The National Disaster-Warning Case Study on heain-core

The Earthquake of 28 March 2025 and the Collapsed Building Replaying the Real Event on a 34-Node Simulation, from the First Minute through 45 Days of Rescue to the Prosecutor: with Core Round C6

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Date: 29 October 2026
Implementation: heain-core 3329b2f (Go 1.26), HP Z840
Repository: github.com/JakkritB/heain-core (casestudies/disaster/, e3.sh)

Abstract

The Sagaing Fault earthquake in Myanmar on 28 March 2025 brought down a high-rise under construction in Bangkok's Chatuchak district at 13:20. DDPM's warning went out 82 minutes later, as SMS in rounds [7]. The count of the missing moved between 81 and 117: there was no central list of who was on site, and the site office's records were destroyed with the building [8]. People reported 14,430 cracked buildings in 72 hours [10], and the case reached the prosecutor on 22 July 2026 [8]. This Volume 7 of the case study [1] reports the replay of this event (series E3).

The author replayed the event on three time scales (1 hour = 1 minute for the first 3 days, 1 day = 1 minute for the rescue, 1 month = 1 minute for the case) on a 34-node layout with gate-log Micro Nodes at two sites and a building-inspection unit, in two runs: "as it happened" and "with HEAIN". Requirements R19–R27 test the first minute, conflicting sources, records that must survive a destroyed machine, the count of the missing, temporary approvers, public reports and case evidence.

The first run on core C5 found the two expected gaps: 4 gate entries were lost with the site's machine, acknowledged before the office had them, and a foreign team's approver right did not end when the team left. Core C6 (f6c46ec) added acknowledgement once the parent has an entry (durability parent) and approver rights that expire (roles.approver_expiry). After the fix the HEAIN run passed 26 of 26 checks with no gap. The first CAP went out in the event's 2nd minute instead of the 85th; all 160 gate entries reached the office with no name lost; the count of the missing matched the simulation's truth at every point; unsafe buildings were closed 0.1 hours after the first report once an engineer confirmed, instead of 26.6; and all 8 case records were kept.

Keywords: *HEAIN Framework, heain-core, Earthquake 2025, Building Collapse, Event Replay, Durability, RPO, Missing Persons Roster, Approver Expiry, Legal Hold, Chain of Custody*

1. Introduction

1.1 Background

The floods of Volumes 4 and 5 came slowly; the system had hours or days before the water arrived [2][3]. An earthquake is different. Everything that matters happens in the first minute, followed by a 45-day rescue and an investigation lasting more than a year. This event therefore tests the HEAIN Framework on three time scales: the speed of a warning in minutes, the accuracy of the list of the missing in days, and the survival of evidence in years.

The event also has a feature no other event in the series has: the machine that held the most important data was destroyed by the event itself. The site office that knew who was inside collapsed with the building. A system designed to keep working when cut off must therefore answer a harder question: where is the data written a few seconds before the machine vanished?

1.2 Why this event

Table 1 summarizes the figures that make this event a good test. Many were uncertain from the start, such as the magnitude two sources reported differently and the count of the missing that changed for weeks. That uncertainty is exactly what the system must handle.

Figure	Meaning	Source
M7.7 / M8.2	The magnitude USGS reported, and that TMD reported at first: two sources that disagree	[8]
82 minutes	From the earthquake (13:20) to DDPM's message reaching the regulator (14:42); first SMS round at 14:44, about 200,000 numbers per round	[7]
81–117 people	The count of the missing, which moved during the rescue because there were many subcontractors and no central list	[8]
14,430 cases	Reports of cracked buildings through Traffy Fondue in 72 h (Chatuchak 1,410, Huai Khwang 859)	[10]
83%	Share inspected by 31 Mar 15:00	[10]
45 days	The rescue, before the site was handed to the police (13 May 2025)	[8]
About 40,000 t	Debris of the building	[9]
22 Jul 2026	The case reached the prosecutor (procedural step as reported)	[8]

Table 1 — Key figures of the earthquake of 28 March 2025

1.3 Status of this volume

This deployment is the author's hypothetical design, not a project of any agency, and no agency has reviewed it. The investigation and the case appear in this volume only as allegations and procedural steps as reported; there is no verdict. No person, company or building owner is named; the building is called "the collapsed building". The site, subcontractors, workers, lists, reports, drawings, drawing changes, material samples and the foreign team in the simulation are all synthetic. The difference between the two runs is not a criticism of the people who worked in the real event.

1.4 Research questions

- **RQ1 The first minute.** How fast can official data at the Primary send CAP from a pre-approved template to the affected area, when two sources report different magnitudes?
- **RQ2 Who was on site.** Does the list of who was on site survive the destruction of the building and the site's machine, and how close does the count of the missing, reconciled from several lists, come to the truth?
- **RQ3 Authority that changes during the event.** Are the change of command from province to district and the foreign team's temporary right limited, and does the right end by itself?
- **RQ4 Public reports.** Do tens of thousands of reports, untrustworthy on their own, lead to closing a building only when an engineer confirms, and how fast?
- **RQ5 Case evidence.** Are the records and evidence the case needs kept in full until it reaches the prosecutor, while other records are pruned by age?

1.5 Contributions

1. A summary of the real event over three periods and 5 systemic failures, with requirements R19–R27 (Sections 2 and 3).
2. The 34-node e3 layout, three time scales, three new apps, and predictions before running (Section 4).
3. The first run on core C5 and its two gaps, traced to their causes in the code (Section 5).
4. Core round C6: durability parent and roles.approver_expiry, with the reruns (Section 6).
5. Final results, lessons, and proposals for construction sites and building inspection (Sections 7 to 10).

2. The Real Event

This section summarizes the event from the reports cited. Many figures differ by source and by the time they were reported; the author cites each source and does not pick one. Figure 1 shows the reported events over three periods, alongside what happened in the HEAIN run.

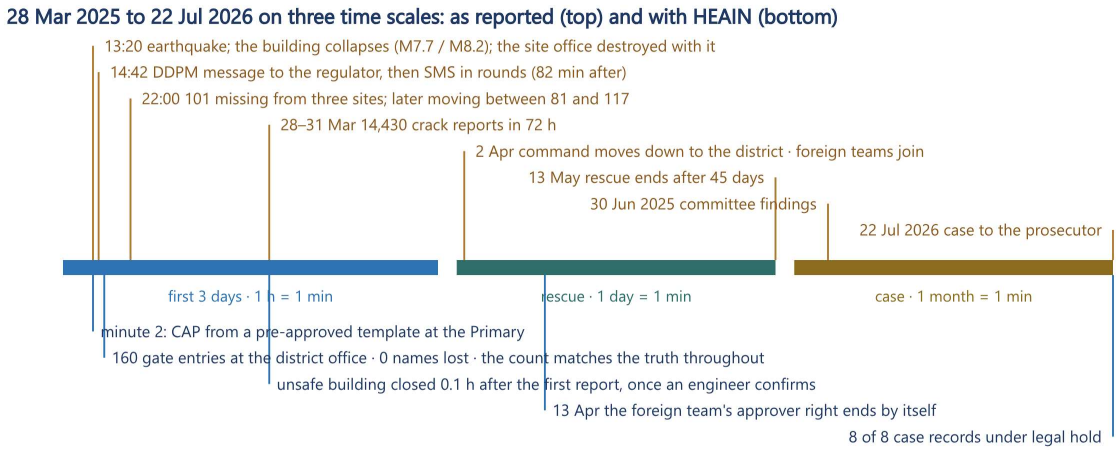


Figure 1 — Events as reported (top) and what the system did in the HEAIN run (bottom), on three time scales

2.1 The first minute and the warning

The earthquake came from the Sagaing Fault near Mandalay. USGS reported M7.7, while the value TMD reported at first was M8.2 [8]. At 13:20 a 30–33-storey building under construction in Chatuchak collapsed entirely [8]. DDPM's message reached the regulator at 14:42, 82 minutes after the event, and the first SMS round went out at 14:44, reaching about 200,000 numbers per round [7]. Thailand had no Cell Broadcast yet, and no pre-approved message template for earthquakes, so every message had to be drafted and approved after the event.

2.2 Who was on site

At 22:00 on the first night, Bangkok's command centre reported 10 dead, 16 injured and 101 missing from three construction sites. The counts of the missing and of workers moved between 81, 96, 101, 103 and 117, because there were many subcontractors and no central list of who was on site; migrant-worker groups said they could not trace their members [8]. The records in the site office were destroyed with the building. A year on, the figures for dead, missing and survivors still existed in two differing sets (95/1/9 and 93/3/8) [8].

2.3 Command and rescue

On 2 April command moved down from the provincial-level centre (Bangkok) to Chatuchak district [8]. The rescue used life detectors, K9 dogs, drones and heavy machinery on about 40,000 tonnes of debris, with teams from the United States, Israel, Japan and China [9]. The rescue ended after 45 days on 13 May, and the site was handed to the police [8]. The foreign teams thus had a part in on-site decisions for a period only, and then left.

2.4 Building inspection across Bangkok

Between 28 and 31 March people reported cracks through Traffy Fondue in 14,430 cases in 72 hours; 83% had been inspected by 31 March 15:00, and the districts with the most reports were Chatuchak

(1,410) and Huai Khwang (859) [10]. News reports cited orders suspending the use of 34 buildings [11], which the author has not checked in detail. These reports are valuable for showing where to inspect, but a single report is not reason enough to close a building; engineers must screen them before any closure.

2.5 The investigation

This part covers only the procedural steps as reported [8]. The investigating agency took the matter as a special case on 2 April 2025; a steel plant was searched on 11 April, and some steel test results were reported below standard. Reports cited several drawing changes, and questions about supervision and signatures of certification. Arrest warrants were sought on 13 May; a committee announced its findings on 30 June 2025, citing flaws in design and construction method; and on 22 July 2026 the case reached the prosecutor. All of these are allegations and steps; there is no verdict. What the event tells the system is that evidence such as changed drawings, certifying signatures and material samples must survive for years with a chain of custody.

2.6 Systemic failures

1. **The public was warned 82 minutes late,** by SMS in rounds, because there was no Cell Broadcast yet and no pre-approved template.
2. **No account of who was on site.** The data was spread across many subcontractors, so the count of the missing did not settle for weeks, and the site's records were destroyed with the building.
3. **Command changed level mid-event,** from province to district, with foreign teams joining temporarily.
4. **A flood of public reports,** 14,430 cases in 72 hours, which engineers, a trustworthy source, had to screen before any building was closed.
5. **Evidence that must last years.** Changed drawings, certifying signatures and material samples need a chain of custody, and their retention must win over age-based deletion.

3. Requirements

The five failures become nine requirements (R19–R27) [6], following R1–R18 of the Hat Yai and Bangkok events. Table 2 shows each requirement and the prediction before running against core C5.

#	Requirement	Prediction against core C5
R19	TMD's official data at the Primary sends a pre-approved CAP template to the affected area within minutes	pass (C1 H7 7.9 s, allowlist)
R20	Two sources disagree (M7.7, M8.2): both values are recorded; the system does not choose	pass (core keeps evidence, does not interpret values)

#	Requirement	Prediction against core C5
R21	Per-person gate log on a Micro Node at the site; if the building collapses, the list of who is inside must survive	probable gap: an event is acknowledged when written to its own node and reaches the parent later
R22	Reconcile the count of the missing from several lists (contractors, relatives, signals) as personal data, with access control and destruction at the end	pass (app + data class in the Zone, consent, crypto-shred)
R23	Command moves down from province to district on 2 April; the audit shows who held authority when	pass (approvers per subtree through P5)
R24	A foreign team joins temporarily: its right expires by itself, is limited to a Zone and is revoked at the end	probable gap: roles.approvers has no expiry
R25	Public crack reports (untrusted), confirmed by an engineer (trusted), before closure through P5	pass (two-source corroboration, a small app)
R26	Case evidence time-stamped by a TSA, with a chain of custody, and a legal hold that wins over audit retention	pass (TSA, custody, legal hold, C3)
R27	Approving a drawing change needs two engineers; every approval is bound to the approver's certificate	pass (P5 quorum)

Table 2 — Requirements from the earthquake and predictions before running

The author decided that R21 and R24 would run as expected gaps, as R15 did in the Bangkok event, and that new apps would be built for R21, R22 and R25 [6].

4. Simulation Design

4.1 Layout e3

Layout e3 is the 29-node base layout of Volume 1 plus 5 nodes (Figure 2). Chatuchak becomes a detailed Zone with heain-notify and heain-sensor at the district office. Two Micro Nodes keep gate logs at two sites (reports cite three), one Micro Node is a building-inspection unit where engineers sign verdicts, and Huai Khwang district is added as a new Zone, because it had the second-most crack reports.

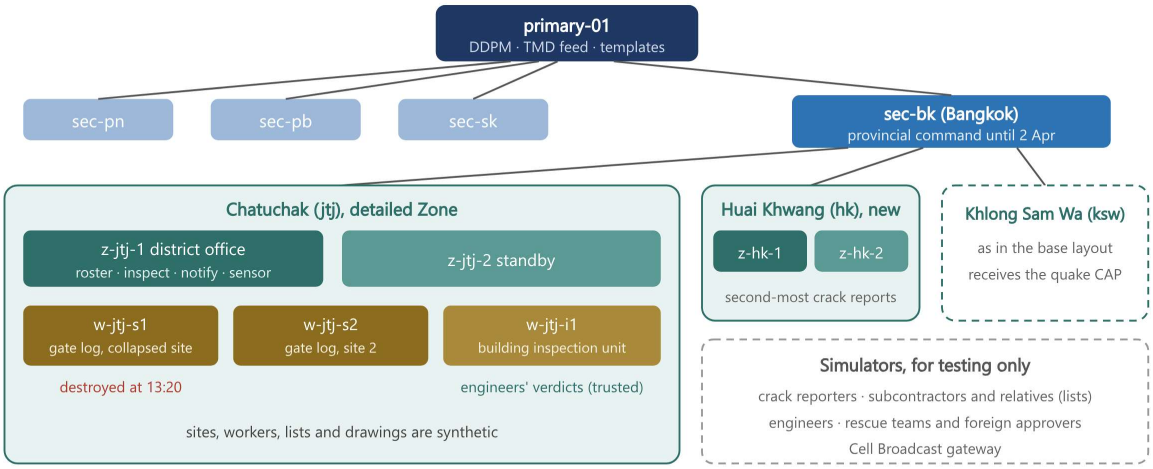


Figure 2 — The 34-node e3 layout: Bangkok in detail

Node	Role	Real-world counterpart
w-jtj-s1	Per-person gate-log Micro Node, destroyed at 13:20	The collapsed building's site office (destroyed with the building)
w-jtj-s2	Gate-log Micro Node of the second site	Reports cite three sites
w-jtj-i1	Building-inspection Micro Node; engineers' verdicts are signed evidence	The district's engineers
z-hk-1, z-hk-2	New Bangkok Zone: office and standby	Huai Khwang district (859 reports)
z-jtj-1, z-jtj-2 (existing)	Chatuchak district office: roster, inspect, notify and sensor	District-level command after 2 April
sec-bk, primary-01 (existing)	Bangkok and the centre: CAP templates, TMD data	Bangkok's command centre, DDPM and TMD

Table 3 — Nodes added in layout e3 and existing nodes with a role in the event

4.2 Timeline

T0 is 28 March 2025 06:00; the earthquake falls at hour 7.33 of the run. The first three days, to 31 March 24:00, run at 1 hour = 1 minute, so in the critical period one minute of the event is one second of the run. The rescue, 1 April–13 May, runs at 1 day = 1 minute, and the case, 14 May 2025–22 July 2026, at 1 month = 1 minute. A full run takes about 147 minutes; a trial uses 10 seconds per hour. Table 4 shows the key events in each period.

Real time	Event in the simulation
28 Mar 13:20	Earthquake: TMD reports M8.2, USGS reports M7.7. The building collapses: Micro Node w-jtj-s1 is deleted with its data
14:42	As it happened: DDPM's message, then SMS in several batches over time
22:00	The command centre's count of the missing, and the roster's snapshot
28–31 Mar	Crack reports from simulated reporters (Chatuchak and Huai Khwang), and engineers' inspections
30 Mar	A foreign team gets an approver right at the Chatuchak Zone through P5 (synthetic date)
2 Apr	Command moves down from province to district; legal hold on the case's records
13 Apr	The foreign team leaves (synthetic date)
20 Apr	The foreign team's right revoked through P5
13 May	Rescue ends; the roster is closed and destroyed through P5
30 Jun 2025–22 Jul 2026	The case: other records pruned by age; case records under legal hold

Table 4 — Key events in each period of the simulation

4.3 The event's apps

- **disapp cap** A CAP 1.2 template [14] for earthquakes, pre-approved through the P5 allowlist at the Primary.
- **disapp feed** TMD's and USGS's reports as two separate pieces of evidence; the system keeps both values without choosing.
- **disapp gate (new)** A per-person gate log at the site, written to the Micro Node's journal.
- **disapp roster (new)** Reconciles the gate logs, the subcontractors' lists and relatives' reports into one list at the district office. Personal data is sealed under a Zone key and destroyed through P5 when the event is closed.
- **disapp inspect (new)** A register of crack reports (untrusted), engineers' verdicts (trusted evidence from w-jtj-i1), and closure proposals that rest on those verdicts.
- **Custody and legal hold** from round 5b and the southern border case [5], for changed drawings and material samples (synthetic), with TSA time-stamping [12].
- **Simulators for testing only** disapp engineers and disapp reporters, subcontractors and relatives, rescue teams, and the Cell Broadcast gateway.

4.4 The as-it-happened run

CAP goes out at 14:42 as several SMS batches with no pre-approved template. The command centre's count of the missing comes from subcontractors' lists that disagree. The gate log is paper in the site office and vanishes with the building. Crack reports are screened by hand at the engineers' pace; a drawing change can be approved by one person; authority moves down on 2 April by a local change; and the audit uses its default retention. The run measures which case records are left on 22 July 2026.

4.5 The HEAIN run

TMD's report at the Primary records M8.2 and the second source records M7.7; both values are kept with the difference. The pre-approved earthquake template reaches Bangkok's Zones within minutes. Gate logs at both sites are on Micro Nodes; the roster reconciles the lists at the district office; crack reports go into a register that merges duplicates; and closure waits for an engineer's verdict (Figure 3). Authority moves down through P5; the foreign team gets a right limited to the Chatuchak Zone; drawing changes need two engineers; and a legal hold is placed on 2 April.

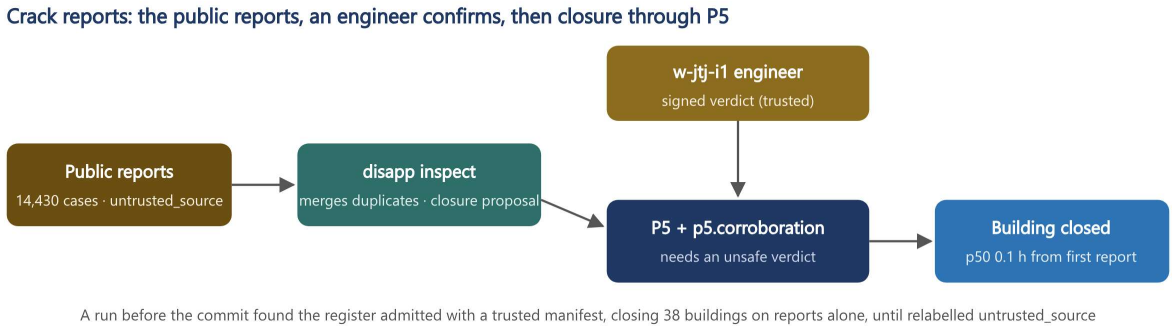


Figure 3 — Crack reports in the HEAIN run: closure needs an engineer's signed verdict

4.6 Procedure and pass criteria

The step script first runs regressions: rounds 0–5b on the base layout and the HEAIN trials of Hat Yai (E1) and Bangkok (E2). It then runs the trials at 10 seconds per hour and the full runs of both modes, and commits only when every run has zero failed checks. Expected gaps do not count as failures but are recorded separately as GAP (expected). Every check uses evidence the system records itself: the audit chain of every node, the Micro Nodes' journals, the apps' databases, the simulated gateway's log, and each run's metrics.json.

5. First Run (core C5)

5.1 What the runs before the commit found

The first run took the script three attempts. The first stopped at the as-it-happened trial: the simulated reporters had no data directory and stopped at start-up; and a pruned record keeps its action but not its trace, so the case's records are now counted as they are written. The second stopped at the HEAIN trial on two checks. At R22, each snapshot of the roster was taken before the

finds up to the same hour were posted, while the truth already counted them (largest error 27), so finds are now posted just before each snapshot. At R25, the report register was admitted with a trusted manifest, so the allowlist closed 38 buildings on public reports alone. Its data class building.report was relabelled untrusted_source, so a closure now waits for an engineer's signed unsafe verdict through p5.corroboration, and an unsafe verdict on a building no report marked severe proposes its closure too. This shows that an app's data labels are what core uses to judge trust. The third attempt passed.

5.2 Full-run results

The full run on core C5 (ed74e31; e3 commit 3e71684) passed 13 of 13 checks as it happened, and 24 of 24 with HEAIN, with the two expected gaps (R21, R24). The trials gave the same results. Every regression passed: rounds 0–5b (25, 53, 31, 56, 39, 26, 34) and the HEAIN trials of Hat Yai (33, with gap G8b already recorded) and Bangkok (26). Table 5 shows the first run.

Measure	As it happened	With HEAIN
Earthquake (13:20) to the first CAP (event minutes)	85 (real 82)	1
Count of the missing at 22:00 on the first night (simulation truth)	96 (103)	100 (103)
Count of the missing on 31 Mar (simulation truth)	104 (90)	90 (90)
Largest error of the count against the truth	14	3
Gate log at the office after the collapse: entries / names lost	lost with the paper	156 / 4
Crack reports / buildings	2,269 / 688	2,269 / 688
Inspected by 31 Mar 15:00	100%	100%
A report's wait for a verdict, p50 / p90 (h)	22.8 / 33.6	23.2 / 34.1
Unsafe buildings closed	12 of 14	12 of 14
Unsafe building: first report to closure, p50 (h)	26.6	0.11
Buildings closed on public reports alone	0	0
Drawing changes approved by one person	3	0
Case records on 22 Jul 2026 / all records pruned by age	1 of 8 / 3,902	8 of 8 / 9,091

Table 5 — First run on core C5: as it happened compared with HEAIN

The reports in the simulation are fewer than in the real event (2,269 cases on 688 buildings), and the simulated engineers finished inspecting before 31 March 15:00 in both runs. A report's wait for a verdict is therefore close in both runs, because the number of engineers is the same. What differs is that once an engineer finds a building unsafe, closure follows at once by rule (0.11 hours from the first report) instead of waiting for another round of paperwork (26.6 hours). More records were

pruned by age in the HEAIN run because the system records more and deletes what is not needed, while the legal hold kept all 8 case records.

5.3 Gaps

Code	What was seen	Cause in the code
R21	156 gate entries reached the office before the site's machine was destroyed, but 4 names were lost: the crew who signed in seconds before the earthquake. They were inside, and the office had no way to know	POST /v1/app/journal/events answers 201 as soon as the entry is in the node's own journal; a background loop forwards it every 3 seconds, so an entry is acknowledged up to about 3 seconds before any other node has it
R24	The foreign team's approver right worked at Chatuchak (200) and was refused in Bangkok (403), as scoped. But when the team left on 13 April the right did not end: the next day it could still approve (200), until revoked through P5 on 20 April	roles.approvers is a list of identities with no time attached. Short-lived certificates expire, but the role is bound to the identity, so a renewed certificate keeps the right

Table 6 — Gaps from the first run

A note on timing. In the first run, the crew who signed in four seconds before the earthquake were compressed to about 0.07 seconds of the run, which no network send could beat. The rerun therefore places the sign-ins before the machine is destroyed in real seconds, as in the event (40–16 seconds), so the test measures what really happened, not an artefact of compressed time.

6. Core Round C6 (f6c46ec)

The author decided the three questions as recommended: fix at once as core round C6; make R21 an option per event that the app chooses; and make R24 a separate Policy key, with roles.approvers unchanged [6].

6.1 R21: a record is safe once the office has it

1. **An event may wait for the parent.** POST /v1/app/journal/events takes durability local (the default; existing apps are unchanged) or parent. With parent, the node writes its journal as before, starts sending at once without waiting for the 3-second loop, and holds its answer until acked_through_seq reaches the entry.
2. **The answer says what is true.** 201 with parent_acked: true once the parent has merged the entry, or 202 with parent_acked: false and state: pending after a timeout (journal.sync_timeout, 2 seconds by default), or at once when the node is STANDALONE, with the reason (timeout, standalone, throttled, unreachable, no_parent). The entry is kept and sent later either way.
3. **Order is kept.** Sends go one at a time through the same mutex as the 3-second loop, so the parent gets entries in order, and several waiting entries can travel in one batch.

4. **Who may ask.** Any registered app, for its own events. The parent still rate-limits journal intake per Zone; a 429 from the parent becomes 202 pending.
5. **The cost of waiting.** One round trip to the parent plus the merge: around ten milliseconds on a LAN and a few hundred on 4G, still faster than a person passing a turnstile.

/v1/app/journal/status counts sync_acked and sync_pending separately. The app can now tell the person at the gate "recorded at the office" or "not there yet: wait or sign the paper", and never claims more than it knows (Figure 4).

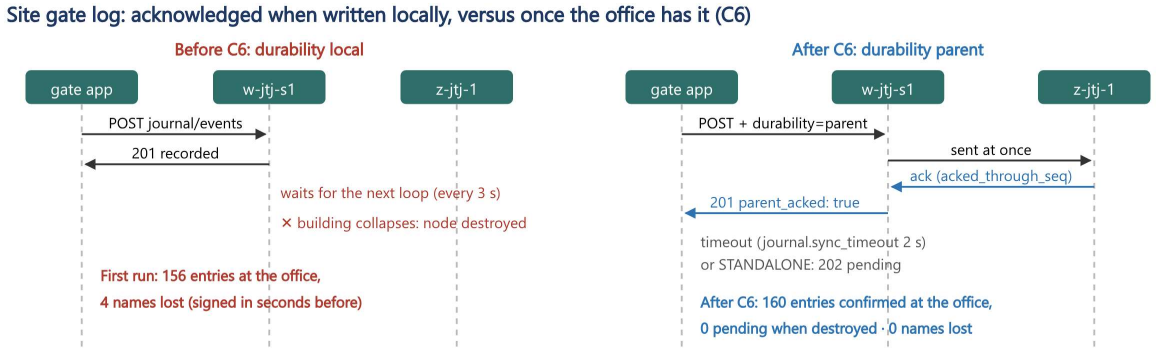


Figure 4 — The site gate log before and after C6

6.2 R24: approver rights that expire by themselves

1. **The new key.** roles.approver_expiry maps an identity to an RFC 3339 time. It changes only through P5 and is inherited by scope in the same way as roles.approvers, which is unchanged.
2. **The check.** From that time the identity is no longer an approver on the node, at the approval endpoints and in relays within the subtree. A refusal is a 403 that says approver_expired and gives the time.
3. **Audit.** roles.approver_expired is recorded once per identity and time, at the moment of expiry, even if no one tries to use the right.
4. **A safety rule.** A change that would leave no approver with an unexpiring right is refused, so the approver list is never empty. If every right ended, an identity matching no certificate would stand in, so the node does not fall back to single-admin mode.
5. **Revocation as before.** Removing the identity from roles.approvers through P5 still ends the right at once, before its expiry.

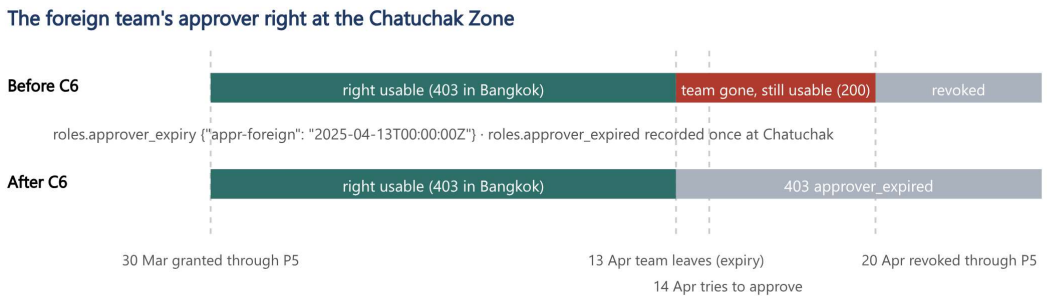


Figure 5 — The foreign team's approver right before and after C6

6.3 The C6 run

A single run passed everything. The regressions: gofmt, the apps, the SDK, notify and sensor, cross-builds for 7 targets, vet, unit tests (including three new ones: TestJournalDurabilityParent, TestApproverExpiredRefusal and TestApproverExpiry), conformance, live tests 51 and 37, the 19 live regressions with test_cert_last_known and test_license, the southern border rounds 0–5b, CineNexus rounds 1, 2, 3, 6 and 7, this case's rounds 0–5b, the Hat Yai trials (22 and 33, with gap G8b as before) and the Bangkok trials (11 and 26). In e3.sh the gate app sends with -durability parent, the crew sign in 40–16 real seconds before the earthquake, and the right's expiry is set with the grant. The result: 13 of 13 as it happened, and 26 of 26 with HEAIN, with no gap; the trials gave the same results (Figure 6).

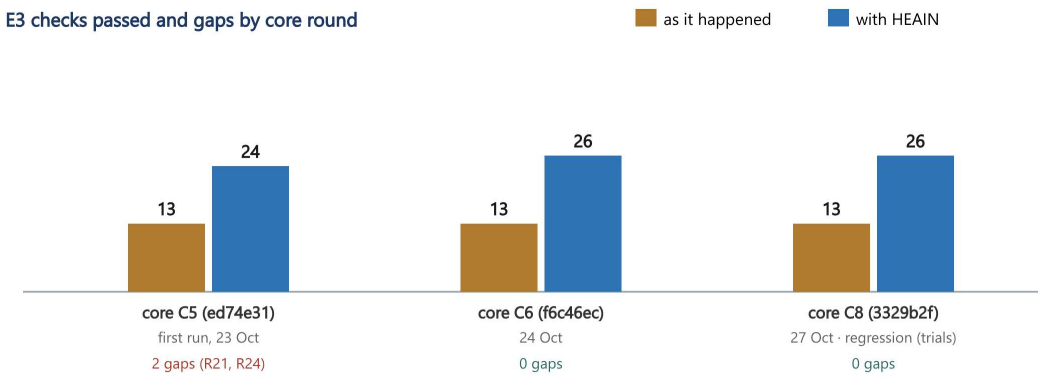


Figure 6 — E3 checks passed and gaps by core round

7. Final Results

7.1 As it happened versus with HEAIN

After C6 the as-it-happened run passed 13 of 13 checks and the HEAIN run 26 of 26, with no gap. The trials gave the same results, and passed again as regressions of core C7, C8 and C10. Table 7 shows the final results, and Figure 7 the count of the missing against the simulation's truth.

Measure	As it happened	With HEAIN (C6)
Earthquake (13:20) to the first CAP (event minutes)	85	2
Count of the missing at 22:00 on the first night (truth 103)	96	103
Count of the missing on 31 Mar (truth 90)	104	90
Largest error of the count against the truth	14	0
Gate log at the office after the collapse: entries / names lost	lost with the paper	160 / 0
Entries confirmed at the office / pending when the site's node fell	not measured	160 / 0
A report's wait for a verdict, p50 / p90 (h)	22.8 / 33.6	23.1 / 34.0
Unsafe buildings closed	12 of 14	12 of 14
Unsafe building: first report to closure, p50 (h)	26.6	0.1
Buildings closed on public reports alone	0	0
Drawing changes approved by one person	3	0
The foreign team's right the day after it left (HTTP)	not tested	403 approver_expired
Case records on 22 Jul 2026 / all records pruned by age	1 of 8 / 3,903	8 of 8 / 9,066
Checks passed / gaps	13 / 0	26 / 0

Table 7 — Final E3 results on core C6: as it happened compared with HEAIN

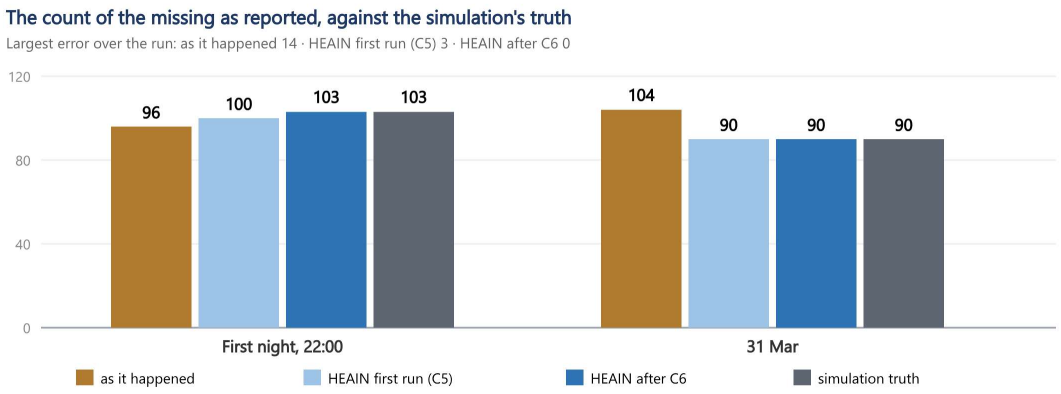


Figure 7 — The count of the missing reported by the system, against the simulation's truth

In the HEAIN run the count of the missing matched the truth at every snapshot, because every gate entry was at the office before the gate answered, and the roster reconciled several sources into one list. In the first run, the error of 3 came from names lost with the site's machine; once C6 closed that gap, the error was zero. The as-it-happened run counted too few on the first night (96 against 103) and too many on 31 March (104 against 90), the same pattern as the shifting count in the real event.

7.2 Results by requirement

#	Result	Evidence
R19	passed	First CAP in minute 2 from a pre-approved template at the Primary
R20	passed	M8.2 and M7.7 kept as two pieces of evidence with their difference; the system did not choose
R21	passed (C6)	160 entries confirmed at the office before the gate answered; 0 pending; 0 names lost
R22	passed	The count matched the truth throughout (largest error 0); data in the Zone, destroyed through P5 at closure
R23	passed	Authority moved from province to district through P5 on 2 April; the audit shows who held it in both periods
R24	passed (C6)	The right worked only at Chatuchak; the day after the team left: 403 approver_expired, recorded once; revocation still works
R25	passed	Closure waited for an engineer's verdict, 0.1 h from the first report; no building closed on reports alone
R26	passed	Changed drawings and material samples (synthetic) TSA time-stamped, with custody, kept in full under legal hold while other records were pruned
R27	passed	Drawing changes approved by one person: 0, against 3 as it happened

Table 8 — Final results by requirement

8. Discussion

8.1 Answers to the research questions

RQ1. The first CAP went out in the event's 2nd minute, because the template was approved in advance and official data needs no one to confirm it. The two conflicting values caused no delay, because the system keeps both and need not choose. **RQ2.** After C6 the list of who was on site survived the destruction of the site's machine, and the count of the missing matched the truth throughout. **RQ3.** Authority moved down through P5 and can be traced; after C6 the foreign team's right was limited to one Zone and ended by itself when the team left. **RQ4.** No building was closed on public reports alone, and once an engineer confirmed, closure came in 0.1 hours instead of 26.6. **RQ5.** All 8 case records were kept until the case reached the prosecutor, while other records were pruned by age.

8.2 Lessons

- **"Recorded" must say where.** The three-second gap between acknowledgement and forwarding does not matter in almost any task, but it matters most when the machine is

destroyed along with what it recorded. C6 lets the app choose per entry, and the answer says plainly where the entry is.

- **A temporary right needs its end built in.** Revocation needs someone to remember to do it. In a 45-day event with teams coming and going, an expiry set together with the grant is safer, and adds a time dimension to Role Ceiling and Duty Profile in the theory of structural immunities [4].
- **A data label is a decision.** A run before the commit showed that a report register wrongly labelled trusted closed 38 buildings on reports alone. Core follows labels faithfully, so an app's labels must be reviewed like rules.
- **Conflicting values need not be resolved before warning.** The system does not need to know whether the magnitude was M7.7 or M8.2 to warn that tall buildings are shaking. Keeping both values for people to judge later is better than choosing wrongly with confidence.
- **Evidence must outlive the operational system.** A legal hold that wins over age-based deletion lets the same system delete what is not needed and keep what the case needs, at the same time.
- **Compressing time can hide the truth.** Four seconds compressed to 0.07 made the gap look unfixable. A simulation must keep the critical moments in real seconds.

8.3 What HEAIN did not fix

HEAIN does not make buildings stronger, does not test material quality, and does not decide who is at fault. The system keeps evidence with its time and signer for those in authority to use. A gate log helps only if everyone passes a gate that records, and reconciling the list depends on how complete the subcontractors' lists are, which is a matter of construction regulation. Workers' personal data, including that of migrant workers, must be protected under the PDPA [15].

8.4 Threats to validity

Internal. The sites, workers, lists, reports and the true number of the missing in the simulation were built by the developer, so the error figures measure the system against data with a known answer, not against the real event. **External.** One machine and a virtual network; the cost of durability parent on real 4G has not been measured. **Measurement.** One full run per mode, with the trials giving the same results. **Context.** The as-it-happened run was built from news reports, not agency records, and the case is simulated only as records that must survive, not as its substance.

9. Proposals for Construction Sites and Building Inspection

These proposals come from the results of this volume and still need to be discussed with the agencies concerned.

- **Gate logs confirmed at the district office.** High-rise construction sites use gates that record with durability parent and show at the gate whether the entry has reached the office.
- **A central list when an event occurs.** A roster at the district office reconciles gate logs with subcontractors' lists at once; the data stays in the Zone, is used for rescue, and is destroyed when the event is closed.
- **A pre-approved earthquake template** at the Primary, with polygons of areas with tall buildings, reviewed every year.
- **Temporary rights always with an expiry.** Every grant to an outside team sets roles.approver_expiry at the same time.
- **A report register labelled untrusted,** and building closures that need an engineer's signed verdict.
- **A legal hold from the first day of an investigation** for decision records, changed drawings and material evidence.

Indicator	Target
Earthquake confirmed by TMD to the first CAP	at most 5 minutes
Gate entries the gate called recorded that the office does not have	0
Error in the count of the missing from the lists available	0
Buildings closed on public reports alone	0
Temporary rights usable after their expiry	0
Case records lost before the case ends	0

Table 9 — Proposed indicators

10. Limitations

- **It is a simulation.** The site's machine is destroyed by deleting a container with its data, not by physical damage.
- **Synthetic data.** Sites, subcontractors, workers, lists, reports, drawings, material samples, the foreign team's dates and the true number of the missing.
- **Two sites of three.** Reports cite three sites; the simulation uses two.
- **Report volume.** The simulated reports (2,269 cases) are fewer than in the real event (14,430 cases).
- **The case.** The simulation keeps records and evidence; it does not model or assess the substance of the case.
- **Time scale.** The case period runs at 1 month = 1 minute, so retention and the legal hold are tested in heavily compressed time.

11. Evidence and Reproducibility

The relevant commits are confirmed with git ls-remote: 3e71684 (layout e3, apps and the first e3.sh run), f6c46ec (core C6) and 3329b2f (core C8, against which the E3 trials passed as regressions). Each round's results are in the progress log and the project's plan and proposal documents [6]. The audit chain uses a transparency log per RFC 9162 [13].

To reproduce, check out heain-core commit 3329b2f, set DIS_LAYOUT=e3, run casestudies/disaster/sim.sh build and up, then run e3.sh in asis and heain modes at 60 seconds per hour for a full run, or 10 seconds per hour for a trial. The test machine needs only Go and Docker.

File on the test machine	Contents
/mnt/xfs_nvme/heain-dis0/sim/e3-asis, e3-heain	metrics.json of each run, every node's log, and the audit chains
~/dis_e3*.out	Results of the first run and the trials
~/c6*.out	Results of core round C6 with regressions
casestudies/disaster/e3.sh, apps/	The event script and the gate, roster and inspect apps
docs/progress-log.md	Each round's results with its commit

Table 10 — Evidence files for E3

12. Conclusion

Replaying the earthquake of 28 March 2025 shows that a pre-approved template puts CAP out in the 2nd minute instead of the 85th, even when two sources report different magnitudes. The event exposed two gaps the designed scenarios missed: a record acknowledged before anyone else had it, and a temporary right with no end. Core C6 closed both. All 160 gate entries reached the office with no name lost, the count of the missing matched the truth throughout, the foreign team's right ended by itself when it left, and the case records were kept in full until the case reached the prosecutor. What remains outside the system is the strength of buildings, the completeness of contractors' lists, and the judgement of the courts.

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