Forty+ Years of Post-Earthquake Reconnaissance: Methodological Evolution Across Three Phases of EEFIT Activity

Yasemin D. Aktas[1], Michael R.Z. Whitworth[2], Emily So[3]

[1] Department of Civil, Environmental and Geomatic Engineering, University College London, UK
[2] AECOM, UK
[3] Department of Architecture, University of Cambridge, UK

Corresponding author: Yasemin D Aktas (y.aktas@ucl.ac.uk)

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Yasemin D. Aktas[1]*, Michael R.Z. Whitworth[2], Emily So[3]

[1] Department of Civil, Environmental and Geomatic Engineering, University College London, UK

[2] AECOM, UK

[3] Department of Architecture, University of Cambridge, UK

* corresponding author: y.aktas@ucl.ac.uk

Abstract

Over four decades, the Earthquake Engineering Field Investigation Team (EEFIT) has undertaken around 50 missions in around 35 countries, evolving from a structural-engineering field programme into a hybrid platform integrating fieldwork, remote sensing, community-based data collection, and longitudinal return studies. Founded in 1982 as a joint venture between UK academic institutions and the structural engineering profession, and hosted by the Institution of Structural Engineers, EEFIT has operated throughout as an academia-industry collaboration in which the boundary between research and practice is intentionally permeable, by design enabling cross-pollination between academic enquiry and engineering practice. This paper examines EEFIT's methodological evolution across three empirically grounded phases, tracing both the innovations that have proved durable and the tensions and limitations that remain unresolved.

We identify three phases: an Engineering Core phase (1982-c.1999) characterised by analogue fieldwork and structural diagnostics; a Expansion and Development phase (2000-c.2019) marked by the integration of tsunami and multi-hazard (including earthquake-induced landslide) reconnaissance, institutionalised socioeconomic analysis, the introduction of return missions, and progressive demographic diversification; and a Methodological Overhaul phase (2020-present), initially precipitated by COVID-19 travel restrictions but sustained and deepened by financial constraints, politically fragile operational environments, and the absence of diplomatic access in several affected countries. All of these factors have made conventional international field deployment impractical or impossible and elevated the strategic importance of remote reconnaissance capabilities. A further driver has been the growing recognition that remote sensing is not merely an operational substitute for fieldwork but an important analytical component, with field data increasingly understood as validating and shaping RS tools in a two-way methodological dialogue rather than RS serving as a one-directional supplement to field observation. Local collaboration and embedded co-production with in-country partners has become the norm in this phase. Alternative data sources - social media analytics, community enumeration platforms, crowdsourced imagery - are actively explored but remain an open research question (Aktas and So, 2022).

Throughout these phases, team size, international composition, women's participation, and early-career researcher involvement have grown substantially, though unevenly. Methodological innovations have extended coverage and enabled new research questions, while also introducing challenges of validation, data quality, and sovereignty that the field has not fully resolved. The EEFIT archive, read critically, offers one of the more sustained longitudinal accounts of methodological change in international post-earthquake reconnaissance, and its open questions are as instructive as its achievements.

1. Introduction: Post-Earthquake Reconnaissance as a Methodological Problem

Post-earthquake reconnaissance has long been characterised as a “full-scale laboratory” for earthquake engineering, in which the built environment under real seismic loading provides observations that no controlled experiment can replicate (Spence, 2014). Yet the methodological foundations of reconnaissance - who deploys, with what tools, asking which questions, under what access constraints, and to what ends - have rarely been examined systematically across a sustained organisational history. Such examination matters not only as historical record but as a basis for assessing which mission approaches have proved most valuable, under what conditions, and how the practice should evolve. This paper does that for EEFIT, using the mission archive as the primary source.

Spence’s (2014) Ambraseys Lecture synthesis provides an essential comparative baseline, tracing post-earthquake reconnaissance from early scientific missions and UNESCO-supported campaigns (1963-1980) through to the modern era of national programmes including EERI’s Learning From Earthquakes, the Geotechnical Extreme Events Reconnaissance Association (GEER), Japan’s JSCE programme, and EEFIT. His Table 1.1 summary of field missions from 1962 to 2013 documents a field whose organisations differ substantially in funding model, disciplinary breadth, institutional home, and mission frequency. EEFIT, founded in 1982, occupied a distinctive position in this landscape: a volunteer collaboration spanning academic institutions and structural and geotechnical engineering practice, hosted by the Institution of Structural Engineers, with no dedicated state funding and consequently a reactive deployment model dependent on event severity and the availability of practitioner and academic volunteers. The academia-industry partnership has been both an asset - enabling rapid mobilisation of practitioners with applied expertise and ensuring that findings are translated directly into professional guidance - and a constraint, given that volunteer availability and industrial support vary with economic conditions and competing professional demands.

This paper proposes a three-phase periodisation grounded in the evidence of the mission archive: (i) an Engineering Core phase (1982-c.1999); (ii) a Expansion and Development phase (2000-c.2019); and (iii) a Methodological Overhaul phase (2020-present). We develop this in Sections 2-4, examine impact pathways in Section 5, outline unresolved questions in Section 6, and draw conclusions in Section 7. Table 1 lists all EEFIT missions to date. Figure 1 shows their geographic distribution.

Table 1. EEFIT missions 1983-2025. Return missions shown in blue. Mw ‘ - ’ for return missions where the original event magnitude applies.

Year	Location	Mw	Mission Type	Methodology
1983	Liège, Belgium	5.0	Immediacy	Field
1985	Algarrobo (Llolleo), Chile	7.4	Immediacy	Field
1985	Mexico City, Mexico	8.0	Immediacy	Field
1986	San Salvador, El Salvador	5.5	Immediacy	Field
1989	Loma Prieta, California, USA	7.1	Immediacy	Field
1989	Newcastle, Australia	5.4	Immediacy	Field
1990	Vrancea, Romania	7.8	Immediacy	Field
1990	Luzon, Philippines	7.8	Immediacy	Field
1990	Manjil, Iran	7.4	Immediacy	Field
1990	Augusta, Sicily, Italy	5.1	Immediacy	Field
1992	Erzincan, Türkiye	6.8	Immediacy	Field
1994	Northridge, California, USA	6.7	Immediacy	Field
1995	Kobe, Japan	6.9	Immediacy	Field
1997	Umbria-Marche, Italy	5.9	Immediacy	Field
1999	El Quindío, Colombia	6.2	Immediacy	Field
1999	Kocaeli, Türkiye	7.6	Immediacy	Field

Year	Location	Mw	Mission Type	Methodology
1999	Chi-Chi, Taiwan	7.7	Immediacy	Field
2001	Bhuj, India	7.7	Immediacy	Field
2004	Indian Ocean / Sri Lanka & Thailand	9.3	Immediacy	Field
2005	Kashmir, Pakistan	7.6	Immediacy	Field
2007	Folkestone, UK	4.0	Immediacy	Field
2007	Central Coast, Peru	7.9	Immediacy	Field
2008	Market Rasen, UK	4.7	Immediacy	Field
2008	Wenchuan, China	7.9	Immediacy	Field
2009	L'Aquila, Italy	6.3	Immediacy	Field
2009	Samoa (South Pacific)	8.0	Immediacy	Field
2009	Sumatra, Indonesia	7.6	Immediacy	Field
2010	Port-au-Prince, Haiti	7.0	Immediacy	Field
2010	Maule, Chile	8.8	Immediacy	Field
2011	Christchurch, New Zealand	6.3	Immediacy	Field
2011	Tōhoku, Japan	9.0	Immediacy	Field
2012	L'Aquila, Italy	-	Return	Field
2013	Tōhoku, Japan	-	Return	Field
2015	Gorkha, Nepal	7.8	Immediacy	Field
2016	Kumamoto, Japan	7.1	Immediacy	Field
2016	Muisne, Ecuador	7.8	Immediacy	Field
2016	Amatrice, Italy	6.2	Immediacy	Field
2018	Central Sulawesi, Indonesia	7.5	Immediacy	Field
2019	Durrës, Albania	6.4	Immediacy	Field
2020	Zagreb, Croatia	5.3	Immediacy	Remote
2020	Aegean (Izmir/Samos)	6.9	Immediacy	Hybrid
2021	Haiti	7.2	Immediacy	Hybrid (remote-first)
2022	Gorkha, Nepal	-	Return	Field
2022	Indian Ocean / Indonesia & Thailand	-	Return	Field
2022	Central Sulawesi, Indonesia	-	Return	Field
2023	Türkiye-Syria sequence	7.8	Immediacy	Hybrid
2023	Morocco (Al Haouz)	6.8	Immediacy	Hybrid
2025	Myanmar & Thailand	7.7	Immediacy	Remote
2025	Eastern Afghanistan	6.0	Immediacy	Remote

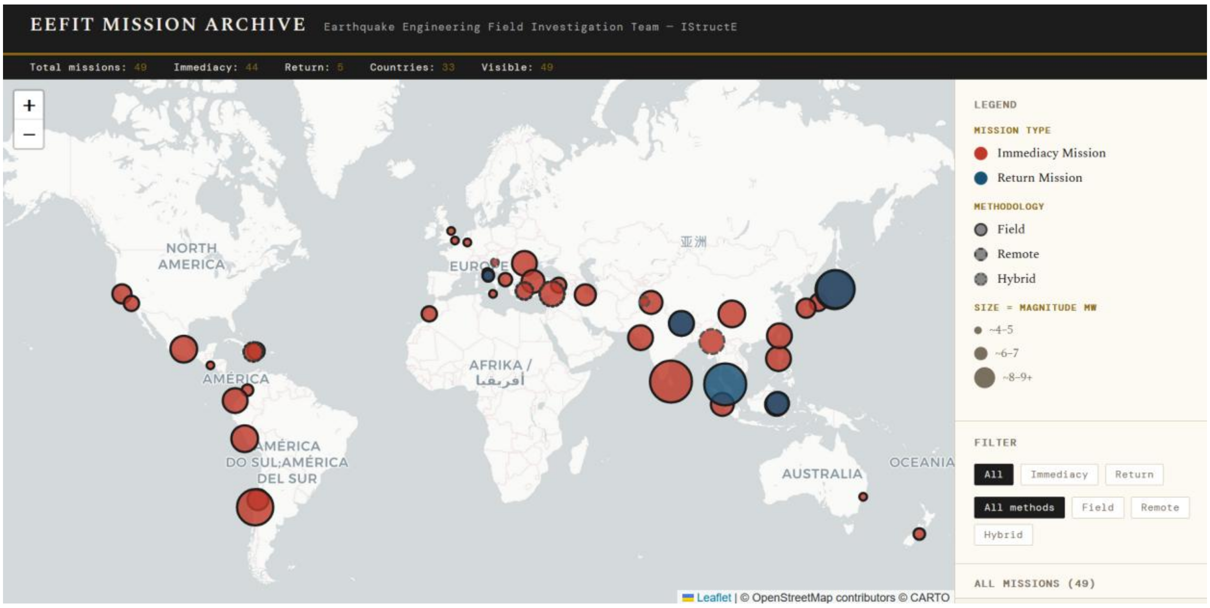

Figure 1. Geographic distribution of EEFIT missions (1983-2025). Red circles = Immediacy missions; blue = Return missions. Size proportional to Mw.

2. Three Phases of EEFIT Development

The following sections trace EEFIT's evolution through the mission archive, drawing on reports, peer-reviewed publications, and team composition data. The phase boundaries are not sharp discontinuities: practices introduced in one phase often persist or are revised in the next. The characterisation of each phase reflects its dominant tendencies and most consequential shifts in methodological approach, thematic scope, team composition, and operational ambition (Table 2).

Table 2. EEFIT phases at a glance.

	Phase 1 (1982–c.1999): Engineering Core	**Phase 2 (2000–c.2019): Expansion and Development**	**Phase 3 (2020–present): Methodological Overhaul**
Ambition / scope	Rapid structural and geotechnical diagnostics; transfer of lessons to UK professional practice	Broader multi-hazard coverage (tsunami, geotechnical, socioeconomic, governance); comparative and return studies; international team composition	Hybrid and remote workflows as standard; longitudinal design from outset; embedded co-production with in-country partners
Key innovations	Standardised damage survey methodology; academia–industry volunteer model; rapid deployment protocol	Tsunami reconnaissance competency (IOT 2004); formalised return missions (L'Aquila 2012, Tōhoku 2013); socioeconomic and governance analysis as full components; UAV and satellite imagery; earthquake-induced landslide reconnaissance (Gorkha 2015)	Hybrid field/remote model (Aegean 2020); standing RS Working Group; community enumeration platforms; multi-hazard distributed working groups (Türkiye 2023); local-language report summaries

	Phase 1 (1982–c.1999): Engineering Core	Phase 2 (2000–c.2019): Expansion and Development	Phase 3 (2020–present): Methodological Overhaul
Limitations	Small teams; limited disciplinary breadth; no systematic return or longitudinal design; analogue data collection	Rising coordination costs with team growth; limited pre-agreed longitudinal frameworks; uneven data comparability across missions	Accuracy and uncertainty disclosure standards for remote data not yet formalised; co-production equity gap between co-authorship and genuinely co-designed analysis

2.1 Phase 1 (1982-c.1999): Engineering Core, Analogue Methods, Structural Diagnostics

EEFIT was established in 1982 by a group of academic researchers and practising structural engineers within the IStructE, against the backdrop of the UNESCO survey campaigns documented by Spence (2014). This founding configuration - academic research leadership combined with practitioner expertise and institutional hosting by the professional body - defined the programme's character throughout Phase 1 and persists today. The early EEFIT template was recognisably structural: macroseismic intensity mapping, building damage surveys, geotechnical failure documentation, and mission reports intended to transfer lessons to UK and international practice. Teams were small - averaging three to five members - almost entirely UK-based, drawn from structural engineering practice and academia, and, by the available composition data, nearly all male.

The absence of socioeconomic analysis from most pre-1989 reports reflects both the disciplinary profile of early teams and the narrower mandate of reconnaissance at the time. Spence (2014) notes that the UNESCO missions of the 1960s and 1970s had in fact been more explicitly interdisciplinary - pairing engineers with geologists, seismologists, and social scientists - but that subsequent national programmes tended toward greater disciplinary concentration. EEFIT's Phase 1 trajectory fits this pattern. Social response and economic losses appear as named sections from Loma Prieta 1989 onward, initially brief and descriptive, growing in prominence through the 1990s. The first signs of international team composition appear in Erzincan 1992 and Northridge 1994, though UK professionals remained dominant. Report structure and analytical depth varied considerably across the phase, reflecting the absence of a pre-agreed analytical framework and the contingent availability of volunteer teams.

Key Mission: Kocaeli 1999 (Mw 7.6)- RC Failures, Lifelines, Code Legacy

The Kocaeli earthquake struck the Marmara region of northwestern Türkiye on 17 August 1999, killing approximately 17,000 people and damaging or destroying over 300,000 buildings. EEFIT deployed a ten-person team including international collaborators from structural engineering practice and academia, producing the most substantive EEFIT report of the pre-2000 era. The mission documented with unusual depth the catastrophic performance of non-ductile RC construction: soft-storey collapses, short-column failures, inadequate confinement, and widespread use of substandard concrete in a rapidly urbanising context with weak regulatory oversight (D'Ayala and Free, 2003). The Adapazari district provided a striking case study in the interaction between pervasive liquefaction, lateral spreading, and building losses. Infrastructure was addressed at a scale new for EEFIT: ports, petrochemical facilities, road and rail networks, and lifelines. Economic damage was estimated at $12-17 billion (D'Ayala and Free, 2003), and EEFIT noted that the Compulsory Earthquake Insurance system introduced following Kocaeli would require substantial strengthening - a prescient observation reconfirmed by the 2023 Türkiye longitudinal mission (Aktas et al., 2024a). Kocaeli represents Phase 1's most complete realisation of the EEFIT template, though its analytical depth was not uniform across the earlier missions of the phase. An earlier typical mission illustrates both the template and its limitations: the Mexico City 1985 (Mw 8.1) deployment, one of the first major EEFIT missions, sent a small team to document the catastrophic collapse of mid-rise RC buildings in the lake-bed zone, identifying soil amplification and soft-storey vulnerability as primary failure mechanisms. The report provided practitioners with direct evidence of failure modes then poorly understood in the UK context; but the team was small, the data collection analogue, there was no subsequent return, and the wider socioeconomic impact on Mexico City's population received minimal treatment. The contrast with Kocaeli fourteen years later illustrates the trajectory of Phase 1 development.

2.2 Phase 2 (2000–c.2019): Expansion and Development - Tsunami, Landslides, Socioeconomic Depth, Return Missions, Team Diversification

The period from 2000 to 2019 represents EEFIT's most expansive phase of substantive and methodological growth, aided by a higher global frequency of major damaging events and by growth in research funding available for field investigation,. Four developments characterise it: the integration of tsunami reconnaissance as a distinct competency; the consolidation of socioeconomic and governance analysis as full mission components; the introduction and gradual formalisation of return missions; and substantial demographic diversification from 2015 onward. These developments were not coordinated from a single strategic plan but emerged from a succession of events that each required methodological adaptation, exposing new capabilities and new limitations.

Key Mission: Indian Ocean Tsunami 2004 (Mw 9.3) - Tsunami Engineering, Scale, Social Impact

The 26 December 2004 Indian Ocean earthquake and tsunami killed approximately 228,000 people across fourteen countries. EEFIT deployed to Sri Lanka and Thailand, producing a landmark report (Pomonis et al., 2006) that ran to nearly 200 pages and addressed seismotectonics, tsunami generation and propagation, wave height measurements, building and infrastructure performance, lifelines, and the social and economic consequences of the disaster. Systematic damage surveys across six coastal zones in Sri Lanka quantified differential performance of construction typologies: RC frames outperformed unreinforced masonry in wave loading resistance, though foundation scour caused failures at up to 800 m from the coast. Wave height measurements of up to 10 m at Khao Lak and survey of over 1,200 buildings on Phuket and Phi Phi islands produced one of the earliest quantitative tsunami damage datasets assembled by a UK team. The mission introduced the EEFIT tsunami damage scale, subsequently adapted in Tōhoku 2011 (Fraser et al., 2013). The 2004 mission also exposed methodological tensions around geographic coverage that remained unresolved: representing spatial variability in damage across a coastline thousands of kilometres long with a single two-week deployment was inherently limited, and later EEFIT tsunami reconnaissance faced analogous constraints.

Key Missions: L'Aquila 2009 (Mw 6.3) and Return 2012 - Heritage Masonry, Governance, Multiple-Mission Value

The L'Aquila earthquake of 6 April 2009 killed 309 people in the historic Abruzzo capital and generated international attention for historic masonry performance, the criminal proceedings against Civil Protection officials, and cultural heritage losses. EEFIT deployed a ten-person team in which five members were women - then unprecedented - and three were early-career researchers. The mission documented failure mechanisms in rubble and dressed stone masonry, brick and mixed-construction historic buildings, and the interaction between traditional construction and post-war RC additions.

The November 2012 return - EEFIT's first revisit to an earthquake site - found that engineered interventions on RC structures had generally performed as designed, while owner-driven repairs to historic masonry were inconsistent, and many heritage buildings remained in fragile provisional stabilisation (Rossetto et al., 2014). Rossetto et al. (2014) documented that this return occurred at a time of active debate within GEER, EERI and EEFIT as to whether return missions should be more regularly conducted, with EERI simultaneously developing returns to Christchurch and Indian Ocean tsunami sites. EEFIT's L'Aquila return was one contribution to an emerging shared practice of return missions across international reconnaissance organisations - meaning that EERI, GEER, and national European and Asian programmes were simultaneously developing their own return mission frameworks - establishing return reconnaissance as a community-wide norm rather than an EEFIT-specific innovation.

Key Missions: Tōhoku 2011 (Mw 9.0) and Return 2013 - Tsunami Defence, Recovery Complexity, Longitudinal Exploration

The 11 March 2011 Great East Japan earthquake and tsunami was at that point the most expensive natural disaster ever recorded. EEFIT deployed to Tōhoku in May-June 2011, surveying ten locations across Iwate and Miyagi Prefectures. Coastal defences including the Kamaishi super-levee were overtopped or destroyed, though they provided measurable mitigation at some locations. RC construction showed the highest resistance to wave loading, but overturning was observed where inundation depths exceeded 16 m (Fraser et al., 2013). The mission refined the EEFIT tsunami damage scale, producing a dataset used in subsequent fragility function calibration.

The 2013 return mission - two years after the event - examined recovery across multiple sectors: coastal defence reconstruction to new dual-level design standards, temporary housing communities, land-use debates about rebuilding on tsunami-inundated land, insurance and catastrophe bond market performance, and the Fukushima nuclear situation (EEFIT Mission Team, 2013). The report was explicit that many communities remained in temporary housing and that recovery was deeply uneven spatially and across social groups. The Tōhoku return demonstrated the analytical value of revisiting an event at a recovery milestone while also illustrating inherent limitations: a two-week return by an international volunteer team cannot systematically sample recovery across the affected coastline; coverage relied on selected localities and stakeholder interviews rather than a representative survey design. These are structural constraints of the reconnaissance format applicable equally to concurrent EERI returns.

Key Mission: Gorkha 2015 (Mw 7.8) and Return 2022 - Multi-Hazard, Education/Healthcare, Remote Villages

The 25 April 2015 Gorkha earthquake killed approximately 8,790 people and destroyed over 600,000 buildings, with the most severe losses in rural mountain communities. EEFIT deployed 11 members in May-June 2015, with UNOCHA logistical support enabling helicopter access to remote mountain villages - a first for EEFIT. The Gorkha report introduced dedicated chapters on education and healthcare facilities as categories of critical infrastructure, addressed stone-in-mud-mortar masonry at scale, included a substantive landslide chapter, and assessed published seismic hazard maps of Nepal against observed ground motion distributions (Wilkinson et al., 2019). Earthquake-induced landslides were a significant secondary hazard: estimates suggest that approximately 10% of fatalities were attributable to slope failures, with satellite and field surveys mapping close to 25,000 coseismic landslides across the Himalayan mountain zone (Zekkos et al., 2017). The combination of satellite imagery, UAV photogrammetry, and helicopter-based reconnaissance employed by the mission to characterise landslide patterns across the Budhi Gandaki, Trishuli, and Indrawati valleys marked a methodological advance for EEFIT in multi-hazard mountain environments. Subsequent longitudinal study of the Ariniko Highway corridor has documented both the recovery of the landscape from earthquake-induced landslides and the ongoing impacts of monsoon-triggered slope failures on critical infrastructure, providing a 30-year baseline for Himalayan mass-wasting dynamics (Jones et al., 2021). The 2022 return mission, seven years post-event, examined reconstruction through stakeholder workshops, RS interpretation, landslide reconnaissance along the Ariniko Highway, social media sentiment analysis, and ludic community engagement activities, and site revisits, finding substantial variability in owner-built reconstruction quality and constrained resourcing of government-supported rebuilding, alongside clear evidence that Nepal was broadly building back better in school construction (Whitworth et al., 2023). The seven-year interval raised methodological challenges around institutional memory and comparability between 2015 observations and 2022 revisits that required deliberate documentary effort.

Key Mission: Amatrice 2016 (Mw 6.2) - Heritage, Team Demographic Inflection

The 24 August 2016 Amatrice earthquake destroyed approximately 70% of the historic town's buildings and killed 299 people. EEFIT deployed 15 members - its largest team for a European mission - of whom eight were women (53%) and four were early-career researchers. The mission examined RC frame structures, unreinforced masonry historic buildings, bell-tower collapses, and soft-storey RC failures, with heritage conservation and cultural loss receiving substantive treatment. Amatrice 2016 represents the clearest demographic inflection point of Phase 2; the academia-industry profile of the team also diversified, with a higher proportion of ECRs reflecting the recognition that post-earthquake field reconnaissance is irreplaceable practical training that early-career researchers must undertake to fully understand the discipline.

Key Mission: Central Sulawesi 2018 (Mw 7.5) - Compound Hazards, EEFIT-TDMRC Co-Production

The 28 September 2018 Central Sulawesi event triggered a scientifically complex compound sequence: major ground shaking, four substantial earthquake-induced landslides, extensive liquefaction including the catastrophic Balaroa and Petobo soil flows, and a localised tsunami in Palu Bay generated primarily by coastal and submarine landsliding. Over 4,300 died and more than 42,000 buildings were damaged or destroyed. EEFIT deployed jointly with the Indonesian Tsunami and Disaster Mitigation Research Centre (TDMRC) at Syiah Kuala University - the first fully co-produced EEFIT mission with an in-country institutional partner - covering ground failure, tsunami inundation, building damage, and infrastructure impacts (Lagesse et al., 2019). Balaroa and Petobo failures were provisionally diagnosed as flow-slide liquefaction, with groundwater conditions and irrigation saturation as contributing factors. The EEFIT–TDMRC partnership marked a significant step toward embedded co-production; how fully co-authorship translates into jointly designed analytical frameworks remains a question subsequent co-production models have progressively tried to address.

2.3 Phase 3 (2020-present): Methodological Overhaul - Hybrid Workflows, Remote Capabilities, Longitudinal by Design

The period from 2020 marks a qualitative change in EEFIT's operating model, driven by a convergence of pressures. The immediate precipitant was the COVID-19 pandemic and the closure of international travel. But the sustained commitment to remote and hybrid methods after travel restrictions eased reflects additional drivers: financial constraints on international deployment; politically fragile or conflict-affected environments - notably Myanmar 2025 and Afghanistan 2025 - where the absence of diplomatic access made conventional deployment inadvisable or impossible; and the growing recognition that remote sensing and alternative data sources could justify investment as a standing capability rather than an emergency fallback.

A critical conceptual shift accompanies this operational change. Remote sensing began its EEFIT career as a supplement to fieldwork. By Phase 3, RS is better understood as a component in its own right, capable of producing structural damage and exposure assessments at scales that ground surveys cannot match, and with its own validation requirements and error structures. The relationship between field data and RS tools is now conceptualised as bidirectional: field observations validate, calibrate, and refine RS-derived assessments, while RS products guide the spatial targeting of field effort and extend coverage into inaccessible areas. This two-way dialogue - rather than a simple hierarchy in which field data is primary - is one of Phase 3's defining methodological contributions. Alternative data sources - social media analytics, crowdsourced imagery, community enumeration platforms, CCTV and drone footage - are actively explored as further inputs, but their reliability and systematic integration remain open research questions (Aktas and So, 2022).

Three features mark the Phase 3 overhaul: formally codified hybrid and remote workflows; a standing Remote Sensing Working Group as a permanent operational unit; and longitudinal design from the outset rather than as a retrospective decision.

The Zagreb 2020 remote study (Mw 5.3) was EEFIT's first entirely remote mission, demonstrating that structural and geotechnical assessment could be conducted at useful analytical depth without field deployment. The rapid adoption of video-conferencing tools such as Zoom and Microsoft Teams was a material enabler: distributed team coordination, remote expert consultation, and real-time field-to-desk data review became operationally feasible in ways that were not routine before 2020. The three key missions of this phase - Aegean 2020, Haiti 2021, and Türkiye 2023 - each operationalised and extended the hybrid model in distinct ways, as described below. Myanmar 2025 and Afghanistan 2025 subsequently consolidated the remote model for conflict- and access-constrained contexts, conducted as part of multi-organisational consortia (J-VAT comprising StEER, GEER, EERI LFE, GeoHazards International, and AIT Bangkok for Myanmar; AFPS, REDR, and NED University for Afghanistan).

Phase 3 has genuinely extended EEFIT's reach and diversified its toolkit. But it has also introduced new analytical responsibilities: greater dependence on upstream exposure databases whose accuracy is hard to verify; RS quality assurance demands not yet standardised across the reconnaissance community; and coordination costs in large distributed teams that smaller field-based missions did not face.

Key Mission: Aegean Sea 2020 (Mw 6.9) - First Formal Hybrid Mission, Izmir Ground Motion Anomaly, Samos Tsunami

The 30 October 2020 Aegean Sea earthquake caused the collapse of several RC frame buildings in Izmir and a localised tsunami on Samos, killing 114 people across Türkiye and Greece. EEFIT deployed a 26-person team - its largest to that point - in a hybrid configuration: locally coordinated field teams in Izmir and on Samos worked alongside a remote team integrating satellite imagery, optical RS, social-media analytics (Contreras et al., 2022), and mobile app-based field data capture, with coordination conducted via video-conferencing throughout (Aktas et al., 2022). The mission documented a striking ground motion anomaly: stiff-soil sites in Izmir exhibited long-period spectral accelerations comparable to soft soils, challenging Turkish seismic code spectrum assumptions and pointing to deep basin effects not captured in standard site classification. Critically, the Aegean 2020 report was the first EEFIT document to systematically evaluate the hybrid methodology itself - what it enabled, where it introduced uncertainty, and how future missions should adapt - making this the first EEFIT document to treat the reconnaissance method as an object of analysis. The team composition (54% women, 65% ECRs) demonstrated that high ECR proportions can sustain analytical depth when supported by structured distributed workflows.

Key Mission: Haiti 2021 (Mw 7.2) - Remote-First Reconnaissance, Local Enumerators, Community Data Sovereignty

The 14 August 2021 Nippes earthquake struck the Tiburon Peninsula approximately 150 km west of Port-au-Prince, killing over 2,200 people and damaging or destroying more than 137,500 structures. The ongoing COVID-19 pandemic, a complex political and security environment, and the absence of diplomatic support made international field deployment impractical. EEFIT instead conducted a fully remote assessment in collaboration with StEER, whose network of locally trained Haitian enumerators used a Creole-language mobile interface to collect building-level damage data rapidly across the affected area (Whitworth et al., 2022). EEFIT experts remotely assessed over 2,000 buildings - including schools, hospitals, churches, and housing - using photographic records and structured damage classification. The mission surfaced methodological questions that have shaped subsequent practice: the reliability of non-specialist damage classification, the design and validation of enumeration interfaces across linguistic and institutional contexts, and data sovereignty - who owns the damage collected in a community and who controls its use. The RS Working Group produced building damage and landslide mapping products using VHR SAR imagery (Macchiarulo et al., 2025), operationalising a data stream that required no field access. Haiti 2021 established the template for EEFIT remote-first operations in access-constrained contexts.

Key Mission: Türkiye 2023 (Mw 7.8 / Mw 7.6) - Multi-Fault Doublet, Compound Hazards, Longitudinal Design from Outset

The 6 February 2023 Kahramanmaraş earthquake doublet - a Mw 7.8 event followed nine hours later by a Mw 7.6 event on an adjacent fault segment - was the most destructive seismic sequence in Türkiye since 1939, causing over 53,000 deaths, destroying hundreds of thousands of buildings, and generating losses estimated at $84 billion. EEFIT deployed a 33-person team across six working groups - seismology and ground motion, geotechnics, infrastructure, structures, remote sensing, and relief-response-recovery - in a hybrid configuration: a field team of 15 conducted structured site visits across three provinces in March 2023 while the full team engaged remotely throughout. The mission was the first in EEFIT's history designed longitudinally from the outset, with explicit plans for phased return visits tracking relief, recovery, reconstruction, and code and policy evolution (Aktas et al., 2024a; Aktas et al., 2023). The RS Working Group fused InSAR displacement products, optical damage proxy maps, and VHR SAR-based building-level collapse classification into a multi-scale damage assessment cross-validated against EEFIT field surveys (Voelker et al., 2024; Macchiarulo et al., 2025). Compound secondary hazards - earthquake-induced landslides, liquefaction and lateral spreading, a small tsunami, and hydrological anomalies - were systematically documented and assessed using the ESI 2007 intensity scale (Boulton et al., 2025). The scale of RC building collapse in areas nominally compliant with post-1999 codes raised urgent questions about enforcement and design standards that the longitudinal framework is designed to track over time.

3. Team Composition Across the Three Phases

Analysis of team records across all missions reveals consistent trends in size, origin, gender composition, and early-career researcher participation, reflecting both deliberate choices and the changing composition of UK earthquake engineering more broadly. In Phase 1, average team size was 5.5 members; in early Phase 2 (2000-2014), 9.1; post-2014, 19.0, with the largest recent missions reaching 33-36 members. Growth reflects the expansion of EEFIT's disciplinary scope and the enabling role of hybrid and remote infrastructure in accommodating larger distributed teams, though whether larger teams consistently produce richer analytical outputs is an empirical question the archive does not clearly answer.

International team composition increased from 26% of pre-2014 missions with substantively international teams to 85% post-2014. The shift from ad-hoc international participation to institutional co-production - Sulawesi 2018 (TDMRC), Haiti 2021 (StEER-trained local enumerators), Morocco 2023 (embedded local experts) - represents a qualitative change in how international collaboration is structured. The academia-industry balance has also evolved: industry representatives have remained a consistent component of teams throughout, but ECR participation has grown substantially, reflecting both EEFIT's growing role as a training ground for earthquake engineers, providing irreplaceable hands-on engagement with real damage, and the expanding pool of doctoral programmes.

Women were non-existent in teams till late 90's while they represented approximately 24% ofmission participants in aggregate in the next decade and a half, rising to 37% post-2014. Individual mission peaks include Aegean 2020 (54%), Amatrice 2016 (53%), and Türkiye 2023 (42%). Early-career researchers represented approximately 11% of pre-2014 participants, rising to 26% post-2014. The Aegean 2020 (65% ECR) and Zagreb 2020 (60%) missions demonstrated that ECRs can lead working groups and contribute substantively to analysis when supported by structured hybrid workflows; they also demonstrated that high ECR proportions require deliberate mentorship to maintain analytical depth. The tension between EEFIT's roles as a data-collection operation and as a training platform for UK earthquake engineering is one it has managed pragmatically rather than resolved theoretically.

4. Evolving the Practice of Reconnaissance: Hybridisation, Remote Sensing, and Longitudinal Design since 2014

The decade since 2014 constitutes the most concentrated period of methodological experimentation in EEFIT's history. The changes reflect both external pressures and the growing maturity of RS, mobile data capture, and digital collaboration tools. EEFIT's hybrid and remote developments were parallel to and drew from work by EERI, StEER, GEER, and others (Wilkinson, 2020), rather than occurring in isolation.

4.1 Hybrid and Remote Reconnaissance: Field and RS in Two-Way Dialogue

The Aegean 2020 mission operationalised a hybrid workflow coupling locally gathered field data with remote analyses drawing on satellite imagery, volunteered digital sources, and social-media analytics (Aktas et al., 2022). The mobile app-based field data captured building-level information at standardised taxonomic depth, but coverage in areas accessible only to local teams depended on their training and supervision, and validation against expert field assessment was partial. Haiti 2021 operationalised a remote-first methodology, extending coverage into areas inaccessible to international teams but raising questions about training adequacy, enumeration reliability, and the transferability of damage classification systems across institutional and linguistic contexts (Whitworth et al., 2022).

The evolution of RS use across Phase 3 moves beyond a simple field-support model toward a conceptually more sophisticated two-way dialogue. RS products - InSAR-derived displacement, optical damage proxy maps, multispectral analysis - are not merely supplements to field observations; they generate spatial coverage and temporal monitoring that field surveys cannot match, and they pose independent analytical questions about resolution, change detection, and uncertainty propagation. Field data, in turn, plays an essential role in validating, calibrating, and developing RS tools: ground-truth observations enable the refinement of damage classification thresholds, the identification of systematic RS biases, and the development of methods for applying RS analyses in future events with similar physical and geomorphological contexts. Cutting-edge methodological contributions have emerged directly from EEFIT-collected datasets: Giardina et al. (2023) demonstrated a new approach combining SAR data with field survey observations for simultaneous building damage assessment and landslide mapping, while Macchiarulo et al. (2025) developed a novel machine learning method using solely post-event very high resolution SAR imagery to classify building-level damage at regional scale, achieving up to 72% accuracy on unseen regions when trained on EEFIT Haiti 2021 and Türkiye 2023 data. The Türkiye 2023 RS Working Group operationalised this dialogue through real-time product fusion and field-RS cross-validation protocols, which are documented in Voelker et al. (2024). Fully standardising accuracy and representativeness reporting in RS-assisted reconnaissance across the community remains an active research problem.

Alternative data sources - social media, crowdsourced imagery, CCTV, drone footage, community enumeration - have been integrated into EEFIT missions since Aegean 2020. Their potential value for rapid damage characterisation, population impact assessment, and sentiment and needs analysis is real, but their reliability, systematic integration, and limits are not yet well enough understood to support unqualified operational use. The 2022 research topic on hybrid reconnaissance in this journal, edited by Aktas and So (2022), documented both the progress and the open questions; the community consensus is that these sources require context-specific validation and that damage bias in remotely gathered data is often higher than missions intend.

4.2 Return and Longitudinal Mission Design

The last decade has seen a more systematic commitment to revisiting affected regions. The 2022 return to Nepal (Adhikari, 2022) evaluated progress since Gorkha 2015. The 2022 missions to Thailand and Indonesia examined long-term reconstruction following the 2004 Indian Ocean tsunami and 2018 Palu events. The Türkiye 2023 mission formalised longitudinal design from the outset, planning explicitly for phased return visits. The methodological challenge of longitudinal reconnaissance - maintaining comparability across intervals during which teams, communities, and built environments all change - is more acute than single-mission reconnaissance acknowledges. Pre-agreed observation frameworks, site registries, and documentation standards are essential but have not been consistently maintained across the EEFIT archive. Developing shared protocols with EERI, StEER, and other partners is a near-term priority.

4.3 Local Partnerships, Capacity Building, and Multilingual Dissemination

The shift from ad-hoc local involvement to institutional co-production is fundamental and analytically consequential. Behind it lies a conscious strategic logic: to maximise spatial and thematic coverage, make efficient use of limited resources, avoid placing undue burden on local hosts, and ensure successive missions build cumulative knowledge rather than repeating the same findings. Haiti 2021 demonstrated that community-based data collection can expand coverage and build local analytical capability simultaneously. Türkiye 2023 produced a Turkish-language extended summary for municipal officers and civil society (Aktas et al., 2024b). Similarly, the report produced remotely in international collaboration following the 31 August 2025 Eastern Afghanistan report has an extended summary in Pashto (Rafi et al., 2026). Morocco 2023 embedded local experts in EEFIT field pods with a UKRI-supported follow-on programme. These developments reflect a broader shift toward equitable, community-centred practice, though the gap between co-authorship and genuinely co-designed research - where analytical frameworks are jointly developed from the outset - remains a recognised challenge across the field.

5. Impact Pathways: Demonstrated and Aspirational

The methodological shifts across three phases have expanded EEFIT's potential to shape practice, policy, education, and knowledge infrastructure. The following sections distinguish, where the evidence supports it, between documented impacts and aspirational ones.

5.1 Professional Practice and Codes

EEFIT findings have contributed to engineering guidance and comparative insights relevant to seismic code revision. The progression from Kocaeli 1999's documentation of non-ductile RC failures to Türkiye 2023's longitudinal analysis of persistent soft-storey failures in nominally compliant new buildings illustrates how repeated reconnaissance to the same country builds an evidential record that single missions cannot provide. Comparable contributions trace to L'Aquila (heritage masonry retrofitting), Nepal (owner-built reconstruction consistency), and Sulawesi (land-use planning on liquefiable coastal soils). The causal chain from reconnaissance findings to code changes are, however, typically long and mediated by regulatory and political processes that EEFIT does not control, and attributions are difficult .

5.2 Policy and Recovery Governance

Return and longitudinal missions reveal how reconstruction strategies and quality have been shaped not only by engineering constraints but by financing, permitting pathways, governance capacity, supply chains, and socio-political priorities. The return mission of Nepal in 2022, the Indonesia-Thailand recovery missions, and the Türkiye 2023 study each contributed to this evidence base. Systematic evidence of policy uptake is not consistently collected; this knowledge gap is itself a methodological priority for the reconnaissance community in the future.

5.3 Education, Training, and Capacity Building

EEFIT's academia-industry structure has been central to its role in developing the next generation of earthquake engineers through exposure to real post-earthquake environments throughout. Industry representatives contribute applied expertise that academic-only teams cannot replicate; academic members contribute analytical frameworks and longitudinal research continuity that practitioner engagements alone do not sustain. The ECR development dimension - reflected in dedicated ECR chapters in mission reports from Gorkha 2015 onward - has attracted dedicated research funding: EEFIT missions have been supported by EPSRC, NERC, UKRI International, and GCRF grants that explicitly identified ECR development and capacity building as research objectives, embedding reconnaissance within funded research programmes rather than treating it as an ancillary activity. The EPSRC "Learning from Earthquakes: Building Resilient Communities Through Earthquake Reconnaissance, Response and Recovery" programme (EP/P025641/1, EP/P025234/1 and EP/P025951/1) exemplifies this model, supporting the Nepal 2022 return mission and the Türkiye 2023 hybrid mission among many others. The growth in ECR participation - from 11% to 26% - has created a training pipeline for UK earthquake and tsunami engineering. Haiti 2021 and Myanmar 2025 demonstrated that local enumerators and regional universities can contribute meaningfully when supported by standardised tools and shared taxonomies. EEFIT functions as one vehicle for UK training alongside, rather than uniquely replacing, EERI exchanges, specialist postgraduate programmes, and bilateral collaborative research.

5.4 Knowledge Infrastructure and Open Dissemination

Extended local-language summaries, open geospatial datasets, RS-derived damage classifications, and validated typology catalogues support a broader research ecosystem. Whether these resources are accessed and used by their intended audiences, and whether their quality and accessibility are sufficient for the range of users they are designed to serve, are empirical questions that systematic evaluation would need to address.

6. Open Questions and Future Directions

The four-decade archive documented here raises questions that belong to three distinct registers: ongoing methodological work specific to EEFIT; broader evolution of field reconnaissance practice across the international community; and the ethical and political dimensions that all reconnaissance programmes will need to address more formally in the years ahead.

6.1 Ongoing methodological work: priorities specific to EEFIT

Two interconnected methodological challenges require near-term attention within EEFIT's own practice. The first concerns longitudinal design. Return missions currently produce findings that are suggestive rather than systematically comparable to their immediacy counterparts, because observation frameworks, site registries, and documentation standards are not pre-agreed and maintained across the interval between deployments. Team composition changes substantially over multi-year periods, and what was observed in 2015 in Nepal was not always recorded in ways that permitted direct comparison with 2022 revisits. Developing shared longitudinal frameworks collaboratively with EERI, StEER, and other partner organisations - and testing them in upcoming return missions - is a concrete, achievable near-term goal that would substantially increase the scientific value of EEFIT's growing portfolio of return studies.

The second concerns the coherence of the academia–industry partnership as missions grow larger and more methodologically complex. Phase 1 missions of five or six volunteers operated with relatively flat coordination structures; the 33–36-person distributed teams of Phase 3 carry substantially greater coordination costs, involve multiple working groups with different methodological norms, and require quality assurance across field, hybrid, and remote data streams simultaneously. The volunteer model has proved remarkably resilient, but whether it can sustain the analytical coherence required for complex multi-hazard, multi-modal missions over the long term is a genuine operational question that EEFIT's governance structures will need to address explicitly.

6.2 Evolution of field reconnaissance practice: community-wide challenges

EEFIT's methodological developments sit within a broader community-wide challenge: how to characterise the accuracy and representativeness limits of hybrid and remote reconnaissance, and how to communicate those limits to the practitioners and policymakers who use the findings. Immediate post-earthquake reconnaissance has always required transparency about coverage gaps and sampling choices; remote and hybrid methods introduce additional sources of uncertainty - in RS product accuracy, in community enumeration reliability, in the representativeness of social media datasets - that are not yet captured by consistent disclosure standards. The review by Aktas and So (2025) in this journal addresses related questions for alternative data collection methods, but the broader challenge of shared uncertainty standards usable by non-specialist audiences remains unresolved across EERI, GEER, EEFIT, and comparable organisations. EEFIT is well-positioned to contribute to the development of such standards through its standing RS Working Group and its comparative experience across field, hybrid, and fully remote deployments.

6.3 Ethical and political dimensions: the necessary frontier

The most fundamental challenges ahead are ethical and political. Post-earthquake reconnaissance has historically operated in a framework of implicit permission: teams arrive in affected areas, collect data, and publish findings without formal community consent processes, on the assumption that rapid data collection serves the public good. That framework is increasingly contested. Questions of data sovereignty - who owns the damage survey data collected in a community, and who controls its use - are becoming live as affected governments and civil society organisations develop their own analytical capabilities and begin to ask them. The reuse of imagery collected by EEFIT teams, or by RS satellites, without explicit permissions from the communities depicted, is a legal and ethical exposure that the reconnaissance field has not adequately addressed.

Co-production arrangements, which EEFIT has progressively developed since Sulawesi 2018, represent a meaningful step toward more equitable practice - but the literature on research co-design in disaster contexts is clear that co-authorship does not automatically translate into co-ownership of analytical frameworks or equitable benefit from resulting publications. The gap between partnership rhetoric and genuinely joint analytical design is a recognised challenge across the field, and EEFIT's emerging model will need to engage with it explicitly, including through structures that ensure in-country partners have real influence over research questions, dissemination strategies, and the use of findings in policy advocacy.

A further dimension that reconnaissance programmes have not adequately addressed is the social and cultural context of disasters and the communities affected by them. Engineering-led teams bring essential structural and geotechnical expertise, but the social, cultural, and governance dimensions of disaster impact and recovery lie largely outside the core competencies of most EEFIT participants. A more coordinated, genuinely multidisciplinary approach - embedding engineers and geologists alongside social scientists, anthropologists, and public health specialists as equal analytical contributors rather than peripheral additions - is a clear future direction for EEFIT and for the wider reconnaissance community. Such an approach would not only enrich findings but would better equip teams to recognise and respond to the community contexts in which they are operating.

Finally, the political conditions under which reconnaissance operates are changing. The Myanmar 2025 and Afghanistan 2025 remote missions were necessitated in part by the absence of diplomatic access and the security risks of international field presence in conflict-affected contexts. As climate change, urbanisation, and geopolitical instability interact to increase both the frequency of damaging events and the complexity of the contexts in which they occur, the reconnaissance community will need clearer frameworks for operating responsibly in politically fragile environments - frameworks that address not only the safety of deployed teams but the potential for findings to be used in ways that harm the communities they are intended to serve.

7. Conclusions

This paper has examined EEFIT's methodological evolution across four decades and approximately 50 missions through a three-phase periodisation grounded in the mission archive. EEFIT was founded as an academia-industry collaboration - a defining feature that has shaped its capacity, its limitations, and its role in educating future professionals throughout.

Phase 1 (1982-c.1999) established a structural-engineering reconnaissance template through missions including Mexico City 1985 and Kocaeli 1999, producing some of the most cited early literature on non-ductile RC performance. Phase 2 (2000-c.2019) substantially expanded scope: the Indian Ocean 2004 mission established tsunami reconnaissance; L'Aquila 2009 and its return contributed to the emerging community debate on multiple missions; Tōhoku 2011 and 2013 explored longitudinal recovery analysis in a format still developing across the community; Gorkha 2015 extended EEFIT into multi-hazard mountain environments; Amatrice 2016 marked a demographic shift; and Sulawesi 2018 achieved EEFIT's first fully co-produced mission with an in-country institutional partner. Phase 3 (2020-present) was precipitated by COVID-19 travel closures but sustained by financial constraints, politically fragile operational environments, and the absence of diplomatic access in conflict-affected contexts. It defines a new operating model: remote and hybrid workflows as standard tools, RS as an independent analytical component in bidirectional dialogue with field data, and alternative data sources as an actively explored but still open research question (Aktas and So, 2022). Longitudinal design is now planned from the outset rather than decided retrospectively.

The next phase will require sustained engagement with multi-hazard complexity, AI-assisted RS data processing, and the equitable and ethical framing of co-production relationships. EEFIT's three-phase heritage provides a foundation that is richer for being read critically.

Competing interests

The authors declare no competing interests.

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Data availability

All EEFIT mission reports and associated lecture materials referenced in this paper are publicly available through the Institution of Structural Engineers at www.istructe.org/resources.

Author contributions

Y.D. Aktas: Conceptualisation, Writing – original draft, Writing – review and editing. M.R.Z. Whitworth: Writing – review and editing. E. So: Writing – review and editing.

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