

## Communication and Coordination Failures in the Process Industries

Jason C. Laberge  
Honeywell Advanced Technology  
Minneapolis, MN  
[jason.laberge@honeywell.com](mailto:jason.laberge@honeywell.com)

Peter Bullemer  
Human Centered Solutions  
Independence, MN  
[pbullemer@applyhcs.com](mailto:pbullemer@applyhcs.com)

Stephen D. Whitlow  
Honeywell Advanced Technology  
Minneapolis, MN  
[stephen.whitlow@honeywell.com](mailto:stephen.whitlow@honeywell.com)

Previous research shows that effective team communication and coordination is required for managing normal and abnormal situations (Laberge & Goknur, 2006). The purpose of this project is to quantify common communication and coordination failures and root causes of abnormal situations in the process industries. Fourteen incident reports were analyzed using the TapRoot® root cause analysis methodology. The top five communication and coordination failures were failures of: planning and preparatory activities (31%), individual and team execution (14%), work direction and supervision (13%), communication between functional groups (12%), and activity assessment (10%). The study of root causes showed that ineffective standards, policies, and administrative controls (SPAC); poor crew teamwork; a lack of communication; and no supervision were common reasons for failures.

### INTRODUCTION

Process industry plants are dynamic environments characterized by distributed processes, skilled performance, dispersed teams, uncertainty, time constraints, high risk, organizational influences, and sociopolitical factors (Vicente, 1999). The sub-systems are often coupled, much is automated, data has varied reliability, and computers mediate most human-machine interaction. Process industry plants are also social work environments in that plant operations function with a teamwork culture such that activities are managed by crews, shifts, and functional groups (i.e., operations, maintenance, supervision, engineering). Team members have to cope with multiple information sources, conflicting information, rapidly changing scenarios, performance pressure and high workload. Therefore, effective team communication and coordination is required for managing normal and abnormal situations (Zwaga & Hoonhout, 1994).

Prior work shows that communication and coordination breakdowns can lead to significant operational problems (Laberge & Goknur, 2006). However, the nature of the breakdowns is still largely undocumented and it is not clear how or why breakdowns occur. The purpose of this Abnormal Situation Management (ASM®) Consortium ([www.asmconsortium.com](http://www.asmconsortium.com)) project was to systematically analyze past incident reports to identify common communication and coordination failures and root causes of abnormal situations in the process industries.

### APPROACH AND RESULTS

A five-step research approach was used to identify and prioritize incidents, identify communication and coordination failures and analyze root causes. Each step is described below.

### Identify Candidate Incidents

In the first step, the study team identified a sample of incident reports that was representative of diverse process industries from multiple public and private company sources. Sources of public incident reports included:

- U.S. Chemical and Hazard Investigation Board (CSB)
- National Chemical Safety Program
- Center for Chemical Process Safety (CCPS)
- IAEA/NEA Incident Reporting System
- U.S. Nuclear Regulatory Commission (NRC)
- Nuclear Events Web-based System (NEWS)
- Institute of Nuclear Power Operators (INPO)
- U.S. Environmental Protection Agency (EPA)
- Major Accident Hazards Bureau (MAHB)
- Google and other internet search engines

To be considered for the study, the incident must have lead to an abnormal situation (i.e., injury, production interruption, equipment damage, environmental release); be described in enough detail so that the sequence of events, conditions, and outcomes could be understood; and have an identified or hypothesized communication and coordination failure. The study team operationally defined communication and coordination failures based on a conceptual model (Laberge, 2008). A communication failure was any problem involving the content (meaning, intent, clarity), type (vocal, non-verbal, written), timing (rate, timeliness), or medium (paper, vocal, display, policy, etc.) of communication. Communication failures could occur within or between teams, across functional groups or companies, or with process equipment. A coordination failure was any problem where two or more people must successfully interact to complete a job. Failures can occur at any of the five stages of coordination: preparation, planning, direction, execution, and assessment (Klein, 2001).

Thirty-two public incident reports were identified that met the search criteria. The oldest incident occurred in 1984, the newest happened in 2006. In addition, eight company

proprietary incident reports were found that matched the search criteria.

### Select Sample of Incidents

During the second step, the incidents were prioritized to emphasize recent refining and chemical incidents (the primary industries represented by ASM® Consortium members) with obvious failures, severe consequences and detailed incident reports. Based on this prioritization scheme, 14 incidents (10 public, 4 company proprietary) were selected for analysis. Given the study team's experience, this sample size was considered sufficient to establish a preliminary understanding of the basic causes of incidents associated with communications and coordination failures.

### Analyze Sample of Incidents

For the third step, the TapRoot® (www.TapRoot.com) methodology and software was used to complete the root cause analysis (Paradies & Unger, 2000). TapRoot® is a structured approach to incident investigations that is based on sound process safety management principles and learnings (CCPS, 2003). Therefore, the methodology has credibility in both research and industry settings. The TapRoot® approach begins with the creation of a SnapChart®, which is a work process diagram, illustrating the sequence of events, the people involved, the related conditions, and the incident. The study team created a SnapChart® for each incident by reviewing incident reports (public or proprietary) and determining what happened before, during, and after the incident. Next, communication and coordination failures were identified for each incident based on the same operational definitions used to select the incidents. In general, a failure was defined as something that occurred prior to the incident, which if corrected, would have either prevented the incident from occurring, significantly mitigated its consequences, or reduced the likelihood that the incident would have occurred. The study team considered a failure as communication or coordination related only if there was sufficient evidence in the incident report to indicate there was a breakdown in communication and/or coordination activities. A total of 207 communication and coordination failures were found across all 14 incidents. The average number of failures per incident was 14.78, though the variability across incident was fairly high ( $SD = 5.90$ ).

After analyzing the communication and coordination failures, the study team identified the root causes of each failure based on the following definition: "the most basic cause (or causes) that can reasonably be identified that management has control to fix and, when fixed, will prevent (or significantly reduce the likelihood of) the [failure's] recurrence" (Paradies & Unger, 2000, p. 52). There are many ways to identify root causes of a failure. TapRoot® uses a pre-defined tree where the investigation team applies the failures to each branch in the tree and discards those

branches that are not relevant to the specific failure. This tree provides the team with structure, enabling a consistent investigation across incidents (CCPS, 2003).

A total of 384 root causes were found across all the incidents. Each incident had an average of 27.4 root causes ( $SD = 13.7$ ) with each individual communication and coordination failure having an average of 1.86 root causes ( $SD = 0.28$ ). The operational definitions of each root cause and the specific questions used to navigate the root cause tree are in Paradies & Unger (2000).

At least two investigation team members reviewed all the incident reports, SnapCharts®, list of failures, and root cause analyses. The two-person team discussed differences of opinion and came to a consensus on the sequence of events, failures, and root causes before analyzing another incident. This difference resolution and consensus process provided a quality control mechanism to increase the consistency of the results and the reliability of the findings across incidents.

### Identify Common Communication and Coordination Failures

In the fourth step, the failures from each incident were clustered into common failure modes. The clustering technique allowed a focus on common failures, rather than failures specific to each incident. This means the common failures highlighted aspects of the failures that were shared across incidents rather than the idiosyncratic aspects specific to each incident. Thus, the concept of common failures is more useful in establishing a general understanding for the process industries, because the concept represents the shared problem elements that can be used to develop solutions to prevent future incidents.

To create the common failure clusters, four team members (including the two team members that reviewed the root cause analyses in step 3) reviewed all the incident reports, SnapCharts®, and root cause analyses to obtain a common level of familiarity. Next, a taxonomy was developed based on prior work (Laberge, 2008) to characterize the communication and coordination common failures. The operational definitions for each failure type in the taxonomy are in Table 1.

The four analysts independently clustered the 207 individual failures from the incident analyses into common failures using the failure mode operational definitions. Each failure could belong to only one common failure. One team member reviewed the common failures that team members assigned and calculated the level of agreement. Level of agreement was calculated as the percentage of team members that agreed on the common failure mode assignment. Average agreement (a measure of inter-rater reliability) was 70%. We discussed the common failure assignments where the team did not agree and came to a consensus on the appropriate common failure before proceeding.

**Table 1. Operational definitions for common failures**

Failure Mode	Operational Definition
<i>Communication Failures</i>	
Within shift team	Between members of a shift team including chief operator, team leader, console operations, field operations.
Between shift teams	Between adjacent shift teams or other shift teams such as between console operators on different shift teams, includes shift handover communications
Between functional groups	Between site management team, operations shift team, maintenance crew, engineering staff, lab staff, and security staff.
Between companies	Between companies as consumer and supplier, as vendor and customer, or as neighbors in community.
With process/equipment	Information acquisition from process or equipment via displays, labels, alarms.
<i>Coordination Failures</i>	
Job or task orientation (preparation)	Seeking out status information associated with work responsibilities when first coming on to work or starting a task.
Planning activities	Conducting activities to establish work plans, conduct job task analysis, review safety hazards, and conduct management of change.
Work direction and supervision	Giving individuals work assignments or direction, prioritizing work for self or others, ensuring individuals understand daily shift work objectives and their specific roles and responsibilities, ensuring people are following standardized work practices and policies.
Individual and team execution	Any group or individual conducting work activities per daily plan or objectives according to standardized work processes or job specific plans.
Activity assessment	Determining effectiveness with respect to plans or objectives: making adjustments in work activities; leveling work load; verifying that jobs are completed satisfactorily; identifying corrective actions.

Table 2 shows that the top five common failure modes were:

- Planning activities (31%)
- Individual and team execution (14%)
- Work direction and supervision (13%)
- Communication between functional groups (12%)
- Activity assessment (10%)

The top five common failure modes accounted for 80% of the total number of failures across incidents. It is noteworthy that four of the top five common failures were coordination related. The only communication common failure mode that occurred regularly across the incidents was “Communication between functional groups.”

**Determine Root Causes of Common Failures**

In the last step, the root cause profiles were extracted for each common failure mode. The profiles show the distribution of root causes that were identified for the common failures across incidents. The profiles help to identify why a particular common failure mode might occur. Organizations that have concerns with specific common failure modes can use the root cause profiles to determine the reasons (i.e., root causes) the failure might occur. Due to the large number of root causes associated with each common failure mode, a frequency analysis was performed to help identify the root causes that were most impactful. The team established a selection criteria that an individual root cause must represent at least 5% of the root causes

associated with a given common failure mode to be considered a significant contributor to its occurrence. If the root cause fell below the significant contributor threshold, it was added to the count associated with a category called “Other.”

**Table 2. Distribution of common failures across incidents**

Common Failure	Type	N	%
Planning activities	Coord	65	31%
Individual and team execution	Coord	30	14%
Work direction and supervision	Coord	26	13%
Communication between functional groups	Comm	24	12%
Activity assessment	Coord	20	10%
Communication within shift team	Comm	14	7%
Communication with process/equipment	Comm	10	5%
Communication between shift teams	Comm	7	3%
Communication between companies	Comm	6	3%
Job or task orientation	Coord	5	2%
<i>Total</i>		207	100%

*Note.* N = number of common failures; % = percentage relative to total; Comm = communication failure; Coord = coordination failure

**Table 3. Distribution of root causes for top 5 failure modes**

Root Cause	Top 5 Common Failure Modes					
	Combined for Top 5	Planning activities	Individual and team execution	Work direction and supervision	Communication between functional groups	Activity assessment
No SPAC	12.2%	20.4%	8.6%	7.8%		15.2%
Crew teamwork needs improvement	11.1%	7.4%	15.5%	17.6%	6.5%	12.1%
SPAC not followed	8.8%	7.4%	19.0%	7.8%		9.1%
No communication	8.4%	6.5%		5.9%	32.6%	
No supervision	7.4%		12.1%	19.6%		15.2%
No procedure	3.7%	10.2%				
Employee communications needs improvement	2.7%				10.9%	9.1%
Situation not covered in procedure	2.4%	6.5%				
SPAC enforcement needs improvement	2.4%		6.9%	5.9%		
SPAC accountability needs improvement	2.4%			13.7%		
Corrective action needs improvement	2.0%					18.2%
Communication system needs improvement	1.7%				10.9%	
Procedure not used	1.7%		8.6%			
SPAC confusing or incomplete	1.0%			5.9%		
Pre-job briefing needs improvement	1.0%				6.5%	
Corrective action trending needs improvement	0.7%					6.1%
Other	30.4%	41.7%	29.3%	15.7%	32.6%	15.2%
<i>Total</i>	<i>100.0%</i>	<i>100.0%</i>	<i>100.0%</i>	<i>100.0%</i>	<i>100.0%</i>	<i>100.0%</i>

Note. % = percentage relative to total; SPAC = Standards, Policies, Administrative Controls

Because the top five common failures accounted for most of the problems across incidents (80%), the root cause frequency analysis was limited to the five most common failures. Table 3 shows the distribution of root causes across the five common failures. The most frequent source of problems relates to ineffective standards, policies, and administrative controls (SPAC). Specifically, failures of SPAC related to enforcement, coverage, clarity, and accountability. Another common root cause across failures was the absence of necessary communication that contributed to incidents. This was not surprising since effective communication is needed for team coordination (Espinosa, Lerch, & Kraut, 2004; Laberge, 2008). Specific root causes included a general lack of communication as well as improving communication systems, particularly between management, leaders, and employees.

Another frequent root cause was due to poor crew teamwork. Specifically, poor teamwork was often characterized by members not questioning improper readings, team members being overly forceful, a tendency to focus on one problem and losing sight of overall plant status, and following directions that are known to be improper. Another common aspect of this root cause was when the person-in-charge sees a problem in the way work was being

performed but leaves the problem uncorrected. The final common root cause was no supervision. This root cause was noted when the person-in-charge should have followed the job or provided support, coverage, or oversight but did not.

### DISCUSSION

The objective of this research study was to identify the role of communication and collaboration failures in causing incidents in the process industry. The analysis of common failure modes provides some specific information on the importance of categories of communication and coordination activities (as shown in Table 2). Unlike previous ASM® Consortium research (e.g. Cochran & Bullemer, 1996; Laberge and Gonur, 2006; Soken, Bullemer, Ramanathan & Reinhart, 1995), which relied on the subjective opinion of operations personnel to determine the relative importance and failures associated with these kinds of activities, this study used recorded artifacts, such as public and private incident reports, and a structured method to identify the root causes of failures.

This study now provides evidence to show that, given the general state of operational practices in the United States, that coordination activities are relatively more likely

to lead to significant incidents than communications activities. Moreover, the examination of root cause profiles illustrates that the ability of an organization to establish and enforce standards, policies and administrative controls as well as provide effective communication, crew teamwork, and supervision is a significant factor in preventing these types of incidents. Focusing on the common root causes and the shared failures will allow researchers to propose solutions with the greatest potential for improvement.

### LIMITATIONS AND FUTURE WORK

There are a number of limitations of this research that are worth mentioning. It is noteworthy that many of these limitations are not unique to this analysis and are common for most incident investigations. The first limitation is that despite our best efforts to find a representative sample, the incidents were skewed towards publicly available incident reports from U.S. companies. Therefore, the sample may not fully represent the process industries as a whole. A 2008 ASM® Consortium study that is in progress will expand the sample size and improve the generalizability of the findings relative to common failures and frequent root causes.

A second limitation is that the TapRoot® analysis method is subjective. The analysis relies on analyst opinion and appropriate training. The potential influence of this factor was mitigated to some degree through the lead analyst review process to ensure consistency in subjective judgments. Furthermore, a consensus-building approach was used to reduce the dependency of the results on one analyst's subjective opinion.

A third limitation is that the incident reports were the only source of information for the root cause analysis. The quality and detail of incident reports varied (especially for site incident reports) and each reporting agency (and site) has biases that influenced the root cause analyses. Consequently, sensitivity to certain kinds of problems (e.g., lack of job preparation) by the team could have skewed the results. Again, the consensus building approach and the use of operational definitions for both root causes and common failure modes was a mitigation technique to ensure the analysis was as systematic and objective as possible.

In terms of future research, the process industries may benefit from this type of analysis that goes beyond communication and coordination activities to examine operations practices more generally. Consequently, in addition to expanding the sample size, the new ASM® Consortium research study is also expanding the scope of failure modes to other types of operational practices. Another research need is to compile and analyze near miss incidents, which are "...an occurrence in which an accident (that is, property damage, environmental impact, or human loss) or an operational interruption could have plausibly resulted if circumstances had been slightly different" (CCPS, 2003, p. 61). Previous research suggested that near miss reporting is a largely untapped source of information on failures and root causes (CCPS, 2003).

### CONCLUSIONS

This study identified the kinds of communication and coordination failures that can occur in the process industries. A number of common failures and root causes were found, which suggests there are consistent problems being experienced across facilities. The industry should focus more efforts on understanding the problems and developing effective solutions to mitigate the failures. The development and analysis of effective solutions is currently the focus of on-going research.

### ACKNOWLEDGEMENTS

This study was funded by the ASM® Consortium, a Honeywell-led research and development consortium. TapRoot and SnapChart are registered trademark of System Improvements, Inc. ASM is a registered trademark of Honeywell International, Inc. All other marks are trademarks of their respective owners.

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