CHAPTER 2
MAINTENANCE ERROR CAUSATION

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2.1 EXECUTIVE SUMMARY

The specific issue addressed through this research is that of human error causation. That is, how do investigators search for the cause of an event, where do they stop their investigation in the causal chain, and how do they describe and document their causal observations? The research has been conducted because today, without formalized rules of causation, there is a wide variation in how investigators make causal determinations. This variation makes data analysis for common trends in the data difficult and makes for widely varying prevention strategies for factually similar events.

A 1998 FAA research report, *"Learning from our Mistakes: A Review of Maintenance Error Investigation and Analysis Systems,"* made two specific recommendation to the FAA regarding maintenance error causation:

> *All Flight Standards staff responsible for oversight of air carrier and repair station maintenance, including all principal maintenance inspectors and their staff, should be provided human error causal concepts training.*[1]

FARs 121.373 and 135.431 should be re-interpreted, given industry understanding of human factors, to require more thorough causal investigation of maintenance errors that impact the conformity of dispatched aircraft and/or endanger safety of flight.[2]

This research was conducted principally to support these two recommendations. Rather than have the FAA require a specific commercial tool (such as Boeing's Maintenance Error Decision Aid), this research provides the research foundation allowing air carrier and repair stations to evaluate the rigor of their own investigative processes. Additionally, it allows the FAA to evaluate the effectiveness of air carrier and repair station investigations within the FAA's oversight.

With the generous help of 231 members of the aviation community, this research was able to identify some of the investigative styles and biases that we all bring to the event investigation process. Through this learning, the following seven recommended rules of causation were developed in order to improve the event investigation process.

1. Causal statements must clearly show the "cause and effect" relationship.
2. Negative descriptors (such as poorly or inadequate) may not be used in causal statements.
3. Each human error must have a preceding cause.

4. Each procedural deviation must have a preceding cause.
5. Failure to act is only causal when there is a pre-existing duty to act.
6. Causal searches must look beyond that which is within the control of the investigator.
7. Statements of culpability must be accompanied by an explanation of the culpable behavior and its link to the undesirable outcome.

With these seven rules, air carriers, repair stations, and FAA inspectors can improve the reliability and effectiveness of their human error investigations. Implementing the rules is not easy – they require training to be used effectively, and, by design, require much more rigor in the actual investigative process. The benefit, however, is that investigations using these rules will more accurately identify and describe the conditions leading to human error.

2.2 INTRODUCTION

Every day, maintenance organizations face maintenance errors; earlier FAA research identified that roughly 48,000 aircraft flights are dispatched into revenue service each year with a maintenance error on board (physical discrepancy which is the result of a human error).[3] Very few of these will result in an accident or major incident, with the vast majority having only an economic effect. If one were to additionally count those maintenance errors that are caught internally by the air carrier before the aircraft is dispatched into revenue service, the number easily runs into the hundreds of thousands of errors each year.

Consider that a large US carrier might generate 500,000 to 1 million maintenance log pages per year. Most of these maintenance logs include an investigation to determine "why" an event has occurred. If the event were an in-flight shutdown of an engine, a technician would investigate far enough to know how to put the aircraft back into revenue service without further complication. The technician will investigate to the extent that he/she is confident that after the repair, the engine will not again shutdown on the subsequent flight. In the case of a maintenance error, the investigation might conclude simply that a bolt was not properly lockwired. Once this is known, the technician will re-secure the bolt and the aircraft will again be put into service.

Under what circumstances, however, should the investigation go deeper into the contributing factors of either a human error or an equipment failure? Once the decision is made to dig deeper than the human error, how does one determine where the further investigation should go in terms of causal explanation? Surely there is little indecision about whether to dig deeper when the maintenance error has caused an accident or incident. Accident and major incident investigations have different goals than the simple event investigation by the technician – these events are investigated to learn how the event may be prevented in the future. Knowing that the bolt was not lockwired is not enough – here the failure of a technician to lockwire a bolt is viewed as the outcome and a search begins to determine why the bolt was not lockwired and how such an error may be prevented in the future.

Each carrier or repair station must decide when it will extend its investigation beyond the mere identification of the human error. Clearly, no carrier will conduct exhaustive investigations of each and every maintenance error occurring within their organization. Unfortunately, human error is complex in that it requires analysis of multiple events to fully understand how a particular process (e.g., shift turnover) might be contributing to human error events. It has become increasingly clear that most carriers today do not extend the investigation often enough to gain information on systemic contributing factors needed to optimize their error reduction efforts.

Once the decision has been made to go beyond mere identification of the human error event, the next and most difficult question is "Where should the investigation stop?" For many observers, the step beyond identification of the human error is a slippery slope; there is simply no clear guidance on when the causal search should stop. As a vivid illustration of this problem, consider the majority and dissenting opinions of the National Transportation Safety Board's recommendations regarding the Britt Airways (dba Continental Express) Embraer accident presented below:[4]

Statement of Probable Cause - Majority Opinion

> The National Transportation Safety Board determines that *the probable cause of this accident was the failure of Continental Express maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the airplane's horizontal stabilizer deice boots that led to the sudden in-flight loss of the partially secured left horizontal stabilizer leading edge and the immediate severe nose-down pitchover and breakup of the airplane.* Contributing to the cause of the accident was the failure of the Continental Express management to ensure compliance with the approved maintenance procedures, and the failure of FAA surveillance to detect and verify compliance with approved procedures [emphasis added].

Statement of Probable Cause - Dr. Jon Lauber's Dissenting Opinion

> The National Transportation Safety Board determines that *the probable causes of this accident were (1) the failure of Continental Express management to establish a corporate culture which encouraged and enforced adherence to approved maintenance and quality assurance procedures, and (2) the consequent string of failures by Continental Express maintenance and inspection personnel to follow approved procedures* for the replacement of the horizontal stabilizer deice boots. Contributing to the accident was the inadequate surveillance by the FAA of the Continental Express maintenance and quality assurance programs [emphasis added].

The difference between these two statements of probable cause is where the majority and Dr. Lauber place their principal cause for the accident. The majority identified as cause the technicians on the floor who did not follow company procedures as the cause; Dr. Lauber, a prominent human factors expert, pointed the causal finger directly at management and the corporate culture they had created within Continental Express. This was a step that the majority of the NTSB members were unwilling to take. The same dilemma follows FAA field inspectors and internal air carrier mishap investigators. That is, what explanation of an event will best serve aviation safety? Is Dr. Lauber's probable cause more accurate than that of the majority? Can an internal corporate investigator reasonably (or politically?) point the finger at corporate culture as the cause of a mishap? Should the search for cause be different if one is investigating a mere delay or cancellation as opposed to an aircraft accident?

At a recent human factors workshop with approximately 40 attendees, I asked small groups to assess the validity of the two causal explanations offered by the NTSB members, and to identify which route they would take if conducting the investigation in their own organization (assuming there had not been an accident). All participants thought that Dr. Lauber's dissenting opinion more accurately addressed the "true" causal aspects of the accident. Nevertheless, not all agreed that they would follow Dr. Lauber's path inside their own carriers. Many felt that Dr. Lauber's opinion put more emphasis on blame, especially where he pointed out the blameworthy disposition of certain Britt Airways managers in the full text of the NTSB report. Additionally, there were some participants who believed that the majority opinion said enough about process deficiencies and need not point to "culture" and "management" as the probable cause. Many participants felt that the implication in the majority opinion was clear that management would have a role in solving the procedural non-compliance on the floor.

The issues raised by the differing opinions of the NTSB are those that this research explored. As investigators, some of us may look to the duties of each individual and breaches of those duties; others may look for rule violations and possibly the human factors behind those rule violations; still others may immediately extrapolate to the system-level problems, such as the CEO's creation of an environment of high pressure. It is not that any of these explanations is incorrect, but rather that system safety may be better served by some causal explanations than others. Today, in the context of broad-scale maintenance error investigation, the lack of standardized rules of causation results in unacceptably varied investigative conclusions from one individual to another. For example, as discussed later in this report, survey respondents were asked to determine the root cause of an event involving an aircraft being towed into a jetway. While some respondents cited the individual error of the tug driver as the root cause, many other respondents cited a much more attenuated marketing error as the root cause of this same event (see first scenario in Appendix B). By understanding how investigators determine the cause of the event under investigation, this research brings more structure to our human factors investigative processes and provides much more predictability and repeatability in investigative outcome.

This research included three major tasks: first, to develop a preliminary taxonomy describing the models of causation available to an event investigator (e.g., probable cause, root cause, but-for causation, proximate cause) as well as the possible environmental factors impacting an investigator's determination of cause (e.g., investigator's experience, investigator's relationship to the erring employee); second, to conduct a scenario-based survey to determine scientifically how different investigative approaches and investigative language shape the determination of cause among a diverse group of Engineering and Maintenance professionals. Through these two tasks, the third step of the research was to develop a proposed set of rules of causation that can be used by both air carriers and regulators in their investigation of mishaps, or oversight of air carrier mishap investigations, respectively. The rules, however, are not a panacea – they do not replace investigative experience and they do not, nor could they, eliminate all investigative biases. Nevertheless, by developing rules of causation, investigators, managers, and regulators can be assured that causal explanations of human error events will be more analytical, more consistent, and in the end, be in the best interests of safety.

To understand the survey data and how the rules of causation were developed, it is advisable to read Appendix A. This appendix sequentially illustrates how an event investigation can proceed from what can be known about an event to a small set of written statements in the final investigative record. With this albeit stereotypical investigation in mind, the survey data and the rules of causation become more clear.

2.3 THE SURVEYS

This research queried whether the selected causal influences listed in Appendix A can be seen in the industry's current maintenance error investigative process. Additionally, the research attempted to uncover any specific investigative biases that may have emerged as air carriers increase their investigation of maintenance errors. For example, would individuals trained as investigators view as dominant certain causes that would not be seen as causal by other non-investigators? The following specific hypotheses were tested through the use of surveys:

- *There will be wide variation in where participants will stop their causal search as they investigate back the causal chain.*
- *Positive and negative descriptors will influence the strength of causal explanations, even when the underlying factual context is unchanged.*
- *The presence of a rule or procedural violation will increase the causal strength of the violation's underlying facts.*
- *The presence of a possible prevention strategy will decrease the perceived contribution of other causal factors, even when the underlying factors leading to subject mishap have not changed.*
- *Rule violations and possible prevention strategies will lessen the relative strength of probabilistic causes such as fatigue or stress.*

- *Different investigative styles will appear, depending upon the job function, education, and investigative training of the individuals involved.*

To test these hypotheses, two versions of three different scenarios were created. Participants received one version of each scenario. Each scenario had two elements: a narrative explanation of the mishap, and a list of open questions that queried what the participant believed to be the causes of the subject mishap. Designed to work as pairs, the scenarios allowed testing of the validity of the six hypotheses discussed above. Each participant was asked to identify the dominant contributor, the second most dominant contributor, the third most dominant contributor, and the "root cause." A summary of the six scenarios is provided in the tables below. The actual scenarios are provided in Appendix B.

First Pair of Surveys

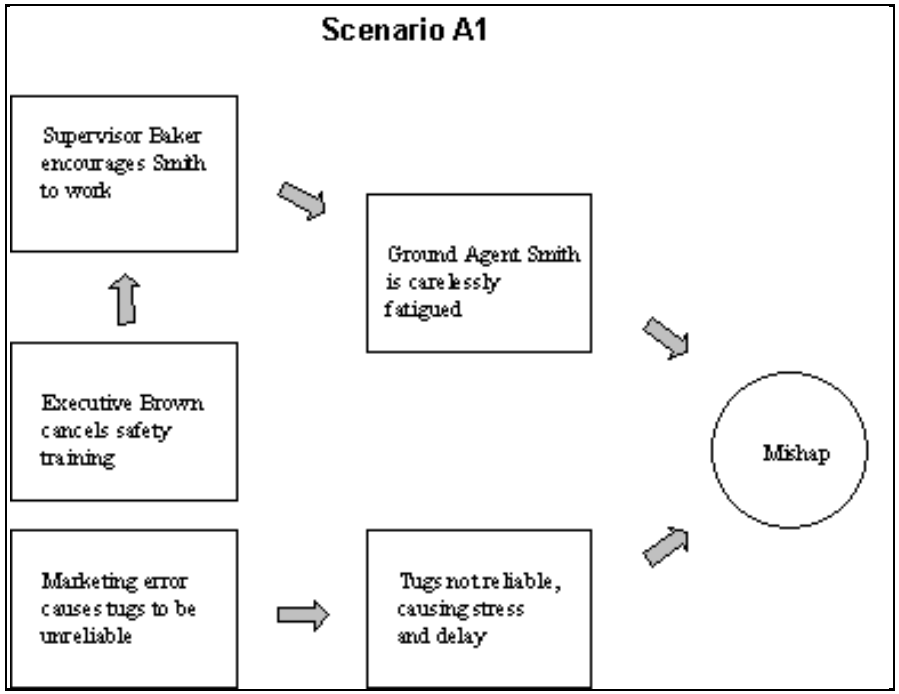

Figure 2.1 Scenario A1

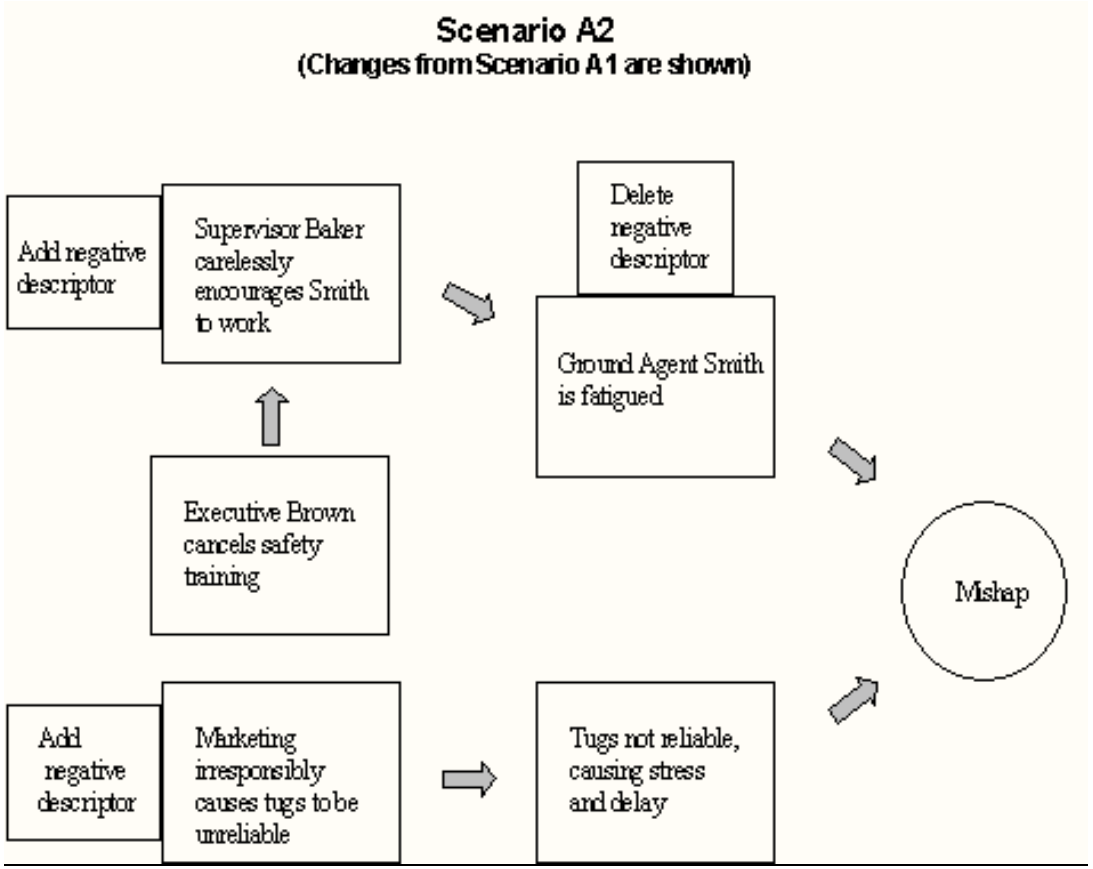

Figure 2.2 Scenario A2 (Changes from Scenario A1 are shown.)

Second Pair of Surveys

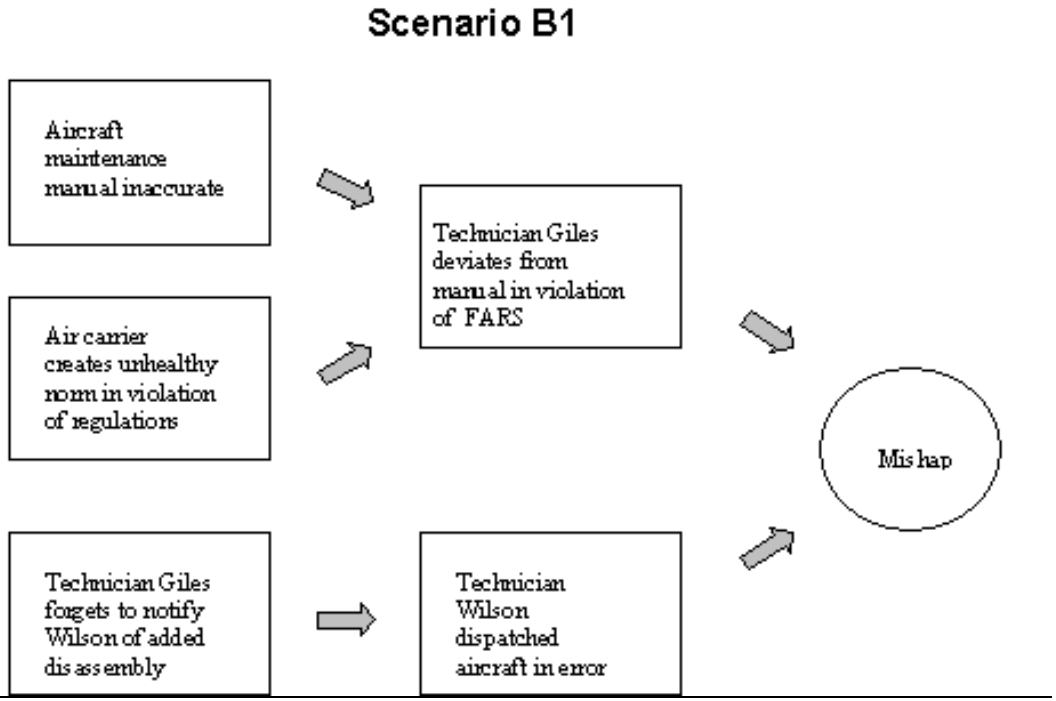

Figure 2.3 Scenario B1

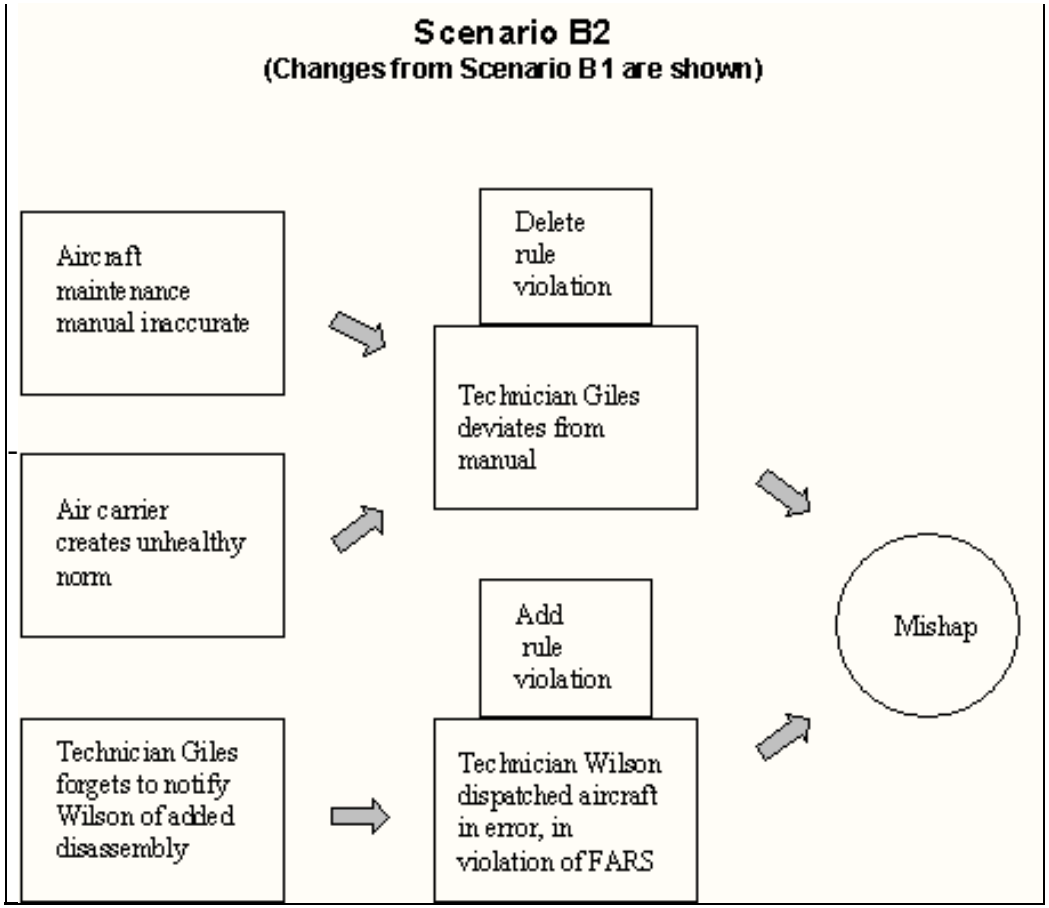

Figure 2.4 Scenario B2 (Changes from Scenario B1 are shown.)

Third Pair of Surveys

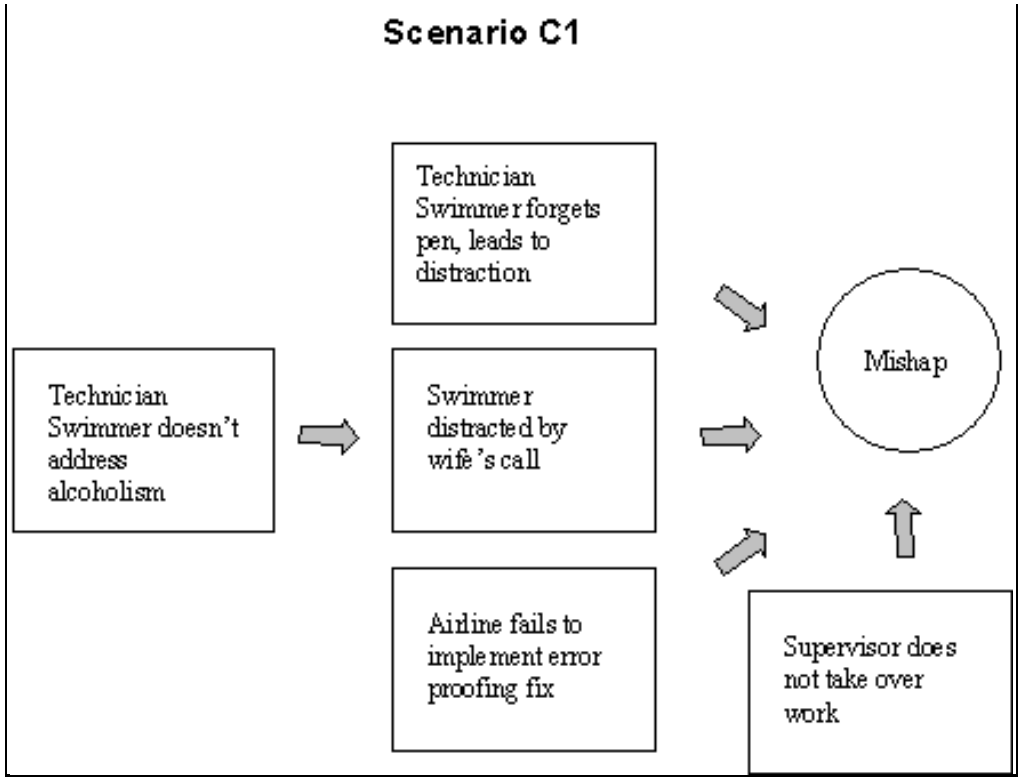

Figure 2.5 Scenario C1

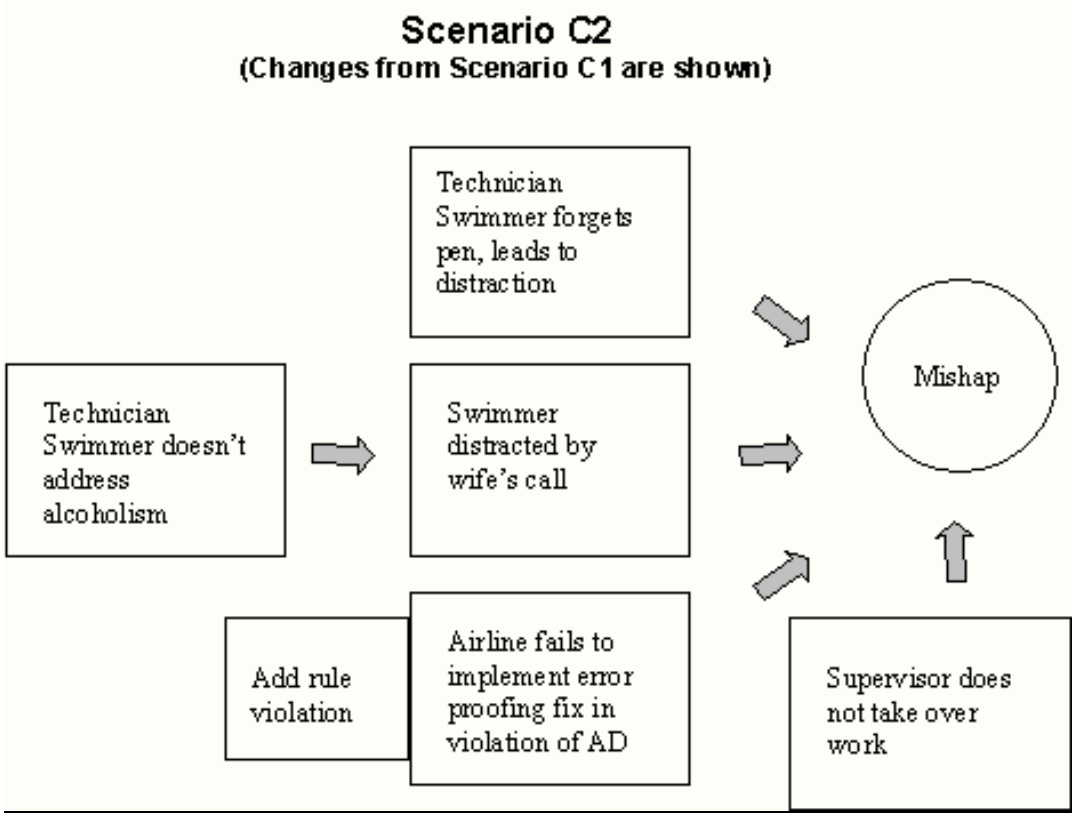

Figure 2.6 Scenario C2 (Changes from Scenario C1 are shown.)

2.4 DATA ANALYSIS

In all, 231 individuals representing 35 different organizations around the world provided over 2700 individual data points on causal biases in the event investigation process. This data has been organized and sorted by region of the world, investigator training, Crew Resource Management training (in maintenance known as maintenance resource management – MRM), years of experience, and by respondent's role within their organization.

Each of the six principal hypotheses discussed earlier is listed below with an analysis of how each was supported by the data.

Hypothesis 1 - There will be wide variation in where participants will stop their causal search as they investigate back the causal chain.

As seen in Figure 2.7, there was extremely wide variation in what each respondent identified as their first, second, and third contributors, as well as root cause. For example, in the first version of scenario A, eleven different dominant causes were identified. That is, the 100 respondents found 11 different dominant causes, ranging from the error of an employee who towed the aircraft into a jetway to the financial troubles of the air carrier. This data vividly confirms that what is dominant in one investigator's mind may not necessarily be the dominant contributor in another's.

To understand these findings, this research must be distinguished from actual mishap investigation. In the actual mishap investigative process, the investigator will stop the investigation for a number of reasons - from natural stop rules to organizationally imposed stop rules. In contrast, in this research the respondent is already provided with investigative conclusions that go back farther in the causal chain than the participant might go in his own organization. In this research, the participant only needed to prioritize which factors he believed were most dominant in the mishap.

In virtually all responses, survey participants were willing to identify three top contributors and a root cause. In the first scenario, over 80% of the respondents identified their root cause at the airline level (i.e., financial troubles, poor decisions made by corporate executives). Importantly, when given a variety of different causes there was very little difference in how far back the causal chain participants were willing to go regardless of whether or not they were trained mishap investigators (research participants were principally Boeing Maintenance Error Decision Aid (MEDA) trained investigators). Respondents, both investigative trained and not, were willing to embrace a long causal chain. At a high level, there was a consistent trend in the data. As seen in Figure 2.8, most individuals in survey scenario A1 put the dominant cause at the level of the erring employee while most put root cause as far back the causal chain as was possible (i.e., at the airline management level). While this effect was seen throughout all three scenarios, as the perceived culpability of the employee increased, the erring employee increasingly became both the dominant and root cause, as shown in the data from scenario C (see Figure 2.9).

It is important to recognize that when investigating events within an actual air carrier or repair station investigation, investigators are rarely, if ever, willing to go up the organizational chain as they did under these scenario circumstances. This raises the important question of what causes investigators in the real world to stop the investigative search and why?

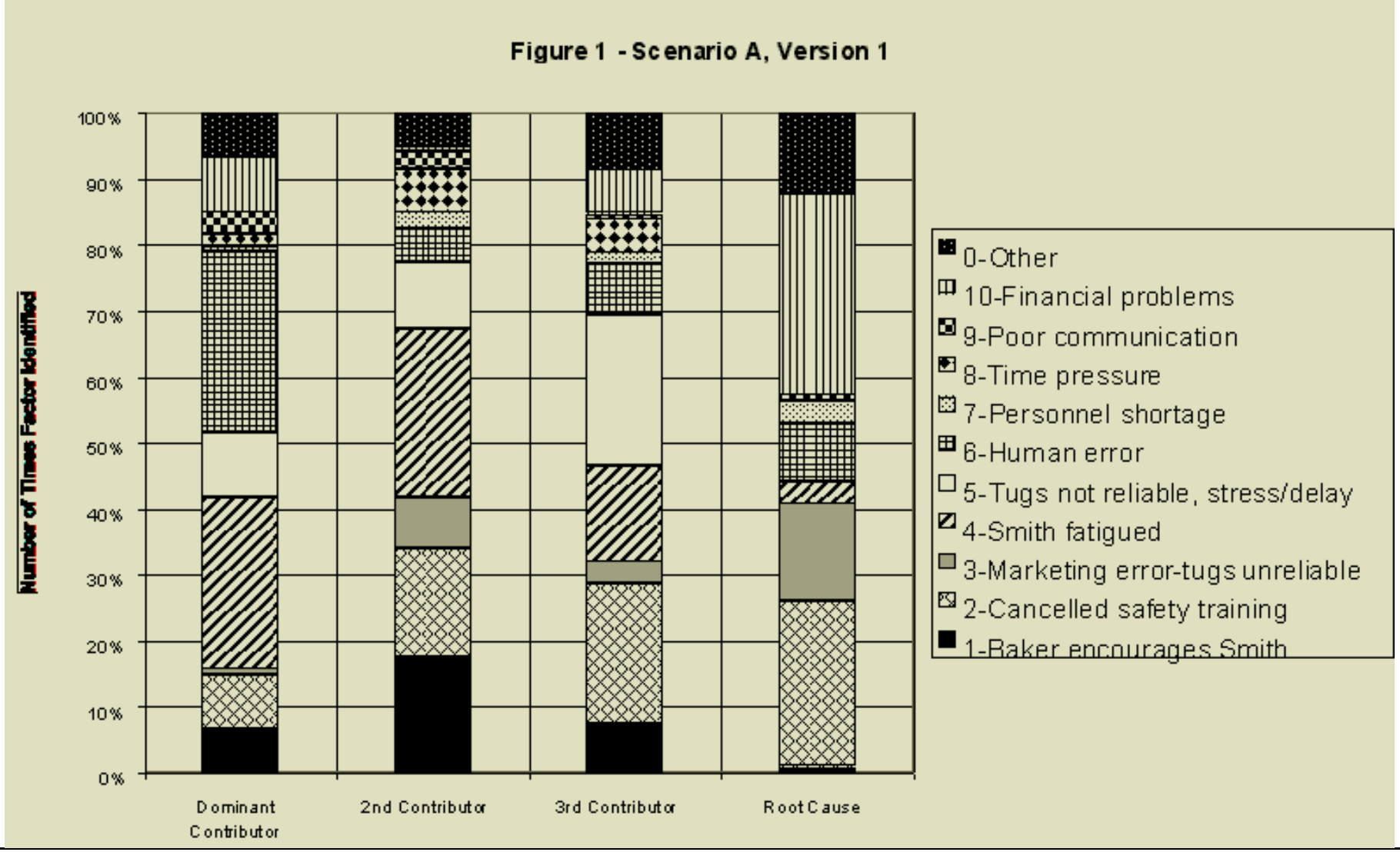

Figure 2.7 Scenario A, Version 1

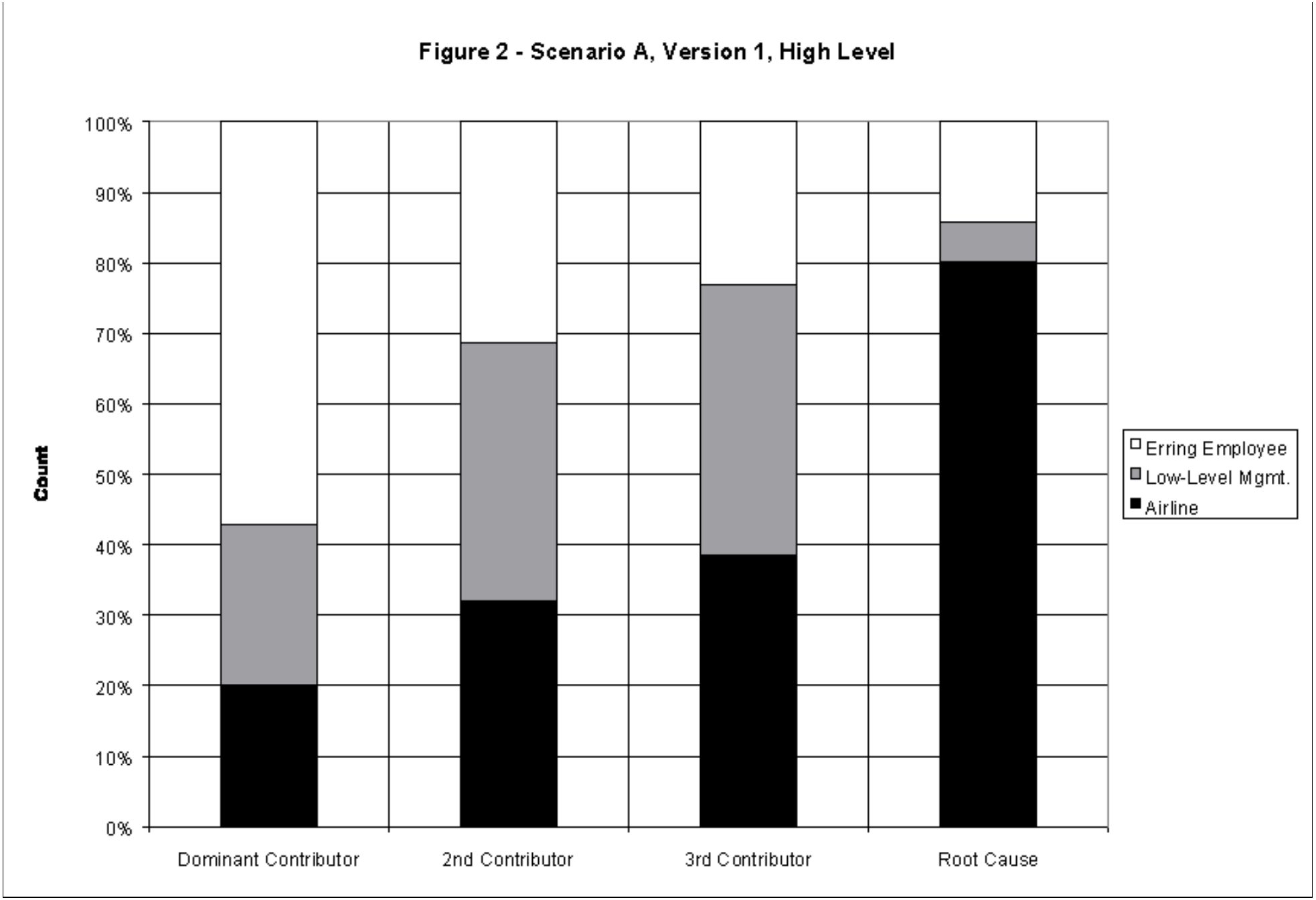

Figure 2.8 Scenario A, Version 1, High-Level

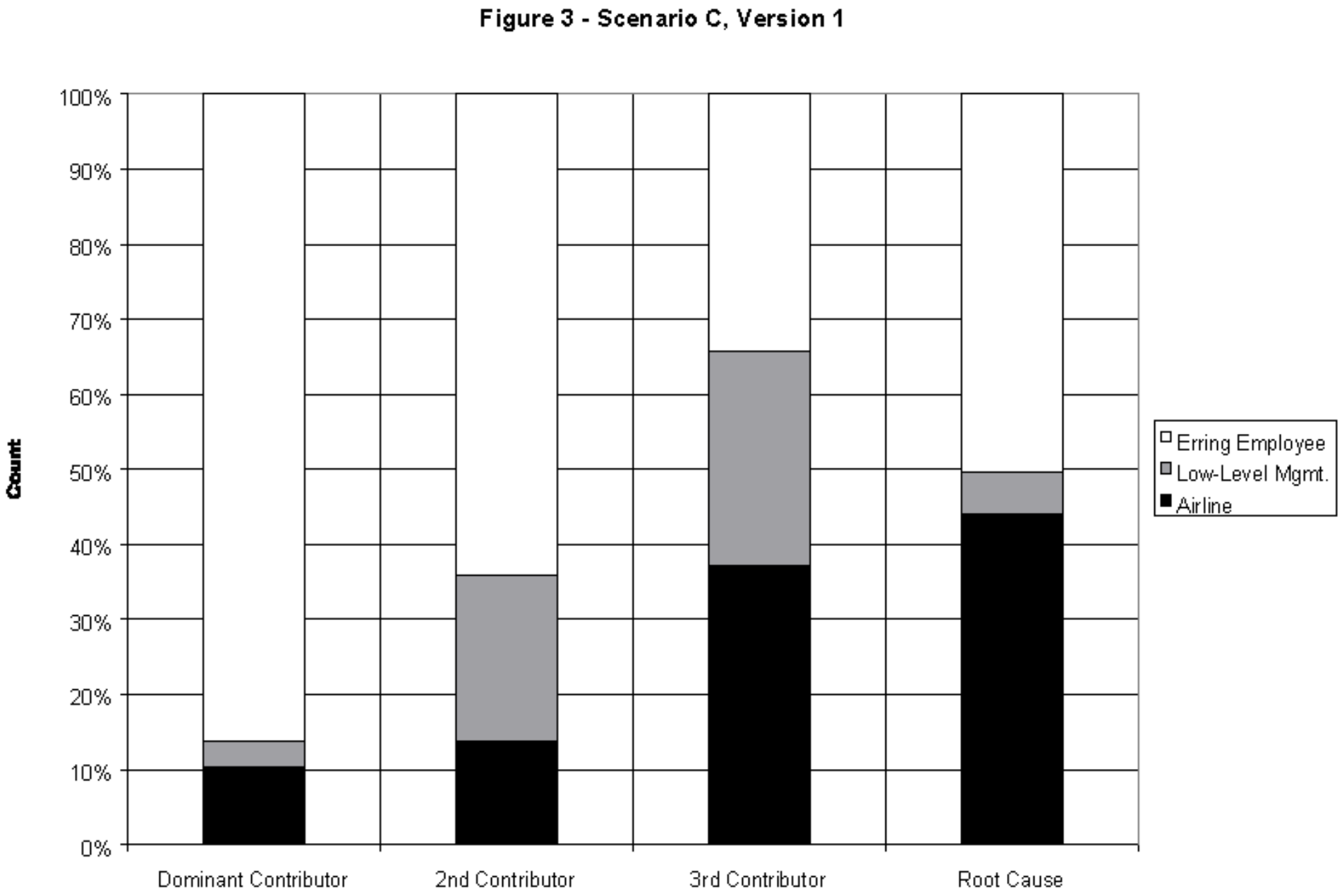

Figure 2.9 Scenario C, Version 1

Hypothesis 2 - Positive and negative descriptors will influence the strength of causal explanations, even when the underlying factual context is unchanged.

An unexpected but encouraging finding was that the data showed little variation when negative wording was attached to particular causes. The factual strength of the underlying causal assertions seemed to control the relative rankings of contributors by the respondents, regardless of the addition of negative descriptors.

However, the relevance of the negative descriptors was found in the quality of the narrative itself. Many narratives used negative descriptors as a "short-hand" to describe the inadequacies (causes) respondents saw in the mishap narrative. For example, one respondent wrote, "maintenance manual was poorly written." These types of causal statements lack the specificity required to fully understand the cause and effect relationship in the detail that would allow a productive prevention strategy to be built. For example, what would be the fix for "maintenance manual was poorly written?" Without a statement of a specific cause and effect relationship, causal statements merely become value judgements about the object under investigation. The table below shows many of the shorthand descriptors used by respondents.

Table 2.1 Use of Descriptive Words

Words Used by Respondents	Scenario A	Scenario B	Scenario C	TOTAL
"Lack of"	143	97	93	333
"Failure to"	22	62	57	141
"Poor"	58	48	27	133
"Insufficient"	13	1	2	16
"Inadequate"	18	27	13	58
"Should or should have"	27	33	61	121
"Bad"	9	4	6	19
TOTAL	**290**	**272**	**259**	**821**

It is significant to note that when the employee was viewed as more culpable (in scenario C), respondents more often chose to use the words "should" and "should have." This would suggest that as the erring employee is viewed as more culpable or there are less obvious contributing factors, the investigator tends to turn away from human error contributors to statements of what the erring employee should have done to prevent the mishap. That is, instead of saying what caused the employee to so what he did (i.e., the error), the respondents showed more propensity for merely stating what the employee could have done differently.

Hypothesis 3 - The presence of a rule or procedural violation will increase the causal strength of the violation's underlying facts.

The presence of a rule violation did, as suspected, affect the strength of the causal statements. When the rule violation involved some amount of intent on the part of the technician, respondents were much more willing to highly rank the violation as causal in the mishap. This occurred even when the underlying behavior was unchanged – except for the behavior being identified as an FAR violation. The specific language where a procedural violation in one version was identified as a violation of the Federal Aviation Regulations.

Scenario B, Version 1

> Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. *Although the deviation is a violation of Federal Aviation Regulations, management felt there would be no harm* [emphasis added].

Scenario B, Version 2

> Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. *As long as the added work was remembered, management felt there would be no harm in the deviation* [emphasis added].

With the mere addition of the FAR violation, respondents were much more willing to identify the deviation in version 1 as higher in causal strength than that in version 2. Unlike violation requiring some level of intent, what did not change the respondents' causal determinations was an outcome-based rule stating that to make the human error was a violation of the FARs. For example, FAR 43.13 states that no aircraft can be dispatched out of conformity with its type design. In this case where there was no intent to violate the rule implied in the scenario, there was no change in the causal strength between scenarios identifying the rule violation and those that did not.

Hypothesis 4 - The presence of a possible prevention strategy will decrease the perceived contribution of other causal factors, even when the underlying factors leading to subject mishap have not changed.

The presence of a possible prevention strategy did lower the ranking of other contributing factors in a scenario. Here, a possible prevention strategy was defined as a strategy, unrelated to the principal human error, that would have nonetheless prevented the mishap. In scenario C, it was a supervisor who might have prevented the mishap by checking the work of the employee. Although there were specific contributors to the principle human error, the possible prevention did rank higher in causal strength than many causes specific to the human error.

Hypothesis 5 - Rule violations and possible prevention strategies will lessen the relative strength given to probabilistic causes such as fatigue or stress.

Both rule violations and the presence of possible prevention strategies did act to lessen the strength of probabilistic causes. The relevance of this finding is important if one believes that better prevention strategies will come from measures to reduce the effect of the more "human factors-oriented" probabilistic causes such as fatigue or confusing procedures. By diverting the causal search toward rule violations and possible prevention strategies, investigators may overlook more manageable causes. Boeing's MEDA tool specifically ignores rule violations because of this possible bias.

Hypothesis 6 – Different investigative styles will appear, depending upon the job function, education, and investigative training of the individuals involved.

There were no clear differences in investigative styles when analyzed according to years of experience, job function, CRM/MRM trained, or error investigation trained. The only finding of statistical validity among these factors is that CRM/MRM trained respondents were more willing to identify the presence of a norm as the dominant contributor to a mishap. This likely results from the focus that many maintenance CRM/MRM programs give to the issue of norms.

2.5 SUGGESTED RULES OF CAUSATION

Based in part on the data collected above, the following rules of causation were developed to help control the direction of the causal search in a mishap investigation, as well as control the language used to describe causal statements. The rules are an initial set of rules on the way to improving the investigative process by improving the repeatability, predictability, and clarity of investigations. Employing these rules is simple: where you attempt to explain "why" an event has occurred, apply these rules to the explanation. If the explanation of "why" the event has occurred conforms to the seven rules, you have met the minimum standards for causal explanation.

1. Causal statements must clearly show the "cause and effect" relationship.

While this is the most basic of causation rules, it cannot go unstated. For a variety of reasons, the investigator who understands the cause and effect relationships in an investigation may nonetheless document only a few of the causal links. If there are multiple links in the causal chain of an event, there should be a causal statement for each link. For example, in the first research scenario, many respondents identified the air carrier's financial problems as the root cause of an aircraft towed into a jetway. While this is acceptable within these rules of causation, the investigator must show the link (s) between the financial troubles and how a technician was able to tow an aircraft into a jetway. Properly identifying all of the causal links is particularly important because an organization may find that breaking the chain of events at an intermediate link is the most effective course of action.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
The cancellation of fatigue training increased the likelihood that Supervisor Baker would not detect the fatigue of her employee.	Because of a marketing error which hurt the financial stability of the carrier, a technician towed an aircraft into jetway. *(Does not show intermediate cause and effect links)*

2. Negative descriptors (such as poorly or inadequate) may not be used in causal statements.

Contrary to expectations, this research did not show that negative descriptors significantly altered the strength of causal determinations. However, the raw data did show that negative descriptors act as a shorthand that can inadvertently mask a more specific cause and effect relationship. The statement "maintenance manual was poorly written" masks the real cause and effect relationship. That is, it fails to specify exactly what was mis-written, which in turn contributed to the error.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician installed oil cap improperly because the maintenance manual mistakenly showed the cap with a 1/8" gap at the cap to flange interface, thus increasing the likelihood of the error.	In-flight shutdown caused by loose oil cap. Maintenance manual procedure was poorly written causing oil cap to be improperly installed. *(No additional information provided beyond the statement of the procedure's inadequacy)*

3. Each human error must have a preceding cause.

Boeing's Maintenance Error Decision Aid (MEDA) tool was designed in large part to take the investigative search beyond the mere identification of the human error, the place where most mishap investigations have tended to stop. This causation rule merely makes explicit what is implicit in MEDA: that the investigation must search beyond the error to why the error has occurred.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by mis-installed oil cap. Technician was distracted by outside noise, increasing likelihood of error. Technician was fatigued after working 12 hours increasing likelihood of the error.	In-flight shutdown caused by mis-installed oil cap. *(No additional information provided beyond the identification of the error.)*

4. Each procedural deviation must have a preceding cause.

The data from this research showed that the presence of a rule violation impacts the causal strength of the underlying facts. In some cases, respondents wrote that "failure to follow maintenance manual procedures" was a cause of the event. To be beneficial, a causal statement involving a rule or procedural deviation must show a link to the undesirable outcome. Additionally, in order to develop a good prevention strategy, the rule violation itself must be explained through a cause of its own. For example, in the example below, the investigator must search for why the maintenance manual procedures were not followed.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule

In-flight shutdown caused by loose oil cap. Technician did not have work card with him at time of error, increasing the likelihood of the error. Technician did not have procedure with him because a norm had developed that tasks would be signed off after completion of all.	In-flight shutdown caused by loose oil cap. Technician failed to follow general maintenance manual requirements. *(No additional information provided beyond the identification of the procedural violation.)*

5. Failure to act is only causal when there was a pre-existing duty to act.

The data in this research showed wide variation in the respondents' willingness to identify failure to implement a particular prevention strategy as a "cause" of the mishap. This rule attempts, at a high level, to distinguish possible prevention strategies from the specific "causes" of a particular event. The classic illustration of this rule is the truck with a brake failure that cannot stop and hits a person in the crosswalk. The brake failure will undoubtedly be seen as the principal contributor to the event. Now consider a bystander on the sidewalk who, if he had run into the street, could have pulled the person from the crosswalk, thus preventing the mishap. The bystander is clearly able to prevent this incident; however, most observers would not identify the bystander as causal in the mishap. Now consider the additional knowledge that the bystander is a school crossing guard and that the person in the crosswalk is a 6 year-old child. In this case, the school crossing guard has a duty to act – to prevent the mishap. In this case, in addition to the brake failure, most individuals will consider the crossing guard to be a contributor to the mishap.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician distracted by outside noise, increasing likelihood of error. In-flight shutdown also caused by failure to complete the engine run-up in the maintenance manual procedure. An engine run-up was not performed because the technician thought that it was already completed by another technician.	In-flight shutdown caused by loose oil cap. The in-flight shutdown might have been prevented had the technician at the next gate checked the erring employee's work. *(No requirement or duty for the technician to act).*

6. Causal searches must look beyond that which is within the control of the investigator.

Although not tested in this research, many investigators do stop the investigation at factors only within their control. That is, if the investigator is not in a position to change the contributing factor, then the investigator will not identify the factor as causal, in the belief that there is no reason to identify as causal what you cannot change. The problem with this belief is that what might not be changeable from a single investigation might in fact be changeable if it is present in an entire class of events. That an investigator feels he will not be able to change an awkward design does not mean that the company will not be able to change the design of the aircraft if it has led to numerous events. This rule makes explicit that investigative conclusions should not be controlled by the investigator's perceived extent of control.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician was fatigued after working 18 hours in the cold, increasing likelihood of the error. Aircraft design made it difficult to turn the cap while wearing gloves, increasing the likelihood of the error.	In-flight shutdown caused by loose oil cap. Technician was fatigued after working 12 hours in the cold, increasing likelihood of the error. *(No additional information provided about the design because the investigator felt it would be too hard to change.)*

7. Statements of culpability must be accompanied by an explanation of the culpable behavior and its link to the undesirable outcome.

Many of the respondents in this research used "carelessness" and other words of culpability as contributors to events. In most cases, however, the culpability "label" was not accompanied by a statement of what behavior was blameworthy nor how the culpable behavior was related to the undesirable outcome. Especially important when assessing personal blame, this rule requires the investigator to identify the culpable behavior and its relationship to the outcome.

Example Causal Explanation that Follows Rule	Example Causal Explanation that Violates Rule
In-flight shutdown caused by loose oil cap. Technician was fatigued, increasing the likelihood of making the error. Technician was reckless in that he took a substantial and unjustifiable risk in working 18 hours straight prior to making the error.	In-flight shutdown caused by loose oil cap. Technician carelessly worked in an unsafe manner. *(No additional information about basis of culpability or relationship to the error.)*

2.6 CONCLUSION

This research showed that there is still wide variation in what individuals will identify as dominant and root causes to maintenance errors. If we are to collect consistent maintenance error data, we must have more standardized rules to provide minimum guidelines on what is an acceptable explanation as to why an human error event has occurred.

The seven rules of causation contained in this report fill this need by adding more rigor to the investigative process. The rules can be used with a specific investigative tool such as MEDA or in pure narrative reports such as an air carrier's voluntary disclosure to the FAA. Additionally, they can be used by FAA field inspectors to help assess whether an air carrier or repair station is conducting effective, safety-supportive investigations. If followed, these rules force the maintenance organization to specific causal descriptions that will serve maintenance error analysis and, consequently, system safety improvement.

2.7 ACKNOWLEDGEMENTS

Special thanks go to William Rankin, Ph.D., at Boeing, for his support in the design of the surveys, Krisiti Schiller for her data entry and analysis and my wife, Dawne Marx, for her tireless editing and support.

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2.9 APPENDIX A THE EVENT AND CAUSATION TAXONOMIES

The Event Taxonomy

In developing a taxonomy of factors that may influence the causal explanation of an event, it was first necessary to document what, in theory, can even be known about an event. In general terms, what can be known about an event is shown in the table below. Depending on what an event investigator deems important, some or all of these elements may be identified in an investigative record.

At a high level, information pertaining to the mishap can be grouped into three basic questions: what was (the error), what usually is (the norm), what was supposed to be (the rule). For example, relative to lighting in a specific area of inspection, the three questions are as follows:

- What was in this mishap: No supplemental lighting at all
- What usually is: A standing electric light
- What was supposed to be (per the manual): A portable flashlight

Specifically, what can be known about an event is as follows:

Item	Description	Example
Particulars	Defines mishap in space and time.	The mishap occurred in Atlanta at 6:00 p.m.
Behaviors	Actions of the people involved.	Bob pressed the switch to open the cargo door.
Intent	Knowledge with respect to individual behaviors.	Bob did not intend to hit the cargo door switch.
Outcomes	Results of behaviors or events.	The aircraft experienced an in-flight depressurization.
Performance Shaping Factors	Conditions present that influenced the performance of system elements (human or equipment).	The technician was fatigued.
Rules, Procedures, and Duties	Prescriptions imposed upon one's behaviors.	Technicians must follow the maintenance manual procedures.
Norms	What is normally done.	Generally, only one wing walker is used.

History	Background information to support a specific fact.	The maintenance manual procedure was modified three years ago.
Prevention Strategies	Actions that could have been taken to prevent the mishap.	A functional test would have caught the discrepancy.
Cause and Effect Relationships	*Relationship between a cause and its resulting effect.*	*A fatigue crack caused the stringer to fail.*

The following scenario shows how these elements might be seen in the narrative story of a mishap.

Mr. Giles and Ms. Wilson are maintenance technicians at the Phoenix airport. *(particulars)* Mr. Giles works first shift and Ms. Wilson works second shift. *(particulars)* Near the end of first shift on May 2, 1994, Mr. Giles was required to troubleshoot an MD-80 that experienced a pressurization fault on its flight into Phoenix. *(particulars, duty)* Mr. Giles isolated the fault to a bleed air valve on the left engine. *(behavior)* Following the maintenance manual, Mr. Giles began to remove the bleed air valve. *(behavior)* Mr. Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the assembly. *(behavior)* Although required by company policy, Mr. Giles did not write on the maintenance log that he had loosened the two additional clamps. *(behavior, rule)* It is the norm in the airline that if you are going to personally complete the work, then no specific write-up is needed for the added disassembly. *(norm, intent)*

Immediately after removing the valve, Mr. Giles took the valve to the storeroom across the airport to look for the spare. *(behavior)* No spare was found, so he was required to borrow the valve from another carrier at the airport. *(performance shaping factor, behavior)* By the time Mr. Giles returned to the aircraft, his replacement, Ms. Wilson was coming on duty. *(performance shaping factor, behavior)* Mr. Giles verbally briefed Ms. Wilson on the condition of the aircraft and her need to install the valve, but forgot to inform her of the two additional clamps he had loosened. *(performance shaping factor, behavior)* Ms. Wilson installed the valve correctly, but never looked to see if the additional two clamps had been loosened. *(behavior)* The airplane departed Phoenix unable to pressurize. *(outcome)* The airplane had to return to Phoenix to have the clamps tightened. *(outcome)*

Upon further investigation, it was discovered that Mr. Giles and Ms. Wilson have known each other for quite some time. *(history)* Ms. Wilson had once dated Mr. Giles's brother and now they were no longer friends. *(history)* Through the testimony of a few of Mr. Giles's colleagues, it was determined that Mr. Giles had repeatedly left Ms. Wilson with incomplete write-ups. *(history, behavior)* In the past, one colleague had overheard Mr. Giles say that it would be up to Ms. Wilson to figure out what to do. *(intent)*

Additionally, the investigation found that Ms. Wilson forgot to perform a leak check of the system as required by the carrier's general maintenance manual. *(rule)* Had Ms. Wilson performed the check, the leak from the two loosened clamps would have been detected. *(possible prevention strategy)*

While the labels attached to each sentence are subject to some interpretation, the important point is that the above elements known about this mishap investigation can be categorized according to the previous taxonomy. The job of the mishap investigator is to determine where the investigation should go and what should be included in the mishap record. That is, what questions should be asked of Mr. Giles and Ms. Wilson? What are mere conditions or facts unrelated to the undesirable outcome, and what in the mishap is causal? Additionally, how should the investigative record be written to avoid likely biases or mis-interpretations by future readers of the mishap record?

While some investigative records may contain a narrative similar to the example described above (typical in self report programs such as NASA's Aviation Safety Reporting System (ASRS) where a respondent tells a narrative story and the reader is left to determine the causal relationships), many investigation records will not include a narrative like the one above. The maintenance technician investigating only to fix the problem and get the aircraft dispatched will not care about most of the information in the narrative above. The MEDA investigator will not include the narrative because MEDA is a causal statement driven tool that lists investigative conclusions in lieu of a narrative description. Lastly, one must consider how investigations are discussed within the corporate context. When the Vice President of Line Maintenance wants to know "why" a forklift was driven into the side of his aircraft he is not asking for the narrative. Rather, he is asking for cause and effect statements – something missing from the narrative description of the mishap above.

The following Taxonomy shows how an investigative process can condense a narrative into investigative cause-and-effect conclusions.

The Causation Taxonomy

In an event investigation, determining the cause and effect relationships are where the most interpretation, and bias, will occur. The following table lists the specific factors that will influence the cause and effect determinations made by event investigators. For an excellent treatise on investigative (attribution) theory, see Fiske And Taylor's book, Social Cognition, to which this taxonomy owes a great deal of credit.[5]

Issue/Bias	Description
Investigative Purpose	Why the investigation is conducted: to merely explain an event, to predict future events, to prevent future events, or to allocate responsibility or blame.
Investigator Model	What is expected of investigator: to search for causation without bounds (the scientific method) or to apply generalizations, assumptions and stop rules to arrive at a "proximate" cause.
Human Error Models	James Reason's Swiss Cheese (multiple links in chain from senior management to erring employee)[6] Contributing Factors (such as in MEDA – largely oriented toward local factors) Human Reliability (oriented toward task reliability – implied that entire organization shapes reliability)

Levels of Causation	In-Fact (if A, then B) Probabilistic (If A, increased likelihood of B) Proximate (limits causal search) Root (extends causal search)
Temporal Contiguity	Factors closer in time to undesirable outcome will more likely be labeled as causal.
Spatial Contiguity	Factors or objects closer in space/location to the undesirable outcome will more likely be labeled as causal.
Perceptually Salient Stimuli	Perceptually salient stimuli (factor first drawing the attention of the observer) will more likely be labeled as causal.
Severity Effects	Big effects must have big causes.
Representative Causes	Inferring that the cause of similar historical events will be the cause of the event at hand.
Hedonic Relevance	Impact of error on investigator's interests. Greater the negative impact on the investigator's interests, the more likely the cause will involve culpable behavior.
Counterfactual Variations	Developing a description first of what should have been. Then, comparing actual events to the counterfactual to determine what is causal.
Mental Models	Investigative data being loaded into the investigator's pre-existing mental model of either the error or the erring employee. For example, if erring employee is thought of as conscientious, then investigator may be less inclined to find culpable behavior.
Personalism	Inference that erring employee's conduct was intended to harm investigator.
Covariation	Observed coincidence of two events, generally over multiple occurrences - coincidence infers causation.
Discounting and Augmenting	Relevance of one causal explanation being enhanced or discounted based upon presence of another causal explanation.

Self Perception	Inferring internal states from external or environmental factors. For example, inferring fatigue based upon remembering work schedule, rather than actually feeling fatigued.
Natural Stop Rules	Natural limits to investigative depth and breadth presumably developed through life experience.
Fundamental Attribution Error	Attributing another's behavior (error) to his disposition (e.g., he's a careless or lazy worker).
False Consensus	Tendency of erring employee to view his own behavior as typical of what others would do under the circumstances.
Self-Serving Bias	Taking credit for one's success, blaming others for one's failures.
Self-Centered Bias	Tendency to take a greater share of responsibility than is actual.
Locus of Control (two meanings)	A style issue: Externals believe that events are caused by external factors; Internals believe that events are under their own control. In the mishap investigative context, many investigators will identify as causal only conditions that are within their ability to change.
Investigative (Attributional) Styles	Tendency to make similar causal inferences across different event scenarios - can be based upon job function, education, and training as examples.
Linguistic Biases	Use of descriptors and sentence structure to augment the strength of a causal statement.
Rule Violation Bias	Identification of rule violation may impact causal determinations.

Each of these factors can be present within the investigative process. For example, consider the following hypothetical view of the Giles and Wilson event investigation discussed earlier. What follows are the specifics of how an event investigator, Fred, might go about his investigation.

> Fred is assigned to investigate Mr. Giles and Ms. Wilson's mishap. He is pressed for time because he has a regular job as a second shift foreman. *(investigator model)* Being a trained MEDA investigator, his boss told him to identify the contributing factors and recommend strategies to prevent the mishap in the future. *(human error model, investigative purpose)*

Fred interviewed both Mr. Giles and Ms. Wilson. Fred, being a second shift supervisor, found the cause of the mishap to be Mr. Giles failure to complete non-routine work performed on the first shift. *(perceptually salient stimuli, group self-serving bias, investigative style)* Fred's only explanation is that Mr. Giles became complacent toward compliance with the rules. *(representative causes)*

Fred had heard that Mr. Giles and Ms. Wilson had some kind of off-work association; however, Fred believed that what happens outside work is of no interest to a company mishap investigation. *(natural stop rule)* Additionally, Fred heard that Mr. Giles had said that he would leave it up to Ms. Wilson to figure out what to do. Nevertheless, it was to him only hearsay and he was not going to ask a technician on another shift about such statements. *(natural stop rule)*

Fred instructed Ms. Wilson to remember the leak check next time. Fred did not list it as causal on the investigation record because the mishap would not have occurred if Mr. Giles had given a good turnover report. *(discounting)*

Once this process has been completed, Fred would articulate what he believes to be the cause or contributing factors to this mishap. Should Fred be using MEDA, the final MEDA contributing factors list might have identified one contributing factor and the following description:

> √ *BOREDOM/COMPLACENCY: First shift technician did not record that additional clamps were loosened. Failure to follow general maintenance manual procedure.*

From what is known in the earlier full narrative, this mishap conclusion leaves much to be desired. Whether the investigator is completing a MEDA report or is merely briefing his management on the cause of an event – this explanation is unhelpful. It has taken the error identification one step further, yet it does not include many details of cause and effect relationships that might further enhance system safety.

2.10 APPENDIX B SURVEY INSTRUMENTS

October 18, 1998

Dear Aviation Colleague,

As you are likely aware, the US Federal Aviation Administration conducts maintenance human factors research in order to improve the safety of our aviation system.

I respectfully request your participation in one of these research projects intended to better understand our industry's process for developing causal explanations in response to human error events. That is, when a technician or manager makes an error, how do we investigate and what possible explanations exist for why the mishap occurred.

Enclosed are three surveys that will take approximately 30 minutes to complete. Each contains a short narrative of a mishap and three questions pertaining to WHY the mishap occurred.

Once you have read the first scenario (I recommend reading it twice), go to the second page and describe why you think the mishap occurred. Your task is NOT to determine which is easiest to fix or to decide who is to be blamed. Rather,

Your task is to simply judge WHY these particular mishaps have occurred.

Once you have completed the survey, please return the survey to me in the enclosed self-addressed envelope.

On behalf of the maintenance human factors research program, I thank you in advance for your participation.

Sincerely,

David Marx
Systems Safety Consultant
David Marx Consulting
W5440 Elkhorn Drive
Elkhorn, Wisconsin 53121
Tel: (414) 742-4874
Fax: (414) 742-4875
E-mail: davidmarx@davidmarx.com

Demographic Data

Name _____

Title _____

Organization _____

Telephone number _____

Years in Industry _____

Have you been through any Human Factors or Crew Resource Management Training? _____

Have you been trained as a human error investigator? _____
(Yes or No)

If so, on what error investigation system? _____

Are you an active error investigator? _____
(Yes or No)

If so, approximately how many human error investigations have you conducted? _____

Note: All data will be de-identified as to the person and the air carrier. Your name is requested in case any follow-up is needed. Please note that your data cannot be used unless the information above is provided.

Denver Ground Damage - Scenario A1

On December 22, 1997, an A-300 aircraft was inadvertently towed into Gate C14's jetway at Denver International Airport.

The aircraft was out of service for 14 hours and the repair to the wing cost $28,000 dollars.

Just before the mishap occurred, Ground Agent Smith was working on an airplane at gate C18. Ground Agent Smith had just spent 5 minutes unsuccessfully trying to start a tug at gate C18. At that point Supervisor Baker told Ground Agent Smith that a tug was available at gate C22. Ground Agent Smith ran over to gate C22 and found the tug running. He jumped in and backed up the tug toward the terminal. Unfortunately, the tug had been hooked to the aircraft by a ground agent at gate C22. When Ground Agent Smith pulled away, he took the aircraft with him about four feet before the wing hit the jetway.

The investigation found that the airline was having financial troubles and tug repair and maintenance had been deferred on much of the ground equipment. As a result, many of the tugs had trouble starting on extremely cold days; hence, Ground Agent Smith was delayed and had to rush to another gate to borrow a tug.

It was found that the airline's financial troubles resulted from a marketing error when the marketing department decided last summer to focus on discount holiday travelers at the expense of higher profit business travelers. Because of the financial troubles, preventative maintenance was reduced on the tugs.

Ground Agent Smith said that he would normally have checked to see that the tug was connected, however, he was extremely fatigued after working 14 hours straight and volunteered that he had been careless.

At the end of Ground Agent Smith's regular shift, Supervisor Baker approached Ground Agent aSmith and asked if he would be willing to work a second shift. Supervisor Baker had just come on herself and found that she was short two ground agents. Ground Agent Smith told Supervisor Baker that he did not believe that working a second shift was a good idea because he did not sleep well the night before. Supervisor Baker nonetheless encouraged Ground Agent Smith to work the extra shift.

Because of a rash of fatigue-related mishaps at this carrier, all Supervisors were once required to go through specific training on the detrimental effects of fatigue. However, Supervisor Baker was a new supervisor and because of budget cuts, Ground Operations Executive Brown decided to suspend all safety training. Had Supervisor Baker been trained, she would likely have asked Ground Agent Smith to go home after his first shift.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Denver Ground Damage - Scenario A2

On December 22, 1997, an A-300 aircraft was inadvertently towed into Gate C14's jetway at Denver International Airport.

The aircraft was out of service for 14 hours and the repair to the wing cost $28,000 dollars.

Just before the mishap occurred, Ground Agent Smith was working on an airplane at gate C18. Ground Agent Smith had just spent 5 minutes unsuccessfully trying to start a tug at gate C18. At that point Supervisor Baker told Ground Agent Smith that a tug was available at gate C22. Ground Agent Smith ran over to gate C22 and found the tug running. He jumped in and backed up the tug toward the terminal. Unfortunately, the tug had been hooked to the aircraft by a ground agent at gate C22. When Ground Agent Smith pulled away, he took the aircraft with him about four feet before the wing hit the jetway.

The investigation found that the airline was having financial troubles and tug repair and maintenance had been deferred on much of the ground equipment. As a result, many of the tugs had trouble starting on extremely cold days; hence, Ground Agent Smith was delayed and had to rush to another gate to borrow a tug.

It was found that the airline's financial troubles resulted from a marketing error when the marketing department decided last summer to focus on discount holiday travelers at the expense of higher profit business travelers. Because of the irresponsible actions of the marketing department, preventative maintenance was reduced on the tugs.

Ground Agent Smith said that he would normally have checked to see that the tug was connected, however, he was extremely fatigued after working 14 hours straight.

At the end of Ground Agent Smith's regular shift, Supervisor Baker approached Ground Agent Smith and asked if he would be willing to work a second shift. Supervisor Baker had just come on herself and found that she was short two ground agents. Ground Agent Smith told Supervisor Baker that he did not believe that working a second shift was a good idea because he did not sleep well the night before. Supervisor Baker nonetheless carelessly pressured Ground Agent Smith to work the extra shift.

Because of a rash of fatigue-related mishaps at this carrier, all Supervisors were once required to go through specific training on the detrimental effects of fatigue. However, Supervisor Baker was a new supervisor and because of budget cuts, Ground Operations Executive Brown decided to suspend all safety training. Had Supervisor Baker been trained, she would likely have asked Ground Agent Smith to go home after his first shift.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Phoenix Depressurization - Scenario B1

In April 3, 1998, a 757 had to turn back to Phoenix Sky Harbor Airport because it was unable to fully pressurize the cabin. It was found that two bleed air duct clamps were not tightened during previous maintenance, allowing pressurized air to escape into the engine compartment.

The outbound flight was delayed 8 hours because of the air turnback and the subsequent rework.

Technicians Giles and Wilson were the maintenance technicians involved in the prior maintenance at Sky Harbor. Technician Giles works first shift and Technician Wilson works second shift. Earlier in the day, Technician Giles was asked to troubleshoot a pressurization fault on the inbound flight into Phoenix. Technician Giles isolated the fault to a bleed air valve on the left engine. Following the maintenance manual, Technician Giles began to remove the bleed air valve. Technician Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the duct assembly. As the work was not complete at the end of his shift, the task was turned over to Technician Wilson who completed the work, although without tightening the two loosened clamps.

Investigation revealed that the aircraft maintenance manual did not reflect that removal of the two added clamps would significantly ease disassembly of the valve installation.

Because of the larger bleed air valve installed on the engine as a post-delivery modification, Technician Giles has to loosen the two additional clamps.

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. Although the deviation is a violation of Federal Aviation Regulations, management felt there would be no harm.

When it came to the shift turnover to Technician Wilson, Technician Giles simply forgot to inform Technician Wilson of the added disassembly.

Not knowing of the two added clamps being loosened, Technician Wilson dispatched the aircraft with the clamps still loose.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a "root" cause to this mishap? If so, what is it?

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Phoenix Depressurization - Scenario B2

On April 3, 1998, a 757 had to turn back to Phoenix Sky Harbor Airport because it was unable to fully pressurize the cabin. It was found that two bleed air duct clamps were not tightened during previous maintenance, allowing the pressurized air to escape into the engine compartment.

The outbound flight was delayed 8 hours because of the air turnback and the subsequent rework.

Technicians Giles and Wilson were the maintenance technicians involved in the prior maintenance at Sky Harbor. Technician Giles works first shift and Technician Wilson works second shift. Earlier in the day, Technician Giles was asked to troubleshoot a pressurization fault on the inbound flight into Phoenix. Technician Giles isolated the fault to a bleed air valve on the left engine. Following the maintenance manual, Technician Giles began to remove the bleed air valve. Technician Giles found the valve difficult to remove, so he loosened two additional bleed air duct clamps to add flexibility to the duct assembly. As the work was not complete at the end of his shift, the task was turned over to Technician Wilson who completed the work, although without tightening the two loosened clamps.

Investigation revealed that the aircraft maintenance manual did not reflect that removal of the two added clamps would significantly ease disassembly of the valve installation.

Because of the larger bleed air valve installed on the engine as a post-delivery modification, Technician Giles has to loosen the two additional clamps.

Although the proper course was to prepare a non-routine work order documenting the added removal, line maintenance technicians were encouraged to deviate from the manual instructions to get the job done. As long as the added work was remembered, management felt there would be no harm in the deviation.

When it came to the shift turnover to Technician Wilson, Technician Giles simply forgot to inform Technician Wilson of the added disassembly.

Not knowing of the two added clamps being loosened, Technician Wilson dispatched the aircraft with the clamps still loose. In doing so, Technician Wilson violated company standards of conduct and Federal Aviation Regulations that prohibit a technician from dispatching an aircraft in an unairworthy condition.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Chicago Oil Loss - Scenario C1

On February 12, 1998 a 767 aircraft departed Chicago O'Hare destined for London's Heathrow Airport. Approximately 30 minutes into the flight, the right engine indicated low oil level. The aircraft declared an emergency and diverted to Detroit International Airport. Upon inspection in Detroit, technicians found that the right engine oil filler panel was left open, the oil cap was off, and oil residue coated the inside of the engine cowl.

The aircraft was out of service for 3 hours to clean up the mess.

In Chicago, Technician Swimmer was the only technician involved in the mishap. As the result of an aircraft swap at the last minute, Technician Swimmer was asked by Supervisor Jones to top off the oil on both engines and record the amount of oil added to both engines. Having added oil to both engines, Technician Swimmer ran up to the flightdeck to record the oil added, and then ran back down to the engines to install the oil caps and close the oil panels. When he arrived back on the tarmac, he installed the oil filler cap on the left engine but did not install the cap on the right engine.

Upon filling both engines with oil, Technician Swimmer was concerned that he would forget how much oil he had added to both engines. Because he had forgot his pen, the only way to write them down was to run up the flightdeck, borrow a pen from the captain, and make the entries directly into the log.

As Technician Swimmer was leaving the flightdeck, he received a call from his wife on his personal cellular telephone. She had just been arrested for driving under the influence of alcohol and was required per state law to spend the night in jail. Technician Swimmer's wife asked that he leave work as soon as possible to come get his children who were also at the police station.

Technician Swimmer knew his wife had a drinking problem. Being a relatively passive person, Technician Swimmer chose not to actively address the problem, hoping it would somehow go away.

Once he had got the call from his wife, Technician Swimmer told Supervisor Jones that he was distraught and would have to leave soon. Had Supervisor Jones recognized Technician Swimmer's distress, she might have prevented the mishap by assisting Technician Swimmer with the task.

There was a service bulletin available to error-proof the engine oil cap. The service bulleting allowed air carriers to modify their aircraft to add a check valve on the oil filler stem. The check valve acts to prevent flow out of the oil filler stem when the cap is not installed. While the air carrier was aware of the fix, it had chosen not to implement the bulletin because it was not cost effective.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

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The second most influential contributor to his mishap:

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The third most influential contributor to this mishap:

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Is there a “root” cause to this mishap? If so, what is it?

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Chicago Oil Loss - Scenario C2

On February 12, 1998 a 767 aircraft departed Chicago O'Hare destined for London's Heathrow Airport. Approximately 30 minutes into the flight, the right engine fire warning annunciated. The aircraft declared an emergency and diverted to Detroit International Airport. Upon inspection in Detroit, technicians found that the right engine oil filler panel was left open, the oil cap was off, and oil residue coated the inside of the engine cowl.

The aircraft was out of service for 3 hours to clean up the mess.

In Chicago, Technician Swimmer was the only technician involved in the mishap. As the result of an aircraft swap at the last minute, Technician Swimmer was asked by Supervisor Jones to top off the oil on both engines and record the amount of oil added to both engines. Having added oil to both engines, Technician Swimmer ran up to the flightdeck to record the oil added, and then ran back down to the engines to install the oil caps and close the oil panels. When he arrived back on the tarmac, he installed the oil filler cap on the left engine but did not install the cap on the right engine.

Upon filling both engines with oil, Technician Swimmer was concerned that he would forget how much oil he had added to both engines. Because he had forgot his pen, the only way to write them down was to run up the flightdeck, borrow a pen from the captain, and make the entries directly into the log.

As Technician Swimmer was leaving the flightdeck, he received a call from his wife on his personal cellular telephone. She had just been arrested for driving under the influence of alcohol and was required per state law to spend the night in jail. Technician Swimmer's wife asked that he leave work as soon as possible to come get his children who were also at the police station.

Technician Swimmer knew his wife had a drinking problem. Being a relatively passive person, Technician Swimmer chose not to actively address the problem, hoping it would somehow go away.

Once he had got the call from his wife, Technician Swimmer told Supervisor Jones that he was distraught and would have to leave soon. Had Supervisor Jones recognized Technician Swimmer's distress, she might have prevented the mishap by assisting Technician Swimmer with the task.

Because of a history of oil cap-related errors, the Federal Aviation Administration has issued an Airworthiness Directive requiring air carriers to modify their aircraft to add a check valve on the oil filler stem. The check valve acts to prevent flow out of the oil filler stem when the cap is not installed. In error and in violation of the Airworthiness Directive, the air carrier inadvertently failed to make the modification to the subject aircraft.

As stated in the introduction, you have been asked to determine the cause of this particular mishap. Do not worry about who is to blame or whether the cause is easily addressed.

Your job is only to determine WHY this particular mishap occurred.

In the space provided below, please identify what you believe was the single most dominant contributor to this mishap, and what you believe were the next two most influential contributors to this mishap.

The single most dominant contributor this mishap:

_____

_____

The second most influential contributor to his mishap:

_____

_____

The third most influential contributor to this mishap:

_____

_____

Is there a “root” cause to this mishap? If so, what is it?

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