procedures that reduce risk.

SWMS need to have thought about rain, vehicles, other works, fumes, dust, food, hygiene, waste disposal, parking, moving gear, running cables, and accessing the strain gauge locations.

Site Generated SWMS

We are often given 40+page SWMS for sites that may include functions that we have nothing to do with.

While it is a statutory requirement for everyone to read this documentation, it is entirely unrealistic to expect it. Consequently, it is essential that the site manager reads, interprets and distils the site safety plan to the team and provides them with the method to achieve it.

Humility

I like to finish all safety briefs with a moment of humility to emphasise "that we are all vulnerable, distractible and do dumb things at times. Consequently, we could all do with others looking out for us. Please speak up and kindly let me know if I'm doing something silly. Help me make sure that care for each other is a central feature of being on site as part of our team."

What People Need

It is most likely that in any deployment you have a team that includes traffic management or protection officers, your own engineers, technicians and possibly the client or their representative. Realise that this larger collection of people is your team and work out how to best work with them to achieve the defined goals.

There are a few essentials to manage this team:

Human Basics

At a minimum, we all need sleep, water, food, access to amenities, care and a plan. Most people work a lot better when they feel connected to others and are collaborating on something meaningful. Below are a series of pointers that we use to help make these deployments more effective.

Base of operations

It is useful to establish a "base" with the necessary support infrastructure including food, water, toilet, access to PPE (hats, gloves, glasses etc), first aid, batteries, access to the plan and resources such as cabling, adhesives, etc.

Toilets, site sheds and lunch-rooms can be hired.

Hierarchy

We also need a defined hierarchy. This needs care and thought in order to provide the right environment for good decision-making.

I'm not great when authority is imposed upon me and I tend towards delegating when possible

Accommodations

We are almost never deploying gear from our hometown. While away, we generally stay in hotels or an Air B&B.

The shared house experience of an Air B&B is generally much more fun and should be considered for any deployment over 2-3 days. Hotels are isolating, difficult to share load and don't work well if there are shared homework or preparation tasks. The addition of a garage allows the team to organise for each successive phase of the project. Getting takeaway food or using uber eats and sitting around a dining table maximises time.

You do need to sort out an agreed-upon lights-out time to avoid trashing the team. In a well-functioning team these sorts of decisions are facilitated by (not dictated by) the team lead.

Wherever possible, get to the site the day/night/afternoon before the installation to familiarise yourself with the problems, maximise the site time and provide some contingency to resources not turning up. Ideally (it never happens) have the project manager turn up early in order get the logistics sorted.

Leadership

The team lead and project manager are different roles and for us often different people. The project manager is responsible for the gear, food, gauges, and maps. The lead is responsible for making sure the people are safe and know what they are doing now and what they are doing next.

I aim to delegate and support. What this means functionally is that i take personal responsibility for stuff-ups and congratulate the team for achievements. The intent is to deliver the message “How can we improve what we are doing?”

Day One

It is ideal to have the most experienced person uncommitted for at least the first day in order to sort out problems and make decisions. Ideal if this person takes tools and water to each team and takes the role of supporting progress, decision-making and safety.

At times, this is a very stressful role dealing with machine breakdowns, unexpected restrictions, and the inevitable lost gear, and variations to the plan.

Despite the challenges, it is essential for this person to see their role in supporting the team and be graceful in providing support and advice. Thank people for asking questions and provide quick and supportive decisions wherever possible. I regularly fail at this, get annoyed at banal small-game questions in the heat of the moment and strive I to do better. I am fortunate that almost everyone on the team at some point feels obligated to tell me how to do better.

Rinse & Repeat

Once the project is settled and the specifics of sensors defined, the project turns to a rinse & repeat mode. At this point, the more experienced people may take the role of providing mentoring to others in the team.

In this phase, the roving supporter is a delegated role and will fall onto someone not teaching. If you find your rover is bossy, hassling, irritating and meddling: discus it and replace them with someone with a more caring approach. Be aware that we all get tired, grumpy and short-tempered when under constant stress.

Food.

People who are decaffeinated, hungry, scared, stressed, hot, cold, wet or tired are much more likely to do a poor job and/or get hurt or hurt others.

Think about food as a safety tool and use it to demonstrate care. Care is one of the most important things to demonstrate and encourage on site (and beyond it).

Be mindful of the other stresses and the inevitable complexities in people's lives and try to discuss the generic problems associated with being away from home early. It's smart to have options for swapping out part of the team if and when required.

We make quite a ritual of getting good coffee, yummy snacks and healthy good lunches.

Eating food requires access to hand cleaning and a comfortable spot to sit. We often take a table, sit on cable rolls and have a picnic somewhere quiet. This 30 minute sharing-a-meal ritual is a lovely addition to a hot difficult and isolated day and closes the loops between the different people working on the project. We generally invite the whole team to these lunches and it is good to sit with Kate & Arun from traffic management and see how they are going.

Determinacy

It seems like a small thing, but if no-one but you knows what happens next or when we might get a chance to go to the loo they get really stressed. Take a moment each morning to outline a plan and give the team including traffic control some idea of what's just about to happen. Get them to talk to you about what in their field of influence might change that plan.

EWP's and Access.

All of our personnel have heights and EWP training. For gauge site preparation, there is generally a need to remove paint and polish (generally grinding). This is a noisy, dirty set of sequential functions that are best completed by a single well-equipped person. Driving your own machine is helpful. It saves a lot of time overcoming the difficulties in describing "a bit further to my right" over a radio to a land based operator.

Some people really aren't good with the heights or are very timid (or gun-ho) operators of the machines. Watch your team and support their use of these tools. Ideally manage a change in behaviour by selecting a more senior operator with better practice to mentor someone struggling and let everyone know why you are doing it. (i.e. setup the lesson and discuss it afterwards).

There are projects and teams that work well for mentoring. Use these opportunities well and make the time to discuss outcomes or pivot people that are not working well together into other parts of the operation. Demonstrate curiosity and ask for ideas in order to make things easier and more efficient.

PPE

We have been using forced air ventilators for all lead-paint-based work and machining concrete. These systems are costly (>$4k/person) but they are comfortable, effective and can accommodate glasses, rain, heat and beards. If I could afford it i would buy every member of staff one of these for Christmas.

Most sites have specific rules including hard hats, safety footwear, glasses, gloves, long sleeve shirts, trousers etc. Some sites have restrictions on the colour of clothing (and tools) as these colours have special meanings on site (for example most rail projects will not allow red or green anything on site). Ask about this well before turning up on site.

Harnesses

The standard Australian safety harness is designed to prevent you from falling off an edge. The standard harness will cause trauma associated with circulation restrictions if a person hangs in it for more than a couple of minutes and the person dangling will be oriented in a face-down aspect with very limited capacity for self-rescue.

These devices for whatever reason are fundamentally dangerous and you need to have a solid and achievable action plan if falling in a harness is a possibility. There are ropes access harnesses that are designed not to kill the occupant and these must be used when not in a fall-prevention mode.

People

Site-work requires a different set of skills to proposals, analysis and writing. Be aware that many people who graduate with a degree in engineering may ask you what way to turn a nut to tighten it and have no hope of achieving a polished flat surface with an angle grinder. Staff selection, teaching and apprenticeship with constant QA and guidance is essential. See the leadership section on mentoring.

There are also combinations of people who don't work well together for a myriad of reasons. Don't try to expand people's social capacities by selecting incompatible people for joint tasks. Most engineers exist towards the boundaries of the human spectrum and need complementary compatible support with defined individual tasks. This is not non-cooperative but we have found it better to give individual tasks (such as mark-out and label, or grind & polish) that are consistent tasks that exploit the teamwork strategy but leave individuals responsible for the entirety of a single task. The advice here is to try to work best with the team you have.

Verification

Lots of things can go wrong on a site but the most common is mislabelling or misinterpreting a label on a cable leading to utter confusion.

For resistance based strain gauges, a shunt calibration provides a great verification of gain, and verification that the sensor you are shunting is correctly labelled in the DAQ and data system. Vibrating wire sensors cannot be shunted the same way but can be pressed on to yield an offset.

FBG sensors have no useful way of shunting and we generally couple these with a magnetic strain gauge under known load where possible to verify the gain settings after a notable failure.

We use a field shaker with 3 frequencies for the verification and calibration of accelerometers.

The main intention here is to highlight that a little care in thinking about verification and then doing it can save weeks of confusion and days of embarrassment later.

Project Updates

Your project manager may not understand the technical details but generally wants to know:

- You are going to deliver what you promised
- On time
- On budget
- Safely

Ideally, they want you to commit answers by some form of written reporting whenever relevant (this could be daily)

- Be honest with this person and let them know about progress.
- Keep it short. Put your updates in a format that they can share.
- I prefer to indicate we are overcoming obstacles by emphasising the solution not the problem.

Debrief

Every project has its challenges.

Have a process for tracking what went right and what you would like to avoid doing in the future. Involve the client and the traffic team.

Think about what would make the projects go better and allow everyone to have more fun. "Better planning" comes up a lot for us particularly on the tricky, last minute, ill-considered critical projects.

Seriously: if you think everyone is happy you're doing a crap job of listening.

Share the love: if you did something clever, learnt something cool or did something so mind numbingly stupid you think you should tell others to avoid a repeat: tell the general community, leak it out in a way that doesn't compromise your confidentiality agreements.

Plan for next time

Work out what can be actioned out of the suggestions and whining. Allocate a budget and delegate fixing it to someone who is vocal and can do something about it.

Conferences News

1. 18th Australian Network of Structural Health Monitoring Workshop (ANSHM2026), 23–25 November 2026, Perth, https://anshm2026.github.io/ANSHM2026/index.html
2. The 2nd International Conference on Engineering Structures (ICES2026), 1 to 4 December 2026, Brisbane, Australia. Website: https://ices2026.netlify.app/
3. The 13th International Conference on Structural Dynamics, EURODYN 2026, 27 September to 1 October 2026, Hannover, Germany. Website: https://eurodyn2026.org/
4. 14th International Conference on Structural Health Monitoring of Intelligent Infrastructures (SHMII-14), June 29 – July 02, 2027, Naples, Italy. Website: https://ishmii.org/shmii-14/
5. 12th International Conference on Experimental Vibration Analysis of Civil Engineering Structures (EVACES 2027), 7 to 10 September 2027, Perugia, Italy, https://evaces2027.com/

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Edition	Submission Deadline	Distribution
Spring	15 Feb	Early March
Summer	15 May	Early June
Fall	15 Aug	Early Sep
Winter	15 Nov	Early Dec

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