

Consequences – Initiating the Path to High-Reliability Organizing (HRO)

Daved van Stralen, MD, FAAP, Sean D. McKay, Thomas A. Mercer, RAdm, USN (Retired)

Abstract:

High-Reliability Organizations emerged as an effective response to consequences. Designing a response from the antecedent events, causation, or the situation misses vital subtle, and nuanced information. Immediate consequences from apparently mundane circumstances, forcing functions, or abrupt catastrophic events share the same possibility of outcomes – dramatic failure. They also share the same approach to engagement. Appreciating the effect of consequences guides every member of an organization toward vigilance for early heralds and engagement that creates enactment.

“Appreciating the effect of consequences guides every member of an organization toward vigilance for early heralds and engagement that creates enactment.”

Introduction

In the 1930s, a man was told he had an intrapericardial foreign body. Upon learning this, he could not work and sought several surgical consultations. The surgeons found the intrusion was extrapericardial; there was no need for an operation. This spurred Harry R. Decker, one of the surgeons, to review 100 cases of foreign bodies in the heart and pericardium between 1900 and 1939. The study showed that operative mortality was higher than non-operative mortality (1, 2). It turned out that the man's incapacitation came from *the knowledge* of the presence of a foreign body, not from the foreign body itself (3).

In Decker's (1) study, patients with retained foreign bodies in the heart lived 5-22 years. The best prognoses for a retained foreign body in the heart were placement in the pericardium or ventricular wall. Sharp foreign bodies could cause fatal perforation, and a foreign body free in the right heart could cause pulmonary embolism and infarction. These should be removed. A later study of intra- or extrapericardial intrusions found that, if there was no hemorrhage or tissue damage, survival could be thirty years before pain, aneurysmal dilatation, migration, thrombosis, or embolism necessitated removal (2).

Before WWII, Dwight E. Harken and Evelyn M. Glidden [4] studied heart surgery and found that one major difficulty with the operative approach was visualization during intracardiac surgery. To prevent

anoxemia, they listed only three alternatives:

1. Work “blindly;”
2. Utilize endoscopic visualization; there was no such scope available; or
3. Devise a temporary mechanical substitute for the heart and lungs; there was no technology enabling this.

Thus, during WWII, only the first alternative was available. Operations to remove a foreign body were considered a last resort, even amongst military surgeons (1-4).

During the D-Day landing in France in June 1944, a soldier with a chest wound lay on the operating table. The chest X-ray showed shrapnel near the heart. On opening the chest, the surgeon, Harken, found the shrapnel was in the right ventricle. He inserted a clamp into the ventricle, able to grasp the fragment. “Then, suddenly, with a pop as if a champagne cork had been drawn, the fragment jumped out of the ventricle, forced by the pressure within the chamber...Blood poured out in a torrent!” (Harken in a letter to his wife). Sutures along the edge of the wound did not stop the bleeding. “I told the first and second assistants to cross the sutures, and I put my finger over the awful leak. The torrent slowed, stopped, and with my finger in situ, I took large needles swedged with silk and began passing them through the heart muscle wall, under my finger, and out the other side...Blood pressure did drop, but the only moment of panic was when we discovered that one suture had gone through the glove on the finger that had stemmed the flood. I was sutured to the wall of the heart! We cut the glove, and I got loose...” (4).

The patient recovered.

“Harken was aware of the risks and the sentiment toward the removal of a foreign body from within a beating ventricle. However, he thought in terms of consequences. He held the view that “some missiles should be removed for the outlined reasons (3)”

Harken was aware of the risks and the sentiment toward the removal of a foreign body from within a beating ventricle. However, he thought in terms of consequences. He held the view that “some missiles should be removed for the outlined reasons (3):

1. to prevent embolus of the foreign body or associated thrombus;
2. to reduce the danger of bacterial endocarditis;
3. to avoid recurrent pericardial effusions;
4. to reduce damage to the myocardium.”

Discussing Harken's experience, Decker further commented, “Statistics do not mean very much.” Each case should be decided

individually, referencing symptoms, interference with cardiac function, and neuropsychiatric reaction. Harken also considered the psychological response to “harboring an unwelcome visitor in one of the citadels of his well-being” (3).

“One surgeon who had reviewed heart and pericardial injuries felt that patients without symptoms during the first few days in a forward surgical unit would probably do better waiting for an operation at a base hospital. He then described a patient who died due to an embolic foreign body ten days after seeming to recover.”

One surgeon who had reviewed heart and pericardial injuries felt that patients without symptoms during the first few days in a forward surgical unit would probably do better waiting for an operation at a base hospital. He then described a patient who died due to an embolic foreign body ten days after seeming to recover. On autopsy, shrapnel was found in the right ventricle – “the overlying myocardium for a distance of several centimeters was black, and death was due to the presence of the foreign body and the squeezing action of the myocardium on that foreign body.” The surgeon had privately told Harken, “he is sure that this patient could have been salvaged by the removal of the foreign body” (3).

Harken advocated the removal of all intracardiac foreign bodies measuring 1.0 cm. or more in two dimensions (2, 5).

Harken responded to the possible consequences of shrapnel retained in the ventricle by removing it. He acted against statistics, conventional wisdom, and the technical impossibility of visualization within the ventricle. This was not trial and error nor a foolhardy act of desperation. His was a well-thought-out synthesis of science, practice, context, and experience within the environment. Harken considered potential outcomes and consequences to make a confident guess as to the *consequences* of his decisions.

His actions directly led to mitral valve repair, open-heart surgery, physiological monitoring in intensive care units, and consideration of the patient’s psychological response to illness (2, 4, 6).

Mastery in High-Reliability Organizing is not a body of knowledge but the ability to solve problems never before encountered. Mastery and specialization in an area continue to exist in HRO. But specialization in domains risks specialization in language, including the development of arcane knowledge, jargon, and specialized terms. With specialization comes categorization. How we define categories and their purpose is heavily influenced by regulators, for example, the ICD codes used in medicine—identifying problems that cross the boundaries of different domains functions as boundary objects, contributing to the distribution of information and distributed problem-solving.

In HRO, the problems we solve prevent or are in response to **consequences**, often developing from various **gaps** that impede our ability to act (7). Through **engagement** with reciprocal **feedback**, we bring structure and resolution to the situation. Systemic and routine response to consequences supports effective, early engagement of the situation by individuals.

Jim Denney, Capt., LAFD, a veteran of two Vietnam combat tours, would remind his medic and fire crews, “The emergency has a vote. In the face of a void, move forward.” A Los Angeles City firefighter, arriving on a confusing, volatile scene to assist one of the authors (DvS) on the Fire Rescue Ambulance, uttered a powerful version of a pragmatic stance: “I don’t know what’s happening, but I know what to do.” Bill Corr, one of the authors’ (DvS) fire captains, and WWII US Navy veteran, South Pacific Theater, gave meaning to rescue work, “What we do is help people when they cannot help themselves.”

“Engaging uncertainty challenges our abilities of perception, sensemaking, and “thinking on the fly” when our actions produce unwanted responses. Some call this “trial-and-error,” except that learning by trial and error is foolhardy when the first trial could be fatal.”

Uncertainty, Risk, Error, Hazard

Engaging uncertainty challenges our abilities of perception, sensemaking, and “thinking on the fly” when our actions produce unwanted responses. Some call this “trial-and-error,” except that learning by trial and error is foolhardy when the first trial could be fatal. Some productive technologies can become destructive in such situations. These technologies have potentially grave consequences. There is *absolute avoidance* of failure when the consequences of major failures are greater than the value of their lessons. The result is an organizational process to “engage *in trials without errors*, lest the next error be the last trial” Todd R. LaPorte and Paula M. Consolini (8).

“Operators in the liminal or VUCA-2T (Volatility, Uncertainty, Complexity, Ambiguity, Threat, and Time compression) expect to encounter grave consequences that necessitate trials without error, possibly a hallmark of an HRO (Tables 1 and 2).”

Operators in the liminal or VUCA-2T (Volatility, Uncertainty, Complexity, Ambiguity, Threat, and Time compression) expect to encounter grave consequences that necessitate trials without error, possibly a hallmark of an HRO (Tables 1 and 2). HRO operators would call “trial without error” “learning by doing,” or the ability to improvise. Rather than “trial” as a singular action, the operator continues engagement in serial trials. There are no failures in common sense, as failure means the operator stopped too soon. What was just learned for each serial iteration generates a series of solutions, reducing damage in unforeseen ways. Engagement can be described as the act of learning by doing in context, not an outcome of rational deliberation, and cannot be objectified for theory-making (9, 10).

Table 1. VUCA-2T (11)

Volatility	The rapid, abrupt change in events
Uncertainty	Lack of precise knowledge, need for more information, unavailability of the necessary information
Complexity	A large number of interconnected, changing parts
Ambiguity	Multiple interpretations, causes, or outcomes
Threat	Impaired cognition and decision-making
Time Compression	Limitations acquiring information, deciding or acting before consequential changes

Table 2. Liminality

Conventional Operations	Liminal Operations	High-Reliability Operations
Familiar Structured	Threshold of transition Passage	A potential unexpected abrupt change
White noise Closed system	Red and pink noise "Cosmology episode" (12)	Red and pink noise Open system
Prevent Failure	Consequence driven	Consequences
Knowledge by description	Gaps in knowledge (7)	Knowledge by acquaintance
Standards Known rules Familiar relations	Learn by doing Old rules do not apply New rules unknown	Adaptive Relations from shared experience
Hierarchical support	Alone	Mutual support
Euclidean space Newtonian physics	Topological space, but learning relations Collapse sensemaking and leadership (12)	Topological space Non-Newtonian physics
	"They attained a sort of tranquility in spite of their anxiety. They had very little need for defensive mechanisms of any sort to deceive themselves or anyone else" (13)	

"We act to prevent consequences, though in our mind, we interpret our actions as our response to the situation, with our understanding of the situation being derived from antecedent events. The central problem of this act comes from theories that don't match the situation and, as the event evolves, plans that do not match the flux of events. Unrecognized in this process is the gratuitous effects of stress and fear on our thinking and acting."

Consequences develop from uncertainties in gaps that form between stable and unstable situations. *Intrinsic* uncertainties come from the essential nature of the system. They can be *information-insensitive* uncertainties natural to the system or *information-sensitive* uncertainties from information analysis. *Extrinsic* uncertainties arise from the performance of tasks or the development of knowledge (14). Novel situations and problems emerge from the

environment that people cannot or will not solve themselves. HRO supports engagement to reduce consequences.

We act to prevent consequences, though in our mind, we interpret our actions as our response to the situation, with our understanding of the situation being derived from antecedent events. The central problem of this act comes from theories that don't match the situation and, as the event evolves, plans that do not match the flux of events. Unrecognized in this process is the gratuitous effects of stress and fear on our thinking and acting. By its temporal-spatial proximity, a threat initiates *functional* stress-restricted cognition, protective fear circuits, and adaptive threat behaviors. When not modulated, threats cause unrecognized situational cognitive distortions (15, 16), stress-induced disorders, fear circuitry disorders, and amygdala-driven behaviors (15-18). Because we use our judgment to judge our judgment, these maladaptive threat effects only become visible in others or after failure. They can become normalized, making the ecology of fear inevitable and invisible (19).

The above approach produces high reliability. Academicians codified HROs from environments where failure could be catastrophic, yet failures were rare or nonexistent despite working with hazards or in hazardous conditions (20). Mistranslated field terms into the business and management science lexicon caused some wash-out of essential concepts and themes. This borrowing has been restricted, mainly from the normative frame for preventing system failure. The inordinate focus on error and failure diminished the pragmatic frame for early identification and engagement of errors. Instead, the organization relies on the normative frame to reduce

the number of errors through plans, structures, and rules (9).

“Out of this concern that operational failures can result in dangerous and harmful consequences, business and management science distinguishes the concepts of risk, error, and hazard (8).”

Out of this concern that operational failures can result in dangerous and harmful consequences, business and management science distinguishes the concepts of risk, error, and hazard (8).

Risk. In the engineering sense, the risk is the product of the magnitude of a consequence and the probability of an event causing the consequence. In management science, the risk is a calculated value from a *measured probability* multiplied by the *cost of that failure*. In the HRO environment, causation of an event or complete knowledge of any significant situation are uncertainties and cannot be reliably known (8).

The International Organization for Standardization (ISO) developed standards for risk, ISO 31000:2009 (21). Risk is the “effect of uncertainty on objectives.” “Risk management” is the “coordinated activities to direct and control an organization with regard to risk.” Risk as an operational measure is less helpful for an HRO.

HROs can continually access and manage *extrinsic* uncertainties to develop effective ‘barriers’ to assess and manage *system risks*. The HRO makes efforts to reduce the uncertainties, reduce the effects of uncertainties, and increase the proper detection, analysis, and correction of the adverse effects of uncertainties (2). Decision-making approaches can generate Shannon information (changing uncertainty to certainty) (22) through what Bob Bea, Professor Emeritus, Civil Engineering, University of California, Berkeley (23), called *interactive-real-time assessment and management of risks*. Harken used this approach when he removed shrapnel from the ventricles of soldiers in WWII.

“This approach was completely overlooked [by academicians] until the early 1990s. We were taught that there was only *proactive* (before operations) and *reactive* (after) - and that was it. And we thought we could capture all of the risks with the proactive approaches - and then provide adequate defenses if ‘justified’ - but we were missing some really major risks that were fundamentally unpredictable and unknowable.”

Bob Bea, 8/30/2005, personal communication

Error. “Inherent or natural uncertainties that are fundamentally information insensitive” cause errors (Bob Bea, 8/8/2007, personal communication). *Extrinsic* uncertainties frequently are identified as ‘human errors’ though they result from human and organizational processes. Human errors are results, not causes (14).

Errors and failures do not appear with the full force of an overt, decompensated state. Such events start from mundane actions and events or routine procedures that work in most contexts but not all (9). Some mundane events stay small, some self-resolve, and a few must be engaged. Though uncommon, if not rare, mundane events can entrain energy and resources, cascading into irreversible failure. It all starts from a covert, compensated event (24-26).

Errors are not errors at first. An act becomes a mistake only late in its development as events evolve (27). Sensemaking appreciates that the smallness of errors and disturbances is not insignifi-

cant. Micro-level actions can have significant consequences (28). For the operator, errors are valuable by making the boundaries of knowledge, capabilities, and performance visible. Errors make the system safe through early identification and management (29).

“From the operator’s view, until we experience something, we don’t know exactly how we would act or what to expect. Error emerges from local, nonlinear interactions, manifesting the environment entwined with human intent. One person’s error, then, becomes another person’s information.”

From the operator’s view, until we experience something, we don’t know exactly how we would act or what to expect. Error emerges from local, nonlinear interactions, manifesting the environment entwined with human intent. One person’s error, then, becomes another person’s information. Environments where people must move between ill-structured and well-structured problems confound people anchored in the normative stance. For the HRO, *error corrects heuristic bias* (26).

Focus on error prevention to achieve HRO has consequences. Behaviors to prevent failure or reduce liability exposure include “doing everything through channels,” “refer all matters to committees,” which should be “as large as possible — never less than five,” “advocate caution,” “urge your fellow conferees to be reasonable and avoid haste,” “worry about the propriety of any decision — raise the question of whether such action as is contemplated lies within the jurisdiction of the group or whether it might conflict with the policy of some higher echelon,” and “apply all regulations to the last letter.” The above quotations exemplify a “type of simple sabotage” that requires “no destructive tools whatsoever and produces physical damage, if any, by highly indirect means.”

“The United States Office of Strategic Services (OSS) used these methods to undermine industrial efforts in occupied Europe during World War II. Operatives taught civilian workers these “simple sabotage” methods (30). Today’s business and healthcare leaders commonly accept these methods as prudent means to prevent error and reduce liability in healthcare.”

The United States Office of Strategic Services (OSS) used these methods to undermine industrial efforts in occupied Europe during World War II. Operatives taught civilian workers these “simple sabotage” methods (30). Today’s business and healthcare leaders commonly accept these methods as prudent means to prevent error and reduce liability in healthcare.

Hazards. Hazard refers to characteristics that, if failure were to occur, can result in significant damage to life and property (8). Hazard is objective and dispassionate, if not passive, while the threat is subjective and can be directed intentionally toward an object.

Hazards, Consequences, Capabilities. During a rope training exercise, a Special Forces (SF) operator asked one of the authors (DvS) about risk management. He was working toward his MBA and didn't quite grasp the concept. The author described it as a calculated value to help a business make investment decisions – how much to spend depending on what can be lost. Too great a risk, and the business does not pursue the venture. The author pointed out that SF cannot refuse an assignment. Instead, they look at the capabilities necessary for the mission. If they don't have the necessary capabilities, or their support groups do not have the required capabilities, they develop them. They match capabilities to expected hazards. They received the mission *because of* the consequences of not completing it. This is the type of thinking Harkens followed standing by a soldier with a rare type of wound.

“If they don’t have the necessary capabilities, or their support groups do not have the required capabilities, they develop them. They match capabilities to expected hazards. They received the mission because of the consequences of not completing it. This is the type of thinking Harkens followed standing by a soldier with a rare type of wound.”

This may better be appreciated when we consider two orthogonal axes to describe the environment – one formed by abstractions and one contextual. Abstract concepts comprise discrete elements and time measures that do not influence other elements on the axis. The other contextual axis oscillates from environmental influences due to internal feedback (auto-correlation) and external feedback with different frequencies. The first axis of abstractions

is stable and can be described by a gaussian distribution, producing the statistics and probabilities necessary for evidence-based medicine. The oscillations of the contextual axis have frequencies with long-period events that carry greater energy. The system must respond to these long-period frequencies that act as infrequent forcing functions.

Consequences and Color of Noise

Stable environments measurable by the gaussian distribution are “white noise” environments. Environments where stability is at risk from forcing functions, are “red noise” environments (24). The interaction between the orthogonal axes of abstractions and contextuality produces periods that have stability or the appearance of stability. However, these environments are punctuated by instability that seems distant until it arrives, then it appears to have been a logical consequence of events (Table 3).

Reddened or pink-noise environments are information *insensitive*. More information (or data) makes the data messier or reveals covert, unexpected influences. With events in flux, current information quickly becomes antecedent information, entrained energy changes circumstances, and what was once relevant becomes irrelevant. We operate more in a mystery, searching for and testing clues using a complete spectrum analysis (31). Our drive is to prevent consequences from becoming a reality.

“Red noise environmental ‘forcing functions’ drive environmental influences into the organization, destabilizing the internal environment. Problems become contextually resolved by practical, pragmatic solutions. The pink noise environment is also ecological, but the problem is embedded into the environment, making these problems contextual and pragmatic (32).”

Table 3. Patterns and Characteristics of Noise (24)

Color	Structure	Variance	Distribution
White	No frequencies dominate Flattened spectrum	Information <i>sensitive</i> Data <i>decreases</i> variance	Gaussian distribution - Elements fully independent - No autocorrelation
Red	Low frequencies dominate Long-period cycles	Information <i>insensitive</i> Data <i>increases</i> variance	Power law distribution - Elements <i>not</i> independent - Mutual/ reciprocal relations
Pink	The midpoint of red noise Slope lies <i>exactly</i> midway between white noise and brown (random) noise	Information <i>insensitive</i> Data <i>continuously increases</i> variance Distinguishes pink noise from red-denied spectra	Power law distribution - No well-defined long-term mean - No well-defined value at a single point

Red noise environmental 'forcing functions' drive environmental influences into the organization, destabilizing the internal environment. Problems become contextually resolved by practical, pragmatic solutions. The pink noise environment is also ecological, but the problem is embedded into the environment, making these problems contextual and pragmatic (32). Problem-solving for red and pink noise environments tends toward practical common sense, focusing on consequences and a broad knowledge base (33).

Decision theories and problem-solving developed in white noise environments tend to be information sensitive, linear, and deterministic. Within the forcing function of red noise or the abrupt catastrophe from pink noise, "white noise approaches" *become* the problem. Using white noise predictions of what would happen during forcing functions or catastrophes is a matter of life or death – inaccurate models could kill (34).

"I Am Data-Driven"

Said with pride by various executives, administrators, and managers. Data is a product of a gaussian distribution, found only in white noise environments. Consequences in red and pink noise environments emerge from forcing functions and abrupt catastrophes. Data provides less support for these emergencies than a focus on capabilities would.

Executives, administrators, and managers learn to rely on data from their experience in white noise environments. These systems have information-sensitive uncertainties that arise from information analysis. Data forms a gaussian distribution; more data decreases variance while providing the information necessary to resolve these uncertainties. Hence, being "data-driven" makes sense.

"Executives, administrators, and managers learn to rely on data from their experience in white noise environments. These systems have information-sensitive uncertainties that arise from information analysis. Data forms a gaussian distribution; more data decreases variance while providing the information necessary to resolve these uncertainties."

In an environment influenced by reddened noise, more data increases variance while forming a power distribution rather than a Gaussian distribution. The uncertainties natural to such systems are *information insensitive*. Hence, "data-driven" approaches can mislead, if not confusing. Data then becomes a tool one may want to drop during an exigency.

In our environments, data becomes stale relatively quickly. Misconstrued data can take away from developing the depth and breadth necessary for reddened noise surges. Data production for a distant administrator may have less operational relevance than more qualitative measures.

Leadership for Consequences

To feel the severity of lung disease in a patient with status asth-

maticus, one of the authors (DvS) hand ventilated a child. Blood gas analysis revealed continuing decreases in arterial pH. In looking at the cardiorespiratory monitor, the author noted the T wave on the EKG was increasingly becoming peaked, an indicator that the heart was becoming affected by increasing serum potassium due to refractory respiratory acidosis. Verbal orders for treatments to lower serum potassium were met with doubt and resistance. "The amplitude on the monitor is high," remarked staff. Adjusting the amplitude revealed the seriousness. The author quickly explained how respiratory acidosis could cause hyperkalemia, influencing some staff to begin preparations. Other staff held the too common belief that if it does not make sense, then it won't happen, or "If I haven't seen it, it can't be."

Cardiac arrest ensued, but because some staff were present in the process of preparing treatment, the child recovered. Two days later, the scenario, exactly as described above, occurred again but with new staff with the same comments. The child again recovered.

An adolescent dependent on long-term mechanical ventilation in a subacute care facility was anxious, not wanting to be left alone. Pulse oximetry revealed variable oxygen saturation ranging from decreasing peaks of 96% to 88% and lows to 78%. Staff prepared to call 9-1-1 to send the patient to the emergency department. The Respiratory Care Practitioner (RCP) noted the ventilator peak pressure was set at 18 cm H₂O, yet she used both hands to expand the chest, effectively a pressure of 32-35 cm H₂O. She also noted his tracheal secretions had changed from thick to sticky while under fluid restriction. The RCP requested a stepwise increase of ventilator peak pressure and enteric fluids for the secretions.

"Healthcare providers want to relieve suffering quickly and not keep a patient in deteriorating condition. They also do not want to leave their patient in extremis. This created tension between rapid engagement and early transport – both will reduce consequences."

Healthcare providers want to relieve suffering quickly and not keep a patient in deteriorating condition. They also do not want to leave their patient *in extremis*. This created tension between rapid engagement and early transport – both will reduce consequences. One of the authors (DvS) reframed the problem as one of hydration and 'interoception.' Administration of an oral or enteric rehydration solution can hydrate the airways in 20 minutes. The new rheological characteristics then mobilize airway secretions, relieving the obstruction. The greater chest expansion brings an interoceptive state of relaxation.

Following the RCPs recommendation, peak pressure was increased stepwise to 32 cm H₂O while a stepwise decrease in the respiratory rate occurred, and oxygen saturation increased. After the enteric administration of an oral rehydration solution, tracheal suctioning recovered copious secretions. Within one hour, the oxygen saturation was 98% on F_{O₂} of 0.36; the respiratory rate was 22, and the patient was comfortably breathing, asking for ice chips, and feeling comfortable being alone in his room.

We experience a sense of danger when we are in circumstances

we cannot adequately control without the threat of negative consequences. This only occurs when we must interact with the problem in context, that is, the problem embedded in the environment. Context accentuates consequences (33, 35, 36). Leaders can accentuate the situation to intensify circumstances (the increasing T wave from acute respiratory failure) or to attenuate the level of concern (focusing on chest expansion and secretions) (37).

“Failures occur, the damage is done, and people are injured or die. Faced with such risks and the desire to operate failure-free, we act carefully, think prudently, and lead judiciously. We become secure in believing we will prevent or mitigate negative consequences. We prepare our workforce, surveil for indicators of problems, generate plans, and create algorithms for actions that prevent or support responses to that failure.”

Failures occur, the damage is done, and people are injured or die. Faced with such risks and the desire to operate failure-free, we act carefully, think prudently, and lead judiciously. We become secure in believing we will prevent or mitigate negative consequences. We prepare our workforce, surveil for indicators of problems, generate plans, and create algorithms for actions that prevent or support responses to that failure. The result is a safer program with few failures but failures that can be attributed to some error or a failure from which we can learn.

This describes more than an ideal system; it describes how someone in an authority or leadership position may see the program they have or aspire to have.

“Leadership scholarship has focused on relatively stable operating conditions with low ambiguity, accessible information, and plentiful time for action (38). Leadership models developed in organizational science or military organizations may not generalize “live-or-die” situations where one must actively avoid death (39).”

Leadership scholarship has focused on relatively stable operating conditions with low ambiguity, accessible information, and plentiful time for action (38). Leadership models developed in organizational science or military organizations may not generalize “live-or-die” situations where one must actively avoid death (39). In such cases, leaders and followers personally face dynamic and

unpredictable situations where outcomes include severe physical or psychological injury (40). This type of leadership requires context-dependent factors and the development of effective thought processes (15, 41, 42).

Sensemaking against consequences is not a matter of gathering information. It is retrospective and ongoing as the situation changes and capabilities come into play, punctuated and not following single sequences (43). We must update our knowledge from the unfolding situation or risk being caught up in dangerous events if we still act upon what happened in the recent past (12).

Sensemaking is actively shared by all who generate information. The leader is receptive to new, especially disconfirming, information. The leader may change plans from a subordinate’s recommendation, not because the original plan had flaws, but to acknowledge the subordinate’s initiative and insight. Subordinates may notice the leader lost focus on events and, through reciprocal sensemaking and sense-giving, might intervene to interpret a situation, suggest appropriate action, or encourage communication with other leaders (44).

Rather than sensemaking or sense-giving, abstractions, decontextualizing, and reliance on data contribute to misconstrual and miscommunication (44). While these approaches can develop into teaching, they can make surmountable problems deadly in instability with high consequences. The leader in these situations strives for distributed cognition.

“Participation in decision-making by subordinates contributes to them crossing the gap from competence to proficiency or proficiency to expertise while developing moral agency that the individual makes a difference (45).”

Participation in decision-making by subordinates contributes to them crossing the gap from competence to proficiency or proficiency to expertise while developing moral agency that the individual makes a difference (45). Through discussions with the leader, subordinates learn of the impact of adverse consequences and inherent moral implications of decisions and actions taken during an unstable event (37). The leader increases performance by modeling and sharing sensemaking and meaning-making to (46):

- foster meaning;
- build competence or self-efficacy;
- encourage the pursuit of value-congruent goals;
- strengthen social identification with a group, department, or organization;
- help subordinates perceive themselves as important, influential, effective, and worthwhile.

Engagement reduces certitude. Certitude is an early herald of failure. Engagement at the point of contact, where line workers operate, is nearly always a liminal space. Neonatal physiology, parents, families, and the local circumstances will never be the same. While creating a PICU, Ron Perkin would tell staff he didn’t care what they did...they just had to stay at the bedside (DvS, personal communication). That is, engagement continued past the point of action, continuing through observation for complications,

effectiveness, and sustainability. The further away one moves from the event, the consequences of certitude decrease. In some sense, certitude can be a hazard from limited field experience or higher status (47).

“Leadership models do not incorporate the characteristics necessary for close-in, quick identification and interpretation of weak signals, uncertainty, and ambiguous information. “A story always sounds clear enough at a distance, but the nearer you get to the scene of events, the vaguer it becomes,” George Orwell, Shooting an Elephant (48).”

Leadership models do not incorporate the characteristics necessary for close-in, quick identification and interpretation of weak signals, uncertainty, and ambiguous information. “A story always sounds clear enough at a distance, but the nearer you get to the scene of events, the vaguer it becomes,” George Orwell, *Shooting an Elephant* (48).

Design for Consequences:

HROs, as an organization, focus on function and consequences. As Karl Weick observed (personal communication), a disruption can distract an organization leading it to misjudge what is happening. While collecting sufficient information to act, circumstances will have changed. Act immediately, and you don't have the necessary information. This is the uncertainty principle bedeviling all who arrive at an exigent situation. With insufficient information as a given, the HRO generates information through action. HROs focus on consequences (49).

Faced with such a situation having a possible uncertain or bad outcome, individuals may hesitate to act. Consequences, in these situations, drive engagement. Yet consequences also arise from inaction and actions taken. Focusing on the consequences of our actions and bottom-up feedback from the environment, rather than a central authority, has common elements with the brain function of motor cognition (9).

“When we engage, we build from perception to observation, which drives inquiry and experience. From our experience, we give meaning to our actions and the information we generate. In the liminal space, we do not have certainty, particularly for antecedent events, which impairs our ability to act from what happened earlier.”

When we engage, we build from perception to observation, which drives inquiry and experience. From our experience, we give meaning to our actions and the information we generate. In the liminal space, we do not have certainty, particularly for antecedent events, which impairs our ability to act from what happened earlier. This also interferes with scientific logic and the Cartesian approach to reaching truth (50) or bringing about a resolution. Instead, we use the possible consequences of our actions to guide inquiry, likely the most challenging tenet of pragmatism to appreciate (51, 52).

Conclusion:

Dwight E. Harken thought of preventing consequences but would act against the consensus of surgeons (3). He would work blindly in the ventricle. He didn't know if he would succeed and, if he succeeded, would he prevent the complications some casualties never experienced.

The RCP observed a patient in distress with poor chest expansion, a large amount of tracheal secretions, and oxygen saturation that did not improve after suctioning. Wanting to make the patient comfortable and appreciating that patient-ventilator asynchrony can be fatal (53), the RCP began hand ventilating for greater chest expansion. Greater tidal volume increased the mean airway pressure, increasing oxygen saturation while also increasing the flow of mucus.

Mobilized secretions created a vibration in the ventilation bag. Suctioning produced thick, then sticky secretions. The RCP, engaging the consequences of discomfort, had changed to the consequences of patient-ventilator asynchrony due to poor chest expansion, then to the effects of sticky secretions and mucous plugs that can rapidly become fatal.

“The dynamic viscoelastic, non-Newtonian properties of mucus ensure efficient clearance, maintain adhesive and elastic strength to resist gravity and coughing and prevent loss of these properties from ambient water. As a hydrogel of glycosylated proteins, mucus rapidly becomes hydrophobic once released from the cell.”

The dynamic viscoelastic, non-Newtonian properties of mucus ensure efficient clearance, maintain adhesive and elastic strength to resist gravity and coughing and prevent loss of these properties from ambient water. As a hydrogel of glycosylated proteins, mucus rapidly becomes hydrophobic once released from the cell. Airway hydration determines mucus stickiness and thickness. If mucus becomes sufficiently thick, bacterial overgrowth and infections can occur (54, 55).

Interoception is the sensation of the internal body, specifically its sense of well-being (56-58). Veterans of combat and public safety from before WWII have encouraged novices to “take a deep breath” during their early experiences under stress. In the past few decades, such deep breathing has been found to reduce stress through interoception to the extent it can help with the symptoms of PTSD (59, 60). Cardiorespiratory vagal activity is the most rapid way to increase activity in the insular or interocep-

tive cortex. We achieve this with a larger tidal volume and shorter inspiratory time (60, 61).

ICU physicians had a greater influence on hospital and facility administration to support early 9-1-1 response and transfer to the Emergency Department or ICU. The standard ED and ICU treatment is n-acetylcysteine, bronchodilators, mechanical devices, and bronchoscopy. Concern by the nursing staff was to follow these newer, informal protocols that had unintentionally created the ecology of fear (19).

One of the authors (DvS) arrived and began using treatments established over 30 years of personal experience described above. The RCP and author worked with physical examination and response to therapy, otherwise blind to standard studies – without arterial blood gas analysis, chest X-ray, or sedation. The child recovered in 30-45 minutes, as described, and remained in the facility.

This description of the incident is a compilation of dozens of such cases regarding smiles (62) and secretions (63). When possible, we use a smile as an endpoint with some children, for the first time, smiling, communicating (64), or talking. The absence of a smile has been used as a sign of serious illness (65), while the smile itself is a sign of joy (66).

“Aside from medical consequences, Dwight Harken considered the psychological reaction to a retained foreign body in the heart (3). In a recent case, Laura Elliot, the RCP considered the suffocation sensation from a low peak pressure and the improved comfort from interoception produced by a faster inspiratory time and higher peak pressure (both hands to expand the chest) (56, 61).”

Aside from medical consequences, Dwight Harken considered the psychological reaction to a retained foreign body in the heart (3). In a recent case, Laura Elliot, the RCP considered the suffocation sensation from a low peak pressure and the improved comfort from interoception produced by a faster inspiratory time and higher peak pressure (both hands to expand the chest) (56, 61). This combination reduces PTSD symptoms and reduces overactivity of the amygdala (59, 67). This type of ventilation also counteracts the synergistic activation of the sympathetic nervous system O₂- and CO₂-sensitive chemoreflexes from hypoxia and hypercapnia (60).

Driven to make the patient comfortable, Elliot uncovered complex ventilator settings and potentially lethal sticky secretions that had not responded to n-acetylcysteine, bronchodilators, and mechanical devices. She was concerned about **consequences**, then came across a series of **gaps** through **engagement** using reciprocal **feedback**. Systemic and routine response to consequences supports effective, early engagement of the situation by individuals. By engaging consequences, we create a living, High-Reliability Organization.

“We do in an emergency what we do every day.”

James P. Denney, Captain, Los Angeles Fire Department, and Vietnam Combat Veteran.

References:

1. Decker HR. Foreign bodies in the heart and pericardium—should they be removed? *Journal of Thoracic Surgery*. 1939;9(1):62-79.
2. Holdefer Jr WF, Lyons C, Edwards WS. Indications for removal of intracardiac foreign bodies: review and report of four case. *Annals of Surgery*. 1965;163(2):249-56.
3. Harken DE. The removal of foreign bodies from the pericardium and heart: A Moving Picture Demonstration. *Journal of Thoracic Surgery*. 1947;16(6):701-9.
4. Miller GW. *King of hearts: the true story of the maverick who pioneered open heart surgery*. New York, NY: Crown Publishers; 2000. 304 p.
5. Harken DE, Williams AC. Foreign bodies in and in relation to the thoracic blood vessels and heart: Migratory foreign bodies within the blood vascular system. *The American Journal of Surgery*. 1946;72(1):80-90.
6. Lefemine AA, Harken DE. Postoperative care following open-heart operations: routine use of controlled ventilation. *The Journal of Thoracic and Cardiovascular Surgery*. 1966;52(2):207-16.
7. van Stralen D, McKay SD, Mercer TA. Identifying Gaps – Entering the Path to High Reliability Organizing (HRO). *Neonatology Today*. 2022;17(8):29-42.
8. LaPorte TR, Consolini PM. Working in Practice but Not in Theory: Theoretical Challenges of “High-Reliability Organizations”. *Journal of Public Administration Research and Theory*. 1991;1(1):19-48.
9. van Stralen D. Pragmatic High-Reliability Organization (HRO) During Pandemic COVID-19. *Neonatology Today*. 2020;15(4):3-9.
10. Zundel M, Kokkalis P. Theorizing as engaged practice. *Organization Studies*. 2010;31(9-10):1209-27.
11. van Stralen D, Mercer TA. High-Reliability Organizing (HRO) in the COVID-19 Liminal Zone: Characteristics of Workers and Local Leaders. *Neonatology Today*. 2021;16(4):90-101. doi: 10.51362/neonatology.today/2021416490101.
12. Weick KE. The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative science quarterly*. 1993;38(4):628-52.
13. Hastings DW, Wright DG, Glueck BC. *Psychiatric Experiences of the Eighth Air Force: First Year of Combat (July 4, 1942-July 4, 1943)*. New York, NY The Josiah Macy, Jr. Foundation; 1944.
14. Bea R. What is safe? *MOJ Civil Engineering*. 2016;1(1):7. doi: 10.15406/mojce.2016.01.00002.
15. van Stralen D, Byrum S, Inozu B. *High Reliability for a Highly Unreliable World: Preparing for Code Blue through Daily Operations in Healthcare*. North Charleston, SC: CreatSpace Publishing; 2017.
16. van Stralen D, McKay SD, Hart CA, Mercer TA. Implementation of High-Reliability Organizing (HRO): The Inherent Vice Characteristics of Stress, Fear, and Threat. *Neonatology Today*. 2022;17(6):26-38.
17. Bracha HS, Bracha AS, Williams AE, Ralston TC, Matsu-kawa JM. The human fear-circuitry and fear-induced fainting in healthy individuals. *Clinical Autonomic Research*. 2005;15(3):238-41.
18. van Stralen D, Mercer TA. During Pandemic COVID-19, the

- High-Reliability Organization (HRO) Identifies Maladaptive Stress Behaviors: The Stress-Fear-Threat Cascade. *Neonatology Today*. 2020;15(11):113-24. doi: 10.51362/neonatology.today/2020111511113124.
19. van Stralen D, Mercer TA. Pandemic COVID-19, the High-Reliability Organization (HRO), and the Ecology of Fear. *Neonatology Today*. 2020;15(12):129-38. doi: 10.51362/neonatology.today/2020121512129138.
 20. Bourrier M. The Legacy of the High Reliability Organization Project. *Journal of Contingencies and Crisis Management*. 2011;19(1):9-13. doi: 10.1111/j.1468-5973.2010.00628.x.
 21. TMB WGoRM. ISO Guide 73:2009 - Risk management — Vocabulary. Geneva, Switzerland: 2009 Nov 2009. Report No.
 22. Shannon CE. A Mathematical Theory of Communication. *Bell System Technical Journal*. 1948;27(3):379-423. doi: 10.1002/j.1538-7305.1948.tb01338.x.
 23. Prud'homme A. Bob Bea, the Master of Disaster. *Men's Journal* 2013;5:72-5.
 24. van Stralen D, McKay SD, Mercer TA. Disaster Series: High Reliability Organizing for (HRO) Disasters—Disaster Ecology and the Color of Noise. *Neonatology Today*. 2021;16(12):96-109. doi: <https://doi.org/10.51362/neonatology.today/2021161296108>.
 25. van Stralen D, McKay SD, Hart CA, Mercer TA. High Reliability Organizing (HRO) for the Color of Noise: Forcing Functions, Collaboration, and Safety. 17. 2022;4:19-30.
 26. van Stralen D, McKay SD, Mercer TA. Flight Decks and Isolettes: High-Reliability Organizing (HRO) as Pragmatic Leadership Principles during Pandemic COVID-19. *Neonatology Today*. 2020;15(7):113-21. doi: 10.51362/neonatology.today/2020715711321.
 27. Paget MA. The unity of mistakes: A phenomenological interpretation of medical work. Philadelphia, PA: Temple University Press; 2004.
 28. Weick KE, Sutcliffe KM, Obstfeld D. Organizing and the Process of Sensemaking. *Organization Science*. 2005;16(4):409-21. doi: 10.1287/orsc.1050.0133.
 29. van Stralen D, Gambino W. Error as a Faulty Failure Signal. *Neonatology Today*. 2020;15(9):114-7. doi: 10.51362/neonatology.today/20209159114117.
 30. OSS OoSS. Simple Sabotage Field Manual — Strategic Services (Provisional) [DECLASSIFIED]. Washington, DC: Office of Strategic Services; 1944.
 31. Wolfberg A. Full-spectrum analysis: A new way of thinking for a new world. *Military Review*. 2006;86(4):35-42.
 32. van Stralen D, Mercer TA. High-Reliability Organizing (HRO), Decision Making, the OODA Loop, and COVID-19. *Neonatology Today*. 2021;16(8):86-96.
 33. van Stralen D, Mercer TA. Common Sense High Reliability Organizing (HRO) in the Response to COVID-19. *Neonatology Today*. 2021;16(7):90-102. doi: 10.51362/neonatology.today/2021716790102.
 34. Heggie V. Experimental physiology, Everest and oxygen: from the ghastly kitchens to the gasping lung. *The British Journal for the History of Science*. 2013;46(1):123-47. doi: 10.1017/s0007087412000775.
 35. van Stralen D, McKay SD, Mercer TA. High-Reliability Organizing (HRO) is Contextual. *Neonatology Today*. 2022;17(7):36-50.
 36. Karrasch A, Levine A, Kolditz T. Leadership When It Matters Most: Lessons on Influence from In Extremis Contexts. In: Sweeney PJ, Matthews MD, Leste PB, editors. *Leadership in Dangerous Situations: A Handbook for the Armed Forces, Emergency Services, and First Responders*. Annapolis, MD: Naval Institute Press; 2011. p. 218-29.
 37. Hannah ST, Uhl-Bien M, Avolio B, Cavarretta FL. A framework for examining leadership in extreme contexts. *The Leadership Quarterly*. 2009;20:897-919. doi: doi:10.1016/j.leaqua.2009.09.006.
 38. Baran BE, Scott CW. Organizing ambiguity: A grounded theory of leadership and sensemaking within dangerous contexts. *Military Psychology*. 2010;22(S42-S69). doi: 10.1080/08995601003644262.
 39. Kolditz TA. Research in In Extremis Settings: Expanding the Critique of 'Why They Fight'. *Armed Forces & Society*. 2006;32(4):655-8. doi: 10.1177/0095327x05283853.
 40. Campbell DJ, Hannah ST, Matthews MD. Leadership in Military and Other Dangerous Contexts: Introduction to the Special Topic Issue. *Military Psychology*. 2010;22:S1-S14. doi: 10.1080/08995601003644163.
 41. van Stralen D, McKay SD, Williams GT, Mercer TA. *Tactical Improvisation: After-Action/ Comprehensive Analysis of the Active Shooter Incident Response by the San Bernardino City Fire Department December 2, 2015*. San Bernardino, CA: San Bernardino County Fire Protection District; 2018.
 42. Palmer NF, Hannah ST, Sosnowik DE. Leader Development for Dangerous Contexts. In: Sweeney PJ, Palmer NF, Hannah ST, Sosnowik DE, editors. *Leadership in Dangerous Situations: A Handbook for the Armed Forces, Emergency Services, and First Responders*. Annapolis, MD: Naval Institute Press; 2011. p. 350-69.
 43. Weick KE. *Sensemaking in organizations*. Dickens G, editor. Thousand Oaks, CA: Sage; 1995.
 44. Dixon DP, Weeks M, Boland R, Perelli S. Making Sense When It Matters Most: An Exploratory Study of Leadership In Extremis. *Journal of Leadership & Organizational Studies*. 2016;24(3):294-317. doi: 10.1177/1548051816679356.
 45. Benner P. *From Novice to Expert: Excellence and Power in Clinical Nursing Practice*. Menlo Park, CA: Addison-Wesley; 1984.
 46. Grant AM. Leading with Meaning: Beneficiary Contact, Prosocial Impact, and the Performance Effects of Transformational Leadership. *Academy of Management Journal*. 2012;55(2):458-76. doi: 10.5465/amj.2010.0588.
 47. van Stralen D, Mercer TA. The Nature of Neonatal Experience during Pandemic COVID-19. *Neonatology Today*. 2021;16(3):87-97. doi: 10.51362/neonatology.today/202131638797.
 48. Orwell G. Shooting elephant. In: Packer G, editor. *Facing Unpleasant Facts: Narrative essays*. Boston, MA: Mariner Books; 2008. p. 29-37.
 49. van Stralen D, Mercer TA. High Reliability Organizing (HRO) is the Extension of Neonatology during Pandemic COVID-19. *Neonatology Today*. 2021;16(5):97-109. doi: 10.51362/neonatology.today/2021516597109.
 50. Legg C, Hookway C. Pragmatism. In: Zalta EN, editor. *The Stanford Encyclopedia of Philosophy*: Stanford University Press; 2020.
 51. Star SL. Living grounded theory: Cognitive and emotional forms of pragmatism. In: Bryant A, Charmaz K, editors. *The Sage handbook of grounded theory*. Los Angeles, CA: Sage

- Publications; 2007. p. 75-94.
52. van Stralen D, Mercer TA. High Altitude Climbing, High Reliability, COVID-19, and the Power of Observation. *Neonatology Today*. 2021;16(1):68-79. doi: 10.51362/neonatology.today/20211616879.
 53. Epstein SK. How often does patient-ventilator asynchrony occur and what are the consequences? *Respiratory care*. 2011;56(1):25-38.
 54. Verdugo P. Supramolecular dynamics of mucus. *Cold Spring Harbor Perspectives in Medicine* 2. 2012;11(a009597):14. doi: 10.1101/cshperspect.a009597.
 55. Lai SK, Wang Y-Y, Wirtz D, Hanes J. Micro-and macrorheology of mucus. *Advanced drug delivery reviews*. 2009;61(2):86-100.
 56. Strigo IA, Craig AD. Interoception, homeostatic emotions and sympathovagal balance. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2016;371(1708):9. doi: 10.1098/rstb.2016.0010.
 57. Brown RP, Gerbarg PL, Muench F. Breathing practices for treatment of psychiatric and stress-related medical conditions. *Psychiatric Clinics* 2013;36(1):121-40.
 58. Jerath R, Edry JW, Barnes VA, Jerath V. Physiology of long pranayamic breathing: neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. *Medical hypotheses* 2006;67(3):566-71.
 59. Zucker TL, Samuelson KW, Muench F, Greenberg MA, Gevirtz RN. The effects of respiratory sinus arrhythmia biofeedback on heart rate variability and posttraumatic stress disorder symptoms: A pilot study. *Applied psychophysiology and biofeedback*. 2009;34(2):135-43.
 60. Jouett NP, Watenpaugh DE, Dunlap ME, Smith ML. Interactive effects of hypoxia, hypercapnia and lung volume on sympathetic nerve activity in humans. *Experimental physiology*. 2015;100(9):1018-29.
 61. Strauss-Blasche, Moser GM, Voica M, McLeod DR, Klammer N, Marktl W. Relative timing of inspiration and expiration affects respiratory sinus arrhythmia. *Clinical and Experimental Pharmacology and Physiology*. 2000;27:601-6. doi: 10.1046/j.1440-1681.2000.03306.x.
 62. van Stralen D, Calderon R, Padgett J, Clements P, Eachus T. Smile and Laughter During Mechanical Ventilation in Children. *Mastering the Challenges Across the Spectrum of Long Term Care*; March 16-29, 2006; Dallas, Texas: America Medical Directors Association, 29th Annual Symposium; 2006.
 63. van Stralen D, Sorensen D, Calderon R, Padgett J, Clements P, Klein S, et al. Fluid Bolus Therapy to Treat Thick Secretions in Ventilator-Dependent Children. *9th International Conference on Home Mechanical Ventilation*; April 2005; Lyon, France 2005.
 64. Eachus HT. Generating Responses in Vegetative Children. *Technology and Persons with Disabilities, 16th Conference*; March 17-22, 2001; California State University, Northridge, Los Angeles, CA 2001.
 65. McCarthy PL, Sharpe MR, Spiesel SZ, Dolan TF, Forsyth BW, DeWitt TG, et al. Observation scales to identify serious illness in febrile children. *Pediatrics*. 1982;70(5):802-9.
 66. Messinger DS, Fogel A, Dickson KL. All Smiles Are Positive, But Some Smiles Are More Positive Than Others. *Developmental Psychology*. 2001;37(5):642-53. doi: 10.1037//0012-

1649.37.5.642.

67. Streeter CC, Gerbarg PL, Saper RB, Ciraulo DA, Brown RP. Effects of yoga on the autonomic nervous system, gamma-aminobutyric-acid, and allostasis in epilepsy, depression, and post-traumatic stress disorder. *Medical hypotheses*. 2012;78(5):571-9.

NT

Corresponding Author



Daved van Stralen, MD, FAAP
Associate Professor, Pediatrics
Department of Pediatrics
Loma Linda University School of Medicine
11175 Campus Street
CP-A1121
Loma Linda, CA 92350
Email: DVanStra@llu.edu



Sean McKay
Executive Partner / Director, Disruptive Rescue & Austere
Medicine
Element Rescue - Response Solutions within Nonlinear Complex
Environments
Greenville, South Carolina, United States



Thomas A. Mercer
Rear Admiral
United States Navy (Retired)

Acknowledgments

Karl Weick, Rensis Likert Distinguished University Professor of Organizational Behavior and Psychology, Emeritus, University of Michigan

William J. Corr, formerly with the Los Angeles City Fire Department, now deceased

Errol van Stralen, Ancora Education

Ronald D. Stewart, Professor, Emergency Medical Services, Dalhousie University, Nova Scotia, Canada