atturra

High Reliability Organisations

Benchmarking Summary Report

Queensland Resources Council

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Summary

Background

Queensland Resources Council (QRC) with support from the Commissioner of Resources Safety and Health, contracted Atturra Solutions Pty Limited trading as Atturra Advisory (Atturra) to review how high reliability organisational (HRO) principles could be implemented in the mining industry.

HRO principles have been discussed in the Queensland mining industry since the independent review of fatal accidents in the mining industry carried out by Dr Sean Brady (the "Brady Review") on behalf of the then Department of Natural Resources, Mines and Energy (now Resources Safety and Health Queensland). This report aims to provide practical ways for HRO principles to be adopted across the Queensland mining industry, including identifying existing practices that align with those principles.

HROs are organisations which are said to consistently avoid serious failures, reliably delivering their organisational objectives despite operating in environments characterised by high levels of inherent risk and/or operational complexity. However, practically applying HRO concepts is not without difficulty.[1] There is little or no 'off the shelf' guidance on how to apply HRO principles in practice.[2]

Approach

It was not feasible to review every operation in Queensland in depth, therefore our approach was to visit a sample of mines across the state to identify if HRO principles are applied, or how they could be applied. Atturra visited eight mine sites to assess the level of understanding of HRO concepts, learn about the practices currently in place which might be relevant to HRO principles, assess the gaps and obtain the views of those we met on adopting HRO principles. Atturra visited underground coal, open cut coal, underground metalliferous and open pit metalliferous mines. Personnel at all the mines visited were very engaged and talked openly about what worked and what could be improved. This report would not have been possible without participating companies and the enthusiasm, support and openness of all of their workforces who contributed.

[1] Andrew Hopkins pointed out in 2009 (in the context of how might HROs be identified so that they can be learned from), that HROs "are very elusive creatures that inhabit the realm of theory more than the real world". See Hopkins, A (2009) Learning from High Reliability Organisations, CCH Australia, Australia p16

[2] See for example Sue Johnston's article Applying High Reliability Organisational Principles in the resources industry (2021) (available at: https://www.ausimm.com/bulletin/bulletin-articles/applying-high-reliability-organisational-principles-in-the-resources- industry/)

Atturra's method to identifying how HRO practices could be applied in mining started with two important assumptions. First, that HRO principles are fundamentally about organisational culture and the practices (in terms of systems and processes)[3] organisations deploy to deal with the hazards they face. Second, practices in use in HROs (or aspiring HROs)[4] have parallels with those deployed in other hazardous industries. As a result, they are likely to have some common features with mining practices.

As a result, we assessed the practices in place in mining companies that work to prevent major accidents in a similar manner to other hazardous industries where principles are relevant. This assessment was through the lens of the **five characteristics of HROs** usually referred to in HRO literature: preoccupation with failure, deference to expertise, sensitivity to operations, reluctance to simplify interpretations and commitment to resilience. This assessment provided for a range of topics to investigate, which were shared with sites ahead of our visits so that examples could be identified.[5]

What was seen

Atturra found a range of practices used at the visited sites similar to those used by organisations who are often cited as being HROs. Examples ranged from the incident and hazard reporting systems, to the risk management arrangements including the critical control approach. These arrangements are underpinned by safety, training, maintenance and other management systems. These systems are not catalogued in the report but are necessary for the adoption of HRO principles. Instead, the report focuses on how well certain practices align with HRO principles and how implementation of these practices might be improved to better adopt them. The report uses case studies identified during site visits to provide learnings that support industry-wide adoption. The learnings are aimed at senior leaders in companies and at site, which we believe will encourage broader adoption of HRO principles throughout the organisation.

Implementation of the practices varied widely. Some were very good, but in most cases our judgment was that further improvements are needed to fulfill the intent of HRO principles. One such example is the critical control approach, which we consider an HRO practice as it involves seeking out signs of failure prior to any incident occurring. While efforts are being made to implement the approach, the importance of the process needs to be more widely communicated, and its implementation can generally be improved. More broadly, encouragement of hazard reporting as well as widening reporting to include 'weak signals' are also considered important to adopting HRO principles.

[3] We have used the terms "systems and processes" to emphasise our view of the importance in any type of organisation improvement to ensure an integrated approach to people and systems.

[4] HROs are rare and not easily identified. Most literature on HRO theories is usually in the context of organisations aspiring to be HROs. This is discussed in more detail at Annex A

[5] The list of topics identified as relevant to adopting HRO principles is included at Annex B.

Atturra found some practices which appeared to work directly against the intent of HRO principles. One example is the practice of targeting incident reporting levels or communicating milestones such as 'days since last injury'. Apart from being lagging indicators with limited relevance to fatal or more severe incidents, these practices may discourage reporting. More consistent with HRO principles is the use of leading indicators, noting that guidance is required on the strengths and weaknesses of specific indicators. Indicators that provide a detailed picture of how well hazards are being managed, such as reporting on the outcomes of critical control verifications, most closely align with HRO practices in other industries.

Other systems and practices used by Queensland's mining industry, although not focused solely on safety, appear relevant to HRO principles because they are aimed at delivering reliable and predictable processes. Inherent in the definition of an HRO is the concept of reliability[6], as well as safe operations. As a result, Atturra's discussions at sites specifically addressed the question of reliability. At some sites it was put to us that planned and predicable practices made it more likely that safe outcomes would result. One example (among others) involved a change to how the practices put in place for underground development[7] work at a coal mine were planned, resourced and executed. These apparently delivered benefits for efficiency, plant reliability **and** safety. The practices suggested that more effective planning and execution of systems and processes is necessary to improve safety. In turn, this could mean that a focus solely on safety could narrow the range of areas of the business where HRO practices apply and may consequently miss opportunities to improve safety and other outcomes.

Strengthening HRO practices

We conclude from this work that there are practical steps which can be taken by companies working in Queensland's mining industry to move towards becoming more like HROs. Every company visited had some opportunities to improve. However, these opportunities varied from one company to another. For the most part these will involve improving some existing practices and giving less emphasis to others. This also means there are opportunities for companies to learn from each other.

Based on the sample of companies reviewed and their different circumstances, Atturra recommends, initially at least, that a discrete range of HRO related topics are chosen to work on which are consistent with work already underway in the industry. These include initiatives being taken by Resources Safety and Health Queensland (such as a reduced focus on LTIs and improving reporting of other incidents), topics discussed at recent CMSHAC and MSHAC meetings (on reporting) and the recommendations in the recent Coal Mining Board of Inquiry on process safety.[8]

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[6] Pantex (2008) High Reliability Operations: A Practical Guide to Avoid the System Accident, Pantex p8 quoting Roberts, K (2003) HRO Has Prominent History, Anesthesia Patient Safety Foundation Newsletter, 18:1

[7] Underground development refers to the excavation of drives or drifts and associated installation of ground/strata support and mine services required to allow production activity or access to infrastructure. It is often a critical path activity for bringing production online.

[8] Clough, A and Martin, T (2020) Report, Part 1, Queensland Coal Mining Board of Inquiry, State of Queensland (Queensland Coal Mining Board of Inquiry) p14

To support the adoption of HRO principles, Atturra has provided a roadmap that can be used by both the mining industry and QRC member companies. While individual member companies can individually progress the adoption of HRO principles, the best outcome will need some collaboration across Queensland's mining industry. The accompanying roadmap is based on the following learnings:

- **Learning 1**: Improve understanding of the value of critical controls in preventing serious accidents, and improve implementation to provide greater clarity on control 'health'. This should take into account existing published guidance.
- **Learning 2:** Encourage the reporting of a wider range of situations including weak signals. This should consider the published guidance documented in "Practical Guide to becoming a High Reliability Organisation".
- **Learning 3:** Reduce emphasis on lagging indicators such as LTIFR and TRIFR.
- **Learning 4:** Increase the use and communication of leading indicators directly relevant to managing hazards. Guidance is required on the strengths and weaknesses of certain leading and lagging indicators.
- **Learning 5:** Encourage predictable, reliable operations to prevent unwanted safety outcomes. This should take into account approaches to operational planning and decision-making which consider the system as a whole.
- **Learning 6:** Improve incident investigations to explicitly review and revise critical control design and verification.
- **Learning 7:** Share best practice on incident investigations.
- **Learning 8:** Give organisational expectations, practices and performance on managing principal hazards equal prominence to other workplace safety and health issues.
- **Learning 9:** Provide guidance for the most senior leaders on good practice in managing low probability, high consequence events including principal hazards.

To obtain the greatest benefit from the work on HROs requires broader consideration than just safety, focusing on how operational systems and processes relate to safety outcomes. This is based on the idea that HROs are not just focused on safety but look more widely at how their systems are designed and implemented to deliver reliable outcomes. HRO systems typically help to avoid unwanted outcomes in terms of events which can have negative consequences for any of the following: health, safety, environment, finance and reputation. In other words, they enable companies to deliver all their goals more reliably.

Introduction

Background

Queensland Resources Council (QRC) engaged Atturra to visit a range of operations in Queensland to identify practices in place that meet the description of High Reliability Organisations (HROs) and opportunities to better incorporate HRO principles across the mining industry. The sites involved include coal, metalliferous, surface and underground operations. The objectives of this engagement were to:

- provide a report for all members of QRC that clearly describes how the mining industry is applying HRO principles including a practical roadmap for Queensland wide implementation
- give participating sites and companies in the benchmarking project an opportunity to determine where and how they can improve the application of HRO principles
- provide a greater understanding of what the practical application of HRO principles in the mining industry looks like.

The project was sponsored by QRC, the Commissioner for Resources Safety and Health and eight participating companies. The project follows from work in the industry after the Review of fatal accidents in Queensland mines and quarries by Dr Sean Brady recommended that the industry adopt the principles of High Reliability Organisations (HROs).

Atturra thanks QRC, the Commissioner and the eight participating companies for their time and cooperation in this project. In particular, the workforce on each of the sites visited were highly engaged and this engagement was instrumental to the success of the project.

Scope

This report summarises the findings of Atturra's visits and recommendations for the industry based on what was observed at participating sites. It identifies anonymised examples of specific practices that align with the adoption of HRO principles as well as areas for potential improvement to better adopt these principles in the Queensland mining industry.

Approach

Project Outline

The project consisted of eight site visits, covering both coal and metalliferous mines as well as underground and surface operations of each. Prior to each visit, Atturra shared a summary of HRO literature as well as key assumptions in how HRO concepts can be applied in the mining industry.

Atturra held discussions with each site prior to the visit and shared examples of the process, systems and practices that could be used to either discuss or to demonstrate HRO principles in action. Sites provided some relevant documentation for Atturra to review prior to the visit and to establish some topics of inquiry once on site.

During the site visit, Atturra held discussions with a range of leaders, including but not limited to:

- Senior Site Executives (SSEs) and site leadership teams
- Mine Managers
- Safety and Health Managers and their teams
- Technical Services Managers and their teams

We also conducted site visits of work areas both underground and on the surface, talking with operators, supervisors and other personnel in their workplace. From these activities, we then shared findings and interpretations with SSEs, including where we believed HRO principles were exhibited and where further application of these principles could lead to safety improvements.

Once all the site visits were complete, Atturra consolidated the observations and findings so that they could be generalised across the industry. Where possible, individual examples are used to illustrate practices consistent with HRO theory, noting that specific sites and companies are not identified.

Methodology

Defining a mining HRO, or determining if a mining company is one, is not achievable, nor was it the intent of the project. The engagement focused on identifying how HRO principles could be applied in mining, based on two observations. First, that HRO principles are fundamentally about organisational culture and the practices (in terms of systems and processes)[9] organisations deploy to deal with the hazards they face. Second, practices in use in HROs (or aspiring HROs[10]) have parallels with those deployed in other hazardous industries. As a result, they are likely to have some common features with mining practices. If so, it was possible to identify a priori some existing mining practices which either meet the intent of HRO practices or could do so with modification. Equally, it was possible that some HRO practices would be absent from the mining industry.

[9] We have used the terms "systems and processes" to emphasise our view of the importance in any type of organisation improvement to ensure an integrated approach to people and systems.

[10] HROs are rare and not easily identified. Most literature on HRO theories is usually in the context of organisations aspiring to be HROs. This is discussed in more detail at Annex A.

With these assumptions, we identified management systems (such as risk, safety and maintenance), processes (such as management reviews, monitoring, investigations and communications) that we would look at across sites. We reviewed these systems through the lens of the five characteristics of HROs commonly seen in literature:

- Preoccupation with failure: seeking out information on where their systems may be failing and accidents may occur.
- Deference to expertise: making sure expert knowledge is brought to bear, irrespective of where it comes from in the organisation.
- Sensitivity to operations: actively seeking feedback from frontline personnel to gather a detailed picture of what is happening in their operations.
- Reluctance to simplify interpretations: having a detailed understanding of the causes of failure, going beyond the surficial explanations.
- Commitment to resilience: learning from past experience, their own and others', and staying focused on preventing failure even when it may be rare.

This process led to a range of topics considered relevant to review at each site visit. The complete list of topics is provided at Annex B. These topics are a mixture of practices that would be common in many operations, as well as some important characteristics of these processes that are required to align with HRO principles.

This report does not catalogue all practices relevant to adopting HRO principles but focuses on those topics discussed in detail during site visits. These topics provide lessons identified either from observing practices that align well with HRO principles, or from areas where improvement can be made.

Important assumptions

In order to provide practical guidance and clear examples for the Queensland mining industry to adopt HRO principles, Atturra made the following key assumptions to help narrow the areas of focus:

- While organisational culture is an important aspect of adopting HRO principles, identifying tangible practices to either encourage or discourage is the best way to influence culture.
- The emphasis of HRO theory is understanding organisations that avoid serious failures (i.e. studying when things go right, rather than when things go wrong). However, the key to the success of HROs is understanding that the absence of failure is not a sign that all is well.
- HRO literature focuses on operations with potential for major accidents. Therefore, HRO principles are most relevant in environments where the consequences of failure are severe.
- Becoming an HRO is not something that can be fully achieved, and what is required to achieve high reliability is dynamic.
- HRO principles require a broader framing than just personal safety, requiring organisations to identify when they have lost control. This is referred to as process safety in similar industries.

More detail on assumptions is provided at Annex A.

Findings and Learnings

In this section Atturra focuses on where it is likely that Queensland's mining industry can effectively improve organisational practices in line with HRO principles, including case studies that demonstrate how improvement may be achieved. The five principles of High Reliability Organisations are:

- preoccupation with failure
- reluctance to simplify interpretations
- sensitivity to operations
- commitment to resilience
- deference to expertise.

In each case we relate the learning back to HRO principles, noting they are interlinked and changes in practices in one area can be relevant to more than one HRO principles.

A Preoccupation with Failure – Reporting Failure

A 'preoccupation with failure' is perhaps the most significant and repeated of the five principles related to HROs. It is also referred to as 'chronic unease.' Atturra takes 'preoccupation with failure' to mean that HROs pay close attention to signals which may indicate a larger problem within the organisation with respect to safety and reliability. Atturra has examined this principle from three perspectives. First, from the perspective of reporting culture, where workers and technical personnel report this information upwards. This might be an actual accident or incident, such as lost time injuries or near misses such as high potential incidents (HPIs). Second, where no accident or incident has occurred, but a deficiency is detected in managerial control over a hazard. One example of this could be a failure detected in a risk control system by a planned check on a control. These are often referred to as critical control verifications. A third category is more subtle and is referred to in HRO literature as "weak signals"[11].

Of these three types of failure, reporting on actual injuries and HPIs is well established and is a current focus of the Queensland Regulator. Reporting on the second category (i.e. critical controls) has significant scope for improvement and the third category, "weak signals" is not widely understood.

Encouraging a reporting culture

We looked at the extent to which sites encourage reporting. Encouraging the reporting of hazards and incidents, and acting upon them, aligns with many of the characteristics of an HRO. This includes 'preoccupation with failure' and 'sensitivity to operations'.

[11] Weick, K & Sutcliffe, K (2015) Managing the Unexpected (2nd ed.), John Wiley & Sons, USA p46

Many of the sites visited had made concerted efforts to encourage reporting or sought to drive reporting in some way, either by designating it as their 'safety focus' in communications or discussing it in pre-shift meetings and 'town hall'-type all-staff discussions. Others had set, and were tracking, specific performance indicators related to the number of reports or safety improvements identified (however, targeting a specific number of reports or improvements is **not** consistent with HRO principles, and this is addressed in a later section).

One site experienced a large uptick in the number of hazards reported by the workforce and tracked these through their action tracking system. While the Safety and Health team at this site admitted that they were working from a low base and still sought more progress, they attributed the improvement to a simpler reporting and tracking system, and to a visible commitment to acknowledging reports, acting to address the hazards and communicating back to workers that improvements were completed. Our discussions with front line workers and supervisors corroborated this improvement and they commented positively on the changes observed.

Other sites that encouraged hazard reporting or safety improvement drives told us consistently that it was difficult to maintain momentum, especially in the absence of serious incidents or near misses. This is consistent with safety literature, which emphasises how acclimatisation to the working environment and its hazards is difficult to avoid[12]. Ongoing emphasis and improvement is required to build and maintain reporting culture. Published guidance on practical steps to support an HRO reporting culture in the long term is already available and that guidance is not repeated.[13]

Where the information was available, we looked at examples of the hazard and near misses reported. We found that for the most part, the hazards recorded were reported by front line workers. This is an important source of hazard reporting. However, encouraging hazard reporting needs to be framed wider than in the context of front-line workers, especially in working environments susceptible to low probability but potentially high consequence events, such as principal hazards.[14] This is because some hazards and controls will not be easily observable by front-line workers. As a result, reporting processes must go beyond hazards or controls observable by operators and take a wider view of the many factors that contribute to accidents, even if these observations may seem minor, or not related to a frontline worker's own safety.

[12] The Brady Review refers to the natural tendency to accept risk in environments that are complex (See page 63).

[13] Prof Andrew Hopkins has produced detailed guidance on how to encourage 'bad news' in Hopkins, A (2021) A practical guide to becoming a "High Reliability Organisation", Australian Institute of Health & Safety, available at https://www.aihs.org.au/sites/default/files/A%20Practical%20Guide%20to%20becoming%20a%20High%20Reliability%20Organi sation%20-%20Andrew%20Hopkins.pdf

[14] We have used the term principal hazards in accordance with its definition in the Coal Mining Safety and Health Act 1999. This definition is applicable across non-coal sites and other industries. The concept is similar to 'major incident hazards' or 'major accident hazards' in other regulatory frameworks.

In many cases where specific observations may have immediate consequences, they are captured in a trigger action response plan (TARP). However, there are instances where changing conditions may be less immediate and obvious, thus more difficult to detect. Some examples discussed with operators and supervisors included deteriorating ground/strata conditions or corrosion on the inside of an acid tank. These changes, and their effect on specific controls in place to prevent accidents, can be missed in reporting systems aimed at front line workers and require processes in place for 'active monitoring'. Active monitoring processes are those in place for managers to seek out information about important risk controls, their effectiveness and how they might fail.

To achieve this, it is important that workers, supervisors and leaders have a shared understanding of how accidents occur, the controls in place to prevent them, and how to tell if these controls are working. With this information, reporting can go beyond identifying incidents and immediate hazards to those that may be harder to detect. This is the intent of a process in place at most Queensland mining operations – the **critical control approach** (CCA).

Active monitoring of safety and health controls

The concept of controls is deeply embedded in workplace health and safety management, and this is reflected in Queensland mining safety and health legislation. Proactively checking safety related controls provides a mechanism to identify failures in controls and take corrective action before an incident occurs (as opposed to waiting for an accident or incident to reveal control failures). As a result, it was identified as an important example of a 'preoccupation with failure' in HRO terminology. The most well-known approach to actively monitoring controls is the use of "critical controls", referred to here as CCA.[15]

All the companies visited had critical control programs in place. In a small number of cases, the CCA was executed effectively. We found the following opportunities for improving the implementation of the CCA to better apply HRO principles.

At some sites there seemed to be a greater focus on compliance with a target for critical control verifications rather than to learn about how well the controls are implemented. Few sites had a method of communicating what was done well in critical control implementation nor what the weaknesses were. As a result, we frequently saw graphs illustrating compliance with targets for verifications but little more qualitative information about how well the control was working and what if any improvements were needed.

[15] This is sometimes referred to as critical control verification, or critical control management as defined in the ICMM Critical Control Management: Implementation Guide (2015), available at: https://www.icmm.com/en-gb/guidance/health-safety/ccm-implementation-guide

Some companies had a reporting rule which made it impossible for a so-called "administrative control" to be given a 'green' rating regardless of the results of whether the verification process had established that it was effective. While it would be desirable to reduce the reliance on administrative controls, in some cases they are considered critical controls. In these cases, it is important that their efficacy is clearly reported upon. The collective effect of these weaknesses in the application of the CCA is to obscure important information – namely whether a control is working properly and how it can be improved.

Given these weaknesses in some cases, it was not surprising that few companies were providing information from the CCA to the workforce on how well controls were working and the deficiencies the critical control verifications were identifying. This is in marked contrast to the information routinely seen on notice boards and on electronic displays at site entrances, site bus stops etc. about injury metrics such as LTIFR or TRIFR. Site safety performance in terms of reportable incidents was displayed on site, but the health of critical controls was not. Weick and Sutcliffe point out in the context of organisational culture, the importance of "…artifacts or visible markers that embody and give substance to the espoused values".[16] The importance of communicating on controls for principal and other fatal hazards is discussed in the section 'Communication and Leadership'.

Applying HRO principles such as a 'reluctance to simplify' and a 'sensitivity to operations' would mean capturing and communicating the key details of control health. However, our judgment was that the weaknesses in the approach to CCA were recognised at most sites we visited. Additionally, there is existing guidance on CCA published by the International Council on Mining and Metals (ICMM). This guidance was produced with substantial input from the Australian mining industry and, if applied, would address these problems.

Based on the above observations, we recommend that companies use the critical control approach to complement reporting processes and actively seek out failures. To align more closely to HRO principles, this will involve greater clarity on what makes controls effective and to report more specifically what is or is not working. In a few cases we met personnel in both operational management and environment, health and safety roles who were unaware of this guidance material. Most sites were aware of some of these problems, keen to improve and in some cases were in the process of being addressed at the time of our visit.

Learning 1: Improve understanding of the value of critical controls in preventing serious accidents, and improve implementation to provide greater clarity on control 'health'. This should take into account existing published guidance.

[16] Weick and Sutcliffe, op cit. p115

Detecting weak signals

A key aspect of an HRO's 'preoccupation with failure' and 'sensitivity to operations' is detecting weak signals and using them to prevent more serious failures from occurring. Weak signals are a broad category of observations or other information that may indicate "unreliability", even if the link to safety may not be apparent in that instance. We discussed this issue with a range of employees at different sites, including senior leaders, technical professionals and workers in high-risk environments.

Weak signals can be sought out and analysed from the activities discussed in the previous sections:

- **Reporting** signals: from hazard reporting, high potential incidents and other types of upward reporting.
- **Active monitoring** signals: from checking critical controls and their performance or applying TARPs.

Both are important ways in which weak signals can be detected. There are, however, categories of weak signals that often do not fall under these definitions or might be considered 'grey areas' for hazard reporting or their relevance to safety. In these cases, some level of inference must be made from the observation about whether it may indicate a larger failure. Some examples of this include:

- an observable difference between how a task is documented (in a procedure, work instruction, standard or even in risk assessment documentation) and how the task is done in practice, sometimes referred to as the gap between 'work as imagined' and 'work as done'
- process upsets, such as processing chemicals ending up in unintended places, even if there is no visible loss of containment
- maintenance errors on plant or equipment, or safety critical maintenance being overlooked or deferred[17]
- corrosion of pipework or minor leaks in fixed plant
- unexpected geological/geotechnical conditions appearing on the face or backs/roof, even if this is not considered significant from a safety or design perspective.

Many of the above conditions may appear gradually or may repeat to the extent that they become difficult to detect. Unfortunately, there is no simple way for front line workers and other personnel who encounter these signals to determine whether they indicate larger failings. An operator may see a weak signal, such as corrosion, but not understand that this could be a serious risk if occurring in different circumstances. Interpreting weak signals requires some 'deference to expertise', either to more experienced operators, to technical teams or to engineering and maintenance teams. HROs encourage workers to report changing conditions or unexpected events so that those with the necessary experience or expertise can use that information to understand how well the 'system' is working.

[17] We note that statutory maintenance in most cases would be considered safety critical, and sites monitor statutory maintenance activity stringently. This would not fall under the category of weak signals in this case.

Our discussions on site identified some examples of good practices that may lead to better reporting of weak signals. One case was the direct training of underground workers by the Technical Services Team on issues of gas management. This training allowed attendees to ask direct questions of the technical team rather than to a trainer or assessor who may not be able to provide the best answers. It also meant that when the Technical Services Team went underground, they were able to gather more information from workers and learn more about the environment than they could previously. This can help to address the gap between work as imagined and work as done, and gives confidence to workers in observing weak signals that might be important to report to the Technical Services Team.

Another example was active engagement by the engineering and maintenance team with operators and mine management teams. The maintenance team aimed to ensure that unusual performance, noise or smells from underground mobile plant were reported so that they could determine the nature of the issue and whether maintenance was required. The case study below shows how regular interaction across functional areas, and therefore deferring to expertise, can lead to safety outcomes.

Case study: Weak Signals – Detecting potentially fatal faults without an HPI or serious accident

One site discussed the benefit of close integration between functions and seeking more active engagement of operations and production teams. The maintenance and engineering teams were closely engaged with operational and compliance issues and shared key issues with production teams.

After actively encouraging operators to seek out maintenance when equipment operation changed, such as different noises, smells or steering/braking deterioration, one operator brought a loader to the workshop suggesting that the equipment had developed an unexpected noise issue. Closer inspection of the loader found an issue with how brake lines had been reinstalled. Left undetected until the next planned maintenance, this issue may have caused a sudden failure of the brakes (and potentially a serious accident).

Maintenance-induced errors cannot be entirely eliminated but making sure that early warning signs of these issues are acted upon can help prevent injuries and fatalities.

In line with the examples of good practice we observed in our visits, of which there are potentially many more examples, we recommend that companies incentivise the reporting of weak signals and ensure that these reports reach the necessary experts in assessing and interpreting them.

Learning 2: Encourage the reporting of a wider range of situations including weak signals. This should consider the published guidance documented in "Practical Guide to becoming a High Reliability Organisation".

Effective Safety Indicators

We were often asked about safety metrics and other indicators in our visits, as most companies sought more useful safety metrics, particularly leading indicators for safety. This section describes the role of metrics and indicators in adopting HRO principles.

De-emphasising lagging indicator targets

HROs seek 'sensitivity to operations' by tracking and communicating indicators that may provide information on how well risks are being managed. However, adopting a 'reluctance to simplify' means ensuring these indicators provide meaningful information on how well risk is being managed. Lagging indicators such as lost time injuries (LTIs) and the LTI frequency rate (LTIFR) are not useful indicators for understanding how well safety is managed,[18] and these weaknesses have long been known.[19] Similar critiques can be made of total recordable injury (or 'all injury') frequency rates (TRIFR).

Additionally, an over focus on reducing incident frequency (whether near misses or injuries) can have the effect of discouraging reporting, to ensure targets are met, or reach a 'milestone', such as a certain number of days without an injury. These kinds of incentives conflict with the core HRO principle of 'preoccupation with failure', where organisations value and actively seek to understand where they may be failing and why, by encouraging reporting of problems.

On our visits, most companies understood that encouraging people to find and report faults means changing perceptions around incident reporting and how targets are made. Leaders we met were also aware of this effect and understood that incentivising safety targets in the form of lagging indicators may drive information underground. Safety managers and SSEs we met invariably agreed that focusing on LTIs and total recordable injury rates was not productive, but many operations still displayed signage showing the number of days since the last LTI in work areas, or some kind of incident rate as part of their management boards ('lean boards' and similar display tools).

In many cases, this tracking and targeting of lagging indicators by site leaders and senior safety management was also influenced by their corporate environment. Anecdotally, we were told that some executives still set management targets related to injury metrics. In some large companies, senior executives still use incident frequency rates to compare sites, focusing their scrutiny on sites with higher rates. We understand that this attitude can be difficult to address in a multinational corporation.

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[18] Brady Review p71

[19] At detailed examination of the limitations of lagging indicators is available in O'Neill, S, Martinov-Bennie, N, Cheung, A, Wolfe, K Issues in the Measurement and Reporting of Work Health and Safety Performance: A Review, Macquarie Lighthouse Press, Australia p19, available at: https://www.safeworkaustralia.gov.au/system/files/documents/1703/issues-measurement-reporting-whs-performance.docx

The goal of safety reporting is to understand how well risk is being managed and seek out early warnings that can be acted upon. Corporate-level safety indicators should be developed to convey this information. 'Preoccupation with failure' means removing the "how good are we?" mindset, as one supervisor we met put it, and demonstrating a preference for raising and addressing 'bad news'. This does not mean that companies and leaders stop recognising and celebrating successes, but it means changing the framing of what success looks like. Success means finding out that things are going wrong prior to an incident occurring, and successful HROs encourage and reward this behaviour.

This extends to reporting on the performance of controls and the underlying systems that maintain them. Site leaders we spoke to believed a healthy scepticism was needed where control verifications report things as going well, or system audits produce few areas of improvement.

For the industry to adopt HRO principles, we recommend that companies move away from focusing on lagging indicators to report on safety, especially injury statistics.

Learning 3: Reduce emphasis on lagging indicators such as LTIFR and TRIFR.

Managing hazards rather than metrics

Displaying and dissecting reporting trends in lagging indicators can conflict with the HRO principle of a 'reluctance to simplify'. Many sites presented dashboards and performance reporting that show the **number** of various safety related actions or events but **not what** these activities discovered. Examples included:

- incidents
- safety observations/interactions (or 'visible field leadership' activities)
- control verifications
- hazard or other safety reports
- safety improvements.

We also heard many instances of leaders or supervisors encouraging a certain number of pre-task risk assessments (Take-5s, SLAMs, etc.) and were told of specific targets or tracking set for safety interactions/observations and safety improvements. We also heard repeatedly that the number of these activities often spiked towards the end of the month (or other relevant reporting periods).

Understanding how well risk is being managed and identifying precursors to failure requires good quality reporting and safety activity. When targets or trends are emphasised on lean boards, dashboards or by senior leaders in their discussions, these can have the effect of changing the focus from the quality of the activity to the quantity. Many areas of safety literature emphasise that this kind of focus reduces the necessary detail required in reporting in complex workplaces.[20] In his guidance, Hopkins suggests that HROs do not have targets, rates and trends in reporting as "aggregate statistics in this situation are largely meaningless".[21]

[20] Hopkins, A (2009) Learning from high reliability organisations, CCH Australia, Australia

[21] Hopkins, A (2021) A practical guide to becoming a "High Reliability Organisation", Australian Institute of Health & Safety, Australia p15, available at:

We often heard support for this approach at site level, and many SSEs and senior leaders shared this focus on quality. One mine manager we met told us that according to site processes in place, there should be up to three pre-task risk assessments per shift. However, with his team he emphasised that he would prefer one that is thoroughly considered and updated when conditions/tasks change than three that were completed just to satisfy a management target. We spoke with workers at another site where individual employee targets for safety interactions had been removed. They noted that while the number of interactions that occurred had drastically decreased over time once this had been removed, they felt the quality of the activity had increased. With fewer interruptions to their workday, they also were able to devote more time to these discussions and delve into topics that were not usually discussed.

This is not to say that organisations should discard all oversight of safety activity and ensuring that it is occurring regularly, but managing the metric is not necessarily linked to managing the hazards when specific targets are sought. This approach has its origins in long-standing principles in Quality Management systems around setting quotas. W. Edward Deming's 14 points for total quality management emphasise that eliminating slogans and targets, and especially numerical quotas, is essential for ensuring quality. This helps retain the focus on doing these activities well and achieves more meaningful improvement.[22]

Some of the most promising developments we observed in our visits were dashboards on risk and hazard management that displayed the most severe hazards on site and the effectiveness of the results of the control verifications to indicate how well they were being implemented. This was instead of reducing safety and risk performance to a metric or trend. This kind of reporting allows key details to be shared on how well risks are being managed and enables leaders to focus on whether quality reporting is occurring. This is illustrated in the following case study from one of the mine sites visited by the Atturra team.

https://www.aihs.org.au/sites/default/files/A%20Practical%20Guide%20to%20becoming%20a%20High%20Reliability%20Organi sation%20-%20Andrew%20Hopkins.pdf

[22] (2013) Deming's 14 Points on Quality Management. In: Idowu S, Capaldi N, Zu L, Gupta A (eds) Encyclopedia of Corporate Social Responsibility. Springer, Berlin

Case study: Quality dashboards to understand how well risk is managed

One site showed us a range of risk management metrics that are displayed on a Microsoft PowerBI dashboard. The temptation with data sources and tools like this is to combine data and trends or 'cut' the data multiple ways, but not delve into what the data represents in terms of managing their biggest risks.

This site certainly had many charts of trends and comparisons. However, when prompted for a view that would show how they view their management of their most important hazards, they had a clear dashboard with the most important site risks and how the site tracks their management. Rather than reducing risk management to a trend or indicator, risk reporting incorporated the outcomes of critical control verifications to give a more nuanced picture of how well risk was managed. This reporting was driven by improvement activity related to managing the risk and, when reviewed, leadership and site staff were often drawn to areas of inactivity or where major risks were given 'green light' reports.

This approach to reporting and how leaders act on reports is consistent with an HRO's reluctance to simplify and sensitivity to operations.

Given these observations, we recommend that the industry work to provide alternatives to the metrics mentioned in this section and the lagging indicators in the previous section. This should be coupled with a greater focus in companies on reporting how well hazards are being managed, rather than on targeting a specific quantity of reporting or other safety activity.

If HRO principles are adopted and further emphasis is given to leading safety indicators, it is less likely that these indicators will be comparable across sites or across the State. Safework Australia's guidance on measuring and reporting on work health and safety argues that:

> "… only a limited range of KPIs are sufficiently generic to be able to be benchmarked across organisations. Instead, each organisation needs to identify and use the lead and lag KPIs that can best inform the particular challenges and issues it faces."[23]

The more mature the leading indicators are, the less comparable they may be. Safework further specifies that these indicators should be based on an organisation's "framework for identifying critical risks and monitoring measures of implementation and effectiveness of relevant controls".[24] In the Queensland mining industry, the critical control approach can provide this framework, with some of the improvements previously discussed.

[23] O'Neill, S & Wolfe, K (2017) Measuring and reporting on work health & safety, Safe Work Australia, Australia p5, available at: https://www.safeworkaustralia.gov.au/system/files/documents/1802/measuring-and-reporting-on-work-health-and-safety.pdf

[24] *Ibid.*

Learning 4: Increase the use and communication of leading indicators directly relevant to managing hazards. Guidance is required on the strengths and weaknesses of certain leading and lagging indicators.

Reliability and Safety

A long-held tenet of safety performance is that organisations which have a good workplace culture actively involve their workforce in safety. This is recognised as building ownership of safety at all levels, recognising and applying the knowledge that employees have about how work is done at the frontline. Active involvement in safety includes participation in hazard identification workshops, risk assessments, plant design and so on.[25] In HRO language, there is a 'deference to expertise' and a 'sensitivity to operations'.

This involvement of the workforce in safety is also recognised as being beneficial for productivity.[26] However, there is also the potential for conflict between safety and productivity. This is also well known. James Reason pointed out in 1997, the balance between production and safety "…is rarely equal".[27] The recent Queensland Coal Board of Inquiry Report gave an example.[28] Reason goes on to explain how and why this is can happen. For example, he points out that those who manage hazardous operations tend to have skills around production rather than safety. After all, it is the production that creates the resources to meet the other organisational needs including safety. He also points out that the feedback to the organisation about production is usually obvious and fast, whereas safety is often characterised by the absence of feedback, in that no accident has occurred today. However, when it does, investigation often reveals risk control weaknesses which could have been discovered earlier but were not. Absence of feedback is often mis-characterised as evidence that all is well. Where data is present it is often hard to interpret.[29] As Reason wrote in 1997, "It is only after a bad accident or a frightening near miss that [safety] comes…uppermost".[30] This issue of feedback is one of the main drivers for this report's emphasis on CCA and other processes that can provide feedback without an incident having occurred.

[25] Common Topic 4, Extract from inspectors human factors toolkit, UK Health and Safety Executive, available at: https://www.hse.gov.uk/humanfactors/topics/common4.pdf

[26] Benefits and costs, Leading health and safety at work, UK Health and Safety Executive, available at: https://www.hse.gov.uk/leadership/benefits.htm

[27] Reason, J (1997) Managing the risks of organizational accidents, Ashgate, UK p4

[28] Clough, A and Martin, T (2021) Report, Part 2, Queensland Coal Mining Board of Inquiry, State of Queensland (Queensland Coal Mining Board of Inquiry) p16-20

[29] This is part of the argument for critical controls, where information on specific systems and processes on site are reported on in the context of a defined control for a defined hazard.

[30] Reason, J (1997) Op cit. p4

HRO practices would seem to have the potential to help with safe and reliable operations in high hazard operations. In our meetings at mine sites, we asked managers, supervisors, and frontline workers for their views on this issue. We were told that reliability (or, as it was usually put to us, predictability) was closely linked to safety. In this context reliability is not just limited to plant or equipment availability, but to how well sites are able to execute work in a consistent, predictable way which matches how it is planned and documented.

We have summarised two of the examples given to us – one case where improvements to reliability have led to safety outcomes and another where safety outcomes that were predicted to affect productivity did not because they increased predictability.

When discussing these examples, it was clear that the companies had applied HRO-type practices when planning and making these changes, even if the link to HRO principles was not recognised at the time. In developing both practices described in the case studies, the responsible teams examined in detail how the operation worked by consulting closely with those with the required expertise and practical experience and taking action on their views.

Case study: More reliable underground development processes

Development mining refers to driving roadways to support the longwall panel and is carried out by a specific crew and equipment from coal cutting machines to that needed for effective ventilation and roof support.

A traditional model of organising this work involves a focus on shift productivity – the number of metres driven. The number of metres cut is directly related to the time spent cutting, so the direct incentive is to maximise the amount of time spent cutting per shift. Similar relationships exist in hard rock underground mining ('activity at the face' measures such as drilling, charging and loading) and in surface mining (such as shovel utilisation time).

One mine we visited had re-envisioned its way of working by looking at the task from a systems perspective. What was needed to deliver the goals of safe production in a planned and predictable way?

This revised way of working examined all the elements of the "system" with the goal of doing the work safely in a repeatable way, including improving production and machinery uptime. Amongst other things this involved more detailed planning, clarity around roles and responsibilities, and crucially a reduction in the planned cutting time per shift, to allow time for planning, restocking of consumables and preparing for the next shift. This approach has resulted in a safer and more reliable process.

Case study: Improving safety in production-critical processes

At an open cut operation, an HPI occurred when some material hung up on a dig face fell and partially covered a bulldozer working in parallel with the face. The operator suffered a minor cut to the hand, but the potential consequences could have been more serious. More importantly, the consistency with which hung up material was occurring on the dig face was leading to frequent near misses and had potentially become a 'normalised' hazard.

Investigating the incident had identified several recommendations to improve geotechnical design and planning, operational procedures and training. A significant change was a decision to reduce the maximum shovel face height from 16 metres to 13 metres, as it had led to a situation where some shovels were repeatedly leading to this issue occurring.

As with any face height/bench height reduction, this change was initially viewed as a reduction in productivity that was necessary to address safety issues. The effect on safety was immediate, as the number of incidents at the shovel dropped from monthly to one every four months. However, over time it became clear that the changes had also led to a productivity gain as more consistent material movement results were obtained. While maximum monthly figures were reduced, there was more consistency over time with fewer incidents interrupting operation. This led to more overall material moved in the long term.

Changes that reduce interruptions and improve reliability are also aligned with broader process safety principles, which seek to take a more systematic approach[31]. This approach integrates the parts that engineering, maintenance, operations and safety disciplines play in preventing unplanned events or loss of control over principal hazards. Process safety-type approaches seek to prevent the loss of managerial control over operational risks recognising that unplanned interruption to the smooth operation of a process (or system) can have a wide range of potentially negative impacts, and not just on safety.

The recent Board of Inquiry makes specific findings on using process safety strategies to manage principal hazards. We recommend that these approaches are considered as part of adopting HRO principles by the Queensland mining industry.

Learning 5: Encourage predictable, reliable operations to prevent unwanted safety outcomes. This should take into account approaches to operational planning and decision-making which consider the system as a whole.

[31] Process safety concepts are defined in more detail in Annex A.

Learning From Incidents

Learning from incidents is an important way that organisations can practice a 'commitment to resilience'. Our discussions with sites tended to focus on incident investigations and their methodology. Many individuals said that ICAM[32] was not their preferred methodology for incident investigation and it was only used because it aligns with regulatory requirements for incident reporting.

In our view, the investigation methodology should be appropriate to the circumstances and no one methodology should predominate. More important is the quality of the analysis produced and how that analysis is acted upon, which is the focus of the following sections. First, looking at how analysis produces change within the context of the site's management systems, including safety, risk, maintenance and other systems. Second, looking at the quality of investigations and whether they provide effective, well understood and actionable insights.

Good quality investigations

We saw numerous good quality incident investigations. These were characterised by an analysis of the immediate and underlying causes of incidents and recommendations to change designs, systems and/or procedures. These aligned with HRO principles by ensuring that failures are well-understood so that they can be prevented in the future.

A key feature of good quality investigations we saw was to revisit how the risk that occurred was originally assessed, what controls were in place to prevent it and why in this instance those controls were either inadequate or ineffective. In a particularly good investigation, this was demonstrated by re-examining bow ties for a key hazard on site, highlighting the controls that were not adequate or were missing, and suggesting a revision to that bowtie and to the definition of specific controls. The value of this approach is to give the organisation an insight into potential shortcomings in their risk management and critical control processes.

While most investigations we reviewed included some analysis of why controls failed or were ineffective, they often did not assess the relevant critical controls in detail and how they could be changed to prevent a failure. We do not know why this link to critical controls was not made, but we note that many investigations used the ICAM terminology of absent or failed "defences" to assess controls. While we understand that "defences" is in practice synonymous with the term "controls", it potentially disconnects the investigation from an organisation's critical controls and how they are defined. Alternatively, it could possibly indicate that the role of critical controls is not well understood across the organisation (and therefore by the investigation team).

Good quality investigations incorporate the organisation's understanding of its hazards and controls in order to contextualise the systems and processes in place to manage these risks.

[32] The Incident Cause Analysis Method (ICAM) was developed by Professor James T Reason in his research on Human Error and its contribution to incidents. It is also the form of analysis that underpins Resources Safety and Health Queensland's incident reporting structure.

Learning 6: Improve incident investigations to explicitly review and revise critical control design and verification.

Resisting simplified interpretations

The HRO principle of 'reluctance to simplify' is interpreted in the mining context as seeking to understand the full explanation for how failures occur and to ensure that the actions taken to address these conditions are equally comprehensive.

This can be seen in many incident investigations that we reviewed, where many factors contributing to an incident were identified. When an operator error was involved, we also saw organisations seeking to understand the circumstances around that mistake or misjudgement rather than assuming that individuals can be trusted to act perfectly all the time. This approach is consistent with how an HRO understands human error, which is something that will inevitably occur but should not result in major failure.

We also saw some examples of how investigations had led to detailed examination of understanding the causal aspects of an incident. Sharing these issues and acting on the knowledge can produce quality safety outcomes. An illustrative case is provided below.

Case study: Using an incident to improve maintenance

A coal mine visited shared an example of how an HPI had been prevented by learning effectively from a past incident and making changes to maintenance to address the cause.

The site reported an HPI when the exhaust manifold gasket on one of its loaders failed underground. The incident was caused by an undetected CAT failure, and the subsequent unburnt soot had blocked the flame arrestor. This led to a pressure increase that caused the gasket to fail.

Analysis of the HPI led to weekly backpressure tests as well as instructions to then look for ceramic fragments which will indicate a failed CAT.

Approximately eight months later, these weekly tests detected a pressure increase in the exhaust manifold gasket and close inspection revealed that the CAT had failed. In this instance, changes to preventative maintenance had directly prevented another HPI by detecting the precursor event

We recommend that good quality investigations, and the approaches that led to this quality are shared more formally across the industry.

Learning 7: Share best practice on incident investigations.

Communication and Leadership

A key aspect of maintaining a 'preoccupation with failure' is in how safety is communicated across the company and what leaders devote their attention to. Leadership can also encourage greater 'sensitivity to operations' by providing guidance to their organisation on how to encourage information to travel upwards so that failures can be rectified before an accident occurs. We discussed with many site leaders the contents of their communications and their experiences with encouraging bad news to reported.

Focusing on the most important hazards

To maintain a 'preoccupation with failure', a challenge for aspiring HROs is dealing with the fact that in many cases, the most significant hazards for the organisations rarely, if ever, cause major accidents. Maintaining a focus on and preparedness for the most significant hazards even though they rarely occur also demonstrates a 'commitment to resilience.' A significant aspect of a commitment to resilience is the preparedness to respond to an incident once it has occurred. An example of this is the maintenance of a mine's rescue capability for underground mines. However, we have chosen to focus on how sites maintain emphasis on principal and other fatal hazards in their communication, as we were able to review and discuss this in our visits.

While fatal accidents are more frequent than is acceptable for the industry, they are too infrequent for effective organisational learning or to keep these hazards 'front of mind'. Major accidents such as explosions or shaft/winder failures are rarer still, yet their severity requires significant ongoing attention and resources to manage. Other types of incidents such as injuries and some categories of HPIs are more frequent, but the extent to which they relate to principal hazards and other fatal hazards is sometimes not straightforward. There are many categories of incident that could not credibly cause multiple fatalities yet are incorporated into aggregate safety performance statistics to the same extent as some rarer but more significant HPIs. We looked at how well organisations maintained their focus on the most important hazards at site despite the lack of 'feedback' on some of these hazards.

We attended a range of site pre-shift meetings, management meetings and other forums, as well as observing the safety information displayed in meeting areas or other parts of site. A lot of useful information is shared, such as recent incidents, incidents at similar operations or within the same company, as well as reported hazards in the workplace. In most cases, the incidents shared were minor (to be expected given the rarity of serious accidents). In one case, we sat in on a shift meeting where the supervisor recited a long list of very minor equipment damage to the audible exasperation of the crew. This example is important as it illustrates the challenge of keeping safety relevant and staff 'preoccupied with failure' in the absence of major incidents.

Focusing on minor incidents or on hazards with lower potential consequence risks unintentionally creating the perception that principal hazards or fatal hazards do not receive management attention. Organisations need to make sure that there is constant communication on preventing major accidents and fatal accidents, even in the absence of incidents. Some sites visited collected a range of information on specific hazards and how they were being managed, but this information was not communicated in the same way as other safety information. This included the outputs of critical control verifications, hazard-specific reporting and other useful information that can help maintain organisational focus on the most important hazards.

We have emphasised the critical control approach in the section on 'Identifying the precursors to failure' as a key feature of maintaining a 'preoccupation with failure'. It is a means of gathering feedback on how well low probability, but high consequence risks are being managed. Using this information and showing it in shift meetings, noticeboards and other communication is one possible means of maintaining suitable attention on the most important hazards on site and not sidelining them for those hazards that may have more frequent incidents but ultimately are not linked to fatal (or even more serious) accidents. We recommend that performance information related to managing principal hazards is given equal or greater prominence than general injury or incident reporting.

Learning 8: Give organisational expectations, practices and performance on managing principal hazards equal prominence to other workplace safety and health issues.

Addressing ways HRO practices are inhibited

In many of the previously described potential HRO practices in mining, senior leaders both at site and beyond have a key role, such as encouraging reporting, removing targets related to safety and focusing on how well principal hazards are managed. This is because where senior leaders set priorities and how they communicate what is important to them cascades throughout an organisation. Our discussions with SSEs and other leaders at site level made it clear that most understood the intent of the 'preoccupation with failure' principle and its benefits. However, there is little guidance in place on how to operationalise this. For instance, most SSEs agreed with the preference for bad news and learning about important failures before an accident occurs, such as in critical control verifications. Despite this, some practices persist within companies (as outlined in other sections) that may discourage bad news from travelling upward in the organisation.

While quality guidance exists for encouraging bad news, such as the previously mentioned guide by Professor Andrew Hopkins,[33] additional guidance specific to leaders in the mining sector would be simple to produce. This would support companies in the Queensland mining industry to better manage the low probability but high consequence incidents that make HRO-type approaches necessary. This is routinely done in other high hazard industries.

Learning 9: Provide guidance for the most senior leaders on good practice in managing low probability, high consequence events including principal hazards.

[33] Hopkins, A (2021) A practical guide to becoming a "High Reliability Organisation", Australian Institute of Health & Safety, Australia p15, available at: https://www.aihs.org.au/sites/default/files/A%20Practical%20Guide%20to%20becoming%20a%20High%20Reliability%20Organi sation%20-%20Andrew%20Hopkins.pdf

Conclusion

This report cannot provide an exhaustive account of all practices relevant to adopt HRO principles given the all-encompassing nature of HRO theory. As a result, it focuses on practices that illustrate one or more of the principles in an actionable way. The report attempts to make explicit how each practice relates to the principles, noting that they are not mutually exclusive. It also provides learnings that can be used to improve how existing practices adopt HRO principles.

Roadmap for Adopting HRO Practices

The following roadmap provides areas of focus for companies and the broader industry to better adopt HRO principles. The roadmap makes direct links between the practices observed and HRO principles, while noting they are often interlinked. For instance, 'deference to expertise' is a principle relevant to operational reporting, decision-making and investigation.

The roadmap shows areas where HRO practices are already in place. It is important to note that these are practices observed during site visits and do not represent all practices relevant to adopting HRO principles. Annex B provides a more comprehensive view of the relevant practices for HRO principles. Furthermore, the practices in the roadmap were not necessarily observed at all sites visited but were important examples we identified that can be adopted across the sector.

The roadmap learnings are aimed primarily at senior leaders at site or in companies' head office, rather than front line personnel or supervisors. Some changes to practices, or even just emphasising some existing practices can have beneficial effects. Practices like critical control processes, hazard reporting, safety indicators and communications can directly influence organisational culture by becoming 'the way we do things around here'.

We recommend that the HRO principles and this roadmap are used as guidance to review and improve existing practices, rather than treating HRO theory as a standalone program or a 'tack on' to current systems and processes. Given what is already in place at most companies, HRO principles can provide a critical lens for improvement rather than a new program or process.

HRO Principles	What is in Place	Where to Next	How to Improve
High-level concepts to help improve to organisational practices. While specific links between principles and practices are shown here, in reality they are interlinked	**Practices in place that meet the intent of HRO principles, or could do with some improvement**	**HRO-like practices were observed in some instances, which can be adopted across the sector. There are also opportunities for the industry to improve as a whole.**	**Improvement of these practices using HRO principles may provide better management of safety across the sector.**
Preoccupation with Failure HROs do not assume all is well just because no accidents have occurred. They seek out information on where their systems may be failing and an accidents may be imminent.	Critical Control Verification	Improve understanding of the value of critical controls in preventing serious accidents, and improve implementation to provide greater clarity on control health. This should take into account existing published guidance.	Monitoring the heath of controls is a preventive measure (or leading indicator). It can detect control failures before they may lead to an incident occurring. Most companies have aspects of this approach already in place.
	Processes in place for incident and hazard reporting	Encourage the reporting of a wider range of situations including weak signals. This should consider the published guidance documented in "Practical Guide to becoming a "High Reliability Organisation."	Implementing this guidance will help individuals understand what a weak signal is and report it to the appropriate experts in the organisation so it can be interpreted and dealt with appropriately. CMSHAC has received a presentation on this and it is mentioned in the Brady Review.
Sensitivity to Operations HROs actively seek feedback from frontline personnel on what is happening in their operations. They want a detailed picture of how well their operations are managed.	Using safety performance indicators and tracking important safety activity Risk management reporting that demonstrates control health for most important risks	Reduce emphasis on lagging indicators such as LTIFR and TRIFR.	A focus by companies on reducing the number of accidents or incidents and/or incident rates (as opposed to improving the work environment) can discourage reporting. The regulator (RSHQ) has reduced its emphasis on certain lagging indicators.
	Leadership in the field, safety observations and task observations Reporting on how well risks are being managed Prioritising quality observations, reporting and improvement rather than promoting targets	Increase the use leading metrics (or indicators) directly relevant to the management of principal and other fatal hazards. Guidance is required on the strengths and weaknesses of certain leading and lagging indicators.	Safety indicators need to go beyond tracking the amount of incidents and safety activity and provide information on how well hazards are being managed. The critical control health can provide an indicator that communicates to all personnel how well important hazards are being managed.
Reluctance to Simplify Interpretations HROs avoid making inappropriate assumptions about the causes of failure. They understand that most failures are complex and have multiple causes.	Investigating incidents to identify the failed controls that allowed the incident to occur	Improve incident investigations to explicitly review and revise critical control design and verification.	Investigations that identify absent or failed defences should also ensure that critical controls, and the monitoring in place for them, are revised based on the findings.
	Going beyond the 'human error' to identify contributing factors to incidents Learning from minor incidents and near misses and acting on them to prevent more serious accidents	Share best practice on incident investigations across industry.	High quality investigations outline multiple causal factors. They seek to understand more about human errors, their causes and how stop these errors resulting in major failure. The outcomes of investigations are already shared across industry. Further collaboration on investigation practices will improve the quality of this information.
Deference to Expertise HROs make decisions using technical and operational knowledge. They make sure expert knowledge is brought to bear, irrespective of where it comes from in the organisation.	Integrating safety into operational planning and design decisions Prioritising consistent and reliable processes to prevent incidents Encouraging front line personnel to detect faults without incidents or failures having yet occurred	Encouraging predictable, reliable operations to prevent unwanted safety outcomes. This should take into account approaches to operational planning and decision-making which consider the system as a whole.	Better safety results are often linked to providing more predictable and reliable operations. Reducing the interruptions, unplanned work and unreliable processes means thinking wider than personal safety to consider all aspects of operations.
Commitment to Resilience HROs learn from past experience within their organisation, other organisations and other sectors. They keep focused on the hazards that pose the greatest threat to their personnel.	Safety reporting, communication and leadership	Give organisational expectations, practices and performance on managing principal hazards equal prominence to other workplace safety and health issues.	Principal hazards require a different management approach to other hazards. Control monitoring information can be used to keep the organisation's focus on managing these hazards even if no relevant incidents have occurred recently.
	Focus on areas where little feedback is available i.e. "green light" reports with limited activity.	Provide guidance for the most senior leaders on good practice in managing low probability, high consequence events including principal hazards.	Leading and managing low probability/high consequence requires additional tools and techniques compared with most fatal accident and other workplace safety risks. This includes process safety tools.

Annex A: Important Assumptions

This section describes the approach we have taken to this work and the main assumptions we have made. This is important to enable critical thinking on the part of readers about how we have approached this work and our conclusions.

HROs are organisations which are said to consistently avoid serious failures, reliably delivering their organisational objectives despite operating in environments characterised by high levels of inherent risk and/or operational complexity. The US Navy's nuclear-powered aircraft carriers, air traffic control and air transport in general (at least in relation to scheduled passenger flying in developed countries) are usually quoted as exemplars of HROs.

However, practically applying HRO concepts is not without difficulty. Hopkins pointed out in 2009 (in the context of how might HROs be identified so that they can be learned from), that HROs "are very elusive creatures that inhabit the realm of theory more than the real world".[34] Since then, organisations operating in diverse environments have shown interest in HRO principles including oil and gas, construction and health care. However, there is little or no 'off the shelf' guidance on how to apply HRO principles in practice.[35]

Researchers on HROs describe several common features about how the HROs are organised. Put another way they describe a particular organisational culture which distinguishes HROs. Due to this emphasis on organisational culture, this section makes clear our assumptions about:

- organisational culture in general
- the applicability of HRO terms and concepts to the mining and minerals sector
- the term "aspiring HROs" to describe organisations trying to apply HRO concepts
- needing to look beyond just safety systems.

Organisational culture and change

On numerous occasions during this work, we were asked about organisational culture. The question was typically framed as; "*isn't becoming an HRO all about culture?*" This question was so prevalent that we felt it important to make our assumptions on this question clear. Atturra has adopted an approach to organisational culture that takes a distinctly practical approach, but one based on the views of respected writers on both organisational culture and HRO concepts. This is explained below.

The assumption that HRO concepts involves organisational culture is correct. For example, in *Aviation – Non-Technical Skills Guidebook*, published by the Australian Defence Flight Safety

[34] Hopkins, A (2009) Learning from High Reliability Organisations, CCH Australia, Australia p16

[35] See for example Sue Johnston's article Applying High Reliability Organisational Principles in the resources industry (2021) (available at: https://www.ausimm.com/bulletin/bulletin-articles/applying-high-reliability-organisational-principles-in-the-resources- industry/)

Bureau[36] the (brief) coverage of HRO concepts appears in the chapter on *Culture*. However, the whole concept of culture, or safety culture (we will use the term organisational culture), is fraught with difficulty. Some examples of these difficulties are briefly covered below together with the approach adopted by Atturra to HRO's.

The Australian Institute of Health and Safety have published a chapter on Organisational Culture in their OSH Body of Knowledge series. The Abstract says, "…safety culture remains a confusing and ambiguous concept in both the literature and in industry, where there is little evidence of a relationship between safety culture and safety performance".[37]In *Managing the Unexpected* by Karl Weick and Kathleen Sutcliffe, a well-known book on HRO's, in a discussion on culture, the authors state:

Analysts still differ on the question of whether culture should be understood as something an organisation **is** (its beliefs, attitudes and values) or whether culture should be understood as something an organisation **has** (its practices and controls).

They go on to suggest that there is some truth in both these statements but come down more firmly on the importance of organisational practices as a more practical approach to changing organisational culture. This is because as James Reason, Andrew Hopkins and others have pointed out, it is harder to change attitudes and beliefs directly than it is to change what people do and how they do it. For example, in a mining context this means that it is easier to change how often picks are changed on a longwall shearer (to reduce frictional ignition risks) than it is to change people's *attitude* to the risk of frictional ignition from the picks. The former can be observed and measured. Peoples' attitudes are much less apparent. As Weick and Sutcliffe and others have pointed out, the practices adopted within an organisation over time eventually shapes attitudes and beliefs.[38] This strongly suggests that changes to an organisations culture are better focused on improving organisational practices.

Atturra has adopted this approach to understanding organisational culture. We are aware that this is an incomplete understanding of organisational culture but, nevertheless, it is a practical approach to improving it. Furthermore, it is supported by experts in this field. These include HRO theorists (Weick and Sutcliffe), organisational psychologists (James Reason), and sociologists (Andrew Hopkins).

As a result, we have focused on those organisational practices which are congruent with an organisation aspiring to be an HRO, rather than the less tangible aspects of organisational

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[36] Defence Flight Safety Bureau (2020) *Aviation Non-Technical Skills Guidebook*, Ed2.0, Defence Aviation Safety Authority, p45, available at: https://www.defence.gov.au/DASP/Docs/Media/AviationNon-TechnicalSkillsHandbook.pdf

[37] Borys, D (2019) Organisational Culture: A search for meaning, In: *The Core Body of Knowledge for Generalist OHS Professionals*. Australian Institute of Health and Safety, Australia, available at: https://www.ohsbok.org.au/wp-content/uploads/2019/10/10.2.1- Organisational-Culture-a-search-for-meaning.pdf

[38] Weick, K & Sutcliffe, K (2015) *Managing the Unexpected (3rd ed.).* John Wiley & Sons, USA p114

culture associated with organisational values. As these authors have pointed out, a focus on the practices ("how we do things around here") shapes attitudes and beliefs.

Applicability of HRO terms and concepts

HROs are organisations which are said to consistently avoid serious failures despite operating in an environment or performing a function where these failures are expected, due to inherent risks and the operational complexity. These failures are often referred to as "system accidents" or "normal accidents". Sociologist Charles Perrow defined three conditions that make systems susceptible to these accidents:

- The system is *complex*, having many overlapping activities and interactions that means failure is not always predictable.
- The system is *tightly coupled*, where interactions between different parts of the system mean that it is difficult to detect or address any errors prior to any flow on effects occurring.
- The system has *catastrophic potential*, meaning the consequences of any failure may cause considerable damage to people, the environment or the future of the organisation.

Whether or not the above conditions apply to mining operations is not simple to assert. For instance, underground mining could be considered to have all three conditions, especially in underground coal

mining in gassy conditions. However, in shallow open cut operations or quarries, these conditions may not be so apparent.

Regardless of the above conditions, many of the ideas and practices reported by those who have studied HROs have considerable overlap with other safety concepts and can be used to drive safety improvement. What distinguishes the work on HROs is the focus on trying to explain why things go right nearly all the time as opposed to studying why things have failed. Both approaches are needed but the focus on doing things right and reliably offers a clearer prescription for organisational improvement.

Probably the most familiar language used when talking about how HROs do things right are the HROs involves the 5 principles referred to in academic studies. These are:

- preoccupation with failure
- reluctance to simplify interpretations
- sensitivity to operations
- commitment to resilience
- deference to expertise.

Other language typically used in the context of HROs includes *mindfulness*, *chronic unease* and *weak signals*, amongst others. All of these terms are associated with the first principle on the list above - *a preoccupation with failure.* Although they are presented above as apparently discrete principles, in practice they are closely connected with each other. For example, to detect "weak signals" requires a *sensitivity to operations* including an acceptance of the potential of a disconnect between operations as seen from above and as actually conducted or experienced at the front line. Input is required from people who know the process and its technical hazards

well – *a deference to expertise* – to determine whether this gap is important and how to best resolve it.

This is but one example of the interconnectivity of the five principles above. As a result, HRO principles, as reported in academic literature may be best viewed as a set of linked ideas which taken together characterise an HRO or an *aspiring* HRO.

HROs vs Aspiring HROs

As one academic has pointed out, in the context of trying to work out how to identify real HROs, "It turns out that these are very elusive creatures that inhabit the realm of theory more than the real world."[39] Academic studies of HROs often emphasise that the organisations examined are usually not yet HROs or are seeking to interpret HRO principles in an environment where they may not have previously been considered relevant. As one study into an organisation's journey in attempting to become an HRO notes:

> Despite everything we know about HROs, there is no recipe for transforming an organization into an HRO. Put another way, there is no easy path to achieving safe and reliable performance. Some HRO scholars emphasize the idea of high reliability organizing rather than high reliability organizations to highlight two issues. First, high reliability is not a state that an organization can ever fully achieve; rather, it is something the organization seeks or continually aspires to. Second, reliability is fundamentally a dynamic set of properties, activities, and responses.[40]

Seeking high reliability in the mining industry will not only look different to other industries, it will also mean understanding the dynamic nature of reliability and how it is maintained and improved.

A focus on safety is too narrow

We suggest the greatest benefit from adopting HROs concepts comes from adopting a broader approach than solely focusing on safety. This is illustrated by an incident which occurred at an Australian metalliferous mine. A leak occurred in a storage tank containing a hazardous substance. Personnel who went to investigate and attempt to prevent the leak were fortunate to escape without injury when the tank collapsed. Before this occurred, the tank contents spilt beyond the bund around the tank. Fortunately, the tank contents were contained on site because of the drainage system. The tank subsequently collapsed. The company and government regulator both decided operations should cease pending investigation even without apparent harm to people or the environment. There were significant financial losses in the 6 months the site stopped operating.

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[39] Hopkins, A (2009) *Learning from high reliability organisations*, CCH Australia, Australia, p16

[40] Christianson, M, Sutcliffe, K, Miller, M & Iwashyna, T (2011) Becoming a high reliability organization. *Critical care* (London, England), 15(6) p314

Because of the sensitivity of the material being mined and processed, there was also widespread negative publicity and non-governmental organisation attention with concomitant reputation damage.

In practice, it is often a matter of chance when a loss of control over an activity results in a safety, environmental, production loss and/or reputation damage. This is widely recognised by those managing hazardous activities in a wide range of industries. For example, the chemical processing and oil and gas industries use the concept of *process safety*. Process safety is defined by the Australian Institute of Health and Safety as:

> Process safety is about managing the integrity of operating systems by applying inherently safer design principles, engineering and disciplined operating practices. It deals with the prevention and mitigation of incidents that have the potential for a loss of control of a hazardous material or energy. Such loss of control may lead to severe consequences with fire, explosion and/or toxic effects, and may ultimately result in loss of life, serious injury, extensive property damage, environmental impact and lost production with associated financial and reputational impacts.[41]

This is consistent with international definitions such as used by the American Institute of Chemical Engineers' Centre for Chemical and Process Safety (CCPS) and major corporations. The definitions may vary subtly but all recognise that the same incident can have a variety of impacts and that it is not possible in most circumstances to manage safety in isolation. This is the basis of our suggestion that the benefits from applying HRO principles come from recognising that a sole focus on safety is too narrow and any application of HRO concepts starts from the position that there are other important and associated benefits.

Implications for Queensland mining

The above sections have the following implications for successfully adopting the principles of HRO theory to improve safety in the mining industry:

- While organisational culture is an important aspect of adopting HRO principles, identifying tangible practices to either encourage or discourage is the best way to influence culture.
- The emphasis of HRO theory is understanding organisations that avoid serious failures (i.e. studying when things go right, rather than when things go wrong). However, the key to the success of HROs is understanding that the absence of failure is not a sign that all is well.
- HRO literature focuses on operations with potential for major accidents. Therefore, HRO principles are most relevant in environments where the consequences of failure are severe.
- Becoming an HRO is not something that can be fully achieved, and what is required to achieve high reliability is dynamic.
- HRO principles require a broader framing than just personal safety, requiring organisations to identify when they have lost control. This is referred to as *process safety* in similar industries.

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[41] (2019) Managing Process Safety, In: *Core Body of Knowledge for the Generalist OHS Professional*, 2nd Ed, Australian Institute of Health and Safety, p3

ANNEX B: HROS IN MINING – TOPICS

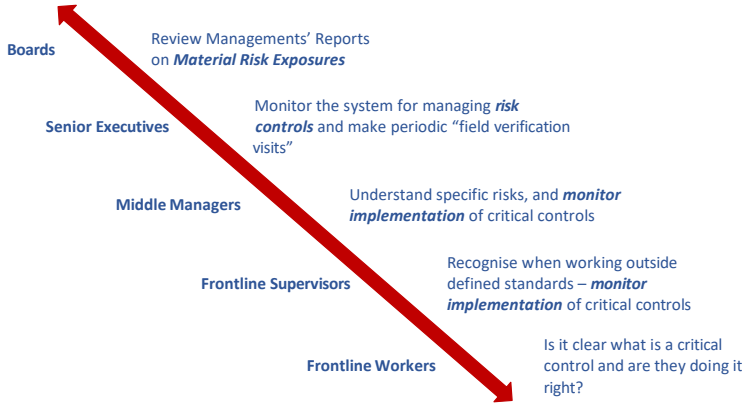
This section details the topics that were considered relevant to the project based on Atturra's review of HRO principles. HROs are organisations which are said to consistently avoid serious failures, reliably delivering their organisational objectives despite operating in environments characterised by high levels of inherent risk and/or operational complexity. Consequently, the topics cover practices necessary to prevent serious failures in the mining environment, particularly safety failures.

This topic list was provided to participating sites to provide an opportunity for sites to assess their own practices against key HRO characteristics. It provides guidance on translating HRO principles into practices that are relevant to mining operations, with suggestions on the type of systems, processes and procedures that are relevant to consider.

Topic	Examples and comments
Clarity of the risk controls	
All relevant personnel (including subject matter experts, front line workers, supervisors, superintendents, managers and senior leaders) are clear about: ▪ the hazards ▪ the risks ▪ the risk controls ▪ how the risk controls are monitored and checked	▪ Sample of documentation on hazards identified and risk assessment. ▪ Identification of controls (including critical controls or other prioritisation approaches). ▪ Sample of controls defined, including any processes and procedures in place to monitor them and provide criteria for effectiveness.
The "health" of important risk controls (i.e., critical controls) is reported upon: ▪ how well controls are working in practice ▪ the action to be taken when risk controls fail ▪ what is being done to rectify deficiencies in controls	▪ Monthly (or other periodic) reporting on control health. ▪ Planning systems, ERP or other action tracking to ensure safety critical improvement actions are closed out.
All the above information is available to all relevant personnel	▪ Examples of reporting on display on site or in office environment.

Governance and Accountability	
Accountability or "ownership" is clear for all important systems, processes and controls	▪ Standards or Procedures outlining who is responsible for identifying hazards, assessing risk and the adequacy of controls. ▪ Documents outlining who is responsible for specific controls and their effectiveness.
Senior leaders review performance of all important systems, processes and controls at regular intervals	▪ Documents defining oversight arrangements that include the role senior leaders. ▪ Outputs of senior leadership monitoring (senior leaders audits, mine manager inspections, etc.).
Periodically they are subject to a "deeper dive"	▪ Documents defining review cycle for principal hazards. ▪ Results of any reviews of critical systems and processes.
Systems and processes on site cover: ▪ Control of major risks ▪ Operating in a modified environment or outside planned parameters ▪ Managing change of designs, processes and practices ▪ Permitting or authorisations for high-risk work, hazardous plant, etc.	▪ Documentation on systems such as: > Principal Hazard Management > Management of Change > Authority to Operate > Permit to Work > Critical Control Management > Site acceptance/Introduction to Site
Reporting	
The following are specific actions that can be taken by leaders at all levels: ▪ Actively seek out "bad news" about technical failures, risk controls and risk ▪ systems and reward this information	▪ The agenda and contents of any ongoing meetings around risk management and HSEC topics with site leadership. ▪ Outputs of senior leadership monitoring (senior leaders audits, mine manager inspections, etc.).

▪ Do not show displeasure when given bad news, such as about risk controls not working	
Clear performance reporting is in place, showing whether critical systems and controls are working to agreed criteria (e.g., traffic light reporting): ▪ Reporting includes why a control or system does or does not meet criteria (i.e., why a red, amber or green is reported) ▪ Incentivise reporting of non-conforming systems and controls (i.e., reds and ambers) – this is providing useful actionable information ▪ Question green lights, and the evidence for those indicators	▪ The agenda and contents of any ongoing meetings around risk management and HSEC topics with site leadership. ▪ Monthly (or other periodic) reporting on system and control health. Example: Traffic light reporting (or similar) for critical systems or controls are supplemented by commentary of approximately 140 characters on why it is red, amber or green. Managers do not focus on red/amber reports, only seeking to support the team to address the issues. Instead, managers interrogate green lights and whether they are reported accurately.
Incident reporting is encouraged, without incentivising reduction of reportable incidents (safety or otherwise)	▪ Management objectives or incentive plans related to HSEC and reliability (in annual business plans or similar). ▪ Incident reporting definitions and statistics, including what measures are displayed on site (lean boards, signage, etc.).

Monitoring	
Active monitoring is in place for business systems and controls where reliability is critical to safety and business performance ▪ 'Who Needs to Know What?' is defined for critical systems and critical ▪ controls ▪ The frequency of monitoring (or verification) of risk controls is based on the seriousness of the risk ▪ Monitoring is based on clear criteria for what constitutes a 'heathy' system, ▪ process or critical control	▪ Approval processes and procedures for key systems, such as Management of Change and permitting processes. ▪ Critical control definition and reporting. Example: control monitoring at a listed company: 
▪ Monitoring and reporting (including what senior leaders are provided) is based on evidence from field verification	▪ Samples of material used in oversight and assurance processes, including verification required.
Investigating Failure	

▪ Failures in risk controls and systems are investigated based on the *potential* ▪ for harm or damage – even where no harm or damage has occurred ▪ Investigations into failures go beyond "human error" or "procedure not followed" as reasons why an incident occurred, understanding the nature and cause of the error ▪ Accidents, incidents and near misses from other domains are used to find learnings relevant to them ▪ Good investigations ask the "So what?" question to learn more about the ▪ causes of failures	▪ Sample of recent incident investigations. ▪ Documents defining reportable incidents and how information is collected. Example: Sites that have significant hazards inherent to their production processes (i.e. gassy coal mines, block caving, minerals processing/smelting with noxious chemicals) often report on major hazard incidents (referred to as "process safety incidents" in the processing or smelting space). These include investigating uncontrolled release of materials or loss of containment of hazard substances in the processing environments. In the mining environment, this can extend to rock slides or pillar failure. These may be reported and investigated regardless of whether they constitute an HPI by conventional definitions.
▪ Reporting or sharing mechanisms exist to observe so-called "weak signals", ▪ which can suggest incipient failure[42]	Example: Sites often formalise the reporting of specific weak signals where they are known, such as 'failure on demand' events for engineered controls or for safety systems such as isolations. Sites also establish additional "freestyle" mechanisms for reporting weak signals at toolbox talks, pre-shift meetings/handovers.

[42] "Weak signals" are "…seemingly small, unexpected system events to help diagnose and correct underlying systemic problems before they escalate and result in system accidents with major consequences." See High Reliability Operations: A Practical Guide to Avoid the System Accident, B&W Pantex 2008, p.16

Learning Lessons	
Distinguish between lessons to be learned and lessons learned Lessons to be learned become lessons learned only after they have been: ▪ Read and understood ▪ Internalised ▪ Acted upon ▪ Verified effective[43]	▪ Planning systems, ERP or other action tracking to ensure safety critical improvement actions are closed out. ▪ Examples of improvements implemented following incident ▪ investigation or 'deep dive' hazard review. ▪ Examples of materials used to share learnings from incidents across site (or across the business). ▪ Follow up inspections/reports to confirm improvements after an investigation or hazard review (i.e. processes to ensure lessons are learnt).
Workforce Involvement	
Frontline workers + SMEs are involved in: ▪ hazard and risk studies ▪ reviewing bowties and controls ▪ reviewing procedures ▪ investigating incidents, accidents, near misses, high potential incidents (HPIs) ▪ reporting "weak signals".	▪ Examples of outputs from hazard identification and risk assessments, including attendees and their roles. ▪ Examples of outputs from reviews of procedures, including task ▪ observations or other processes to review "work as done". ▪ Existing guidance on reporting incidents provided to workers/contractors. ▪ Sample of incident reporting forms available to workers/contractors.
When problems arise at the front line there is always access to someone with the authority to act	▪ Policies or procedures detailing how workers/contractors can manage their own safety and that of their team. ▪ Case studies of instances where workers have acted to prevent risks eventuating.
Expertise	

▪ When problems arise – is there always somebody with the appropriate expertise who can be consulted ▪ Expertise is valued more than organisational rank	▪ Approval processes and procedures for key systems, such as Management of Change and permitting processes. ▪ Organisation charts showing key areas of expertise, including beyond single site if available, such as geotechnical, ventilation, process and chemical, mechanical, etc. Example: Many organisations function with a 'Technical Authority' distinct from production and HSEC teams, which provides engineering, technical or scientific advice and must be involved in major decisions to change the design or operation of assets. This approach occurs across sites and across the Sometimes this distinction is across sites (i.e. company-wide technical or engineering functions). In these cases, these teams should have strong relationships at site and a formalised role in supporting decision making.

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