Research in Nearly Failure-Free, High-Reliability Organizations: Having the Bubble

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Abstract—**High-reliability organizations such as nuclear power plants, air traffic control centers, and aircraft carriers pose special challenges to organizational researchers. These organizations, where the consequences of failure can be catastrophic, are made relatively inaccessible to organizational research by their technical complexity and sensitivity to scrutiny. Successful entre, problem formulation, data collection, and interpretation all hinge upon the researcher–organization relationship. Methods for conducting research in these organizations are explicated along with the consequences of failing to bring organizational knowledge to high-reliability work units.**

Introduction

HIGH-RISK organizations [8] are those organizations operating technologies sufficiently complex to be subject to catastrophic accidents [15]. High-reliability organizations are a subset of high-risk organizations designed and managed to avoid such accidents. Some high-risk organizations claiming they are highly reliable, in fact, do not manage themselves to be nearly error free (e.g., Chernobyl, Three Mile Island). Globally, while the number of high-risk organizations is increasing arithmetically, the probability of accidents increases geometrically. Some organizations that today operate with high performance reliability (e.g., air traffic control) may tomorrow change their characteristics and consequently reduce reliability.

Most organizations engage in trial and error and other experimental forms of learning every day. But in high-reliability organizations, the cost of this kind of learning can far exceed the value of the lessons learned. In addition, such organizations can destroy themselves and perhaps a larger public, entirely wiping out evidence that might be used for learning. Reports suggest that operators at the Chernobyl nuclear power reactor were experimenting to determine how long turbine generators would run emergency equipment in case of a stream-flow loss when part of the reactor's uranium fuel source melted down [5]. The magnitude of the damage at Chernobyl, and in other disasters, suggests that we cannot afford to study failure, to wait for accidents to occur, and then investigate what makes high-reliability systems tick. The costs are too high.

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Research is needed on the successful management and operation of high-reliability organizations [8], [18]. Yet, as researchers become interested in high-reliability organizations, numerous research design and strategy problems emerge. This paper defines some major characteristics of high-reliability systems and discusses how they affect research on such organizations. It addresses issues of entre, problem formulation, data collection, data interpretation, researcher relationships with the organizations, and product "packaging."

Our discussion of research on high-reliability organizations is meant to be both descriptive and normative. Our objective is to promote both understanding of the challenges inherent in conducting organizational research in such settings and to encourage such societally important investigations. Organizational researchers until now have had little experience with nearly failure-free work systems. Our discussion is probably relevant to other kinds of extremely complex organizations, as well. True and complete pictures of these organizations cannot be based on the kind of research often seen in organizational science: that which focuses on only a few variables, on subsystems of the organization, has short time duration, collects limited data using limited techniques, and is informed by only one discipline.

Distinctiveness of High-Reliability Organizations

Properties that distinguish high-reliability organizations from other kinds of organizations raise questions about the adequacy of conventional organizational research methods for understanding them. These organizations have at least eight primary characteristics.

1) Hypercomplexity—extreme variety of components, systems, and levels. Air operations on an aircraft carrier, for instance, involve the navigational bridge (piloting the ship), the air tower (directing flight operations), the deck personnel, and the flight crews themselves, along with their respective computer systems, binoculars, arresting wires, and the aircraft themselves. Each operational unit has its own standard procedures, training routines, and command hierarchy.
2) Tight coupling—reciprocal interdependence across many units and levels [8]. In contrast with loosely coupled systems, tightly coupled systems have more time dependent processes which cannot wait to be attended to, more invariant sequences (B must follow A), overall designs that allow only one way to reach a

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goal, and little slack as in the case in certain types of continuous process manufacturing.

3) Extreme hierarchical differentiation—multiple levels, each with its own elaborate control and regulating mechanisms. Aircraft carriers have a captain at the top, an executive officer, followed by seventeen department heads. These men are generalist advisors, with limited duty officers, masterchiefs, senior chiefs, and chiefs as specialist operators. Below these flourishes a hierarchy of enlisted personnel. These levels intertwine in that decisions such as when to conclude day flight operations and begin night flight operations involve consideration of the carrier air group commander's training needs, the admiral's battle exercise needs, supply officer's concern with meal service, the captain's desire to obtain a particular position for the next day's exercise, and the air departments desire not to work the deck too late into the night.
4) Large numbers of decision makers in complex communication networks—characterized by redundancy in control and information systems. Linked to the principle of requisite variety [1], [18], hypercomplex systems require sensors, control mechanisms, and operational units to be as complex as the system they intend to regulate. Along with the extreme hierarchical differentiation comes numerous interdependent individuals making decisions simultaneously, while employing highly redundant communication systems. Control for the setting of the arresting gear for aircraft recovery ultimately rests in the hands of at least three different people with oversight by the airboss. The captain standing watch over replenishment of a ship's million gallons of jet fuel (while fuel ship and carrier travel in tandem at about 12 knots) observes the entire event (often lasting over two hours) while his conning officer is relieved every 30 minutes to preclude fatigue. His relief stands behind him for at least 15 minutes. The need for interdependence and redundancy multiplies decision makers and the links between them.
5) Degree of accountability that does not exist in most organizations—substandard performance or deviations from standard procedures meet with severe adverse consequences. Nuclear reactor operators speak of the enormous amount of training required to do their jobs and the amount of tension caused by having to do things right all the time. Flight deck personnel on aircraft carriers are constantly cross checked to insure reliability and consistent adherence to procedure.
6) High frequency of immediate feedback about decisions. Quick decision making and feedback are especially characteristic of operational decisions: to direct a commercial airliner on approach to a runway for landing or defer landing until other aircraft are repositioned; to respond to a carrier-based aircraft's message that its landing gear are unsafe (should the plane land unassisted on the ship or be sent to a land-based airfield?). The longer it takes to make and implement these decisions, the greater the danger for plane and personnel. Whether the aircraft lands successfully constitutes rapid feedback about whether the decision was correct.
7) Compressed time factors—cycles of major activities are measured in seconds, as in the case of naval flight operations where aircraft are launched and recovered in 48 to 60 second intervals.
8) More than one critical outcome that must happen simultaneously—simultaneity signifies both the complexity of operations as well as the inability to withdraw or modify operational decisions—as in the case of simultaneously catapulting and recovering aircraft on carriers or the landings and takeoffs of commercial airliners handled by the Federal Aviation Administration's (FAA) air traffic control system.

Although other organizations may have some of these characteristics, their simultaneous occurrence identifies a high-reliability organization. Hospital emergency rooms, for instance, are characterized by several of the above dimensions, including hierarchical structuring of physican–nurse teams, immediate feedback and tight coupling; yet other dimensions (e.g., hypercomplexity and large number of decision makers) are largely irrelevant. Emergency rooms also seldom self-destruct. In contrast, petroleum refineries are capable of self-destruction and as such can be classed as high-risk organizations. Yet, these and many other continuous processing facilities do not specifically involve compressed time frames or simultaneity of critical outcomes. The technology itself has a high degree of predictability unlike that found in high-reliability organizations.

These characteristics are related to three other features that influence the kind of research strategies appropriate to high-reliability organizations. One is the *response of the organization's constituencies when it fails*. To most people, whose primary experience is with organizations in which productivity dominates reliability as a goal, high-reliability organizations are invisible until something happens. A shuttle explodes, a meltdown is threatened, two planes collide, and attention focuses on the operation of a complex system that has now failed. An external public demands change and the organizations themselves become extremely defensive. That defensiveness is illustrated by the utilization of high security, the technical content of operations, and the distinct social and technical languages of organizational members. Failures in other kinds of organizations are often ignored and usually tacitly accepted by their customers, suppliers, and the public at large.

The second feature associated with these characteristics is the tendency for operators in high-reliability organizations to operate at or near the *edge of human capacity* (referred to in one such organization as being "at the edge of the envelope").[1] This push to the limits of human capability is linked to the tendency of such systems to enlarge capacity by increasing the number of operations performed but not the number of operators, often because of public demands for greater efficiency with fixed revenues [12]. Although efficien-

[1] A term used by U.S. Navy personnel to refer to the human limits during flight operations.

cies are important to other kinds of organizations as well, most organizations lack the characteristic of extreme complexity that exacerbates the human limitations of operators and managers. Constant training and frequent rotations are often used by such organizations to maintain efficiency in human operators.

A final facet of high-reliability organizations is their *diverse constituencies*. Designers are one element in these diverse constituencies. They are often unaware of the human limits to operating such systems [8], and assume people can operate any kind of system they design. Operators and managers (two other constituencies) are left with technologies developed by designers who did not include them in technological development. Policy makers constitute yet another constituency. Research undertaken to understand and improve high-reliability organizations must involve the various stakeholders to obtain their varied perspectives and to better identify the boundary conditions (or the edge of the envelope) under which these systems operate. The structuring of these constituencies (i.e., their interrelatedness) needs to be examined because it is likely that this, too, is different than it is for less complex organizations.

The eight defining characteristics of high-reliability organizations plus the associated factors of the salience of failure, operation at or near the edge of the envelope, and diverse constituencies combine to create distinctive problems and methodological difficulties. These problems are different largely in degree from research problems in other complex organizations.

Research Design: Method and Process

Entre

While credibility and trust are obviously desirable for researchers and operators to have in all organizations, in high-reliability systems they are *sine qua non* because of the danger inherent in these organizations. Researchers must learn how to act while at the research site to avoid harm to themselves and others. In some other very complex organizations the issues of personal conduct and safety are substantially less important. Learning the organization is part of building trust. Operators and managers must be able to have confidence that the presence of the researcher will not interfere with safe or successful operations.

In most organizational research, researchers usually spend modest amounts of time at the field site. Research on business organizations, for instance, frequently operates on the assumption (sometimes erroneous) that key explanatory variables (e.g., technology, structure, culture) are readily accessible and interpretable by researchers. In contrast, frequent and often long-term interactions among researchers, designers, operators, and managers are important if any *real* understanding of high-reliability organizations is to be obtained. Their complexity and distinctiveness make learning about them difficult. The inaccessibility of such organizations typically renders it impossible for researchers to design all or most of their research before going into the organization. A well specified research project can emerge only after the researcher has sufficient training in the ways of the organization.

Given the complexity of the subject, research teams are more likely to carry out such research than are individuals. Successfully matching common interests and concerns among researchers and managers is one element in building trust and credibility that is not quite as necessary in other kinds of organizations. Engineering operators often feel more comfortable with their technical counterparts on research teams than with social scientists. The researcher is responsible for recognizing and dealing with this fact. Open discussion of the different goals participants have is important to the continued development of both the network of relationships and the research problem.

Involving all constituents in the research process is also important to the development of research expertise and credibility. Typically, by the time organizational researchers begin studying such organizations, the designers have left. They are an absent constituency unless the research team makes the effort to involve them (e.g., engineers, planners) in the program, especially in its problem generation and feedback phases. Facilitating such interaction can have long-term benefits for high-reliability organizations as demonstrated by interaction between Apollo astronauts and aeronautical design firms in the 1960's.[2]

Trust and credibility are critical to gaining entre and maintaining researcher–organization relations. Both are also important to the researcher's success in getting the organization to train her. In other kinds of organizations researchers are often familiar with the technical basics of the system, the language used, and acceptable dress and behavior before they begin the study. Most of us know something about banks, schools, and hospitals before we ever try to do research in them. This is not true in high-risk organizations that wish to remain invisible. Very complex organizations are given to acronyms, a telegraphic language required to operate within tight time frames. Without knowledge of the lingo, there is no way a researcher can function, study, and be accepted by the organization. This knowledge not only enhances trust and credibility, it provides the basic tools necessary to operate in the organization.

Researchers must be patient during this learning process. They need not exhibit such patience in organizations in which they arrive and leave the same day or even within a few weeks. Much data, seemingly important at first, will become irrelevant as the enterprise becomes more focused. Because outsiders cannot know these systems, what is irrelevant is difficult to know at the outset. From the organization's perspective, the willingness of researchers to take the time to learn aspects of the organization that might not prove pertinent later demonstrates a commitment to understanding the organization. High-reliability organizations demand massive commitment from the people who manage and operate them (e.g., irregular shifts, long tours of duty, responsibilities which for security reasons cannot be shared with others, responsibilities for the lives of others, etc.). A similar commitment and appreciation is required of the researcher.

[2] David Scott, Apollo astronaut, personal communication.

Problem Identification

Their nature and multiple constituencies make mutual problem identification imperative in studying high-reliability organizations. Unlike the case of organizations in which researchers have had greater experience, clearly defined research questions or agendas are not really feasible: research from high-reliability organizations has not yet informed the organizational literature. Knowledge of system components and variables is hard to come by in invisible organizations and is essential to phrasing research questions, therefore insider involvement in problem identification is mandatory. This insider involvement can raise fears of bias and loss of objectivity, especially when the public has an interest in an independent monitoring of prominent high-reliability organizations such as the FAA. Cooptation of researchers by the organization and the use of research to showcase effective operations or even a poorly equipped one (e.g., by a tax dollar seeking public agency) are reasonable fears. The best remedy is perhaps involvement of many researchers and internal constituents to provide for a multiplicity of interests.

The most fruitful way to use insiders to formulate research questions is to bring together different constituencies in the problem generation process. This is absolutely critical if what we said before is true, that system designers do not consider the situation system operators will face. Somewhere along the line parties with different perspectives have to come together if knowledge is to be furthered. Designers concerned with system limits and operators concerned with handling unpredictable events can together identify important research questions, such as: What factors enhance the organization's capacity to handle complexity? How well delineated are the organization's operational limits (the edge of the envelope)? How do influence and authority affect the organization, especially error and failure rates?

The research team benefits from being interdisciplinary, reflecting different theories and paradigms (behavioral, political, economic, technical, etc.) to match the complexity of the subject. Ashby's [1] law of requisite variety applies here: much as we need psychiatrists as complex as the patients they seek to help and computer systems as complex as the problems they are supposed to solve, there must be variety and complexity in the research team and problem identification group sufficient to accommodate that in the organization they study. This variety in the research team itself enhances responsiveness to system complexities.

Studying Systems and Events

After becoming familiar with the organization, the research team must develop clarity of purpose. That purpose will determine where in the organization to obtain data. There are as many choices as there are levels of people, cycles of events, subsystems, and organizational outcomes. Following the principle of requisite variety, design must include multiple units and levels, diverse methods, and many variables if it is to veridically map even a few parts of very complex organizations.

Since the whole is the focus, (e.g., air traffic control, not merely the control tower *per se*) not simply one department, or set of procedures, or cycle of events, the organization's component building blocks must be described. A major task is to formulate rich descriptions of relevant processes, events, and behaviors. If not done, misunderstandings about organizational processes are likely. As discussed by Rousseau and Cooke [13], technical systems are comprised of three distinct types of components: concrete (people and hardware), abstract (performance programs and procedures), and activity (cycles of events). Prescriptions for the design or operation of high-reliability organizations should not be made without careful description of these components. Habits and heuristics represent the performance programs March and Simon [6] saw as key to organizational processes. Experienced operators may deviate widely from standard procedures, and in highly rationalized systems operators might try to disguise this [3]. It is important to observe behavior (and not rely only on self-report) in such organizations because understanding deviation in tightly coupled systems is important for better design and operation.

All of this requires observation of vertical slices of the organization using different methods at each level (for example, individual versus departmental versus organizational), and across different kinds of elements (for example, people versus procedures). Researchers need to do this to get the big picture because operators in high-reliability organizations must be continually aware of events occurring at different levels (since these can change rapidly, influencing operator behavior). Consider the impact of unexpected (and unpredictable) air traffic on the pattern of takeoffs and landings at a particular field and the interconnections with activities at nearby air traffic control centers. Data obtained from one unit or level cannot yield the "bubble" necessary to comprehend air traffic control events.[3]

The choice of which units to focus on, the control room of a nuclear power plant or its maintenance and safety systems, the bridge or tower of an aircraft carrier, its combat information center, or whatever, focuses the study on particular sets of events and omits others. Since a major purpose of studying high-reliability organizations is to understand successful complex operations, it is important to build contrasts into the focal units—it is important to survey both high-reliability as well as less risk-oriented units in the organizations we study reflecting normal operations of very different types of units. For instance, including units with looser time frames in the study of the effects of tight operational time frames helps identify variances in system functioning. Given the distinctiveness of high-reliability organizations, contrasting units *within* the system provides perhaps a better comparison than does comparing high-reliability units from different settings. Contrasting units in the same organization allows for control over organization type and governance (e.g., military, civil aviation) which in many cases makes the organization unique (e.g., FAA). Contrasting functional units is the simplest way to begin (for example, comparing flight deck with combat operations or the mess on aircraft carriers). Each functional

[3] The bubble is U.S. Navy lingo for maintaining a big picture view of operations.

unit can be examined from the perspective of its normal operations, and then units can be looked at together to examine their interdependencies, elucidating issues of hierarchical structuring, complex communication networks, and tight coupling.

Although it is in some cases desirable to contrast high-reliability organizations that are in different businesses (for example, chemical companies and nuclear power plants), this is probably beyond the capabilities of a single research team. System research of this kind is physically demanding, intellectually intense, and expensive. Thus, organizations will probably have to be taken one at a time with internal comparisons as the basis for establishing validity and generalizability.

Data Gathering

Unlike traditional quantitative studies of organizations which are either bottom–up or top–down in data gathering, aggregation, and analysis, studies of high-reliability organizations must be conducted at the top and bottom simultaneously. The combination of intensive contact with management along with frequent interactions with operators (both necesary for developing a working relationship), means that research is conducted simultaneously at several levels. This is desirable in other complex organizations, but where the issue is total organizational reliability it is paramount. Aircraft on final approach to an aircraft carrier do not readily complete questionnaires and the big picture or bubble is hard to capture if one is limited in observations of air traffic control to looking only at airport control towers. The only viable strategy is to use a mixture of research methods and diverse sources of data. The principle of requisite variety again applies [18]; just as we need computer programs as complex as the problems we seek to solve, we need a multilevel and multifaceted data-gathering study to capture key processes and attributes of high-reliability organizations.

Of necessity, data gathering in high-reliability organizations employs both public and private methods. Public methods (well specified, readily shared, and replicable), such as questionnaires and structured interviews, are appropriate where the focal unit 1) is represented in large numbers (for example, in examining the effects of compressed time factors on regional air traffic controllers), or, 2) is observable by many (for example, in studying accountability in attack or fighter plane carrier takeoffs and landings) who can act as raters. Private methods, those that involve intensive, but less specifiable and structured approaches, such as participant observation, field notes, and impressions, are researcher specific [16]. As such, they are less subject to replication and are suited to investigations at one or a few sites (such as complex decision making in a chemical plant or the shutdown of a nuclear power plant). The large number of components in high-reliability organizations (e.g., people and departments) makes public methods desirably efficient. However, inability to gauge the sheer complexity of high-reliability organizations at the outset of the research makes private, researcher-specific assessments critical to the study's veridicality and interpretability.

Data Interpretation

Rigor and relevance are attributes of "good" research [17] and are constantly at issue in research on high-reliability organizations. Rigor is the confidence with which the data or interpretations from them are held. Since conventional design features (for example, control groups and random samples) are impossible to incorporate in studies of in some ways unique organizations, rigor is achieved differently. It is achieved through triangulation, reality testing, and intensive investigation across events and system levels. Relevance, the incremental increase in knowledge a study provides, derives from the very issues impeding rigor.

To assure relevance it is imperative to feed data back to managment to assess its veridicality and aid in interpretation. A major concern is whether description rings true to both researchers and those closest to the organization. Summaries of field notes, aggregations of survey data, and the researcher's personal understanding of the organization must be reality-tested because the invisibility of such organizations makes them more difficult for us to understand than some other kinds of organizations. This step is not typically taken in organizational research because of the potential for loss of objectivity by the researcher who might be influenced by managerial biases. However, the complexities of high-reliability organizations and the many years it takes their internal constituents to develop expertise about them, combined with the inability of research teams to spend those same years learning them, require the research team to work with members to check the veridicality of its interpretations.

There appears to be no other way to assess data veridicality than to check the data with those who are part of the system. However, as Perrow [8] points out, designers, operators, and managers of very complex organizations have implicit assumptions about them that differ widely from each other. Designers tend to believe that automatic controls reduce the need for operator intervention and errors, while operators frequently override or ignore such controls due to the constraints they impose or a lack of trust in their effectiveness. World views of these organizations are likely to vary and multiple perspectives are imperative.

Another reason for feeding back interpretations is to confront directly concerns regarding disclosure and close scrutiny. Much of the data will be sensitive and their disclosure must be approved by the organization itself. Explicit discussion of the interpretations and presumptions must be carried out to maintain both the research relationship and the goal of producing a valid and usable set of products (for example, reports, recommendations, etc.).

The Relationship Between Researchers and Organizational Members

As described above, the nature of high-reliability organizations requires a different relationship between researchers and the organization than we usually find in organizational research. Usually, researchers negotiate with organizations to collect a limited amount of data in specific units and then leave. The investment required to learn about such technically complex and invisible organizations prohibits that approach.

Both researchers and organizations must be willing to expend the set-up costs of doing research. Research team members must learn *each others'* languages *and* the organization's, and then begin to function for a common purpose. This requires considerable time. The team must come together with key organizational players and suggest some initial questions and strategies. The organization must develop its own team to work with researchers, and these people must develop their own list of issues of concern to the organization. All of this requires more time and is an unsuitable activity for people seeking knowledge in the short term. High-reliability organizations in which every day operations occur in cycles of seconds and minutes are unlikely to take the time to engage in this endeavor. But they must and thus require extensive efforts to build commitment to the research project.

Attributes and behaviors of researchers are under more scrutiny in high-reliability organizations than they might otherwise be. This is because trust and credibility are essential, and because high-reliability organizations are often inherently dangerous. They are potentially too vulnerable for characteristics of individual researchers to be overlooked, something probably not as true in other very complex organizations.

What researcher attributes encourage the development of good relationships with high-reliability organizations? Senior researchers may have an advantage over junior colleagues in relating to senior management who control access. Studying high-reliability organizations is probably not a task to undertake early in one's career, particularly if one accepts our point that entire systems must come under scrutiny. The set-up time required and the time required to do the research and obtain release of the data is so extensive, nontenured researchers probably would be at risk conducting this kind of study.

High-reliability organizations are often very macho. Operators are "heroes" and "aces" (e.g., Wolfe's *The Right Stuff* [19]). Sometimes being a female researcher is advantageous and sometimes it is not. In our experience, insiders often make the assumption that a woman knows little about technologically sophisticated organizations and will take on a teaching role. They may fail to make the same assumption about a male researcher, and thus fail to provide him with the same educational experience. Alternatively, females are likely to run into resistance in male-oriented organizations.

Researchers must engage in certain behaviors to gain the trust and confidence necessary in studying sensitive organizations. Asking numerous questions and listening attentively serves several ends. Not only is it a means to collect information, it is also a means to establish trust and credibility, and for imparting information about the specifics of the project. Senior managers frequently fail to inform those below them about why outsiders are around (this is especially true in hierarchically structured, complex, control-oriented organizations). Further, asking questions and showing knowledge of organizational functioning and lingo provides organizational members with good evidence that researchers share their respect for their organization.

Knowledge of protocol and titles is particularly important in hierarchically complex organizations. Similarly, following the dress code of the organization is important because of the messages it sends. Wearing hard hats in plant areas conveys to organizational members respect for their technology and safety rules. In some organizations uniformed personnel wear their resumes on their shirts, announcing their status (commander), personal history (aviator), and current position (operations officer). The researcher's status (e.g., position, expertise) is more ambiguous to organizational members and must be conveyed in both dress and other behavior. This is more important in high-reliability organizations than in other kinds of organizations because of the ongoing nature and intensity of researcher involvement.

Integrity is an issue throughout interactions with the organization. Information learned from one member should be conveyed to others only after withholding person-specific content. Opinions regarding control systems, design or management practices, are only relayed in the aggregate (as in the case of survey data), or while otherwise protecting the confidentiality of informants. Through ignorance of social and personal dynamics, researchers can easily fail to heed this advice and shoot themselves "in their feet" which is probably a greater concern in high reliability than in less sensitive organizations.

Respect for the hierarchy of the organization and the confidence of its members is important during both data gathering and feedback. The necessarily close relationships that develop between researchers and organizational members means that friendships are formed that tempt disclosures or confidences that conflict with the researcher role. It is important to stay "in role," though this means walking a tightrope between getting close and staying apart from the situation.

Another temptation is to go native. High-reliability organizations are exciting places to be and it is sometimes necessary to live in them to study them. Not surprisingly, the activity level, the intense culture, and the criticality and significance of the work people do in these cultures (as evidenced by the manned Flight Control Center run by NASA at Houston) are tantalizing environments to become a part of. There are at least two strategies that can prohibit going native. One is to use a team of researchers so the biases among investigators differ and can be checked against one another. A second is to rotate research team members into and out of the organization frequently. If the organization itself has a policy of frequent rotation, as does the U.S. Navy, the researcher is helped in that he or she cannot get too close to one viewpoint. In fact, researchers in this situation may provide continuity, being the only people on site who know why a certain procedure was established after the establisher is gone.

If managers develop sophistication with regard to using researchers they can make certain requests of them that will help their organizations. They can ask researchers to make independent analyses of trouble spots (for example, Roberts [10]) to triangulate their own investigations. They can request researchers to collect systematic information from low level organizational participants where channels of communication upward may not exist, or at least are not perfect. They can ask researchers to make independent presentations to outside constituencies. But for organizational members and researchers to reap the mutual benefits of these activities, researchers must be seen by members at both the top and bottom of the organization as trusted external constituents of the organization, people who can provide information to outsiders in ways that do not create embarassment or threats to members.

Prescriptions for the Research Team: In sum, researchers in high-reliability organizations and to a somewhat lesser extent in other complex organizations, must:

1) Spend time in the system and engage in active discussions with members at all levels.
2) Build bridges and networks among research team and system members.
3) Consider the attributes they bring to the organization that may influence the research enterprise (for example, maturity, gender).
4) Be concerned with messages conveyed nonverbally, as in dress and personal style, as well as those conveyed verbally.
5) Summarize information to protect anonymity before conveying it onward.
6) Learn and use organizational lingo.
7) Carefully avoid going native (for example, by rotating team members).
8) Use data from multiple sources and methods.
9) Employ comparison units within the organization (such as operational and support units) to identify distinctive characteristics of extremely complex organizations.
10) Maintain an organizational view by continually asking how a particular piece fits into the whole.
11) Preserve impartiality. Do not become the organization's advocate, nor its attacker.

Prescription for Managers: For their part, managers of high-reliability organizations should:

1) Develop a questioning stance vis-à-vis researchers to clarify the focus and scope of the research.
2) Be ready to discuss and tackle problems important to the research.
3) Engage in activities that use researcher skills in ways beneficial to the organization or its constituencies (e.g., identification of trouble spots).
4) Listen and react to research results and feedback; check out and reality test conclusions.

While these recommendations may be good ones to make for any organizational research, we are unaware of any research program that has followed all of them. In high-reliability organizations they are required in the interests of maintaining safety and uncovering the subtle implications of the eight defining characteristics of such organizations.

The Product

Disseminating results of research on high-reliability systems poses a difficult problem: how to make what is private public in such a way that many constituencies can use the information. Constituencies cannot use well information that arouses their defensive postures. On the other hand, research into high-reliability operations might well reveal conditions that managers, operators, or designers would prefer to keep hidden. Given the relationship between researchers and organizational members, the first obligation for the researcher is to inform organizational members about findings. Part of our role is to act as a mirror to designers, managers, and operators providing them with a different view of the organization and perhaps a more inclusive one than they might have without the mirror. Having provided members with the opportunity to react and possibly intervene in response to research findings and their dissemination, description, and prescription for a larger public is our next obligation.

Since spokespersons in high-reliability organizations can find it difficult to voice their concerns to the public without appearing self-serving, dissemination of results by independent researchers might at times promote the system's objectives. Analyses revealing the reasons for redundancy in aircraft control systems may be relevant information to a defense budget-cutting Congress. However, while researchers report on the organization, they cannot be its advocates.

It is perhaps most useful to employ events as the focus of reporting. Telling a story of takeoff and landing control in the FAA introduces information about interaction between pilots and controllers, and the use of equipment and procedures, framed in terms of their role in the event. The story of events includes detailed description, illustration, and hypothesis development and testing. In a recent study of nuclear aircraft carrier flight operations, reports range from thick description [10], decision tree and methods analysis [4], [11], and quantitative cultural assessment [14], to prescriptions laced with case study illustrations [12], [18].

Given the close relationship to members of the system that must emerge in this kind of research it may be important for both researchers and operators to have a part in putting together the kinds of reports that emerge. An interactive reporting process provides opportunities for managers to address the issue of how failure-free operations can be maintained in the future, and to correct misinterpretation of data.

Conclusions

High-reliability nearly error-free organizations are very sensitive and complex, and seek invisibility. As such, they have not been the ready subject of organizational research. Organizational researchers are likely to see these organizations only after they have failed [8], [15] when the tendency is to engage in "damage control." The real challenge is to understand the successful functioning of such organizations in the interests of identifying design and management strategies that will promote their safe operations, or of identifying operational requirements of the organization that can at times exceed limits to human capacity. To a somewhat lesser extent these concerns hold for all very complex organizations.

As it stands, we are in a situation in which increasing numbers of serious errors will occur in high-reliability organizations. Problems can propagate through large numbers of these kinds of organizations. We advocate the study of these kinds of organizations before this happens, and hope this paper makes clear to researchers some of the research strategy problems and challenges involved in such studies.

Studying high-reliability organizations requires an enormous commitment of resources from everyone involved. Data are difficult to obtain because of their potential sensitivity. Researchers must commit time not only to the research but to developing trust and confidence with the operator/manager. The researcher–organization interaction is by far more of a relationship than a transaction, a characteristic not unique to high-reliability research but most certainly a necessary condition of it. A strong relationship between organizational members and researchers is a major by-product of the successful study of high-reliability operations. The ultimate product of such research is information that can be used to understand the human limitations involved in operating high-reliability organizations and identification of the critical factors in successful operations.

One can argue that it is too soon to know the "right way" in which to conduct research on nearly failure-free organizations. We counter that we know more about what researchers cannot or should not do in such settings than we know about the settings themselves. This is a beginning. As Maier [7] argued, it is the beginning of the problem-solving process that offers the richest array of alternatives and potential. This paper presents an approach to organizational research in settings we seldom see, let alone study. To conduct such research now is to encounter the research problem at its richest phase.

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