Identifying Organizational Risk Factors in Space Support Environments: The Use of Surveys

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Introduction

Organizational factors can affect system risk. In the aviation environment, organizational factors have contributed to many aircraft accidents. Some of these organizational factors have been lack of training, time pressure, over-scheduling (and resulting fatigue), policies on resource management (fuel use), and faulty procedures (e.g., shift handovers in maintenance, check list procedures in the cockpit) [1].

Spacecraft accidents have also had organizational issues as contributing factors. Some of these factors have been the lack of coordination between NASA and a non co-located contractor (Mars Climate Orbiter) [2]; lack of clearly defined roles and responsibilities (Titan IV/Milstar) [3]; inadequate documentation practices (Ariane 5) [4]; and the lack of communication channels for engineers who strongly hold a minority opinion (Challenger) [5]. Organizational factors were cited in the Columbia Accident Investigation Board (CAIB) Report [6] as contributing to the Columbia accident. One of the recommendations of this board was the necessity for

> . . .organizations committed to effective communication [to] seek avenues through which unidentified concerns and dissenting insights can be raised, so that weak signals are not lost in background noise. . . [These avenues] must mitigate the fear of retribution, and management and technical staff must pay attention. (p. 192)

Surveys are one of these avenues. Anonymous surveys administered at regular intervals can identify some of these problems early on, as well as provide communication channels for anonymous input. Hence surveys are a first step in reducing risk from organizational factors. Engineering for Complex Systems (ECS), a NASA research and technology program, is funding research to develop a model of organizational risk. It supports development of organizational risk surveys that are shaped by and will feed data into the organizational risk model [7] [8].

In this paper, we first discuss constructive ways to develop risk surveys in space support environments. We then discuss survey items that tap risk factors in the following work contexts: organization-wide, teams/work groups, and individual. Next we discuss the adequacy of documentation, software/hardware, and computational and support tools. Finally, we discuss the importance of asking respondents to describe what they see as serious organizational vulnerabilities.

Developing Surveys in Space Support Environments

Many of the risk factors found in the organizational risk literature apply to space environments and can be used to develop survey items. (See especially the literature regarding High-Reliability Organizations—HROs) [9] [10], Generative Organizations [11], and Learning Organizations [12].) There also are risk factors specific to aerospace domains that are important to assess, as will be discussed throughout this paper. However, we have found that the more the survey is tailored to the specific domain, the more useful the information it yields. Therefore, it is helpful for the survey designer to become familiar with the domain through standard ethnographic techniques of observation and interviews. It is essential to collaborate on the survey with future respondents—those with something to say. In addition, it is important to collaborate with the managers. What do they want to know? What decisions do they have to make? Answers to these questions will help in the construction of relevant and useful survey items.

We have found that most engineers and scientists in space environments are comfortable with taking electronic surveys via email or on the web, and prefer this method to paper and pencil surveys. Items can be phrased as statements and rated using Likert-type scales, e.g., frequency of occurrence on a five point scale. We recommend that free text spaces be provided next to the rating items so that respondents can elaborate if they choose to do so. An alternative is to provide space for comments for a whole section.

Analysis of Risk Factors at Multiple Levels

Risk factors can be identified at multiple levels of an organization and can exert their effects at higher or lower levels [13]. Organization-wide, team-level, and individual level risk factors can be addressed in a survey. Obviously, management decisions made at the organizational level influence the operational effectiveness of both teams and individuals.

Organization-wide Risk Factors

Factors influencing organizational decision making. Factors such as schedule, cost, and pressure from governmental bodies have been shown to play a critical role in decisions that have contributed to spacecraft accidents. In both the Challenger and Columbia investigations, it was determined that schedule concerns overrode safety concerns. One way to ascertain the prevalence of this pattern in ongoing missions is to ask respondents to rate how often they think various factors play a role in upper management decisions. Respondents can also be asked to rate how often the same factors play a role in their own decisions and recommendations. These data can be used to measure the extent to which schedule and other factors are perceived as playing a role at different organizational levels, how they

change with time, and whether they are in alignment with management goals and safety considerations. A possible survey format is shown in Figure 1.

*When **upper management** makes decisions about the mission, how often do you think the following factors play a role? When **you** make a recommendation about the mission, how often do you think the following factors play a role?*

	Never	-	-	-	Always
Crew safety	☐	☐	☐	☐	☐
Vehicle safety	☐	☐	☐	☐	☐
Science output	☐	☐	☐	☐	☐
Cost	☐	☐	☐	☐	☐
Schedule	☐	☐	☐	☐	☐
Contract negotiations	☐	☐	☐	☐	☐
Public opinion and support	☐	☐	☐	☐	☐
International cooperation	☐	☐	☐	☐	☐
Interpersonal conflict	☐	☐	☐	☐	☐
Influence from other governmental bodies	☐	☐	☐	☐	☐

Figure 1. Possible survey format for assessing the perceived frequency of various factors in organizational decision making (by upper management and self).

Organization-wide characteristics. As discussed earlier, there have been many studies on organization-wide risk factors. Features associated with high-reliability organizations relate to organizational values, policies, and safety practices. Examples of survey items that capture these risk factors are the extent to which:

- goals are shared throughout the organization,
- relevant information gets to the decision makers—including "bad" news,
- management respects those who spot problems,
- management is responsive to problems that are pointed out,
- decisions are being made at the correct level, and
- rapid response teams are formed to deal with unexpected crises.

Other items involve the extent to which the organization is "blame-free" in its response to identified safety problems, i.e., is an organization in which mistakes are investigated to identify cause, not to cast blame. Obviously, an organization's policy in this regard affects the willingness of mission personnel to create and benefit from "Lessons Learned" databases instead of hiding the errors that will inevitably occur. An example of items that tap organization-wide safety practices, along with a rating form and space for comments, is shown in Figure 2.

Throughout the mission, how often do you think the following occurs?

	-					Comments?
	Never	-	-	-	Always	
Relevant information gets to the decision makers.	☐	☐	☐	☐	☐	
Appropriate task teams are promptly formed to deal with unexpected crises.	☐	☐	☐	☐	☐	
People who spot and elevate problems are respected by higher management.	☐	☐	☐	☐	☐	
Management is responsive to problems that are pointed out.	☐	☐	☐	☐	☐	
Mistakes are investigated to identify cause, and not to cast blame.	☐	☐	☐	☐	☐	
Those making technical decisions which affect my work are knowledgeable in the area.	☐	☐	☐	☐	☐	
Spacecraft history, decisions, and rationales are easily accessible.	☐	☐	☐	☐	☐	

Figure 2. Example of survey items that tap organization-wide safety culture

Survey items that are especially important to space support environments are the last two items in Figure 2, "Those making technical decisions which affect my work are knowledgeable in the area," and "Spacecraft history, decisions, and rationales are easily accessible." Being able to access the written history and rationales of previous decisions enables one to assess the risks involved in current decisions. If written rationales are not accessible, personnel must rely on verbal rationales, which can become distorted over time and can degenerate into "We've always done it this way," or "We've never had a problem with it." Access to accurate information on spacecraft history, decisions, and rationales also mitigates the consequences of attrition and creates “corporate memory.” Other items to include in this section depend on the structure of the mission. For example, if multiple groups were participating in the mission, such as contractors or international partners, it would be important to assess the extent to which information flows freely between these parties.

Team Risk Factors

Risk factors at the team level include the quality of collaboration between members of the team and between teams, morale, turnover rates of team members, and the extent to which people who spot problems are respected by team members. It also is important to assess the perceived adequacy of training of team members—both regarding their assigned duties as well as their knowledge of the overall spacecraft system. Lack of system knowledge is a risk factor, since decisions involving one spacecraft subsystem frequently must be integrated with decisions and constraints from other subsystems. Another important team factor is the extent to which team members are co-located. One of the major lessons learned from the successful Mars Pathfinder Mission was the importance of co-location in the design and engineering phases of the mission [14] [15]. Bradner and Mark have studied in depth the adverse impacts of not being co-located during the design phase of a mission [16]. Many others also have shown that face-to-face interactions reduce misunderstandings (see especially the work on shift handovers in various domains [17]). To determine the extent of team member co-location, one can ask what proportion of their team the respondents have face-to-face contact with on an average day. Further questions can address the work locations of team members, e.g., other buildings or cities. It is also helpful to ask how many times a week the team meets, and what proportion of meetings the respondent can attend.

Mission decisions and recommendations are typically made in formally scheduled meetings. A major risk factor that affects decision quality in team meetings and team interactions is failure to communicate [18] [19] [20] [21] [22]. Common causes of failure to communicate in team meetings are low rates of member participation, not considering team member inputs, members not feeling free to disagree, and unilateral decision making by the leader without team members' input. Respondents can be asked to rate their team meetings on these characteristics, as well as to rate the effectiveness of their team meetings.

Individual Risk Factors

Back-up. A major risk factor in organizations is specialized knowledge being only “one deep.” To uncover areas where expertise is thinly stretched, respondents can be asked whether there are people who can back them up in case they get sick, and if so, how many people. They can also be asked whether there are areas where they think there should be more "back-up," i.e., more people with knowledge in an area, and if so, which areas.

Workload. Risk can be associated with not meeting deadlines. If problems are being worked past deadlines, it is an indication of an area needing more staff or fewer projects. High workload issues may be involved, along with reduced job satisfaction, increased job-related fatigue, lower team morale, and higher attrition rate. If a team is central to mission success and other teams rely on it, many projects can be delayed if team members are overloaded. Respondents can be asked how close to deadlines problems are being worked in their area: before, at, or past deadlines. If they select "past deadlines,"

they can be asked how many days past. It is also important to ask whether the respondents have to put in over time hours, and if so, how many hours a week, on average.

Working conditions. Relevant survey items in this section have to do with job satisfaction, working conditions, schedule-related fatigue issues, adequacy of training, and the extent to which respondents are recognized for good work. Other important issues include accessibility of supervisors and their willingness to listen to respondent's input, as this influences information flow up to the next level. Whether respondents trust their supervisors also is important.

Obstacles to effective work. Respondents can be asked to rate the extent to which there are obstacles to their work effectiveness. Many factors such as crowded working conditions, computer incompatibilities, and communication issues with on-site and off-site colleagues can severely compromise work effectiveness and hence contribute to risk. Other obstacles might be bureaucracy, contract negotiations, and reporting requirements.

Risks in Information and Technology Support

Documentation and databases. Accurate, up-to-date, and accessible documentation and databases are essential to ensure safe mission operations. We have found that it is helpful to list the names of the documents and databases used in a domain and to provide ratings scales for both their accessibility and accuracy, as well as room for free text comments. It is useful to list even the documents that are known to be accessible and accurate, because the ratings for these documents provide a baseline for comparison with other documents.

Software/hardware. Software/hardware issues are extremely important in space operations and have contributed to many spacecraft accidents [23]. Input must be sought on the quality of software development, the thoroughness of its testing, and its ultimate adequacy and robustness. Again, it is essential to provide free text spaces adjacent to rating items.

Possible new or improved tools. New and improved tools can fill technology gaps and reduce risk. Surveys can elicit suggestions for new or improved tools for both computational and support tasks. Areas to inquire about include the types of analyses helped by the suggested new tool, the capabilities of the new tools, the number of hours currently spent on tasks, and the number of hours saved with the new tools.

Perceived Organizational Vulnerabilities

It is important to provide space for respondents to state in their own words what they perceive as the most important organizational vulnerabilities in their environment, what the consequencesmight be, and what they would suggest to remedy these vulnerabilities. Also valuable to managers are the respondents' ratings of how serious these vulnerabilities are, and the degree to which they affect the respondents personally. There are two advantages to including these responses on the survey. First, they allow new concerns to percolate up, concerns which might not have been tapped by the interviews

used to develop the surveys. Second, they enable one to assess the relative importance of the organizational vulnerabilities that have been rated earlier in the survey.

Conclusion

Space operations are extremely risky and hence the support environment must be monitored continuously for vulnerabilities. Surveys are one tool for doing this effectively, especially if they have been designed in collaboration with individuals working within the space domain and are a vehicle for transmitting information from those who want to be heard to those who want to hear. In this way surveys can help identify vulnerabilities before they become critical.

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