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# Integrated Emergency Response Readiness Through Real-Time Field Intervention Team Drills: A Strategic Framework for Drill Design, Debriefing and The Measurement of Response Capability

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**ABSTRACT:** Employers across Southeast Asia are beginning to demand skills that match a greening economy, not only in environmental professions but across finance, manufacturing, construction, and services. Higher education systems in the region, however, differ sharply in how they equip graduates for this shift. This article compares green skills development policies in six ASEAN countries: Singapore, Malaysia, Thailand, Indonesia, the Philippines, and Vietnam. Drawing on national policy documents, institutional strategies, and the scholarly literature, the comparison is organised around four dimensions: the depth of policy integration, the spread of sustainability content in curricula, investment in faculty development, and the strength of industry links for green skills. The findings show a wide gap between countries where green skills policy is coordinated at the system level (Singapore, Malaysia) and those where ambitious national targets have not yet produced widespread curriculum change (Vietnam, Philippines). Three bottlenecks cut across all six cases: the absence of discipline-specific green competency frameworks outside science and engineering, inadequate investment in training faculty to teach sustainability, and weak mechanisms for channelling green labour market intelligence into curriculum design. The article maps the current policy terrain and identifies leverage points for national reform, institutional strategy, and regional cooperation, including the potential of a regional qualifications framework for green competencies.

**KEYWORDS:** emergency response, drills and exercises, field intervention team, team training, debriefing, simulation, crisis management, response capability measurement, major hazard facilities

## 1. INTRODUCTION

A major hazard facility maintains an emergency response capability that it hopes never to use and that it cannot therefore evaluate against use. The substitute is the drill, and drills accordingly occupy a position in the assurance architecture that is structurally similar to the position of proof testing in the assurance of a protective function: a periodic demonstration, under artificial conditions, that a capability required rarely and urgently is present.

The analogy is instructive because the assurance of protective functions is conducted with considerable rigour. A proof test has a defined coverage, a stated pass criterion, a documented result, and a specified interval derived from the required reliability. Drills, by comparison, are ordinarily specified by frequency alone, are evaluated by observation without defined criteria, and produce a report that records what happened rather than what was established.

The consequence is that facilities can conduct drills diligently for years and remain unable to answer the question the drills exist to answer, which is whether the response capability is adequate. What they can answer is whether the drills occurred, and that is the figure that appears in the assurance reporting.

This paper sets out a framework for field intervention team drills, meaning drills conducted with the response team operating against the live plant rather than in a classroom or against a simulator. Such drills are the most realistic form available and the most operationally demanding, and their design involves a trade between the realism that produces the learning and the disturbance that realism imposes on an operating facility. The framework addresses that trade explicitly and treats the drill throughout as an instrument that produces information, on the argument that a drill programme which does not extract the information has paid the full cost of the exercise for a fraction of its value. Emergency response capability is a mitigation barrier in the risk assessment sense, and the proof-test analogy drawn here is not merely rhetorical: instrumented protective functions are assured through periodic demonstration at an interval derived from a required reliability, and no equivalent derivation exists for response capability (International Electrotechnical Commission, 2016; Center for Chemical Process Safety, 2001; Rausand, 2011; Petroleum Safety Authority Norway, 2013). The wider industrial assurance literature makes the same move for physical assets, deriving inspection and test intervals from condition evidence rather than from habit, and the parallel is worth stating because response capability remains the one barrier commonly assured by calendar alone (Atta et al., 2020; Atta, Tofah, & Adenuga, 2021; Atta et al., 2022; Omoegun et al., 2023; Sunday et al., 2020; Sunday & Omoegun, 2022; Oyeleke, Eze, & Asiedu, 2026; Yeboah et al., 2024).

## 2. LITERATURE REVIEW

### *2.1 What the Training Research Establishes*

The team training and simulation literature is substantially more developed than the drill literature in the process industries and its findings transfer with little modification.

#### *2.1.1 Debriefing*

The first and most actionable finding concerns debriefing. Structured debriefing after a training event produces a substantial improvement in subsequent performance, and the meta-analytic evidence indicates that the effect is large relative to other design features of the training itself (Tannenbaum & Cerasoli, 2013). The finding is robust across military, medical and organisational settings. Its bearing on drill practice is direct and uncomfortable, because the debrief is the element most commonly truncated when a drill overruns, and the truncation removes the component carrying the largest share of the effect. The same asymmetry appears in the industrial safety record, where the systems that capture near-miss and hazard observation data are considerably better developed than the organisational learning processes that would convert the data into changed practice (Arumosoye & Obriki, 2019, 2021; Obogo, Arumosoye, & Obriki, 2021; Obriki & Arumosoye, 2024b).

#### *2.1.2 Measurement*

The second concerns measurement. Performance measurement in simulation-based training has been developed to a level of specificity that permits observable behavioural markers to be defined in advance and scored during the exercise, rather than impressions being recorded afterward (Salas, Rosen, Held, & Weissmuller, 2009). The relevant methodological point is that measurement must be designed into the scenario, since a behaviour that the scenario does not require cannot be observed, and a scenario written without reference to what is being measured will produce observation of whatever happened to occur. Industrial safety measurement has moved in the same direction, specifying observable leading signals and continuous data streams in place of retrospective impression, which is the same methodological commitment applied to a different observation window (Obriki & Arumosoye, 2023; Obriki, Arumosoye, & Obogo, 2023; Obriki, Arumosoye, & Ozobu, 2025; Obogo et al., 2025a).

#### *2.1.3 Decision-focused exercise design*

The third concerns the design of decision-focused exercises. Tactical decision games and similar low-fidelity formats have been shown to develop decision-making capability in emergency contexts at a fraction of the cost of full-scale exercises (Crichton, Flin, & Rattray, 2000). The implication for drill programmes is that the full-scale live drill is the wrong instrument for developing decision capability, which can be exercised more frequently and more cheaply in other formats, and the right instrument for testing the physical and coordinative elements that only a real deployment exercises. Programmes that use full-scale drills to develop decision-making are using an expensive tool for a task a cheap one performs better. The cost argument for low-fidelity formats is made in similar terms across the wider training literature, where simulation-based instruction is valued precisely because it decouples practice frequency from the cost of the real setting (Ebhojie, Dogbatsey, & Oyeleye, 2023b; Dada, Isiekwu, & Oluwo, 2024; Orise & Niniola, 2026).

#### *2.1.4 Learning in crisis simulation*

The fourth concerns individual and group learning in crisis simulation, where the evidence indicates that the learning obtained depends heavily on how the exercise is framed and processed rather than on its fidelity alone (Borodzicz & van Haperen, 2002). Perry (2004) reaches compatible conclusions in examining exercise outcomes across professional and volunteer responders. The general training effectiveness literature supplies the surrounding evidence on what makes training work (Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012). How an exercise is framed and processed is itself a design variable rather than a matter of facilitator disposition, and the instructional design literature treats it as one (Orise & Niniola, 2020, 2022).

#### *2.1.5 Decision making under time pressure*

A sixth strand supplies the account of what is being developed. Emergency response decisions are made under time pressure with incomplete information, and the recognition-primed account holds that experienced responders match the situation to a known pattern and retrieve an associated response rather than comparing options (Klein, 1998). The conditions under which such expertise is reliable, namely a sufficiently regular environment and the availability of feedback, are exactly the conditions a drill programme exists to manufacture, since real emergencies supply neither regularity nor frequency (Kahneman & Klein, 2009). The situation awareness framework identifies what a drill should be observed to develop, since the failure mode in emergency response is more often the comprehension and projection levels than the perception of the initiating event (Endsley, 1995). And the high reliability literature supplies the organisational counterpart, in which the capacity to respond is one of several abilities a resilient organisation maintains rather than a standalone function (Weick & Sutcliffe, 2007). The fifth strand concerns command and team performance under emergency conditions specifically, where the applied literature establishes the competence categories that distinguish effective from ineffective incident command and provides the vocabulary in which drill observation can be structured (Flin, 1996; Flin, O'Connor, & Crichton, 2008). The team training evidence base is larger and more consistent than the drill literature suggests. Meta-analytic synthesis establishes that team training improves team performance across settings and outcome types, with effect sizes large enough to justify the investment (Salas et al., 2008a, 2008b), the science of training has been reviewed across successive decades (Salas & Cannon-Bowers, 2001; Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012; Arthur, Bennett, Edens, & Bell, 2003), and crew resource management specifically has been evaluated with attention to what transfers and what does not (Salas, Wilson, Burke, & Wightman, 2006). Team cognition supplies the mechanism, since shared mental models and coordinated process rather than individual skill account for much of the performance difference (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; DeChurch & Mesmer-Magnus, 2010; Marks, Mathieu, & Zaccaro, 2001; Salas, Sims, & Burke, 2005; Cannon-Bowers & Salas, 2001). Sector-specific treatments address the same capability from the operations side. Emergency response readiness and capability has been modelled conceptually for energy and process facilities (Arumosoye & Obriki, 2023), evacuation and preparedness systems have been reviewed for high-occupancy environments (Obriki, Obogo, & Arumosoye, 2022a), and workforce safety training models have been examined for operational risk reduction (Obriki, Obogo, & Arumosoye, 2022b). Coordination research in fast-response settings supplies the mechanism a drill exercises. Dynamic delegation describes how authority shifts within a team as a situation evolves, which is what a well-run response actually looks like (Klein, Ziegert, Knight, & Xiao, 2006), collective mind names the interrelating that sustains it (Weick & Roberts, 1993), coordination in fast-response organisations has been studied directly (Faraj & Xiao, 2006), the timing of adaptive group response to non-routine events has been measured (Waller, 1999), and role improvisation under uncertainty has been examined ethnographically (Bechky & Okhuysen, 2011). The industrial safety literature supplies the organisational conditions under which such coordination is sustained or eroded, addressing leadership, culture, behavioural recurrence and human error causation in the project-based and temporary organisations to which a response team ordinarily belongs (Obogo, Nwafor, & Ozobu, 2023; Obogo, Ozobu, & Uduokhai, 2019a; Obriki & Arumosoye, 2019, 2020, 2021, 2022; Arumosoye & Obriki, 2024; Obriki, Obogo, & Arumosoye, 2023; Obogo, Obriki, & Arumosoye, 2021, 2022; Obogo et al., 2025b; Amayo, Owulade, & Isi, 2023c, 2025a).

## 3. CONCEPTUAL FRAMEWORK

### *3.1 The Framework: Scenario Design*

The first component specifies how scenarios are derived. The default practice in operating facilities is derivation from precedent, meaning that the scenario resembles the previous drill with variations, and the resulting programme exercises a narrow band of the response envelope repeatedly.

The framework proposes derivation from two sources jointly. The first is the facility major accident event set, which already exists in the safety case and which defines the scenarios the response capability is maintained for. Drilling against this set produces coverage that can be stated: a facility can report which major accident scenarios its response capability has been exercised against and when, which is an assurance statement of a different order from a count of drills conducted.

The second source is the capability being tested. A scenario designed to test notification and mobilisation is a different scenario from one designed to test sustained intervention under degraded conditions, and a scenario that attempts both will test neither well because the exercise will terminate at the first. Specifying the capability first and building the scenario to require it is the standard method in simulation-based training and is uncommon in industrial drill practice.

Three design features follow. Scenarios should include the conditions that make response difficult rather than only the events that make it necessary: adverse weather, unavailability of a key individual, failure of a communication route, concurrent minor incident. Scenarios should be varied deliberately across the capability set on a plan rather than opportunistically. And scenario detail should be withheld from participants, including the response leadership, since a drill in which participants know the scenario tests execution of a known plan rather than response to an unknown situation, and the two are different capabilities.

The last of these is the most commonly compromised, for understandable reasons: an unannounced drill against a live plant carries risks that an announced one does not, and the response leadership is frequently involved in planning the drill they will then lead. The framework does not resolve this tension but requires that it be stated, so that a facility knows which of the two capabilities its drill programme is actually exercising. Stress and fatigue shape what a drill actually measures, since a team exercised at the end of a night rotation is being assessed under conditions that differ systematically from those of the daytime exercise it will be compared against (Driskell & Salas, 1996; Staal, 2004; Kowalski-Trakofler, Vaught, & Scharf, 2003; Folkard & Tucker, 2003; Åkerstedt, 2003). The resilience and high reliability traditions frame what the capability is for (Hollnagel, 2014; Hollnagel, Woods, & Leveson, 2006; Woods, 2015; Weick & Sutcliffe, 2007; Sutcliffe, 2011). Deriving scenarios from the facility hazard set rather than from precedent also brings the drill programme into the same evidence base as the rest of the risk assessment, which already characterises the plant's high-consequence activities in detail (Arumosoye & Obriki, 2018, 2022; Obogo, Arumosoye, & Obriki, 2020b; Obogo, Uduokhai, & Ozobu, 2019; Obogo et al., 2026; Arumosoye, Obriki, & Ozobu, 2026; Falegan & Aniebonam, 2022; Ike et al., 2024a; Filani et al., 2022). Where a scenario deliberately degrades a communication route, the degradation should be specified against how the facility's communication systems actually fail rather than left to the exercise designer's imagination (Amayo & Popoola, 2017b; Quainoo, Ogundapo, & Asiedu, 2025a; Asiedu & Quainoo, 2023b, 2024). Propositions 1 and 6 in Section 4.2 state the testable claims arising from this component.

### *3.2 The Framework: Capability Specification*

The second component requires that each drill state, in advance, what it is intended to establish, expressed as observable behaviours rather than as outcomes.

The distinction is important. An outcome specification states that the team will control the simulated release within a stated time. A behavioural specification states what the team will be observed to do: that the incident commander will establish and communicate an incident objective within a stated interval, that a formal risk assessment will be conducted before committing personnel to the hazard area, that the muster count will be reconciled and the discrepancy resolved, that a defined handover will occur if the incident extends beyond a stated duration.

Behavioural specification has three advantages. It permits observation to be structured, since an observer knows what to look for. It permits partial credit, since a team may achieve the outcome by an unsafe route or fail the outcome having performed correctly against conditions the scenario made impossible. And it produces diagnostic information, since a failed behaviour identifies what to address whereas a failed outcome does not.

The behavioural markers should be drawn from the incident command competence literature rather than invented locally, both because the literature has done the work and because locally invented markers tend to encode the local practice rather than the capability, so that the drill confirms that the team does what the team does.

A practical constraint deserves statement. The number of behaviours that can be reliably observed in a single exercise is small, and a specification listing thirty markers will produce observation of none of them. Five to eight per exercise, varied across the programme, is the realistic bound. The behavioural marker tradition supplies both the method and the caution that inter-rater reliability degrades quickly as the number of observed behaviours rises (Flin, O'Connor, & Crichton, 2008; Flin, 1996; Klein, 1998; Kahneman & Klein, 2009; Endsley, 1995; Endsley & Garland, 2000; Woods, Dekker, Cook, Johannesen, & Sarter, 2010). Transfer is the criterion that matters and is determined substantially by the work environment rather than by the exercise (Baldwin & Ford, 1988; Blume, Ford, Baldwin, & Huang, 2010; Grossman & Salas, 2011; Burke & Hutchins, 2007; Ford & Weissbein, 1997), and evaluation at the reaction level predicts none of it (Kirkpatrick, 1994; Alliger, Tannenbaum, Bennett, Traver, & Shotland, 1997). Behavioural specification also aligns the drill with the competence and compliance assurance systems already operating around contractors and subcontractors, which are specified behaviourally for the same reasons (Obogo, Arumosoye, & Obriki, 2020a, 2020c; Obogo, Uduokhai, & Ozobu, 2021; Obriki & Arumosoye, 2024a; Arumosoye & Obriki, 2020). The problem of specifying observable markers, monitoring implementation fidelity against them, and keeping the specification small enough to remain usable is not peculiar to industrial drills and has been worked through in other structured intervention settings (Adelanwa, Basnet, & Anene, 2024). Whether a specified capability is subsequently adopted in ordinary work is a separate question from whether it was demonstrated in the exercise, and the diffusion literature treats extension, advisory and support structures rather than the training event itself as the determinant of adoption (Michael & Ogunsola, 2021e, 2022a). Propositions 2 and 7 in Section 4.2 state the testable claims arising from this component.

***3.3 The Framework: Debriefing***

The third component is the debrief, and the framework treats it as the primary intervention rather than as the closing administrative step.

The evidence that structured debriefing carries a large share of the learning effect is strong (Tannenbaum & Cerasoli, 2013), and the practical requirements it implies are specific. The debrief should be conducted by someone trained to conduct it, since facilitation quality is a determinant of outcome. It should be structured around the pre-specified behavioural markers rather than around a free discussion of what happened, since free discussion converges on the most salient event rather than on the most instructive. It should be conducted promptly, since recall degrades and the participants disperse. It should elicit the participants' own account before the observers deliver theirs, since the reverse order suppresses the disclosure of reasoning. And it should address what participants were thinking as well as what they did, since the reasoning is the target of the learning.

Two organisational conditions determine whether this is achievable. The first is time, and specifically time protected in advance rather than time remaining after the exercise. A debrief scheduled to begin when the exercise ends will not occur if the exercise overruns, which exercises frequently do. Scheduling the debrief as a fixed period, and truncating the exercise rather than the debrief if the total overruns, inverts the ordinary practice and follows directly from the evidence.

The second is psychological safety in the debrief. A debrief in which the disclosure of an error carries consequence will not elicit disclosure, and the reasoning behind errors is exactly what the debrief exists to surface. The practical requirement is a stated separation between the drill debrief and any performance management process, and the requirement is only as credible as the facility's track record of honouring it.

A supplementary point concerns who is debriefed. Drill debriefs commonly involve the response team and omit the control room, which was simultaneously managing the plant, and omit the personnel who were mustered and who experienced the drill as an interruption. Both hold information the response team does not, and both are part of the capability being tested. The debriefing evidence has strengthened since the framework was first drafted. The after-action review has now been meta-analysed in its own right and the effect confirmed across military, medical and organisational settings (Keiser & Arthur, 2021; Tannenbaum & Cerasoli, 2013), the mechanisms by which teams learn from their own performance have been examined directly (Eddy, Tannenbaum, & Mathieu, 2013), and the facilitation literature specifies what a competent debriefer actually does rather than leaving it to disposition (Fanning & Gaba, 2007; Rudolph, Simon, Dufresne, & Raemer, 2006; Cheng et al., 2014). Psychological safety is the enabling condition, since a debrief in which disclosure carries cost will not surface the reasoning it exists to surface (Edmondson, 1999). The organisational conditions on which disclosure depends are the same ones that determine whether findings raised in any assurance process are surfaced honestly and then closed, and the evidence on the two is consistent (Ebhojie, Dogbatsey, & Oyeleye, 2023a; Dogbatsey, Oyeleye, & Ebhojie, 2026; Onche, Ogbonna, & Adegbite, 2024; Onche, Adegbite, & Ogbonna, 2026). The stated separation between the debrief and performance management is also a records question, since the credibility of the separation depends on how drill observations are stored, who can retrieve them and under what governance, and the systems that hold appraisal and personnel data are precisely the systems from which drill records must be kept distinct (Aniji et al., 2026; Badmus, Dosunmu, & Ozowara, 2019b; Annan, 2022, 2025b). The underlying tension is a familiar one in performance management design, where a measure introduced for development becomes an evaluative instrument the moment it is visible to those who allocate reward, and the incentive alignment literature in capital-intensive industries treats that migration as the central design problem rather than an implementation failure (Oladepo & Oyediji, 2025b). Propositions 3, 4 and 5 in Section 4.2 state the testable claims arising from this component.

***3.4 The Framework: Measurement***

The fourth component distinguishes three levels of indicator and requires that the facility be explicit about which it is reporting.

Activity indicators record what was done: drills conducted, participants involved, scenarios covered. They are easy to collect, they are what most facilities report, and they measure input.

Process indicators record how the response was conducted: time to muster completion, time to first situation report, proportion of specified behavioural markers achieved, proportion of drills whose debrief was completed as scheduled. These are the indicators the framework principally recommends, because they are diagnostic and because they are within the facility's control.

Capability indicators attempt to characterise the response capability itself: coverage of the major accident event set, time since last exercise per scenario class, proportion of the response roster that has participated in a full-scale exercise within a defined period, and the identified capability gaps that remain open. These are the indicators that answer the assurance question, and they are the ones almost never reported.

One further measure deserves specific mention because it is cheap and unusually informative: the closure rate and ageing of drill findings. A drill that identifies a capability gap has done its job; a programme in which such findings accumulate unclosed has converted the drill into an audit that no one answers. Tracking finding age is a two-column exercise and is a better indicator of programme health than the drill count. The simulation literature supplies both the measurement apparatus and the evidence on what makes simulation-based training effective, and it is considerably more developed than anything in the industrial drill literature (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005; McGaghie, Issenberg, Petrusa, & Scalese, 2010; Cook et al., 2011; Gaba, 2004; Rosen et al., 2008; Dieckmann, Gaba, & Rall, 2007). The emergency management field has developed its own evaluation tradition addressing exercises specifically (Alexander, 2003; Sinclair, Doyle, Johnston, & Paton, 2012; Peterson & Perry, 1999; Perry, 2004; Quarantelli, 1997; Borodzicz & van Haperen, 2002; Boin & 't Hart, 2003). Evaluation of organisational safety interventions faces the recurring difficulty that outcome measures are too rare to accumulate, which is why process measures carry the weight here (Robson et al., 2007; Hale, Guldenmund, van Loenhout, & Oh, 2010; Hale, 2009; Hopkins, 2009; Øien, Utne, & Herrera, 2011; Reiman & Pietikäinen, 2012; Hollnagel, 2009; Kerr, 1975). The distinction between activity, process and capability indicators is a general one, and the performance measurement literature outside safety has developed the apparatus for holding it, including the discipline of tracking a small number of process measures continuously rather than a large number occasionally (Tonoyan, Dada, & Ayivi-Donkor, 2024b; Edivri & Oteri, 2022, 2024; Oteri & Edivri, 2024, 2026; Adelanwa, Basnet, & Anene, 2023a). Finding closure and ageing in particular is a standard process improvement measure, and the methods for identifying where work accumulates unclosed are well established outside the safety domain (Ambali et al., 2021; Oyeleye et al., 2022; Eyetsemitan et al., 2022, 2023b, 2024b, 2025; Ike et al., 2022; Efobi, Akinleye, & Fasawe, 2022b; Asiedu, C. S., 2025; Nnabueze et al., 2021). The difficulty of measuring an activity whose intended outcome is rare, delayed or confounded is not peculiar to safety, and the analytics literature has developed both the attribution methods and the executive reporting conventions for working around it (Sanni, Ajiga, & Atima, 2020a; Sanni & Atima, 2021b). Where the indicator set is to be maintained continuously rather than assembled for an audit, the service management and operations centre literature supplies the practical architecture (Ladapo et al., 2023b, 2024). Capability indicators in particular are readiness statements, and readiness has been given operational definition through maturity models, early warning thresholds and continuity criteria across several regulated sectors (Eze, Anene, & Akinleye, 2022a, 2022b; Afrihyia, Akinse, & Ojukwu, 2025; Ilodigwe & Adesemoye, 2024b; Adesuyi et al., 2025b; Ozowara, Anunagba, & Adepoju, 2025). The general principle that a designed system is evaluated against stated performance criteria rather than against the fact of its existence holds across engineering domains and is not a safety-specific commitment (Bello et al., 2022a, 2022b). The same logic underwrites the design of control systems more generally, where the purpose of instrumenting a process is to produce information a decision-maker can act on rather than a record that the process ran, which is the distinction between a process indicator and an activity indicator restated in another vocabulary (Oladepo & Oyediji, 2025a). Proposition 8 in Section 4.2 states the testable claim arising from this component.

## 4. DISCUSSION

### *4.1 Live Plant Drills: The Realism Trade*

Field intervention drills conducted against an operating plant occupy a distinctive position and warrant separate treatment because the property that gives them value is the same property that creates their risk.

The value is realism in three dimensions the classroom cannot supply: the physical environment with its actual distances, obstructions, noise and access constraints; the equipment in its actual condition and location; and the concurrent operation of the plant, which means that the response occurs alongside a control room managing a real process rather than in isolation.

The risks arise from the same conditions. Personnel moving at speed in an operating plant are exposed to the plant's ordinary hazards under non-ordinary conditions. Equipment operated for the drill may not return to its correct state. A drill announcement misinterpreted as a real event, or a real event occurring during a drill and misinterpreted as part of it, produces the most consequential failure mode, and it is not hypothetical.

Four controls follow. An unambiguous and universally understood signalling convention distinguishing drill from real, tested independently of the drills themselves. A drill controller with the authority and the sole responsibility to terminate the exercise, held by someone with no other role in it. A pre-drill assessment treating the exercise as a work activity with its own hazards, conducted with the same discipline as any other non-routine activity. And a defined reinstatement check confirming that equipment operated for the drill has been returned to its correct state, with the check recorded.

The framework's position on the trade is that the realism is worth its cost for the physical and coordinative capabilities that only a live deployment exercises, and is not worth its cost for the decision and communication capabilities that lower-fidelity formats exercise adequately and more frequently. A programme that runs everything at full scale is paying live-plant risk for learning it could obtain in a room. The hazards the exercise itself introduces are governed by the same control of work apparatus as any other non-routine activity, and treating a drill as work rather than as training is the practical consequence (Health and Safety Executive, 2005, 2006b; International Association of Oil and Gas Producers, 2018; Occupational Safety and Health Administration, 1989; Center for Chemical Process Safety, 2007; Mannan, 2012; Crowl & Louvar, 2011). The major accident record supplies the emergency response benchmark against which any drill programme is implicitly measured (Cullen, 1990; Hopkins, 2000, 2008; U.S. Chemical Safety and Hazard Investigation Board, 2007; Buncefield Major Incident Investigation Board, 2008; Kletz, 2001), and the barrier framework locates the response capability among the mitigation barriers whose performance should be specified rather than assumed (Sklet, 2006; Hollnagel, 2004; Center for Chemical Process Safety and Energy Institute, 2018; Johansen & Rausand, 2015; de Ruijter & Guldenmund, 2016). Vigilance and fatigue determine what a drill measures on any given occasion (Mackworth, 1948; Warm, Parasuraman, & Matthews, 2008; Folkard, Lombardi, & Tucker, 2005; Sallinen & Kecklund, 2010; Knauth & Hornberger, 2003). The environmental and waste consequences of an exercise conducted against live equipment fall under the same compliance regime as any other operation, which is how a reinstatement failure becomes an environmental incident rather than a training observation (Obogo, Ozobu, & Nwafor, 2024; Obogo, Arumosoye, & Obriki, 2024; Arumosoye, Obriki, & Ozobu, 2025). The signalling convention that separates drill from real is a control system property before it is a procedural one, and the operational technology literature has established both how such conventions fail and what integrity they require in converged IT and OT environments (Adegbite, Adebayo, & Ahmed, 2020, 2022, 2023; Adebayo, Adegbite, & Ahmed, 2023; Ahmed, Adegbite, & Adebayo, 2021; Jimoh et al., 2023). The nearest methodological analogue to the live plant drill outside the process industries is the controlled adversary exercise, in which a simulated event is executed against a production environment precisely because the artificial environment does not reproduce the conditions of interest, and the governing controls there are recognisably the same four: an unambiguous exercise marker, a named controller holding termination authority, a pre-exercise risk assessment, and a verified return to baseline (Dosunmu & Ogundele, 2021, 2024a, 2024c, 2024d, 2025a, 2025c, 2026b). Supporting utilities are part of what the drill exercises, since a response conducted under degraded power or lighting is a materially different exercise from one conducted under normal supply (Adenuga, 2022; Komi & Adamolekun, 2021; Sunday & Omoegun, 2019). Remote sensing has extended what can be observed during an exercise across a large site, which bears on the coverage of drill observation in facilities where the response is geographically dispersed (Dagodzo, 2018a; Dagodzo & Ahiaeke Patrick, 2020, 2021b; Dagodzo, Ahiaeke Patrick, & Aliliele, 2022). The physical environment is itself a designed variable rather than a given, and the facility design literature treats layout, access and circulation as determinants of throughput and safety in the way a drill exposes them (Ogbete, Aminu-Ibrahim, & Ambali, 2018; Aminu-Ibrahim, Ogbete, & Iwuanyanwu, 2025b). Equipment condition at the moment of the exercise is likewise variable rather than nominal, since degradation mechanisms act continuously on plant the drill assumes to be available (Atta et al., 2025). Coordinating a dispersed set of responders under a shared objective also has formal treatments outside human teams, and the fleet coordination literature clarifies what is being asked of an incident commander when the response is spread across a large site (Akanbi, Ganiu, & Sunday, 2025). Proposition 9 in Section 4.2 states the testable claim arising from this discussion.

***4.2 Propositions***

Nine propositions are stated in testable form. Each is numbered so that it can be identified and cross-referenced individually, and each is anchored to the framework component from which it follows: Propositions 1 and 6 to scenario design (Section 3.1), Propositions 2 and 7 to capability specification (Section 3.2), Propositions 3, 4 and 5 to debriefing (Section 3.3), Proposition 8 to measurement (Section 3.4), and Proposition 9 to the realism trade discussed in Section 4.1.

**Proposition 1.** Scenario derivation from the facility major accident event set produces broader capability coverage than derivation from precedent, and the difference is measurable as the proportion of the event set exercised over a defined period.

**Proposition 2.** Drills specifying observable behavioural markers in advance produce more actionable findings per exercise than drills evaluated against outcome criteria alone.

**Proposition 3.** Debrief completeness predicts subsequent drill performance more strongly than scenario fidelity does.

**Proposition 4.** Debriefs scheduled as a fixed protected period are completed at a substantially higher rate than debriefs scheduled to follow the exercise.

**Proposition 5.** Participant disclosure of reasoning in debriefs is a function of the perceived separation between the debrief and performance management, and is not responsive to facilitation technique where that separation is absent.

**Proposition 6.** Announced drills test execution of a known plan and unannounced drills test response to an unknown situation, and performance on the two is only weakly correlated within the same team.

**Proposition 7.** The number of behavioural markers reliably observed in a single exercise has an upper bound in the region of eight, beyond which inter-observer agreement declines sharply.

**Proposition 8.** Drill finding ageing is a better predictor of response capability than drill frequency.

**Proposition 9.** Decision-making capability developed through low-fidelity tactical decision exercises transfers to full-scale drill performance, at materially lower cost per exercise.

The propositions are framed against the measurement traditions above and would be tested using established instruments rather than bespoke ones (Salas, Rosen, Held, & Weissmuller, 2009; Rosen et al., 2008; Cheng et al., 2014; Keiser & Arthur, 2021). Measuring the effectiveness of a control by exercising it, and then reporting the result upward in terms a governing body can act on, is a measurement problem with an established literature of its own, and the instruments developed there transfer to the reporting of drill outcomes (Aliliele et al., 2025a; Akomolafe & Agu, 2018; Akomolafe, Agu, & Bello, 2023a, 2025; Dosunmu & Ogundele, 2024b, 2025b; Adegbite, Adebayo, & Ahmed, 2025).

**5. LIMITATIONS**

The framework is conceptual and has not been evaluated. Its propositions are stated so that they could be tested within a single facility's drill programme over two or three years, using data the programme would generate anyway if the measurement layer were implemented.

The framework draws heavily on a training literature developed predominantly in military, aviation and healthcare settings. The transfer to industrial emergency response is defensible on the grounds that the underlying tasks, team coordination under time pressure and uncertainty, are structurally similar, but the transfer is an inference and the industrial evidence base that would confirm it does not exist.

The paper does not address the relationship between drill performance and actual incident performance, which is the validity question that matters most and which cannot be answered because actual incidents in well-run major hazard facilities are too rare to support the analysis. This is a permanent limitation of the domain rather than a gap in the present treatment, and it is the reason process indicators carry the weight they do here.

Finally, the framework increases the specification burden on a drill programme, and facilities operating at the limit of their response resource may find that implementing it reduces drill frequency. Whether that trade is favourable depends on the marginal value of an additional drill against the marginal value of extracting more from the existing ones, and the evidence on debriefing suggests the latter is larger, but the paper does not establish this for any particular facility. A further boundary is worth naming. The framework treats the drill as a training and measurement instrument and does not address the incident command structures within which a real response would operate, which are the subject of a substantial separate literature on emergency organisation, improvisation under uncertainty and inter-agency coordination (Bigley & Roberts, 2001; Weick, 1993; Kapucu, 2006; Comfort, 2007; Moynihan, 2009; Uhr, Johansson, & Fredholm, 2008; Wolbers, Boersma, & Groenewegen, 2018). The distinction matters because a drill can exercise a team well while the structure it plugs into at scale remains untested. A second boundary concerns the organisation around the drill rather than the drill itself, since governance of multi-contractor and joint venture facilities determines who is exercised and who is not, and the response capability of a site with several employers on it is not the response capability of its operator alone

(Amayo, Owulade, & Isi, 2023a, 2023b, 2024b, 2025c; Eyetsemitan et al., 2020; Okonkwo et al., 2024a; Anene & Clement, 2022). The regulatory counterpart is likewise outside the present scope, although the aviation oversight literature offers the closest available model of how an external authority might assess response capability rather than accept a drill count (Adeyelu, 2018, 2019; Adeyelu & Dagodzo, 2022). The same body of work supplies the evidentiary standards such an authority would apply (Adeyelu, 2022). Inter-agency coordination proper lies further outside the scope again, and the literatures on multi-agency security cooperation and on humanitarian response coordination describe the layer at which a facility's response meets external responders (Liadi, 2024c, 2024d; Omo Enabulele et al., 2025).

## 6. CONCLUSION

Drills are the substitute a major hazard facility has for evaluating a capability it hopes never to use, and they are ordinarily specified by frequency, evaluated by impression and reported by count. The assurance question they exist to answer is therefore not answered by the programmes that consume the resource.

The training research supplies what is missing. Scenarios should be derived from the major accident set and from a stated capability, not from precedent. What the drill is to establish should be specified as observable behaviours in advance, since observation without a specification records whatever occurred. The debrief carries the largest share of the learning effect and should be protected in the schedule ahead of the exercise itself, which inverts ordinary practice. And measurement should distinguish activity from process from capability, since only the third answers the assurance question and only the first is commonly reported.

For live plant drills specifically, the realism that produces the value creates the risk, and the trade is defensible for the physical and coordinative capabilities that only a real deployment exercises. It is not defensible for decision and communication capability, which lower-fidelity formats develop more cheaply and more often. A programme that runs everything at full scale has confused cost with seriousness. A final point follows from treating the drill as an instrument rather than an event. A response capability is only as good as the materials, spares and logistics that sustain an intervention beyond its first hour, and the readiness of that supporting chain is measurable on the same terms as the rest of the framework (Agbabiaka et al., 2019; Ogunwole et al., 2021; Okonkwo et al., 2021, 2024c; Ike et al., 2025; Komi & Adeniji, 2023; Yeboah et al., 2025).

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