Sending up a FLARE: Enhancing resilience in industrial maintenance through the timely mobilization of remote experts

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Abstract. Turbine maintenance is a highly planned operation, but field teams regularly encounter situations that challenge the implementation of the plan. Maintaining control of the schedule of operations in the face of anomalies is a complex task for project managers. This paper describes the Front Line Anomaly Response (FLARE) process, wherein remote expertise is connected to operators directly in touch with the situations within an hour of the issue being raised. Anomalous situations typically represent complex problems for which no clear-cut path exists. Often, the process, rather than solving the problem at hand, serves as a means to expose and discuss the relevant aspects of problem and solutions. This paper describes how the FLARE process leverages external expertise and diversity of perspectives in anomaly response during complex maintenance operations. This paper also describes the organizational challenges faced by the organization in implementing such process, and the approach it adopted to address the associated trade-offs.

1 INTRODUCTION

The Front Line Anomaly Response (FLARE) process was designed for responding rapidly to emerging issues in power plant maintenance. Turbine maintenance involves the disassembling, inspecting, repairing, reassembling and re-starting of the turbine-generator system. It relies on expert workers with specialty tools mobilizing to remote locations to work in a plant they may not be familiar with. Turbine maintenance is a highly planned operation, but field teams regularly encounter situations that challenge the implementation of the plan; challenging situations can arise from adverse events such as an incident with a power tool or from unanticipated conditions such as related to weather or to particular site characteristics. During a power plant maintenance outage, teams work around the clock to meet tight schedules necessary to bring the power plant back to service as soon as possible, since the cost from lost generation of a shut down power plant ranges from several hundred thousand to millions of dollars a day. Maintaining

control of the schedule of operations in the face of anomalies is a complex task for project managers: operations involve numerous tasks that are highly synchronized and interdependent; anomalies also represent multi-faceted problems that might require specific technical expertise. Successfully and efficiently managing unexpected situations that arise is critical to the success of turbine operations and to the power plant owner's business objectives.

The situations of interest in this paper are of a challenging and variable nature and arise unexpectedly. Typically, a person working at the front lines initiates the process by a call to a central group of experts in risk management. These experts send up a "flare" and, within one hour, a geographically separated group convenes via telephone conference to address the problem. Participants are diverse in terms of knowledge, skills, function level, and roles. During the one-hour call, they describe and diagnose the problem (explore risks and multiple solutions), they agree on and produce a plan that includes actions, decisions, decision authority and accountability, check-in points, iterative solutions, and contingencies.

The paper describes how the successful implementation of this process relies on the capacity of the system to identify and mobilize the relevant participants for the particular problem faced. Through the practices described in this paper, an ever changing, ever expanding pool of knowledge is tapped into and brought to bear at point of need (often the frontline) to address emerging situations. In his analysis of conversations that occurred prior to the Columbia shuttle accident, Garner (2006) concluded "Connecting people is not always enough…" A central question addressed here is: If connecting people is not enough, what else is important?

2 CONNECTING REMOTE EXPERTS TO FRONTLINE OPERATORS

The identification of participants is one of the most important parts of the process and sometimes continues up until minutes before the call (and occasionally into the call). Critical roles for the process include: risk decision owner (usually the person responsible for profit and loss), a contrarian, design experts (what to do), repair experts (how to do), person(s) with related experience, practitioners needing help, and risk knowledge broker. Other keys roles emerged from conducting the process over the years: "one person who makes a difference", "matchmakers", and "critical participants". Several key roles are described below.

2.1 Diverse expert knowledge

Weick and Sutcliffe (2001) note the importance of bringing expertise to bear on complex problems. "HROs cultivate diversity" as it "helps them notice more in complex environments, but also helps them do more with the complexities they do spot." "HROs push decision making down and around. Decisions made on front lines […] migrate to people with the most expertise, regardless of rank."

It is commonly accepted that a group of diverse problem solvers will outperform a homogenous group. Hong and Page (2004) take this a step further with their model of functionally diverse problem-solving agents; they conclude that "a random group of intelligent problem solvers will outperform a group of the best problem solvers." Their results are based on a random group bringing more diversity in

problem solving approaches through differing perspectives and heuristics. Project and work teams tend to stay within the team in solving problems. Key to the FLARE process is bringing in people who have not been involved with the situation or the project in order to challenge and bring fresh perspective.

2.2 Risk Knowledge Brokers

Knowledge brokers are "persons or organizations that facilitate the creation, sharing, and use of knowledge." (Sverrission, 2001). In responding to dilemmas and disturbances, the knowledge broker brings together specialists and practitioners for problem centered collaboration and co-creation of knowledge. They link "know-how, know-why and know-who" (Blondel, 2006). According to Garner (2006), "some organizations recognize the importance of getting information to the right people and designate a central person or group to manage expertise recognition. Network centrality would be an appropriate indicator of that person or group." Garner uses the term "bridge" people or teams; they span organizational and knowledge boundaries. He shares the example of NASA's Mission Management Team, which is comprised of representatives "from every part of the organization". Meyer (2010), emphasizes that knowledge brokers do more than link knowledge: they facilitate co-creation of knowledge and participate in constructing a common language. In this case, the common language is the language of managing risk. The Risk Knowledge Broker holds distinctions for risk management terms, actively translates the conversation into these terms, and helps the group formulate the situation around the risks.

The Risk Knowledge Broker is the first responder to the front line call for help. During the initial call, they probe the situation, possible solutions, and who the practitioner thinks could be of help. Probing potential solutions in the initial call enables identification of repair specialists who can support exploring solutions, which in turn, enables defining a plan of action during one call. The Risk Knowledge Broker then transmits the alarm ("Heads-up. We have this problem. Who can help? A call will occur within 1 hour.") and identifies participants by talking to people with project or technical knowledge. Strategies for this step include contacting "matchmakers" (especially for novel events – see below), reviewing a list of experts, and conducting a quick check for similar issues in risk database. They may brainstorm with other knowledge brokers to get ideas of who, outside commonly tapped knowledge clusters, could bring value and who may have experience with similar but different situations.

During the call, the Risk Knowledge Broker orchestrates the conversation (who to speak-up or who to quiet down; when to bring focus or let drift). However, this role involves much more responsibility and knowledge than typical facilitation roles. They probe concerns and listen for phrases that indicate risk; they tune into risk and uncertainty. Risk management is about asking the right questions; thus the knowledge broker challenges and questions, using specific questions designed to raise risks. They close with asking each participant if they have concerns or comments. This final probing almost always surfaces information or a concern important to the issue. After the solution has been implemented, the knowledge broker follows back around with the practitioner to see how the situation turned

out. They then share this information with those who supported resolving the issue and with those who might benefit from the knowledge.

In order for the knowledge broker to be able to guide such a brief conversation to solution, they need fundamental knowledge of product and process so they can speak the technical language. In order to support decisions being made at the appropriate level, by the person accountable for that part of the business, they also need knowledge of limits of authority and domain responsibilities, as well as an understanding of the business considering the potential consequences of the decided actions. In order for the knowledge broker to invite people who can come to effective solution, they need access to networks of people who know where certain knowledge resides within the organization, "matchmakers" so to speak.

Table 1. Summary of key competences of the Risk Knowledge Broker

Skills & attributes	– Ability to understand & probe concerns – Ability to hear or tune into risk statements – Ability to orchestrate fast moving, focused conversation – Are part of the team, typically in operations
Knowledge	– Product / Process – Limits of authority & accountabilities – Who has knowledge, who's had certain experiences – Roles within the organization

2.3 Other essential roles

There are people in an organization who "know what others know"; such people can act as *Matchmakers*. They have wide networks and deep or broad experience. They may have held many roles or held one role for a long time. When approaching an especially novel problem, the knowledge broker's first step is to reach out to Matchmakers and brainstorm with them on who might know something related to the issue at hand. This brainstorming sometimes identifies a person whom those involved in planning the project may not have thought of and whose relevant knowledge could make a difference in the outcome

The *one person who makes a difference* shares unique and particularly relevant knowledge during the risk assessment that significantly impacts the plan or project and they were not previously known by the project team. All knowledge brokers have identified such people on multiple occasions as part of the FLARE process and they speak of feeling like they got lucky, as if they found this person by pure chance. This has happened frequently enough that the authors speculate finding this person actually emerges from the process: through a mechanism not entirely understood, it may be a function of contacting Matchmakers (who have deep history) and then following the threads they provide.

A *critical participant* is a person who has critical knowledge needed to solve the problem at hand. Their identity as having critical knowledge emerges from the network as multiple people suggest to include this person in the risk assessment.

2.4 Constituting the group of participants

Participants are raised through sending out a call for help (sending up a flare) that flows through the organizations in an organic, interconnected way; one person contacts another who contacts others until "hits" are identified. The flow of communication transcends organizational hierarchies and quickly spreads throughout the organization.

In their book "The Management of Innovation" (1961), Burns and Stalker compared linear, hierarchical, mechanistic organization models to non-linear, flexible models, which they termed "organic". According to the authors, mechanistic organizations work well for stable conditions while organic models are "appropriate to changing conditions which give rise constantly to fresh problems and unforeseen requirements for action which cannot be broken down or distributed automatically arising from the functional roles defined within a hierarchic structure."

Between 10 and 15 participants are typically on the calls with a 3 to 1 ratio of workers / professionals to managers. This is a size that is manageable in terms of assembling the group within an hour then orchestrating a conversation via conference call and coming to solution within a short duration. The worker to manager ratio demonstrates that the risk assessments almost always have more workers, including experts, than managers, in alignment with HRO and resilience engineering philosophies to listen to the experts and the frontline workers.

3 SUCCESSES AND CHALLENGES IN SUPPORTING RESILIENCE

Woods and Branlat (2011) discuss how failures to adapt successfully to adverse events can occur in a system and identified three basic patterns of adaptive failure: (1) failure of adaptive responses to match the *tempo* of the disruptions faced (before events cascade and situations get out of control); (2) failure to maintain sufficient *coordination* while implementing adaptive responses; and (3) failure to recognize the novel character of the situation faced and devise *new forms* of adaptive behavior. The FLARE process represents a way to enhance resilience through avoiding these patterns. Furthermore, the success of the process depends on the organization's capacity to manage difficult trade-offs: associated with the implementation of solutions to complex problems, and associated with the use of the organization resources to explore such solutions.

3.1 Supporting distributed anomaly response

Anomalous situations in this domain typically represent complex problems for which no clear-cut path exists: affected sites often present specific characteristics, anomalies can be of novel nature, and different dimensions of the situations need to be considered. Often, the assessment process, rather than solving the problem at hand, serves as a means to expose and discuss the relevant aspects of problem and solutions. The process represents a form of distributed anomaly response that leverages external expertise and diversity of perspectives to handle the complexity of the problem and responses. The process represents a mechanism to avoid patterns (3) and (2) described above, respectively: identifying and implementing

appropriate adaptations to unanticipated situations, and managing interactions across the system due to interdependencies between tasks. The rapid conduction of the conference call supports the avoidance of pattern (1), i.e., of a fast degradation of conditions into an even bigger problem. In addition to identifying potential courses of action, the FLARE process allows the project manager on site to better anticipate constraints and risks associated with re-planning portions of the mission, in order to balance these constraints against each other. It therefore supports the project manager in anticipating and managing difficult trade-offs associated with anomaly response in the context of large maintenance operations.

Key operational aspects of successful calls reside in the preparation of the material to be discussed and exchange of information among participants, and in the rigorous exploration of courses of actions and associated constraints. The conversations were semi-structured, free flowing, open with no tolerance for blaming, and a focus on better understanding the situation and risks. The oral exchange enabled emotions and level of concerns to be heard and improved sharing context. In addition to the role played by participants in leveraging diversity of expertise (as discussed in the previous section), the process requires a capacity to correctly assess the situations at a distance. Use of technology, such as streaming video or other forms of real-time exchanges of information, could improve the process by improving the completeness and timeliness of information between the site and the remote experts. Exchanges of material (pictures, diagrams, etc.) are currently made mostly up-front, based on the anticipated informational needs. At times, particularly for situations with a lot of uncertainty, the process was adapted in order to address these issues of availability of information to correctly assessment the situation: a first call (initial probing) would be conducted in order to frame situation and identify gaps in information and knowledge; the group would then come back together in a second call with additional information, and decisions would be made at that point.

Goal conflicts faced by both Risk Knowledge Broker and requestor included:

- Risk Knowledge Broker balances subtle escalation of “sticky” issues while attempting to maintain trust of requestor / front line.
- Risk Knowledge Broker does not address why the situation arose to begin with (which could bring blaming tone) to maintain trust of requestor.
- Requestors balance the value of help versus the loss of autonomy that comes with making the issue public. When an issue was raised to this forum, it went from private (site / local had more autonomy) to public (inputs of crowd must be considered). The calls changed course of action to one that was not favored by front lines on several occasions (“When you call, we gonna come and you might not like what you hear.”)

3.2 The difficult management of resources

For organizations that spread operations across space, responding to risky anomalies relates to resource allocation trade-offs: the most relevant people for a particular situation might not be at the location of the event, and the organization needs to temporarily make these resources available for the process. For the

conduction of the FLARE process, the organization's pool of experts represents the critical resource. However, participants are conflicted between being temporarily deployed for anomaly response or tending to their own urgent work (they are highly solicited as experts). The process requires their ability to sacrifice other professional (or personal) activities, and the organization's support of shifts in priorities. Organizational measures include creating the conditions for the involvement of the highly experienced members of the organization, as well as of the divisions they belong to through negotiated agreements that are based on the recognition that the calls are valuable to all organizations involved.

A variety of issues associated with resource trade-offs were experienced during the conduction of the process. First, there were no different levels of urgency (at least in a formal sense). Most calls were high priority, requiring all resources to be available immediately. Initially there was pushback from people who were requested to support with short notice but over time they began to act with a level of urgency that matched the need of the front lines. Occasionally the requestor indicated less urgency and the call was scheduled for a later point in time. Also, 24/7 support was offered but in reality everyone knew that a 3 am call would get less help so most calls occurred during the work day until 10 pm. A more flexible design for the process should consider real criticality of events in order to avoid creating unnecessary resource constraints. On the other hand, the unavailability of key resources could constitute serious challenges: there was a minimal "must participate" list but it was occasionally violated with a requirement to follow-up and actions held up until the risk decision owner approved.

FLARE was assessed as valuable by the field managers and organization. Resource management issues become crucial and the trade-offs grow in complexity as the organization is experiencing and adapting around the tool's successes. As resources are stretched further conflicts increase relative to how trade-offs are managed. One issue relates to how field teams decide whether or not a call is valuable for them, and how the organization reacts immediately and after the fact Trade-offs associated with the deployment of valuable resources for the process appear analogous to those related to the use of resources in the investigation of adverse events: selecting which events constitute worth investments of resources requires recognizing the signification of events and balancing against pressures that steer efforts toward the obvious cases only. While numerous events would benefit from those calls, after-the-fact analyses could view them as superfluous given the use of valuable resources. When asked whether the situation was worthy of a call, the risk team took the approach of always recommending it based on the philosophy that up-front cost was low compared to potential losses. Ironically, the expansion of the FLARE process (international operations, more general scope) risks being the source of future challenges by stressing the demands for resources and associated trade-offs further (the organization's pool of available experts is not expandable beyond certain limits or without important modifications to their roles).

4 CONCLUSION

Quickly assembling distributed knowledge at point and time of need is a common

problem in critical outcome industries and a problem, albeit with less urgency, faced by industry in general. This paper documents the FLARE process which has proven successful at solving this problem and could be used across industries.

The FLARE process is contingent on diverse, knowledgeable people being available to help and willing to respond with an urgency that matches the needs of the front lines. Diversity was brought in through both designed and evolved roles. The question initially posed was "If connecting people is not always enough, what else is important?" This paper attempted to answer one aspect of this question, focusing on characteristics and roles of people, who, when brought together to solve a problem, will be able to use their skills, knowledge, and diversity to thoroughly explore risks and design solutions. The Risk Knowledge Broker appeared as a central role in this process due to its responsibility in managing the diversity.

Edward Deming (1980) said "Uncontrolled variability is the enemy of quality." Yet variability is inevitable in complex work. Planning for variability (*in* control rather than *under* control) is necessary for system resilience. This paper describes a practice wherein variability is embraced and managed in a way that brings risk to an acceptable level.

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