



Reimagining Safety Leadership: Principles of Team Autonomy, Energy Control, and Adaptive Capacity in High-Hazard Operations: A Practitioner-Researcher Thesis

Vol 3, edition 3, October 2026

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DOI: <https://doi.org/10.26686/nzjhsp.v3i3.10942>

Abstract

Traditional safety management in high-hazard industries remains anchored in compliance-driven, top-down paradigms that treat frontline workers as sources of error rather than reservoirs of expertise. This paper argues for a fundamental reconceptualisation of where the locus of safety expertise resides within organisations, drawing on Safety-II (Hollnagel, 2014), Complex Adaptive Systems theory, High Reliability Organisation principles (Weick & Sutcliffe, 2007), the Energy Damage Model (Haddon, 1973), Critical Steps methodology (Muschara, 2018), and dual-process cognition (Kahneman, 2011) to expand how safety management is understood and enacted.

Rather than prescribing a singular organisational model, the paper distils principles of team autonomy—decision-making authority, resourcing for capacity and capability, transparency of information, and peer-to-peer accountability—and demonstrates how these principles create the conditions for positive control over critical steps involving damaging energy.

Two case studies are examined: farm vehicle operations on a New Zealand dairy operation, and atmospheric hazard management in maritime confined spaces. Both assessments employ human-centred methodologies to examine the critical gap between "Work as Intended" and "Work as Done," revealing a common structural pattern: safety systems that are typically over-reliant on administrative controls and dependent on the adaptive expertise of frontline workers to compensate for engineering and design shortfalls. Each case is assessed qualitatively using a fragile–brittle–resilient framework.

The paper proposes a four-stage team maturity model, and links the approach to (Pink, 2009), a model of intrinsic motivation. The author draws on direct experience establishing and leading a safety management programme using these principles within the aerospace sector.

Keywords

Safety-II, Safety Differently, High Reliability Organisations, Energy Damage Model, Complex Adaptive Systems, Antifragility, Critical Steps, Team Autonomy, Intrinsic Motivation, Work as Done, Self Directed Work Teams, Human Performance, Confined Space, Aerodrome Safety, Complex Adaptive Systems

1. Introduction

1.1 The Problem with Traditional Safety Management

The dominant paradigm in occupational safety management still largely supports the assumption that safety is achieved through compliance with procedures, elimination of human error, and hierarchical control.

While this paradigm has delivered measurable reductions in workplace injury rates over several decades (Hopkins, 2005), it has reached a plateau of diminishing returns, particularly in complex, high-hazard environments where the gap between "Work as Imagined" and "Work as Done" (Hollnagel, 2018) is most pronounced. The importance of understanding "Work as Done versus Work as Imagined" was underscored in a 2025 case involving the Ports of Auckland and is now part of best practices recommended by WorkSafe and the Institute of Directors in New Zealand.

This paper compares two independent pilot assessments that applied human-centered control effectiveness methodologies in markedly different operational contexts. Case Study A examines the use of motorbikes and utility vehicles across a New Zealand dairy operation – a task involving kinetic energy hazards, solitary work across large distances, and continuous judgement about terrain, load, and speed. Case Study B examines technicians entering confined spaces aboard international cargo vessels to monitor atmospheric conditions during overseas agricultural produce voyages — a task involving atmospheric displacement hazards, variable vessel conditions, language barriers, and constrained emergency response capability while out at sea.

Despite their surface differences, the two cases share a common structural architecture of risk. Both involve workers performing high-consequence tasks within environments using systems that depend heavily on human performance to compensate for engineering and design shortfalls. In both cases, the formal safety architecture — procedures, permits, communication protocols, monitoring equipment — appears adequate on paper but is revealed through human-centred assessment to be brittle in practice.

The comparative analysis identifies a recurring pattern: experienced workers adapt, innovate, and compensate for systemic weaknesses, effectively masking the true condition of the control systems upon which safety depends. This adaptive expertise is simultaneously the most valuable safety resource in both systems and the most fragile. Rather than implementing further control, the means of improving resilience lies in identifying reliance on, and then strengthening, adaptive human performance in systems.

Serious harm, fatalities, and process safety disasters continue to occur despite ever-increasing regulatory requirements, technological barriers, and procedural controls. In many of these events, the people closest to the hazard—those with the most relevant operational expertise—were structurally excluded from critical decisions, or lacked the authority, information, or organisational support to exercise positive control at the moment it mattered most.

These patterns encapsulate the central argument of this paper: that safety systems which rely on technological barriers and procedural compliance, without also investing in and enabling the human capacity for adaptive, expert decision-making at the point of operation, will continue to produce catastrophic failures. When organisations concentrate decision-making authority away from the point of operation, they systematically undermine the conditions for what (Muschara, 2018) calls "positive control" over critical steps—the moments when damaging energy is released with irreversible consequences.

This not an abstract concern. In March 2026, at the time of writing this paper, in one of the most heavily regulated operational environments in the world, an aircraft and an emergency response vehicle came to occupy the same ground at La Guardia Airport in New York. At the time of writing the investigation is ongoing and no conclusions can properly be drawn as to cause. What the event nonetheless illustrates is the concern of this paper: catastrophic energy release happens at a single point in time and space, at the sharp end, where a person is executing a task. The layers of procedure, oversight, and compliance activity accumulated upstream do not act at that point; only a control that operates at the moment of release supported by adaptive human capacity does.

1.2 An Alternative Proposition

This paper proposes that the most effective path to sustained safety improvement in high-hazard operations lies not in adding more rules, more technology, or more supervisory oversight, but in recognising where genuine safety expertise resides—at the frontline—and creating the organisational conditions for that expertise to function effectively.

Drawing on the literature of Self-Directed Work Teams (Hackman, 1987; Wageman, 1997; Cohen & Ledford, 1994), the paper distils four enabling principles that can be adapted to any corporatised structure:

1. **Authority** to make decisions at the point of operation
2. **Resourcing** to ensure the necessary capacity and capability
3. **Transparency of information** to support decision-making
4. **Peer-to-peer accountability** as the primary mechanism for performance and safety standards

These principles are not presented as a prescription for a particular team structure, but as foundational conditions that must exist—in whatever organisational form is appropriate—for frontline expertise to translate into reliable safety performance. This is consistent with Weick and Sutcliffe (2007) principle of "deference to expertise" in High Reliability Organisations, where decision-making authority migrates to the person with the most relevant knowledge, regardless of hierarchical position.

1.3 Author Positionality

The author writes as a practitioner-researcher with direct experience establishing and leading a safety management programme in the aerospace sector using the principles articulated in this paper. This programme was built on the premise of full and complete ownership and trust at the team level, with the safety function serving as an enabling capability rather than a compliance enforcement mechanism. The insights presented here are therefore grounded in the practical realities of implementing these principles within existing safety management systems, recognising the political, cultural, and resource challenges that accompany any departure from traditional safety management orthodoxy. This positionality informs the paper's emphasis on practical applicability alongside theoretical rigour.

1.4 Paper Structure

The paper is structured as follows. Section 2 establishes the theoretical framework, integrating Safety-II, Complex Adaptive Systems, High Reliability Organisation principles, the Energy Damage Model, Critical Steps methodology, dual-process cognition, and the principles of intrinsic motivation (Pink, 2009). Section 3 presents two case studies with qualitative assessment using a fragile–brittle–resilient framework. Section 4 presents the team maturity development model. Section 5 offers conclusions and recommendations.

2. Theoretical Framework

2.1 Safety-II and Safety Differently

Hollnagel's (2014) Safety-II framework represents an evolution from understanding why things go wrong to include an understanding of why things go right. Where Safety-I treats human variability as a threat to be constrained, Safety-II recognises that the same variability is the source of the adaptive capacity that keeps complex systems functioning safely under conditions of uncertainty, time pressure, and incomplete information.

Dekker's (2014) "Safety Differently" extends this insight into organisational practice, arguing that safety improvement requires engaging with the complexity of work as it is actually performed, rather than as it is imagined in procedures and risk assessments. This demands a fundamental shift in the relationship between safety professionals and frontline workers: from auditor and auditee to collaborative partners in understanding and improving work.

The implications for organisational design are profound. If safety expertise resides primarily at the frontline—in the accumulated tacit knowledge, pattern recognition, intuitive expertise and adaptive responses of experienced practitioners—then the role of the organisation is to create conditions that enable this expertise to flourish, not to constrain it through prescriptive control.

2.2 Complex Adaptive Systems and Emergence

Dekker (2011) and Hollnagel (2012) argue persuasively that high-hazard workplaces function as Complex Adaptive Systems (CAS): characterised by non-linear interactions, emergent behaviours, and sensitivity to initial conditions. In such systems, safety is not a static property that can be engineered in advance but an emergent property of the ongoing interactions between people, technology, procedures, and environment.

This has direct implications for how we think about safety management. Traditional approaches assume that if individual components are controlled (trained workers, maintained equipment, documented procedures), system-level safety will follow. CAS theory demonstrates that this assumption is fundamentally flawed: system-level behaviours emerge from interactions between components in ways that cannot be predicted from the properties of individual components alone (Holland, 1995).

The practical consequence is that safety management must focus not only on component reliability but on the quality of interactions—the communication, coordination, and mutual adjustment that allow teams to maintain safe operations in the face of variability and surprise.

2.3 High Reliability Organisations

The High Reliability Organisation (HRO) literature provides a complementary lens through which to understand how some organisations achieve sustained safety performance in high-hazard environments. Weick and Sutcliffe (2007) identified five principles that characterise HROs:

1. **Preoccupation with failure:** A chronic unease that treats near-misses and weak signals as windows into systemic vulnerability, rather than evidence that the system is working.
2. **Reluctance to simplify:** Resistance to the organisational tendency to reduce complex situations to simple narratives, recognising that oversimplification obscures the conditions that produce both success and failure.
3. **Sensitivity to operations:** Sustained attention to the real-time conduct of work at the operational level, maintaining situational awareness of how "Work as Done" diverges from "Work as Imagined."
4. **Commitment to resilience:** The capacity to detect, contain, and recover from errors before they escalate into failures, through distributed expertise and flexible response.
5. **Deference to expertise:** Decision-making authority migrates to the person with the most pertinent knowledge, regardless of their position in the formal hierarchy.

The fifth principle—deference to expertise—is the most directly relevant to this paper's thesis. It establishes the theoretical foundation for the argument that the locus of decision-making authority in safety-critical operations should rest with those closest to the hazard, provided they have the necessary competence, information, and organisational support.

The consequences of violating this principle are well documented across high-hazard industries. When organisations concentrate decision-making authority at a single point—whether a controller managing multiple frequencies, a supervisor authorising entry to a confined space, or a manager overriding frontline concerns—they structurally exclude the expertise of those closest to the hazard. The system concentrates rather than distributes decision-making authority at the critical moment or point of no return.

2.4 The Energy Damage Model

Haddon's (1973) Energy Damage Model provides a foundational framework for understanding how harm occurs in any workplace. At its core, the model proposes that all injuries and damage result from the uncontrolled transfer of energy (or the absence of essential energy, such as oxygen) to a vulnerable target. This deceptively simple concept has profound implications for how we conceptualise, assess, and control risk.

The model identifies categories of damaging energy not limited to: kinetic (mass in motion), thermal, electrical, chemical, radiation, and atmospheric (the displacement or absence of life-sustaining atmospheric conditions). For each energy type, the model maps the pathway from source to target through existing barriers, enabling systematic identification of where controls are present, absent, or degraded.

When integrated with Safety-II thinking, the Energy Damage Model becomes a powerful analytical tool. Rather than simply cataloguing hazards and prescribing barriers, teams can use energy pathway analysis to understand the dynamic interaction between energy sources, barriers, and human performance—including the adaptive behaviours that maintain safety when barriers degrade. This understanding is essential for Muschara's (2018) concept of positive control over critical steps.

2.5 Critical Steps and Positive Control

Muschara (2018) defines a critical step as "a human action that will trigger immediate, irreversible, and intolerable harm to an asset if that action or a preceding action is performed improperly." The concept is directly linked to the Energy Damage Model: a critical step is the point at which a human action releases, transfers, or fails to contain damaging energy.

The central insight of Critical Steps methodology is that positive control—the deliberate, conscious management of actions at critical steps—requires specific conditions:

- **Identification:** The worker must know that they are approaching or executing a critical step.

- **Attention:** The worker must be in a state of heightened awareness, what Kahneman (2011) would characterise as System 2 (slow, deliberate) thinking rather than System 1 (fast, automatic) thinking.
- **Verification:** The worker must have the means to verify that conditions are correct before proceeding.
- **Authority to stop:** The worker must have unambiguous authority to halt work if conditions are not met.

In airfield operations, for example, the critical step of clearing an emergency vehicle onto an active runway demands System 2 (slow, deliberate) cognitive engagement. Yet the operational context—time pressure, multiple radio frequencies, competing demands—can systematically force controllers and personnel into System 1 (fast, automatic) processing. Runway environments can be featureless and disorienting, particularly at night or in reduced visibility. Multiple radio frequencies are often monitored simultaneously, and communication with the operations control centre is the primary means of ensuring separation between vehicles and aircraft. When the conditions for positive control—identification, heightened attention, verification, authority to stop or question—are undermined by the operational context, the consequences involve the uncontrolled release of kinetic energy with catastrophic potential as we see in the March 2026 accident at La Guardia Airport in New York.

2.6 Dual-Process Cognition and the Case for Autonomy

Kahneman's (2011) dual-process theory distinguishes between System 1 thinking (fast, intuitive, automatic, effortless) and System 2 thinking (slow, deliberate, analytical, effortful). In routine operations, System 1 thinking is efficient and adaptive—experienced practitioners draw on pattern recognition and heuristics to manage familiar situations effectively. However, at critical steps—moments where the uncontrolled release of damaging energy is possible—System 2 thinking is essential.

The challenge for safety management is that System 2 thinking is cognitively expensive. It requires attentional resources, working memory capacity, and freedom from competing cognitive demands. Workers who are overloaded, time-pressured, fatigued, or operating under conditions of high cognitive load are more likely to default to System 1 thinking even at critical steps.

This is where the principles of team autonomy become essential. Teams that have:

- **Authority** to pace their own work and change plans when conditions demand it
- **Resourcing** that supports adaptive human performance
- **Transparency** of information to provide real-time information on energy sources and system state
- **Peer accountability** that normalises challenge and verification behaviours

are teams that create the conditions for System 2 engagement at critical steps. The organisational investment in team autonomy is, in this analysis, a direct investment in the cognitive conditions required for positive control over damaging energy.

2.7 Pink's Model of Intrinsic Motivation

Pink (2009) identifies three elements of intrinsic motivation that drive sustained, high-quality performance: **Autonomy** (the desire to direct one's own life and work), **Mastery** (the urge to get better at something that matters), and **Purpose** (the yearning to do what we do in the service of something larger than ourselves).

The relevance to safety-critical work is direct and powerful. Extrinsic motivators—compliance requirements, audit scores, KPI targets, punitive consequences—can produce surface-level adherence to rules but do not generate the deep engagement, professional commitment, and adaptive expertise that sustain safety in complex environments (Deci & Ryan, 2000).

The four enabling principles identified in this paper map directly to Pink's motivational framework (Table 1)

Table 1

Enabling Principle	Pink's Element	Safety Application
Authority to make decisions	Autonomy	Workers who own their safety decisions invest more deeply in getting them right
Resourcing for capacity & capability	Mastery	Adequate training, time, and tools enable the development of genuine expertise
Transparency of information	Autonomy + Mastery	Access to information enables informed decision-making and continuous learning
Peer-to-peer accountability	Purpose	Mutual accountability creates a shared sense of responsibility to the team and to the mission

When these conditions are met, safety ceases to be an externally imposed obligation and becomes an intrinsic expression of professional identity and team commitment. Workers do not merely comply with safety requirements; they actively seek to understand, improve, and own the safety of their operations. In order to develop the team maturity (discussed in Section 4) required to support team autonomy, intrinsic motivation must be considered in safety system design and improvement.

2.8 The Role of Operational Expenditure and Capital Expenditure

A critical and often overlooked dimension of team autonomy is the authority to influence resource allocation. This paper argues that teams operating in high-hazard environments must have meaningful input into both operational expenditure (OPEX) and capital expenditure (CAPEX) decisions that affect their safety and capability where there is reliance on intuitive expertise and adaptive human performance at the point of energy transfer.

This is not a suggestion that frontline teams should control organisational budgets, but rather that:

- Teams should be able to identify and articulate resource needs through formal business case processes
- Management should commit to prompt and transparent evaluation of such business cases
- Teams should have visibility of the resource constraints and trade-offs that affect their operations
- Capital investment decisions and prioritisation affecting safety-critical equipment and systems must incorporate frontline expertise to enable adaptive capacity

This principle is grounded in the recognition that the people closest to the work are best positioned to identify where investment will have the greatest impact on safety and operational capability. It also reflects Weick and Sutcliffe's (2007) principle of sensitivity to operations and Reason's (1997) argument that latent conditions—including chronic under-resourcing—are the primary drivers of organisational accidents.

Aviation is already a mature expression of positive control: licensing, airside controls and discipline, ground-movement procedures, and radio protocols all embed elements of identification, attention, verification, and authority. Yet resilience is not a steady state. When operational pressure degrades the conditions for team autonomy — when authority to challenge or stop becomes psychologically costly, when information is broadcast but not usable at the point of decision, when attentional capacity is overwhelmed by task load, and when peer verification is diluted by pace and hierarchy — even a high-regulation system can fail at the critical step.

The response to the La Guardia accident is not to add more rules, but to make autonomy practical through the four enabling principles: explicit stop-work triggers and protected challenge rights (**authority**); decision-support tools such as shared ground-movement displays rather than raw voice streams (**transparency of information**); simulation and scenario rehearsal that develop System 2 judgement under cognitive load (**resourcing of capability**); and team norms that normalise challenge even when time is short (**peer-to-peer accountability**). These measures are not substitutes for regulation; they are what make regulation resilient at the sharp end. The case studies that follow apply the same logic to an environment where formal controls are far less developed, and where the consequence of autonomy failure is no less serious.

3. Case Studies

3.1 Introduction to Case Studies

Two case studies are examined to illustrate the practical application of the theoretical framework. Each case involves a high-hazard operational environment where the uncontrolled transfer of damaging energy poses immediate threats to life. The cases are assessed qualitatively using a **fragile–brittle–resilient** framework:

- **Fragile:** The system is likely to fail under stress and lacks the capacity to recover. Controls are weak, degraded, or absent and there is a high dependency on perfect human performance at critical steps. Small disruptions can produce catastrophic outcomes.
- **Brittle:** The system functions adequately under normal conditions but lacks adaptive capacity at critical steps. Controls exist but are rigid and procedural. The system is vulnerable to unexpected variations which intuitive expertise is currently masking.
- **Resilient:** The system maintains safe performance across a range of conditions, including novel and unexpected situations. Controls are layered, adaptive, and supported by competent, empowered teams with the authority and information to respond dynamically.

This paper employs a comparative case study design, analysing two independent pilot assessments conducted in operational environments during 2024 and 2025. Both assessments used learning team methodologies and structured workshops with frontline workers to capture "Work as Done" insights.

3.2 Case Study A: Farm Vehicle Operations

3.2.1 Context

This case study examines the management of kinetic energy hazards associated with farm vehicle use – two-wheel motorbikes and utility vehicles (utes) – across a dairy farm operation. The farm presents a deceptively ordinary operational environment in which multiple high-energy systems interact: motorbikes and utes moving across paddocks, races and public roads; towed trailers with loads; livestock; and personnel on foot.

The primary energy hazard is kinetic. Data generated using the Energy Wheel (Hallowell, n.d.) indicates that a rider and machine exceed the 1,500-joule threshold at which fatal injury becomes possible at any speed above approximately 15 kilometres per hour, depending on rider and machine mass. Since almost no purposeful farm task can be performed below that speed, the uncontrolled transfer of kinetic energy is a routine rather than exceptional possibility. These calculations assume flat ground. The slopes and uneven terrain typical of New Zealand farms make them conservative.

The farm environment presents a paradoxical risk profile. Work is highly time- and season-dependent, performed alone and unobserved across large distances, in variable weather, and on ground whose condition changes daily. Unlike the regulated environments examined in aviation or maritime operations, there is no controller, no permit, and no independent party verifying that conditions are safe before a worker commits to a movement. The consequence of a misjudgement – striking debris, losing traction on a slope, or meeting traffic when entering a public road – can be fatal, yet the task itself is so familiar that it attracts little deliberate attention.

Common critical steps were identified as: committing a loaded or unbalanced motorbike to a slope or to ground of unknown condition, entering or crossing a public road, towing a trailer whose loaded mass is over the vehicle's rated limit, and carrying a passenger or load outside the vehicle's rating.

3.2.2 Human Dependencies and Error Traps

The typical safe system of work is currently reliant on:

- **Seatbelts and vehicle safety features** – the principal means of mitigating energy transfer once a crash has begun. The assessment revealed a divided fleet: newer leased utes carry a full engineering control layer – five-star crash rating, autonomous emergency braking, electronic stability control, and front and side curtain airbags – while older light utility vehicles used by one team carry none of these systems. Motorbikes, by contrast, carry no control that operates independently of the rider. Seatbelts, where fitted, remain wholly dependent on the decision to wear them, and that decision was reported to vary with the length and perceived triviality of the trip.

- **Speed and route selection** – the primary means of limiting the energy available for release. Both assessments found that riders and drivers continuously adapt speed and route to workload, terrain, weather and the presence or absence of supervision. This adaptive capability is genuine expertise and is largely what keeps the work safe.

Industry guidance recommends a maximum operating speed of 30 km/hr for farm vehicles of this type. In practice, workers routinely operate above this speed, driven by the workload, conditions and constraints described above. Significantly, workers report situations in which higher speed is the safer option: maintaining momentum to ascend a steep hill or responding to a runaway animal. This is not simply normalisation of deviation. It is adaptive expertise operating in the gap between generic guidance and the specific demands of the task — and it is precisely the kind of situated judgement that a compliance-based system can neither see nor support.

The assessments revealed that experienced workers develop sophisticated mental models of the terrain and of their machines, together with informal practices – route choice, speed moderation, mutual warning about paddock conditions – that strengthen human performance. These adaptations are largely undocumented, inconsistently transferred to newer or less confident workers, and invisible to the formal safety management system. Where competence is unevenly distributed, the more competent workers absorb a disproportionate share of the demanding work, and the resulting pressure feeds back into the speed and equipment choices they make.

Key error traps include: debris and changing ground conditions in paddocks, identified in incident analysis as the largest single contributor to events; unclear load and towing limits; gaps in off-road driving and trailer towing training; the habituation that accompanies routes ridden hundreds of times; and the tension between the pace of seasonal production (operational goal) and unhurried movement across uncertain terrain (safety goal).

A further detail illustrates the tension between formal safety management and adaptive expertise. Farm workers had previously received training in how to fall, roll and tumble from a motorbike — a harm-reduction measure intended to minimise injury when a fall occurred. The training was withdrawn on the grounds that it could be seen as condoning the incidents it sought to mitigate. The episode is instructive: a control oriented toward the energy-damage model — accepting that falls will occur and reducing the harm when they do — was removed because it sat uncomfortably with a compliance narrative in which incidents should not happen at all. The effect was to leave workers wholly reliant on preventing the fall, while removing the one measure that acknowledged the reality of the work.

Only the engineering safety system fitted to the new utes – autonomous emergency braking, electronic stability control, and airbags – function independently of human performance, and these are absent from part of the fleet and from every motorbike. The safety architecture is therefore structurally reliant on the assumption that individual workers will perform consistently, alone and unobserved, under all conditions of weather, terrain, and workload, making it a brittle system.

3.2.3 Human Performance Analysis

Reliance on Human Performance

Analysis of the control architecture reveals a structural dependency on human cognition and human choice.

Table 2.

Controls & Control Supports	Human Performance Dependency
Seatbelts	Effective only if worn, the decision is made by the driver, trip by trip, and is most often omitted on short in-paddock movements.
Speed and route selections	Requires driver self-regulation against seasonal production pressure and competing task demands.
Pre-start checks	Requires consistent completion.
Load and towing limits	Requires the driver to know the rating and estimate the load – information not readily available at the point of use.
Driver training & licensing	Licensing confirms legal status, not off-road or towing competence; monitoring detects license loss only.

Human-Centred Assessment

A human-centred assessment shifts the analytical focus from "did the person comply?" to "did the system create conditions for success?" Applied to the farming case:

- **Habituation and familiarity:** Routes ridden hundreds of times, on machines used daily, generate strong automaticity. Nothing in the task marks the transition into a critical step, so System 2 (Kahneman, 2011) engagement is neither cued nor supported at the moment it is needed.
- **Production pressure:** Seasonal and daily workload generates powerful time-pressure cues (calves to feed, cows to bring in, irrigators to shift) that systematically promote System 1 (fast, automatic) processing precisely when deliberate assessment of ground, load, or traffic is most needed.
- **Verification without information:** Workers are expected to operate within load and towing limits, and to judge ground conditions, without ready access to the information that would make verification possible. The condition for positive control is absent by design rather than by choice.
- **Normalisation of deviation:** Repeated successful outcomes due to high levels of intuitive expertise in personnel can create a progressive drift toward acceptance of degraded practices unwittingly, eg the unworn seatbelt on the short trip, the trailer of unknown weight, the paddock not yet cleared. (Dekker, 2011).

The human-centred assessment reveals that the operational context requires reliable and adaptive human performance continuously, yet supplies neither the information nor, in the case of motorbikes, the engineered barrier that would make such performance dependable.

3.2.4 Pathway to Resilience:

Applying the principles of team autonomy to support human performance in farm vehicle operations involves:

- **Authority:** Workers require explicit, exercisable authority to decline a route, a load, a tow, or a task where ground, weather, machine condition, or fatigue make it unsafe, and to defer non-urgent work accordingly. This must include the ability to influence workload and staffing arrangements to support adaptive performance according to the conditions. This supports positive control over critical steps and should be a team driven commitment rather than a top-down platitude.
- **Resourcing:** A formal mechanism for frontline input into farm safety capital and operating expenditure, with workers presenting annual business cases for vehicles, equipment and training, to support active team input to decision making based on where human performance mitigates risk in the systems. Fleet decisions that place an engineering control layer under every worker rather than some, so that no worker is asked to supply the protection a modern vehicle supplies through design.
- **Transparency:** Visibility over the resource constraints and trade-offs that shape what management can approve, including work planning and scheduling. Load and towing limits displayed in-cab and taught, so that verification is possible at the point of use. Systematic sharing of terrain and debris hazards between teams and shifts, so that ground condition is known information rather than personal discovery.
- **Peer accountability:** A team culture in which challenge at critical steps – on speed, load, carrying a passenger or whether a slope should be ridden at all – is normalised, expected, and read as professionalism rather than as a lack of confidence. Because much farm work is performed alone, peer accountability must be built deliberately through shared planning, debriefs after difficult or unusual work, and mentoring of less experienced workers by the most capable.

3.3 Case Study B: Atmospheric Hazards in Maritime Confined Spaces

3.3.1 Context

This case study examines the management of atmospheric energy displacement hazards for technicians performing agricultural produce monitoring within maritime confined spaces (ship cargo holds). The primary hazard is the natural accumulation of carbon dioxide (CO₂) emitted by ripening produce during transit. As produce respire, it consumes oxygen and releases CO₂, progressively displacing the breathable atmosphere within enclosed holds.

Unlike kinetic energy hazards, atmospheric energy displacement operates invisibly. At moderate concentrations (3–5%), CO₂ causes increased respiration, headaches, and dizziness; at higher concentrations (8–10%+), it produces rapid incapacitation and death. Critically, while CO₂ has a slight acidic odour at very high concentrations, the onset of dangerous levels typically occurs without adequate sensory warning—particularly in enclosed holds where gradual accumulation desensitises occupants. The transition from a safe to an immediately dangerous to life or health (IDLH) atmosphere can occur progressively and without obvious alert. Entry into a CO₂-enriched, oxygen-depleted atmosphere can produce incapacitation within minutes and death shortly thereafter.

The critical step was identified as going through the opening into a confined space with a possible oxygen-deficient atmosphere. Although the hazards differ from those in farm vehicle operations, both settings depend on workers exercising judgement within systems that do not reliably provide the information, authority and resources needed to maintain positive control. Technicians must enter the holds of cargo vessels to monitor atmospheric conditions and produce quality and are dependent on ship-side systems (ventilation, mounted gas monitors) that they may not own, control, or maintain, depending on the nature of contractual arrangements.

3.3.2 Human Dependencies and Error Traps

The typical safe system of work is currently reliant on:

- **Personal Handheld Gas Monitors** — provided monitors that measure CO₂ and O₂ levels. While generally reliable, due to the separate management of some ship environments, discrepancies between personal and ship-mounted readings can require technicians to make judgement calls about which reading to trust. Commonly, the current system focuses primarily on CO₂ measurement, with oxygen monitoring being secondary despite breathable oxygen being the actual critical parameter.
- **Ship-Mounted Gas Monitors** - ship-provided fixed monitors that vary significantly in availability, accuracy, and maintenance across vessels. While mounted CO₂ readers are available, it is estimated that only 50% of ships have mounted O₂ monitors. Readings then conflict with personal monitor data, undermining trust in the monitoring system as a whole.
- **Hold Ventilation Systems** - ship ventilation systems must be activated by ship crew. Technicians are dependent on crew cooperation, which is variable depending on crew experience, language competence, competing priorities, and the quality of the interpersonal relationship between technicians and ship personnel.

Experienced technicians develop adaptive strategies: informal verification protocols, relationship-building techniques with ship crews, personal checklists not necessarily recognised in the safety management system, and pragmatic judgement about alarm response. These innovations reflect adaptive human performance, as the system as designed requires intuitive expertise to close the gap between design and real-world conditions.

Key error traps include: conflicting gas monitor readings requiring human judgement; reliance on ship crew for ventilation activation despite competing priorities and language barriers; limited radio communication from within holds out at sea due to coverage; and the practical reality that experienced technicians will complete 10–15 minutes of remaining work after low-level alarms, knowing they remain within safe atmospheric parameters.

Maritime confined space operations involving cargo holds with respiring produce frequently exhibit brittleness. They rely on human performance due in part to the isolated nature of the work while at sea. Moving from brittleness to resilience requires understanding how teams adapt in this context, regardless of contractual arrangements, and how to strengthen team performance across the work ecosystem.

3.3.3 Human Performance Analysis

Reliance on Human Performance

Analysis of the control architecture reveals that 100% of the assessed controls are dependent on human performance for their effectiveness (see Table 3). The maritime confined space architecture contains no controls that function independently of human judgement and action. The entire safety system is a human performance system.

Table 3.

Controls & Control Supports	Human Performance Dependency
Atmospheric monitoring (personal gas detectors)	Requires the technician to wear, check, calibrate, and respond to the device—technology provides a signal, not a decision
Permit-to-work systems	Requires accurate completion, honest atmospheric verification, and ongoing compliance—a paper-based snapshot of a dynamic environment
Ventilation systems	Requires correct deployment, capacity assessment, and continuous monitoring of effectiveness by human operators
Signage and access restrictions	Requires recognition, comprehension, and voluntary compliance—no physical barrier to entry
Rescue equipment and procedures	Requires trained, equipped, and available rescue personnel who must themselves enter the hazardous atmosphere
Training on atmospheric hazards	Effective only to the extent that classroom knowledge translates to real-time recognition of invisible hazards

Human-Centred Assessment

Applied to the maritime case, the human-centred assessment shifts the focus from meeting contracted expectations, to creating the conditions for entire ship team success and reliable performance at critical steps:

- **Invisibility of the hazard:** CO₂ accumulation and oxygen depletion are invisible, largely odourless at dangerous concentrations, and produce no immediate sensory warning. This fundamentally undermines the human capacity for threat detection that safety systems implicitly rely upon.
- **Gradual onset and habituation:** Unlike a sudden event (explosion, collision), atmospheric degradation occurs progressively. Technicians already inside a hold may experience incremental cognitive impairment—the very faculty they need to recognise the danger is the faculty being degraded.
- **Permit-as-proxy behaviour:** The existence of a completed permit-to-work creates a cognitive shortcut: "the permit says it's safe, therefore it is safe." This substitutes a procedural artefact for real-time atmospheric verification, particularly when time pressures or task focus compete with monitoring behaviours.
- **Task focus narrowing:** Technicians conducting produce quality inspections are cognitively engaged with their primary task. Atmospheric monitoring becomes a secondary, easily displaced activity—precisely the kind of divided attention that degrades System 2 vigilance.
- **Social pressure and normalisation:** If experienced colleagues routinely enter holds without apparent concern, newer team members absorb the implicit message that the hazard is manageable without rigorous precautions.

3.3.4 Pathway to Resilience:

Applying the principles of team autonomy to support human performance in ship holds involve:

- **Authority:** Technicians have absolute authority to refuse entry to any space where they cannot verify atmospheric safety to their own satisfaction - this authority extends to halting operations if conditions change during work. Training builds the pattern recognition and

physiological awareness that support confident exercise of this authority. The safety management system must be continuously redeveloped in collaboration with the teams it governs, by capturing the adaptive strategies technicians have already developed—informal verification protocols, personal checklists, and pragmatic judgements—and giving those teams the authority to redesign the system itself, transforming individual workarounds into organisational capability.

- **Resourcing:** Investment in continuous atmospheric monitoring systems (fixed and portable) with real-time CO₂ and O₂ telemetry. Require team input into the design of atmospheric monitoring and ventilation systems. The people who use these systems daily are best positioned to identify their limitations and recommend improvements. This principle—frontline expertise informing CAPEX decisions through developing business cases—is a direct expression of the enabling framework.
- **Transparency:** Real-time visibility of atmospheric conditions across all relevant spaces and accessible to all team members. Trending data to support understanding of atmospheric migration patterns. Every team member operating in proximity to produce cargo holds should have real-time access to CO₂ and O₂ readings from all relevant spaces—on their personal device, not on a remote monitoring station. This is a CAPEX investment in transparency.
- **Peer accountability:** Effective peer accountability depends on relational investment with contracted ship crews: regular face-to-face engagement, joint pre-entry briefings, and the deliberate cultivation of shared safety language that transcends organisational boundaries. These protocols are developed jointly with ship crews to reflect operational realities and build shared ownership—peer accountability is formalised, trained, and practiced across organisational boundaries.

4. Team Maturity Development Model

4.1 Rationale

The aim of this paper is to create the conditions for adaptive performance which depends on trust between frontline teams and the wider organisation. That trust cannot develop unless organisations are willing to grant teams genuine autonomy – authority to act, resources to act with, and information to act on – so that competence and mutual reliance are exercised and reinforced in practice.

The principles articulated in this paper therefore cannot be implemented overnight, nor should they be. The evolution from a traditional, compliance-driven safety culture to one grounded in team autonomy, adaptive expertise, and positive energy control is a developmental journey that requires sustained commitment, skilful change leadership, and realistic expectations about the pace of cultural transformation.

This section proposes a four-stage team maturity model that maps the progressive integration of the paper's core themes—Safety-II, the Energy Damage Model, HRO principles, Critical Steps methodology, with the importance of intrinsic motivation. Figure 1 summarises the journey to a fully mature team.

Figure 1.



4.2 The Four Stages

Stage 1: Start-Up Team

Characteristics: The team is newly introduced to the principles outlined in this paper. Members are accustomed to traditional approaches and may be sceptical of or unfamiliar with concepts such as Safety-II, energy pathway analysis, or autonomous decision-making.

Theme Integration:

- **Safety-II:** Introduced conceptually. Team begins to explore the distinction between "Work as Imagined" and "Work as Done" but defaults to compliance as the primary operating mode.
- **Energy Damage Model:** Haddon's framework is introduced as an analytical tool. Team learns to identify energy sources, pathways, and targets but applies the model mechanistically rather than intuitively.
- **HRO Principles:** Preoccupation with failure and reluctance to simplify are introduced through structured debrief processes. Deference to expertise is aspirational rather than practiced.
- **Critical Steps:** Team learns to identify critical steps and understands the concept of positive control but relies on procedures and supervision to manage critical step execution.
- **Intrinsic Motivation:** Autonomy is limited; mastery development is beginning; purpose may be unclear beyond task completion.
- **Control Focus:** Relies heavily on administrative controls (procedures, permits, checklists) with limited ability to critically evaluate their effectiveness.
- **Systems:** Use of top-down system design and verification to maintain control. Managers and leaders make decisions and prioritise Capex and Opex.

Stage 2: Transitional Team

Characteristics: The team has internalised the basic concepts and is beginning to apply them in practice. Members demonstrate growing confidence in identifying energy pathways and critical steps. The team begins to question established procedures and practices, comparing "Work as Imagined" with their experience of "Work as Done."

Theme Integration:

- **Safety-II:** The team actively explores why things go right, not just why they go wrong. Team members begin to articulate the adaptive strategies they use to maintain safety in routine operations.
- **Energy Damage Model:** Energy pathway analysis becomes a routine part of pre-task planning and post-task debrief. Team members develop intuitive recognition of energy sources and begin to evaluate barrier effectiveness qualitatively.
- **HRO Principles:** Sensitivity to operations develops—team members pay closer attention to the real-time state of their operational environment. Challenge and verification behaviours emerge but may still feel uncomfortable.
- **Critical Steps:** Team members reliably identify critical steps and begin to exercise positive control through deliberate System 2 engagement. Peer verification at critical steps becomes more common.
- **Intrinsic Motivation:** Autonomy grows as the team demonstrates competence; mastery development accelerates through experience and reflection; purpose begins to shift from "following rules" to "keeping each other safe."
- **Control Focus:** Beginning to prioritise engineering controls over administrative controls. Team questions the adequacy of procedures and proposes improvements. Teams are consulted regarding prioritisation of business cases.
- **Systems:** Delegated authority is granted case by case rather than by design, and still typically requires management sign-off. The need for transparency of information is openly discussed, and the team begins to ask for data: cost, planning and performance information, that was previously held above them.

Stage 3: Well-Trained, Experienced Team

Characteristics: The team operates with genuine autonomy within its domain of competence. Members possess deep expertise in their operational environment and demonstrate consistent ability to manage safety adaptively. The team has a strong internal culture and professional identity.

Theme Integration:

- **Safety-II:** Safety-II is the default operating philosophy. The team understands that safety is created through competent, adaptive performance—not merely through compliance. "Work as Done" is openly discussed, documented, and used to improve "Work as Imagined."
- **Energy Damage Model:** Energy pathway analysis is intuitive and comprehensive. Team members instinctively assess energy sources, pathways, targets, and barrier integrity as part of their routine situational awareness. The team proactively identifies novel or emerging energy pathways.
- **HRO Principles:** All five principles are evident in team behaviour. Deference to expertise operates naturally—decision-making migrates to the most knowledgeable person regardless of seniority. Commitment to resilience is demonstrated through effective response to unexpected events.
- **Critical Steps:** Positive control at critical steps is consistent and culturally embedded. The team has developed specific rituals, language, and practices for managing critical steps that reflect their operational context (not generic procedures imposed from above).
- **Intrinsic Motivation:** High autonomy, growing mastery, strong sense of purpose. Team members identify as safety professionals regardless of their formal role. Pink's framework is visibly operating.
- **Control Focus:** Actively prioritises engineering controls and elimination/substitution strategies over administrative controls. Team are involved in presenting informed business cases for CAPEX investment in engineering solutions.
- **Systems:** Authority in practice is devolved – the team decides how the work is done and increasingly when – but the formal system has not caught up, so delegation limits, approval pathways and accountability remain written for a directive model. Information transparency is negotiated rather than systemic.

Stage 4: Well-Trained, Mature Team

Characteristics: The team is fully autonomous, self-sustaining, and antifragile—it does not merely withstand stressors but uses them as opportunities for learning and improvement. The team actively contributes to organisational learning and mentors other teams in their developmental journey.

Theme Integration:

- **Safety-II:** The team operates as an exemplar of Safety-II practice. It actively contributes to the development of Safety-II theory and practice within the organisation, sharing insights from "Work as Done" that inform organisational learning.
- **Energy Damage Model:** The team proactively identifies and eliminates energy pathways before they produce harm. Energy pathway analysis extends beyond the immediate operational environment to upstream and downstream processes, supply chains, and organisational interfaces.
- **HRO Principles:** The team embodies all five HRO principles consistently and unconsciously. It serves as a reference point for reliability within the organisation and contributes to inter-team learning and benchmarking.
- **Critical Steps:** Positive control at critical steps is automatic and culturally non-negotiable. The team innovates in critical step management, developing context-specific practices that are adopted by other teams.

- **Intrinsic Motivation:** Full autonomy, advanced mastery, deep purpose aligned with organisational mission. Team members experience their work as a vocation rather than a job.
- **Control Focus:** The team operates a sophisticated understanding of the hierarchy of controls, advocating for elimination and engineering solutions while maintaining robust administrative controls as defence in depth. CAPEX and OPEX business cases are data-driven, frontline team lead, professionally presented, and taken seriously by management.
- **Systems:** Authority is devolved to team level, who make all decisions about rules, processes, and integrate critical step management into all they do. They are supported by complete transparency of information which is designed into systems, including transparency with supply chain and regulators.

4.3 Reimagining the Safety Function

The principles articulated in this paper also demand a fundamental reimagining of the role of the safety professional within organisations. Under the framework proposed here, the safety function shifts from a singular focus on audit, inspection, enforcement, and reporting— to include a focus on **enabling capability**: its primary purpose is to create the conditions in which frontline expertise can be exercised effectively.

This means:

- **From auditor to coach:** Safety professionals work alongside teams to develop their capacity for energy pathway analysis, critical step identification, and adaptive decision-making—not to catch them doing things wrong.
- **From rule-writer to sense-maker:** Safety professionals help teams navigate the inevitable gap between "Work as Imagined" and "Work as Done," contributing analytical frameworks (such as the Energy Damage Model) rather than additional procedures.
- **From gatekeeper to enabler:** Safety professionals advocate for the resourcing, information access, and decision-making authority that teams need to manage safety at the point of operation.
- **From incident investigator to learning facilitator:** When things go wrong—or, crucially, when things go right under difficult conditions—safety professionals facilitate organisational learning that strengthens adaptive capacity rather than assigning blame.

5. Conclusions and Recommendations

5.1 Summary of Argument

This paper has argued that sustained safety improvement in high-hazard operations requires a fundamental shift in how organisations understand the locus of safety expertise. The evidence from Safety-II research, Complex Adaptive Systems theory, High Reliability Organisation studies, and the case study analysis presented in this paper converges on a single conclusion: safety is created by competent, empowered people making good decisions at the point of operation, not only by the accumulation of rules, technologies, and supervisory oversight.

The paper has identified four enabling principles—authority, resourcing, transparency, and peer accountability—that create the organisational conditions for this expertise to function. These principles are grounded in the science of intrinsic motivation (Pink, 2009), the cognitive requirements for positive control over critical steps (Muschara, 2018; Kahneman, 2011), and the operational characteristics of High Reliability Organisations (Weick & Sutcliffe, 2007).

Through two case studies—farm vehicle operations and maritime confined space atmospheric hazards—the paper has demonstrated how the Energy Damage Model provides a unifying analytical framework for identifying, assessing, and controlling the pathways through which damaging energy reaches vulnerable targets. The qualitative fragile–brittle–resilient assessment framework offers a practical alternative to quantitative scoring systems, enabling teams and organisations to honestly evaluate the adaptive capacity of their systems of work.

The four-stage team maturity model provides a developmental roadmap for implementing these principles to support identifying the organisational foundations that must be in place for the approach to succeed.

5.2 Recommendations

1. **Recognise the locus of expertise.** Organisations should formally acknowledge that the primary source of safety expertise in high-hazard operations resides at the frontline and structure their safety management systems accordingly.
2. **Invest in the four enabling conditions.** Authority, resourcing, transparency, and peer accountability are not optional enhancements; they are the minimum conditions for reliable safety performance in complex environments.
3. **Adopt the Energy Damage Model as a unifying framework.** Haddon's model provides a simple, powerful, and universally applicable language for understanding and communicating risk that transcends industry boundaries.
4. **Develop team maturity systematically.** Use the four-stage maturity model to assess current capability and guide developmental investment. Do not attempt to leap from Stage 1 to Stage 4; honour the developmental process.
5. **Commit to the pre-conditions.** Honest assessment of organisational readiness—leadership alignment, cultural maturity, resourcing adequacy—should precede and inform implementation planning.
6. **Examine whether your systems distribute or concentrate expertise.** Catastrophic failures in high-hazard operations are consistently associated with safety management approaches that concentrate rather than distribute expertise and authority. Every organisation should examine whether their systems create the conditions for positive control at critical steps—or whether they structurally exclude frontline expertise from critical decisions.

Author declarations

The author acknowledges the limitations of practitioner-led research while asserting its essential contribution to bridging the gap between safety theory and operational practice. The principles presented here are offered not as dogma but as a framework for adaptation to the specific contexts, cultures, and constraints of individual organisations.

This article has not been published elsewhere and will not be published elsewhere in the same or any other form in English or another language without the written consent of the New Zealand Journal of Health and Safety Practice.

The work was self-funded, and I have no known conflict of interest.

AI declaration: all content, research, review of theory, hypothesis, and conclusions were purely the work of the author. AI was used to assist with writing and structure during the preparation of this article.

Note on public-domain commentary: references in this paper to the March 2026 accident at La Guardia Airport are based solely on publicly available information reported at the time of writing. They are offered as illustrative observation only. The investigation was ongoing at the time of submission, and no conclusions as to cause, contributing factors, or the conduct of any party are drawn or implied.

Some of the analytical techniques used in the case studies were informed by methodologies from the Art of Work Academy. Other techniques, findings, interpretations and recommendations are the author's own.

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