



PLAYBOOK SERIES • EDITION 1.0

The CCHI Rollout Playbook

A sequenced path from the first site to the enterprise.
Hierarchy of controls first: remove the energy, engineer the
barrier, verify what is left.

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Critical Control Health Index (CCHI) • Organisational Resilience Factor (ORF)

Implements *Critical control health: methodology proposal, version 2.0*

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START HERE

How to use this playbook

This is the proposed rollout sequence for critical control health: from a leadership commitment, through a first site in 100 days, to an enterprise rhythm. It is ordered by one principle, the hierarchy of controls: remove the energy where you can, engineer the barrier where you cannot, and verify honestly whatever is left.

WRITTEN FOR

Chief executives, operations directors and HSE leaders who sponsor the rollout; the rollout lead who runs it; engineering and maintenance managers who own the hardware barriers.

WHAT IT ASKS OF YOU

A named executive sponsor, a first site chosen by fatal exposure, one or two independent verifiers, an upgrade budget, and the willingness to let a crew stop a job.

STATUS OF THE METHOD

This playbook implements **Critical control health: methodology proposal, version 2.0** ^[19]. The method builds on established practice (ICMM critical control management, the hierarchy of controls, bow ties, layer of protection analysis, Tripod Beta) and on practitioner experience in high-hazard operations. Its point values and thresholds are planning conventions that have **not yet been empirically validated**. The sequence is therefore gated: you advance on your own evidence and claim only what it supports (Section 10). The method does not replace quantitative risk assessment or any legal duty.

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01

The case: injury rates cannot see fatal risk

Injury rates tell a board how often people were hurt. They do not tell it whether the controls that stand between a crew and fatal energy were in place this morning.

The largest statistical study of the recordable injury rate analysed 3.2 trillion worker-hours. It found that 96 to 98% of the change in the rate was random variation, and that the rate showed no discernible association with fatalities ^[1]. Data from the members of the International Council on Mining and Metals (ICMM) show the same decoupling at industry scale. Between 2017 and 2025 their recordable injury rate fell by about 44%, from 3.94 to 2.21 per million hours worked, while annual fatalities stayed between 33 and 50 and did not fall in step ^[2]. ICMM's own review links 67% of member fatalities in 2021 to 2024 to ineffective execution of controls ^[3].



Figure 1. Four figures behind the case for verifying controls. ICMM injury rates as published in its report on 2025 data; change calculated by RISKOPLOT.

Critical control management exists to close that gap. ICMM's 2026 good practice guide strengthens the criteria for identifying, implementing and verifying critical controls, and adds readiness checks and maturity assessments ^[4]. Critical control health builds on it with three things: a binary gate applied before exposure; protection points that show how much each fatal-energy pathway depends on people; and indicators that test whether the barriers, and the checks on them, can be trusted.

What this rollout is designed to change

- **Fewer people meeting fatal energy behind barriers that depend on someone getting everything right.** This is the result that matters, and the rollout measures it directly (Section 10).
- **Work that does not start when a critical control is missing.** The gate gives crews the authority, and leaders the duty, to stop.
- **Capital that moves controls up the hierarchy,** decided on evidence from the field and not on injury statistics.
- **Field data the board can trust,** because its honesty is tested every month and not assumed.

WHY THE SEQUENCE IS GATED

The gate changes who holds power over production, and self-verified data drifts under pressure, the pattern Diane Vaughan called the normalisation of deviance ^[12]. Both are proven at one site before they are multiplied across many. A rollout that skips this step scales paperwork, not protection.

02

First principle: the hierarchy of controls

Everything in this playbook is ordered by one idea that every safety practitioner, risk manager and executive already shares. The higher a control sits in the hierarchy, the less it depends on a person acting correctly at the moment of risk.

NIOSH orders five levels by effectiveness and explains why the upper levels win: they control exposure without significant human interaction ^[7]. Critical control health turns that ordering into numbers. Each barrier earns **protection points** on a logarithmic scale in which one point is roughly a tenfold risk reduction, the convention of layer of protection analysis and IEC 61511 ^{[9][10]}. Credit follows how the barrier functions ^[8], not what it is called.

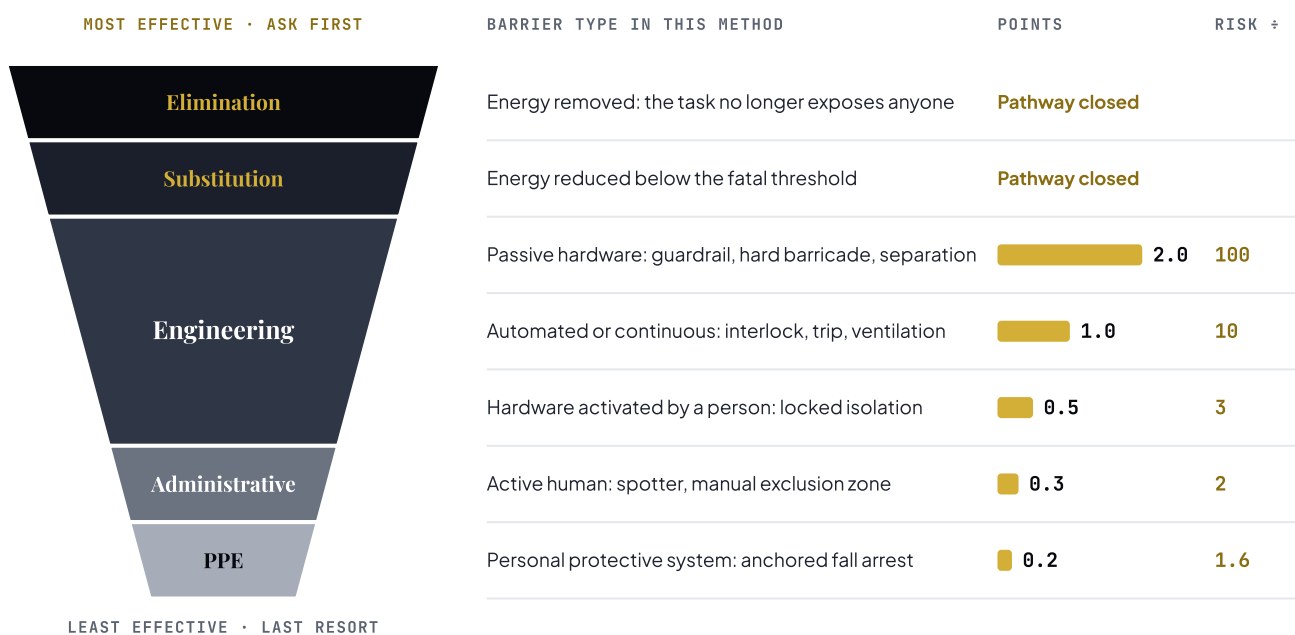


Figure 2. The hierarchy of controls mapped to barrier types and protection points (methodology proposal v2.0 [19]). Points are planning conventions, not site-measured failure probabilities, and are not for use in quantitative risk assessment.

DISPROPORTIONATE BY DESIGN

A fixed guardrail (2.0 points, risk ÷ 100) is worth about fifty times a spotter (0.3 points, risk ÷ 2). Three procedures carried out by the same crew share a common cause, so they count once: 0.3 points.

Procedures cannot buy engineering.

PROTECTION ON ONE PATHWAY	POINTS
One fixed guardrail	2.0
Three procedures, fully independent	0.9
Three procedures, same crew	0.3

TWO RULES THAT KEEP THE SCALE HONEST

- **Direct-control test.** A control earns points only if it is aimed at the fatal energy and stays effective when a worker makes an unintentional error ^[6]. Anchored fall arrest passes. Training, signage and general procedures do not: they support barriers and are measured at the blunt end.
- **Independence rule.** Barriers that share a person, a power supply, a procedure or a maintenance task count once, at the lower value.

What comes first: the hierarchy as the order of work

WHO	THE QUESTION ASKED FIRST	WHAT IT CHANGES IN THIS ROLLOUT
Planner and crew	Can we do this job without the energy, or without the person near it?	The hierarchy challenge comes before the control list (Stage 1, days 6 to 12). Every "not yet" becomes an upgrade candidate.
Supervisor at the task	Are the barriers we rely on working, and how much rests on people?	The gate, then protection points. Fragile pathways need authorisation.
Engineering and maintenance	Which barrier keeps failing, and what sits one level above it?	Repeated gate failures on a human barrier are the case for hardware.
Board	Where do most people meet fatal energy behind the lowest levels?	Capital follows fragility and exposure. O1 counts pathways moved up or closed, not money spent.
Design and procurement	Can the next plant, modification or purchase arrive with the pathway closed or at 2.0 points?	A design standard from Stage 3, so that fragility stops being built in.

Verification keeps a weak control honest. Only the hierarchy makes it strong. A rollout that verifies a spotter every day for five years, and never builds the barricade, has missed the point.

03

The method in brief

Two questions are asked at the task, and five indicators are read at the enterprise. There is no single averaged score.

At the task: the gate, then protection points

Gate $G = v_1 \times v_2 \times \dots \times v_n$ each critical control is verified working ($v = 1$) or not ($v = 0$)

Rule If any $v = 0$, then $G = 0$ and the task stops. Three out of four is a stop.

Pathway protection $P_p = p_1 + p_2 + \dots + p_k$ (independent barriers with $v = 1$; capped at 3.0)

Task protection $P_{task} = \text{lowest } P_p \text{ across all pathways}$

The gate answers "may we start?". Protection points answer "how much does this pathway depend on people getting everything right?". The CCHI is always reported as the pair (G, P_{task}). Points add along a pathway, which is the same as multiplying the risk reduction of independent barriers, so more protection always means more points. Task protection takes the weakest pathway, because a fatal outcome needs only one open route.

DECISION RULE

GATE	P _{TASK}	DECISION
$G = 0$	Any	Stop. Restore the control.
$G = 1$	≥ 2.0	Robust. Proceed.
$G = 1$	$1.0-1.9$	Tolerable. Proceed; log the weakest pathway.
$G = 1$	< 1.0	Fragile. Proceed only with authorisation at a defined level; escalate.

THREE FIELD RULES FOR THIS ROLLOUT

- **No barrier is fragile by definition.** A pathway with no direct control scores 0 points and needs authorisation like any fragile pathway.
- **An unforeseen pathway is a stop.** If the crew finds a fatal energy the card did not list, work pauses, the pathway is added and the register is corrected.
- **The gate is re-run on change:** new shift, interruption, change of scope or weather, or anyone entering the work area who was not briefed.

At the enterprise: five indicators, weakest first

CODE	INDICATOR	THE QUESTION IT ANSWERS	HOW IT IS MEASURED
E1	Gate failure rate	How often does the gate stop work? Always read with O3, never set as a target.	Executions with $G = 0 \div$ all executions
E2	Fragile exposure share	How much fatal exposure depends mainly on people?	Exposures on pathways below 1.0 point $\div$ all exposures
O1	Control upgrade rate	Are we removing fragility or living with it?	Fragile pathways raised to 2.0 or eliminated $\div$ fragile pathways at start

02	Safety-critical element health	Will hardware barriers work on demand?	Overdue assurance; failures on test or demand; expired bypasses (target zero)
03	Verification integrity	Can we trust the field data?	False-pass rate from independent re-checks in the same shift, with Cohen's kappa

O1 to O3 form the **Organisational Resilience Factor (ORF)**. If one ORF value is needed, it is the lowest of the three, never their average. E2 and O1 are the two indicators that speak the language of the hierarchy: one shows how much exposure sits at its lowest levels, the other how fast it is moving up.

Honest gaps

E1 high, O3 low. Honest checks reveal real gaps. Fix the controls; protect the reporting.

Intervene

E1 high, O3 high. Controls are failing and checks are unreliable.

Credible

E1 low, O3 low. Controls in place, checks trusted.

Paper checks

E1 low, O3 high. Checks are probably being completed on paper.

Figure 3. E1 is only meaningful when read against O3. A low gate failure rate is good news only if the checks are honest.

L

Locate

the fatal energies and pathways

O

Observe

see it, touch it, test it

C

Confirm

all pass, or work stops

K

Knock out

engineer out the energy

Figure 4. L.O.C.K. is the communication aid for crews and leaders. It must never replace or abbreviate lockout and tagout terminology.

The rollout sequence at a glance

Five stages. Each ends at a gate, and each must deliver physical upgrades as well as data. Advance when the gate conditions are met, not when the calendar says so.

STAGE 0 · WEEKS 0-4 Commit Sponsor, conditions, upgrade budget. First site chosen by fatal exposure and fragility.	STAGE 1 · DAYS 1-100 First site L.O.C.K. on three to five task types. Cards and a spreadsheet. First upgrade under way. Board read-out.	STAGE 2 · MONTHS 4-9 Extend Two or three more sites with a different energy mix. Same cards, same charter, local expert panel.	STAGE 3 · MONTHS 9-15 Embed Digitise what worked. Automate equipment-health data. Design and procurement standard.	STAGE 4 · MONTH 15 ON Sustain All fatal-energy work. O1 over rolling twelve months. Outcome evidence builds.
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Figure 5. The proposed sequence. Durations are indicative for a multi-site operator; a single-site organisation runs Stages 0, 1, 3 and 4.

STAGE	WHAT IT MUST PROVE	HIERARCHY DELIVERABLE	GATE TO THE NEXT STAGE
0 Commit	Leaders will protect a stop and fund upgrades.	Indicative upgrade budget agreed before any data exists	Conditions 1, 2 and 5 met (Section 5)
1 First site	The gate works on real tasks; checks are reliable; the data is honest.	Hierarchy challenge on every pathway; at least one physical upgrade under way by day 100	Stage gate criteria (Section 10)
2 Extend	Results hold across sites, energies and contractors.	Every fragile pathway has an owner and a dated plan; repeat failures converted to hardware	Criteria met at every site; stable sensitivity results
3 Embed	Digital tools reproduce the paper results; O2 is automated.	Design and procurement standard: new work arrives closed or at 2.0 points	Parallel run passed; O3 resourced permanently
4 Sustain	Fragile exposure keeps falling; precursors follow.	O1 on a rolling twelve months; protection profile reported to the board	Continuous. Public claims match the evidence level.

SEQUENCE BY EXPOSURE AND FRAGILITY, NOT BY CONVENIENCE

Choose the first site and the first task types where the most people meet fatal energy behind the weakest barriers. Use your own high-potential events, your sector's fatality record and a quick estimate of design protection per pathway. Starting with the tidy site produces a tidy report and changes nothing.

05

Stage 0. Commit: ten conditions before day 1

ICMM's 2026 guide introduces readiness checks for good reason ^[4]. A rollout launched into the wrong conditions teaches crews that the gate is theatre. Answer these honestly before you set a start date.

#	QUESTION	IF THE ANSWER IS NO
1	Has the chief executive or site director agreed, in writing, that a good-faith stop will never be sanctioned, whatever the production cost?	Do not start. This is the one non-negotiable condition.
2	Does the same protection cover contractors, including their commercial scoring?	Extend it first. Contractors carry much of the fatal exposure on most sites.
3	Are any bonuses, site league tables or contractor scores tied to injury rates or to stoppages?	If yes, suspend them where the rollout runs. They will distort E1 and O3.
4	Do you have current risk assessments or bow ties for the first three to five task types?	Build them in days 1 to 15. Budget the time.
5	Can you name one or two independent verifiers outside the production line of the crews they will sample?	Borrow them from another site or function. Without them there is no O3.
6	Can maintenance tag the equipment that forms hardware barriers and extract its overdue list by hand each month?	Start with a list of 20 to 50 items. No system integration is needed.
7	Is there a register of bypasses, overrides and inhibits on safety-critical equipment?	Create one. Any expired bypass is always red.
8	Can someone with authority reach a stopped job quickly, with the means to restore the control?	Define the response route and target time before go-live.
9	Have worker representatives been consulted, including on any use of photographs or location data?	Consult first. In many jurisdictions this is a legal duty, not a courtesy.
10	Has the board agreed an indicative upgrade budget, and is it prepared to hear that routine tasks are fragile?	Agree it now. Without money to move up the hierarchy, the K in L.O.C.K. has no meaning and crews will see it within weeks.

COMMITMENT RULE

Questions 1, 2 and 5 are conditions, not preferences. If any of them cannot be met, postpone and fix that first. The other seven can be closed during days 1 to 30.

Stage 1. The first site in 100 days

Four phases that follow L.O.C.K. One site, three to five task types, paper cards and a spreadsheet. By day 100 the board has its first dashboard and the crews have seen at least one barrier move up the hierarchy.

DAYS 1-30 Locate Pathways, the hierarchy challenge, barrier classification, verification standards, fragility map.	DAYS 31-60 Observe and Confirm Charter signed, crews briefed, gate live, independent sampling from week two. First quick upgrades.	DAYS 61-90 Test the data Verification integrity, equipment health, sensitivity test, learning reviews, upgrade ladders.	DAYS 91-100 Knock out and decide Board read-out, funded upgrades, stage gate decision.
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Figure 6. Stage 1. The phases mirror, in miniature, phases A to C of the validation protocol in the methodology: content review, reliability and field run.

Days 1 to 30: Locate

Aim: know which fatal-energy pathways are in scope, whether each could be closed or engineered, which controls are critical, and what counts as proof that a control works.

WHEN	ACTION	OUTPUT
Days 1-5	Confirm the sponsor and the rollout lead. Close conditions 1, 2 and 5. Confirm three to five task types with real fatal energy and regular frequency, so that data accumulates.	Rollout charter, one page
Days 6-12	For each task, list every fatal energy and each pathway by which it can reach a person. Work with the crews who do the job: they know the routes the documents miss. Then run the hierarchy challenge on every pathway, from the top: can the energy be removed? reduced below the fatal threshold? can people be separated from it by passive hardware? can an automated barrier act without anyone deciding? Record each answer and the reason.	Pathway register; hierarchy challenge log. Every "not yet" is an upgrade candidate.
Days 10-20	Select critical controls with the ICMM definition: a control that is crucial to preventing the event or mitigating its consequences ^[5] . Apply the direct-control test to each. Do not strip PPE by category: anchored fall arrest passes the test; safety glasses against a dropped load do not. Classify every critical control by barrier type, assign its points and apply the independence rule.	Classified control list; items that fail the test moved to the blunt-end list
Days 15-25	Write a verification standard for each control: what the supervisor must see, touch or test to record v = 1. Documents support verification but never replace it. A photograph of a tag is a record, not proof of zero energy; the proof is the attempted start or the test reading. Train supervisors to apply the standard and the direct-control test.	Verification card per task; trained supervisors

Days 20–30	A small expert panel (operations, engineering, HSE, a crew representative) reviews the register, the challenge log and the classifications, and records disagreements. Compute design protection for every pathway. Define who may authorise work on a fragile pathway. Pick the quick upgrades that need no capital approval.	Baseline fragility map; first E2 estimate; authorisation rule; quick-upgrade list
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PATHWAY REGISTER: TEMPLATE WITH ONE EXAMPLE ROW

TASK	PATHWAY	HIERARCHY CHALLENGE	CRITICAL CONTROL	BARRIER TYPE	PTS	VERIFICATION STANDARD	OWNER
Pump overhaul	P2 Release of line pressure	Removal: no. Automated isolation: not yet (trapped-key interlock feasible, +1.0)	Isolation locked, zero pressure proved	Hardware activated by a person	0.5	Locks on both valves seen; bleed opened; gauge reads zero	Maintenance supervisor

GATE FOR THE LOCATE PHASE

Do not go live until every task in scope has a reviewed pathway register with its hierarchy challenge, a verification card and a named owner for each critical control, consistent with ICMM guidance on accountability ^[5].

Days 31 to 60: Observe and Confirm

Aim: run the gate on real work, start testing the honesty of the data almost immediately, and let crews see the first hardware change.

WHEN	ACTION	OUTPUT
Days 31–35	The sponsor signs the stop-work protection charter (Section 7) and presents it in person to every crew in scope, contractors included. Supervisors brief the card: see it, touch it, test it; any failed control stops the task; re-run the gate on change.	Signed charter; attendance record
Day 36	Go live. Each execution records, per control: pass or fail, a reason code for every fail, and an optional short note. Keep the note. The reason a control failed is the most valuable data this stage produces.	Completed cards; stop log
Daily	Every stop is reviewed within the day: what failed, how long restoration took, what the crew needed. The sponsor or site director acknowledges each stop personally in the first weeks.	Stop review notes
From day 43	Independent verification starts. A verifier outside the crew's production line re-checks a random sample of controls recorded as passes, within the same shift, stratified by energy type.	2 × 2 agreement table, weekly
Days 45–60	Reliability check. Two assessors classify and verify the same controls independently. Report Cohen's kappa; values below 0.61 indicate less than substantial agreement on the Landis and Koch scale ^[11] , and mean the verification standards need rewriting.	Kappa by task type; revised cards

By day 60	Deliver the quick upgrades. Hard barricades in place of tape, a fixed anchor point, a guard refitted: changes a site director can approve. Tell the crews which stop or which challenge answer led to each one.	First barriers moved up the hierarchy
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WHAT TO EXPECT, STATED HONESTLY

Expect stops, and expect them to cluster in the first weeks. We know of no published figure for the production effect of introducing a control-verification gate, so this playbook does not quote one.

Measure it instead: stops per 100 executions, median time to restore the control, and hours lost. Those three numbers, from your own site, are what the board should see on day 100.

Days 61 to 90: Test the data

Aim: find out whether the numbers can be trusted, whether the hardware behind the barriers is being kept alive, and what each fragile pathway needs next.

WHEN	ACTION	OUTPUT
Weekly	Compute the false-pass rate: controls the crew recorded as passes that the verifier found failed, divided by all crew passes in the sample. With fewer than 30 sampled controls, report "sample too small" and not a percentage.	O3 trend
On every false pass	Run a learning review, structured with Tripod Beta ^[20] . The first question is what in the system made a false pass the easier choice: time pressure, an unclear standard, a control that cannot be tested in practice. Track actions to closure.	Learning review; actions
Days 61–75	Maintenance extracts, by hand, the status of the tagged safety-critical elements: share overdue for inspection, test or calibration; failures on test or demand; bypasses open without valid authorisation or beyond their authorised period.	First O2 reading
Days 75–85	Sensitivity test. Move each point value one step up and one step down the scale and recompute every pathway. Record which decisions change (robust, tolerable, fragile). Stable decisions support the scale; unstable ones go to the expert panel.	Sensitivity table
Days 80–90	Read E1 against O3 and place the site in its quadrant (Figure 3). Review gate failures by control: a barrier that fails repeatedly is an engineering signal. Build an upgrade ladder for every fragile pathway (Section 8): the next level up, the level that would reach 2.0 points, and whether the pathway can be closed. Get an order-of-magnitude cost and lead time for each.	Quadrant reading; upgrade ladders, costed

Days 91 to 100: Knock out and decide

WHEN	ACTION	OUTPUT
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Days 91–95	Assemble the first dashboard by hand: E1 with its quadrant, E2, O2 and O3, weakest first. O1 is reported as "baseline set", with the quick upgrades already delivered. Add the three production numbers, the protection profile (Section 10) and the team's own account of what worked and what did not.	Board paper, four pages at most
Days 96–100	Board read-out. The board takes three decisions: which upgrade ladders to fund, starting with the highest exposure; whether the stage gate criteria are met; and whether to extend, adjust and repeat, or stop. Report back to the crews within the week, in person.	Funded upgrades; recorded decision

A NOTE ON TIMING AND CLAIMS

Day 100 gives about nine weeks of live field data at one site. The methodology asks for two to three sites over at least twelve weeks before the method itself may be described as **piloted**. Stage 2 supplies that evidence. Keep the first site running while the board decides.

The stop-work protection charter

The gate only works if recording a failure is always safer for the crew than recording a pass. That is a leadership commitment before it is a procedure.

Amy Edmondson's research on psychological safety shows that teams report problems when they believe they will not be punished or humiliated for doing so ^[13]. James Reason's just culture adds the complementary line: trust, with a clear boundary between acceptable and unacceptable behaviour ^[14]. The charter needs both. A charter built on a threat, such as naming a "fireable offence", invites concealment, prejudices an investigation and, in many jurisdictions, would not survive employment law. Ask what was responsible before asking who ^[15].

TEMPLATE CHARTER: ADAPT THE WORDING, KEEP THE SIX COMMITMENTS

1. **Protected stops.** Anyone who stops a task in good faith because a critical control is missing or not working will never be sanctioned, whatever the cost to production.
2. **Everyone on site.** This protection applies equally to employees, contractors and visitors. A protected stop never counts against a contractor in commercial scoring.
3. **We come to you.** When a task stops, a named leader responds within [agreed time] with the authority and resources to restore the control.
4. **Stops are evidence the system works.** We report stops to the board as such. The gate failure rate will never be a target, a league table or a bonus measure.
5. **Honest records.** A pass means the control was seen, touched or tested. If a pass is found to be wrong, we first ask what made it the easier choice, and we fix that. Deliberate falsification is handled under our existing just-culture process, after a fair review.
6. **We close the loop, in hardware where we can.** Every crew that stops a task hears what was done about it, and repeated stops on the same barrier lead to a stronger barrier, not to more coaching.

Signed: chief executive or site director · operations director · contractor principal(s) · worker representative

WHAT THE SPONSOR SAYS TO THE CREWS

"From today, on these tasks, every critical control is checked before the work starts. If one is missing or not working, you stop, and you have my personal word that nobody will be blamed for the delay. A stop is not a failure. It tells me something I need to know and could not see from my office. I would far rather explain a late job to a customer than explain anything else to a family. What I ask in return is an honest card: a pass means you saw it, touched it or tested it. If something makes that hard, tell us, and we will fix the system, not the person."

THREE THINGS THAT BREAK THE CHARTER IN A WEEK

- A manager who asks "how long will this take?" before asking "what do you need?"
- A stop that appears in a contractor's performance review.
- A stopped job restarted by someone senior without the control being restored.

Track charter breaches as a rollout measure. The target is zero, and one breach is a board matter.

Three worked examples, with their upgrade ladders

Three scenarios, scored with the withdrawn version 1 formula and then with version 2, each followed by its ladder up the hierarchy. The barrier classifications are illustrative: your expert panel decides yours.

WHY VERSION 1 WAS WITHDRAWN

Version 1 multiplied hierarchy weights together, so every added barrier lowered the score: a guardrail scored 0.90, a guardrail plus anchored fall arrest scored 0.18. It also averaged results into a single enterprise score, which let 99 passing tasks hide one exposed crew. If you hold an earlier draft that uses "wCCHI", multipliers of 1.0, 0.9, 0.5 and 0.2, or an "Enterprise Score", it is superseded.

Example 1. Confined space entry: tank cleaning

Pathway P1: a toxic or oxygen-deficient atmosphere reaches the entrant.

CRITICAL CONTROL	BARRIER TYPE	POINTS	V	NOTE
Forced ventilation, airflow tested at the task	Continuous hardware	1.0	1	A safety-critical element: its inspection status feeds O2
Personal gas monitor with alarm and trained withdrawal	Hardware activated by a person	0.5	1	Bump-tested before entry
Attendant at the entry point with communication and stop authority	Active human	0.3	1	Mitigation: raises the alarm, starts the rescue plan

METHOD	RESULT	WHAT IT TELLS THE CREW AND THE BOARD
Version 1 (withdrawn)	$0.9 \times 0.2 \times 0.5 = 9\%$	Three verified barriers look like near-total failure. The score would improve if the crew listed fewer controls.
Version 2	$6 = 1 \cdot P = 1.8$ TOLERABLE	Work may proceed. Two of the three barriers depend on people, so the pathway is logged for upgrade.

closed Eliminate remote cleaning	closed Substitute	2.0 Passive	1.0 Automated	0.5 Human-activated	0.3 Active human	0.2 PPE
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Reading the ladder: ■ verified in place ■ failed the gate □ upgrade to fund ■ not present

Knock out. The top of the ladder is the real prize: clean the tank remotely so that nobody enters, and the pathway closes. A common trap one level down is to add fixed gas detection that acts only through the same fan: under the independence rule, two barriers with a common cause count once. Do not engineer out the attendant: many confined-space regulations and company standards require one, and the rescue plan depends on it. **Blunt end.** If the ventilation fan is overdue for inspection, it appears in O2 as overdue safety-critical assurance, whatever the card says.

Example 2. Lifting a 10-tonne chiller onto a roof by tower crane

Pathway P1: the suspended load falls onto people below. Wind is handled on a separate pathway (loss of control of the load).

CRITICAL CONTROL	BARRIER TYPE	POINTS	V	NOTE
Rated, inspected lifting gear, selected and attached by a competent rigger and checked before the lift	Hardware activated by a person	0.5	1	A certificate is not the barrier; correct rigging is
Crane rated capacity limiter, function-tested	Automated hardware	1.0	1	Safety-critical element
Exclusion zone under the load path, tape and cones, controlled by a spotter	Active human	0.3	0	An unauthorised person entered the zone

METHOD	RESULT	WHAT IT TELLS THE CREW AND THE BOARD
Version 1 (withdrawn)	0%	Correct stop, but the zero also erased all information about the other barriers.
Version 2, as found	$G = 0$ STOP	The load is landed. The zone is cleared and re-established. The stop is protected and logged with its reason code.
Version 2, control restored	$G = 1 \cdot P = 1.8$ TOLERABLE	The lift proceeds.
After upgrade	$0.5 + 1.0 + 2.0 = 3.5$ capped at 3.0 ROBUST	A hard barricade (passive, 2.0) replaces tape and cones.

closed Eliminate	closed Substitute	2.0 Passive hard barricade	1.0 Automated	0.5 Human-activated	0.3 Active human tape and cones	0.2 PPE
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The lesson is in the pattern. If the same exclusion zone has failed the gate four times in a month, that is not a discipline problem to coach away. It is evidence that an active human barrier cannot hold at this location, and it is the business case for the barricade one level up. This is a quick upgrade: a site director can approve it in Stage 1. Gate failures by control, not by crew, are what the weekly engineering review should read.

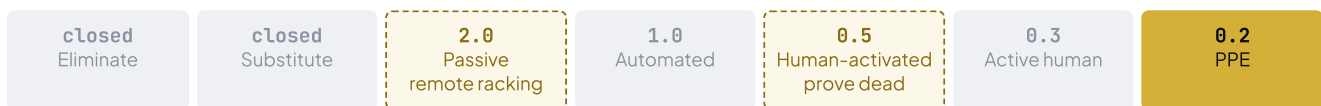
Example 3. Racking a breaker on an energised 480 V panel

Pathway P1: arc-flash thermal energy reaches the electrician. 480 V is low voltage under IEC 60038 (up to 1,000 V a.c.)^[17]; the arc-flash hazard is no less fatal for that.

CONTROL LISTED IN THE EARLIER DRAFT	DIRECT-CONTROL TEST	POINTS	NOTE
Arc-rated suit, 40 cal/cm ² , matched to the incident energy	Passes. Mitigation only.	0.2	Reduces the consequence of the arc; does not make it less likely
Insulated matting	Fails for this pathway. It addresses electric shock, not arc-flash thermal energy.	0	Belongs on the shock pathway

Switching procedure	Fails. A general procedure supports barriers but does not stop the energy.	0	Blunt end: degradation control
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METHOD	RESULT	WHAT IT TELLS THE CREW AND THE BOARD
Version 1 (withdrawn)	$0.2 \times 0.9 \times 0.5 = 9\%$	The right instinct, reached with two controls that do not act on this energy.
Version 2	$G = 1 \cdot P = 0.2$ FRAGILE	The only thing between the electrician and the arc is clothing. Work needs authorisation at the defined level, and the pathway is escalated.
Option A: de-energise upstream and prove dead before racking	$0.5 + 0.2 = 0.7$ FRAGILE	Better, and the first choice under NFPA 70E ^[18] , yet still dependent on a person applying and proving the isolation.
Option B: remote racking from outside the arc-flash boundary	$2.0 + 0.2 = 2.2$ ROBUST	Physical separation works by being present. This is the upgrade the board should be asked to fund.



Blunt end. The earlier draft judged this division by how its safety budget was split between PPE and capital. Version 2 withdrew that measure: spending is not protection. O1 asks a harder question: of the pathways that were fragile a year ago, how many are now at 2.0 points or closed?

SCENARIO	VERSION 1 SCORE	VERSION 2 PROTECTION POINTS (SCALE 0 TO 3.0)
1. Confined space, as found	9%	1.8
2. Lift, control restored	0% then 20%	1.8
2. Lift, hard barricade	36%	3.0 (cap)
3. Racking, as found	9%	0.2
3. Racking, remote	n/a	2.2

Figure 7. Version 1 gave scenarios 1 and 3 the same 9%. Version 2 separates a tolerable pathway from a fragile one, and rises as protection moves up the hierarchy. Version 1 values for the lift use the draft's weights (0.9, 0.9, 0.5, 0.5 as found; a 0.9 barricade after upgrade).

Stages 2 to 4. Extend, embed, sustain

Each later stage repeats the logic of the first: locate, verify, test the data, move barriers up the hierarchy. What changes is scale, tooling and how far upstream the hierarchy reaches.

Stage 2. Extend (months 4 to 9)

- **Two or three further sites**, sequenced by exposure and fragility, with a different energy mix or contractor profile from the first. Same cards, same charter, a local expert panel at each.
- **Transfer people, not only documents.** Supervisors and the verifier from the first site help launch the next. Registers are rebuilt locally with the hierarchy challenge; copied registers miss local pathways.
- **Deliver the funded ladders from Stage 1** and publish them internally. Nothing recruits the next site like a barricade, an interlock or a closed pathway that crews at the first site asked for.
- This stage supplies the multi-site, twelve-week evidence that the methodology requires before the method is described as piloted.

Stage 3. Embed (months 9 to 15)

WORKSTREAM	WHAT TO DO	CAUTION
Digitise what worked	Move the cards to a mobile tool that works offline and keeps reason codes and notes. Run paper and digital in parallel until results match.	The software specification is written from the paper process, not the reverse.
Maintenance system (any CMMS) to O2	For equipment tagged as safety-critical elements: overdue assurance tasks, failures on test or demand. Link the bypass and override register.	Tag the barrier equipment first. Maintenance ratios across all assets say little about barriers. Any expired bypass is red.
Work-order data to O1	Count upgrades completed against the fragile-pathway list.	Count pathways upgraded, not money spent. No finance-ledger link is required.
Machine-state sensors	Isolator position, interlock status, gas readings, to corroborate field checks.	Supports O3. Never a substitute for independent verification.
Design and procurement standard	New projects, modifications and major purchases run the hierarchy challenge at concept stage and specify each fatal-energy pathway closed or at 2.0 points by design, or record why not. Any change to a barrier re-opens its pathway in the register.	A recommendation of this playbook. Without it the organisation keeps buying fragility and then verifying it.

Stage 4. Sustain (month 15 onwards)

- **All fatal-energy task types in scope.** Thresholds set from the organisation's own baseline. O1 measured over a rolling twelve months.
- **The board reads weakest first:** the status of the worst of E1 (read with O3), E2, O1, O2 and O3, by site, with the protection profile (Section 10). No enterprise average.
- **Three conditions are always red:** any unauthorised or expired bypass of a safety-critical element; false passes at the same site in two consecutive samples; any fragile pathway past its upgrade deadline without

an approved plan.

- **Capital follows fragility and exposure**, not a site ranking. Ranking sites on a score rewards the ones that hide fragility.
- **Outcome evidence builds**. Precursor events are trended against exposure (Section 10), and the organisation can contribute to the twelve-to-twenty-four-month criterion-validity study.

CONTRIBUTE TO THE VALIDATION

Organisations that implement the method can contribute anonymised reliability, field and outcome data to the validation protocol. Write to contact@riskopilot.com.

10

Is fatal risk really falling? Measures and stage gates

A completed card has never saved anyone. The rollout succeeds only if fewer people meet fatal energy behind weak barriers, and if the events that precede fatalities become rarer. Measure that, and claim no more than the evidence supports.

#	LEVEL OF EVIDENCE	WHAT IT SHOWS	HOW TO USE IT
1	Activity	Cards completed, people trained, sites launched	Management information only. Never report it as a result.
2	Control state	E1 read with O3; O2; charter breaches. Controls were present and the data is honest.	Necessary, not sufficient. A credible quadrant earns the right to believe the rest.
3	Exposure	E2 falling; O1 rising; pathways closed; the protection profile moving up the hierarchy	The primary result of the rollout. It is measurable within months and it is what capital can change.
4	Precursors	High-energy incidents and near misses in which a direct control was absent or failed, per exposure hour ^[6] ^[22]	Trend from Stage 2. Expect reporting to rise before events fall; read it with O3.
5	Outcomes	Fatalities and life-altering injuries	Always reported, never used to claim success at site level. They are too rare for their count to show, within a year or two, whether risk has changed ^[1] .

PROTECTION PROFILE: SHARE OF FATAL EXPOSURES BY STRONGEST VERIFIED BARRIER

Start of Stage 1



Month 18



Figure 8. The shape of success: exposure migrating up the hierarchy of controls. **Illustrative shape, not data.** The profile is a way of displaying E2 and O1, not a new indicator.

Operating measures

MEASURE	HOW	READING IT
E1 Gate failure rate	Stops ÷ executions, by task type and by control	No target. Read with O3 only. Illustrative boundary: "low" below 3%.
E2 Fragile exposure share	Executions on pathways below 1.0 point ÷ all executions	Illustrative: green ≤ 10%, amber to 25%, red above
O1 Control upgrade rate	Fragile pathways raised to 2.0 or closed ÷ fragile pathways at start, rolling twelve months	Illustrative: green ≥ 50%, red below 20%. A fragile pathway unfunded for 26 weeks is always red.
O2 Equipment health	Overdue share; failure on test or demand; expired bypasses	Illustrative: overdue green ≤ 5%, red above 15%. Any expired bypass is always red.
O3 False-pass rate and Cohen's kappa	Crew pass and verifier fail ÷ crew passes in sample (minimum 30 controls); kappa from the 2 × 2 table	Illustrative: green 0%, amber ≤ 3%, red above. Kappa below 0.61 forces at least amber ^[11] .
Production effect and check burden	Stops per 100 executions; median time to restore; hours lost; minutes per card	Report as found. Set no target.

Table 1. Thresholds marked illustrative are the defaults used in the RISKOPLOT simulator. Set your own from your baseline; none has been validated.

NEVER TURN E1 INTO A TARGET

When a measure becomes a target, people improve the measure and not the condition it describes ^[16]. Neither E1 nor O3 should ever be linked to individual bonuses or contractor scoring.

Stage gate: what must be true before extending

- ☐ Agreement between paired assessors reaches kappa of 0.61 or more on every task type in scope.
- ☐ The false-pass rate is at or below 3% on a sample of at least 30 controls, with no false passes in two consecutive samples.
- ☐ Robust, tolerable and fragile decisions stay stable when each point value is moved one step up and down.
- ☐ Zero charter breaches, confirmed by the crews and contractors, not only by management.
- ☐ Every fragile pathway has a named owner and an upgrade ladder that is funded, dated or formally declined by the board.
- ☐ **At least one barrier has physically moved up the hierarchy**, and the crews know which stop or challenge led to it.
- ☐ The crews, asked directly, say the gate helps them. If they say it is paperwork, believe them and adjust.

If any criterion is missed, the right answer is to **adjust and repeat** for another eight to twelve weeks, not to extend and hope.

11

Roles, three lines of verification, rhythm

ACTIVITY	EXECUTIVE SPONSOR	ROLLOUT LEAD	SITE DIRECTOR	SUPERVISORS AND CREWS	ENGINEERING AND MAINTENANCE	INDEPENDENT VERIFIER
Stop-work charter	A, R	C	R	C	I	I
Pathway register, hierarchy challenge, points	I	A, R	C	R	R	C
Verification at the task	I	C	A	R	C	I
Response to a stop	I	C	A, R	R	R	I
Independent sampling (O3)	I	A	C	C	I	R
Equipment health (O2)	I	C	A	I	R	I
Upgrade ladders and funding (O1)	A	R	R	C	R	I
Board read-out	A	R	R	C	C	C

Table 2. R responsible, A accountable, C consulted, I informed. The independent verifier reports to the rollout lead, never to the production line being sampled.

Three lines of verification

ICMM's guidance applies structured verification across all organisational levels ^[4]. The rollout uses three lines, each with a different purpose.

LINE 1 · EVERY TASK

Supervisor and crew. The gate: see it, touch it, test it. Purpose: no exposure without working controls.

LINE 2 · PLANNED, MONTHLY

Line leaders, up to the executive. Each verifies selected critical controls in the field, in person, and asks the hierarchy question: what would it take to move this one up? Purpose: leaders see the barriers they fund.

LINE 3 · RANDOM, SAME SHIFT

Independent verifier. Re-checks a sample of recorded passes. Purpose: O3, the test of the data itself.

Governance rhythm

FREQUENCY	WHO	FOCUS
Every task	Supervisor and crew	Locate, Observe, Confirm. If G = 0: stop, restore the control physically, re-verify, then resume. Re-run the gate on change.
Daily	Site director, rollout lead	Review every stop: what failed, what the crew needed, how long restoration took. Acknowledge the crew.
Weekly	Engineering and maintenance managers	Gate failures by control, not by crew. A barrier that keeps failing goes on an upgrade ladder. Prioritise work orders on safety-critical elements.

Monthly	Site director, verifier	O3 and kappa; learning reviews on false passes, aimed at the system that made a false pass easier. O2 extract and bypass register. Line 2 verifications completed.
Quarterly	Board or executive committee	Dashboard, weakest first, with the protection profile. Fund upgrade ladders by exposure and feasibility, top of the hierarchy first. Review evidence levels before any external claim.

12

Eight ways rollouts fail

#	FAILURE	WHAT TO DO INSTEAD
1	Verifying weak controls for ever. The cards are perfect and the spotter is still the only barrier.	Run the hierarchy challenge before the control list, build a ladder for every fragile pathway, and hold the board to O1.
2	Software first. Months go into an app and integrations before anyone knows what is worth automating.	Cards and a spreadsheet through Stage 2. Let the field write the software specification.
3	A photograph treated as proof. A picture of a tag shows a tag.	Functional evidence only: the attempted start, the gauge at zero, the airflow reading. Photographs are records that support it.
4	No free text. Binary toggles only, to keep data "clean".	Binary verdict, plus a reason code and an optional note for every fail. The why is the asset.
5	Padding the card. Extra procedures and PPE are listed to raise points.	Apply the direct-control test and the independence rule strictly. Barriers that share a person count once.
6	E1 becomes a target. Stops fall, and leadership celebrates.	Read E1 only with O3. A low E1 with a high false-pass rate is the most dangerous quadrant on the page.
7	Contractors left out of the charter, the training or the protection.	Include them from day 1, with their principals as signatories.
8	Claiming too much. "Our fatal risk is down 40%."	Points are conventions. Report the evidence level reached (Section 10): what was verified, what was fragile, what moved up the hierarchy.

ON SENSORS, GEOFENCES AND TELEMATICS

Machine-state data can usefully corroborate field checks, for example whether an isolator was open when the card said so. It supplements independent verification and does not replace it. Location tracking of workers is a different matter: in the European Union, systematic monitoring of employees will usually call for a data protection impact assessment under Article 35 of the GDPR and consultation of worker representatives ^[21], and comparable duties exist elsewhere. A rollout that feels like surveillance will not get honest cards.

A CLOSING THOUGHT

Most fatal risk is decided long before the shift starts: in design, in maintenance and in what gets funded. The gate protects the crew today. The hierarchy protects every crew after them. Protect the people who stop the job, test your own data harder than anyone else would, and spend the credibility that earns on engineering the energy out.

13

Crosswalk to ICMM critical control management

If you already run critical control management, this rollout extends it. If you do not, it is a focused way to begin. The nine steps below are those of the ICMM good practice guide ^[5]; the 2026 edition consolidates the good practice and implementation guides and adds readiness checks and maturity assessments ^[4]. Check the step wording against the edition you use.

#	ICMM STEP	WHERE IT SITS IN THIS PLAYBOOK	WHAT THIS METHOD ADDS
1	Planning the process	Stage 0 conditions; rollout charter	Explicit go or no-go conditions; upgrade budget first
2	Identify material unwanted events	Sequencing by exposure and fragility; choice of task types	The pathway as unit of analysis
3	Identify controls	Pathway register with the hierarchy challenge (days 6–12)	Elimination asked before controls are listed
4	Select the critical controls	Direct-control test, barrier type and points (days 10–20)	Protection points; independence rule
5	Define performance and reporting	Verification standards and cards (days 15–25)	"See it, touch it, test it" evidence rule
6	Assign accountability	Named owners; roles table	Owners for pathways, ladders and ORF indicators too
7	Site-specific implementation	Charter, training, go-live (days 31–36); Stage 2	Binary pre-exposure gate; re-run on change
8	Verification and reporting	Three lines of verification; O2 extract; dashboard	False-pass rate and kappa; weakest-link reading
9	Response to inadequate performance	Stop reviews; Tripod Beta learning reviews; upgrade ladders	O1: fragility removed, not money spent

ANNEX

Glossary and formulas

TERM	MEANING IN THIS PLAYBOOK
Fatal energy	An energy source large enough to kill: gravity, pressure, motion, electricity, chemical, thermal.
Pathway	A route by which a fatal energy can reach a person. The unit of analysis for protection.
Hierarchy challenge	The questions asked of every pathway, from the top of the hierarchy of controls down, before controls are listed.
Upgrade ladder	For a fragile pathway: the next level up, the level that reaches 2.0 points, and whether the pathway can be closed, each with cost and lead time.

Critical control	A control crucial to preventing the event or mitigating its consequences, as defined by ICM [5].
Direct-control test	A control earns points only if it targets the fatal energy and stays effective when a worker makes an unintentional error [6].
Gate (G)	Product of the verification values of all critical controls. $G = 0$ stops the task.
Protection points (P)	Sum of the points of independent, verified barriers on a pathway, capped at 3.0. One point is roughly risk $\div 10$.
CCHI	Critical Control Health Index: the pair (G, P_{task}) .
Fragile / tolerable / robust	Below 1.0 / 1.0 to 1.9 / 2.0 or more protection points.
Safety-critical element	Equipment that forms, or is needed by, a hardware barrier on a fatal-energy pathway.
ORF	Organisational Resilience Factor: O1, O2 and O3. As a single value, the lowest of the three normalised indicators.
False pass	A control recorded as working by the crew and found not working by an independent verifier in the same shift.
Cohen's kappa	Agreement corrected for chance: $\kappa = (p_o - p_e) \div (1 - p_e)$. Substantial agreement from 0.61 [11].
L.O.C.K.	Locate, Observe, Confirm, Knock out. Not an abbreviation of lockout.

$$G = v_1 \times v_2 \times \dots \times v_n$$

$$P_p = p_1 + p_2 + \dots + p_k \quad (\text{independent, } v = 1, \text{ cap } 3.0) \quad \cdot \quad P_{task} = \min(P_p)$$

$$E1 = \text{executions with } G = 0 \div \text{all executions} \quad \cdot \quad E2 = \text{exposures on pathways with } P < 1.0 \div \text{all exposures}$$

$$O1 = \text{fragile pathways raised to } P \geq 2.0 \text{ or eliminated} \div \text{fragile pathways at period start}$$

$$O3 = \text{crew pass and verifier fail} \div \text{crew passes in sample} \quad \cdot \quad ORF = \min(O1, O2, O3), \text{ normalised}$$

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MEASURE THE PRESENCE OF SAFETY

*A falling injury rate protects no one.
A verified critical control does.*

Bruno Hounkpati

TO PLAN YOUR ROLLOUT, OR FOR FURTHER INFORMATION

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