WHY'D THEY DO THAT?
ANALYZING PILOT MINDSET IN ACCIDENTS AND INCIDENTS

Ed Wischmeyer, Ph.D., ATP/CFII
Prescott, AZ

In teaching a series of classes that analyzed "classical" airline accidents, it was observed that human behavior in such accidents was often understood better when the "mindset" of the protagonists was studied explicitly, rather than implicitly, and that the time element was also useful in such analyses. Occasionally, mild obsessions and task completion errors were observed. These observations started a series of iterations that eventually converged on the PEEMBO model (Predispositions, Environment, Events, Mindset and mental condition, Behaviors, and missed Opportunities.) None of the human error models (e.g., Reason, SHEL) are universally applicable, but the PEEMBO model now appears mature enough for routine use in accident and perhaps other analyses.

Summary

In teaching an introductory graduate level class which addressed "classical" airline accidents, it became apparent that a direct, rather than indirect, focus on flight crew "mindset" provided an extremely useful analysis perspective complementary to existing analysis models. This observation co-evolved with the PEEMBO (pronounced pim-bo) model, whose elements are Predispositions, Environment, Events, Mindset, Behavior, and missed Opportunities. Initial analyses of both NTSB accident reports and ASRS anecdotal reports indicate high value to this approach and model.

The central hypothesis of this note is that there is a significant class of airline accidents where pilot mindset is the central, identifiable, and addressable contributor to the accident. An example of mindset is this classic quote:

> *"When anyone asks how I can best describe my experience in nearly 40 years at sea, I merely say, uneventful. Of course there have been winter gales, and storms and fog the like, but in all my experience, I have never been in any accident of any sort worth speaking about. I never saw a wreck and never have been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort". Edward J. Smith, Captain, RMS Titanic.*

The PEEMBO model was evolved to support analysis of accidents that have a large human error component, such as airline accidents. Key elements of such accidents include:

- The accident is caused by the conjunction of multiple factors
- The accident sequence usually progresses over a non-instantaneous time frame, with strong correlation over time between many observed phenomena
- One or, more usually, many of the observed phenomena are best described by human factors
- Actions and decisions of the flight crew are driven by the mindset (motivations and beliefs) of the crew, and occasionally by mild obsessions in task performance.
- The failure to employ available "defenses"[1] often appears to be a clear consequence of mindset. If the flight crew believes their goal is achievable, there is no reason to abandon that goal by employing a defense.

The perceived advantages of the PEEMBO model include:

- Puts focus on influences on the protagonist (e.g., the flight crew), not on a "probable cause."
- Focus on the mindset of the protagonist. This mindset may not be considered an actual "cause," but the protagonist's mindset may provide motivation for a variety of decisions made, actions taken, and defenses bypassed.
- Recognition of the time element in such accidents, where the relationship between significant phenomena may be described by vehicle dynamics or logical consequences.[2]
- Recognition of individual events as significant in the progression of the accident. Events have a specific time or a short time range associated with them, as opposed to environment, which is applicable over the entire event timeline.
- Differentiation between those factors under the control of the protagonist and those not

This paper describes the PEEMBO model, gives examples, and is compared to the other accident analysis models.

---

[1] Reason, James.

[2] Leveson has a good discussion on "chains of (time ordered) events."

Evolution of PEEMBO

Determination of "probable cause" has been a goal of accident investigation at least since the founding of the National Transportation Safety Board. Presumably, the focus on probable cause is to identify specific factors and thus to permit the initiation of remedial action. Thus, other analyses that similarly permit the initiation of remedial action will ultimately achieve the same goal, even without the explicit focus on "probable cause."

Traditional accident analysis classes frequently uses the SHELL model and Reason's model as ways of identifying such remediable factors. However, the combination of these two was often observed to be weak in describing the time sequence of events in an accident chain; the immediate mindset of the protagonist; the occurrence of significant chance events; and the degree of contribution of various elements. Leveson's STAMP model provides another excellent means of analysis, but is weak in accommodating variations in human motivation.

Similarly, the *information-decision-action* model of Nagel ignores "the possibility of… inappropriate high level goals." [3] The PEEMBO model would express some its analogous concepts as *inputs-mindset-behaviors*, hypothesizing that the information processing included in the first stage of Nagel's model is very heavily influenced by the mindset of the crew. Indeed, Nagel quotes Monan (1986): "Pilots heard what they expected to hear, heard what they wanted to hear and frequently did not hear what they did not anticipate hearing – amendments to just-issued clearances." To rephrase this, "pilots remolded what they heard to be consistent with their mindset," or to expand this further, "pilots remold their perceptions, decisions, and actions to be consistent with their mindset."

Similar to the PEEMBO model, but not part of its evolutionary chain, is the 5-M model by T.P. Wright of Cornell University: originally man-machine-medium, mission and then management were added.

The basic PEEMBO model is shown in Figure 1, with only the major relationships between blocks shown.

Elements of the PEEMBO model

Predispositions are those pre-existing, repeatable factors that shape the way that the protagonist thinks about and reacts to the operating environment and events. Predispositions share the characteristic that they will be repeatedly observable in the protagonist over a period of months and years, across multiple situations and events.

[3] Wiener and Nagel, Chapter 9

Safety training, such as windshear avoidance training, CRM training, and runway incursion awareness training, are well known examples of attempts to reshape a pilot's predispositions to:

- have a mindset that dangerous conditions may be present
- perform behaviors to detect any dangers and to resolve them
- not miss opportunities to employ defenses

Predispositions include self-image, the way the protagonist wishes to be perceived by others,[4] training, experience, policy, procedures, skills, confidence, values, beliefs, personality style, techniques in executing procedures (whether formally sanctioned and taught or learned ad hoc), and interpersonal communication style.

Training and self-improvement are common techniques used to improve an individual's predispositions. However, in the course of a single event, an individual will have no control over his predispositions.

"*Environment*" refers to the operating environment for this particular event, particularly as it affects the style of human operation and the probability of various events. Examples of environment include night, windy, runways in use, thunderstorm, traffic level, competence of various individuals, capabilities of the aircraft, capabilities of other hardware, being late, equipment installed on the ground or in the air, equipment not operational on the ground or in the air, and many other factors.

The protagonist will have little control over the environment. Usually, the one choice available is to leave the environment. For example, an airline crew may choose not to land at some airport, leave the environment of that airport, and go elsewhere. Less commonly, a protagonist may attempt to reshape the environment by requesting that additional equipment be activated, or by requesting that some other individual improve their performance (e.g., to "shape up!")

[4] Associate Dean Mike Polay, Embry-Riddle Aeronautical University, Prescott, AZ, personal conversation

The environment can influence mindset. Recognition of a hazardous environment can induce a cautious mindset, or schedule pressures can induce a risk-tolerant mindset. Similarly, a high workload environment can induce a mindset of excessive focus on the task at hand, with errors being a result. Similarly, such a high workload environment can increase the odds that opportunities are missed.

Events are occurrences external to the protagonist, beyond his control, that occur during the time frame of the event. Events can be considered in two ways:

- Events would commonly be thought to include lightning strikes, wind shear, mechanical failures, radio transmissions, an aircraft on the runway, and other chance events that occur within the environment being considered.
- Events are also changes in the environment. For example, a change in which runway is active is appropriately considered an event.

The likelihood of events is predictable from the environment, but not the occurrence of a specific event at a specific time. For example, the presence of a severe thunderstorm will increase the likelihood of lightning, rain, gusty winds, and wind shear, but will not determine when each lightning stroke will occur. Similarly, an environment of high radio traffic will increase the likelihood of a transmission being blocked.

Note that only the likelihood of events can be predicted, not a particular occurrence. For example, gusty winds can be predicted, but not the specifics of any one encounter with a gust. Thus, events provide a way for "chance events" to be incorporated into the error model. Events cannot be controlled, only reacted to.

A point implied by the PEEMBO model is that the protagonist will be susceptible to chance events. The protagonist will be prepared for these chance events by training, equipment, experience, and perhaps warning systems, but those preparations frequently will be designed to reduce susceptibility to chance events, not to handle all chance events nor to avoid all chance events.

"External" implies that the PEEMBO model is contextual, and considers the context of the protagonist(s) as "the" context.

Mindset / Mental Condition In many accidents, the mindset of the protagonist is the central factor in the accident, and the decisions and actions taken, and the opportunities missed, are manifestations of this mindset. Thus, Mindset is central to the PEEMBO model.

Mindset includes the attitudes, motivations, expectations, knowledge, feelings, plans, goals, and self-image of the protagonist in this situation. Examples of mindset are, "I can do this," "I have to do this," or "I'd better not do anything until I figure this all out."

An alternative expansion of the "M" in PEEMBO is "mental condition." The protagonist's mental condition can be strongly influenced by factors such as the perceived or anticipated degree of difficulty of the flight; complacency or apprehension; anticipated competency of others; impatience; expected environment; physiological stresses of all sorts; psychological stresses of all sorts; and knowledge of conditions, including observations of other flights & environment. Similarly, skills and competence are components of mental condition.

"Mental condition" seems a more complete, more clear, and more useful analysis tool than "mindset." However, many accident scenarios indicate that pilot mindset, unfortunately adopted and never challenged, is a major factor in many accidents.

Although predispositions are presumed to be relatively consistent over a period of weeks or months, the mindset of the protagonist is considered within the context of each accident occurrence. Thus, mindset will not necessarily be repeatable from event to event.

Just as the protagonist will have no control over predispositions and events, and at most limited control over the environment, the protagonist may have little if any control over his mindset.

Explicit examples of mindset are not hard to find. In the Cali accident, at time 2136:38, the First Officer expressed mindset by saying, "We can do it." Similarly, in the Burbank accident, there is a strong implied mindset, "we can do this." Although this is speculative, one wonders at what point "we can do this" transforms into the dangerous mindset, "we have to do this."

In a set of 10 NASA ASRS reports on unstable approaches,[5] mindset statements included:

1. "We'll be all right." (ASRS 458452)
2. "Enough is enough." (ASRS 450568)

[5] Selected by graduate student Mukul Mishra for a class on flight safety

3. "I do not like the looks of this" and "Let's see how it is at 1000 feet" (ASRS 144766)
4. "[I said] we could make it." Later, the captain did in fact go around, indicating a more safety conscious mindset of, "we can make it, if…" (ASRS 253786)
5. "[he said] he could still do it." (ASRS 302878)
6. "Try to save an approach visually." (ASRS 521341)
7. "He tended to want to 'fly solo.'" (ASRS 305526)

Although no detailed study of mindset in ASRS approaches has been conducted, it is impressive to see such clear statements of mindset in such a high proportion of reports.

Leveson states "explanations for human goals and motives will depend on assumptions that cannot be *directly* [emphasis hers] measured or observed by the accident investigator." ASRS reports indicate that mindset information is available, if not in accidents per se, at least in anecdotal voluntary submissions.

Personal conversations with pilots from an airline with a strong FOQA program conveyed another mindset. One pilot told me that when an approach may be exceeding allowable limits, he asks himself if completing the approach will be worth having to make explanations to the FOQA monitoring committee on why he did what he did.

One valuable source of mindset is the phrasing and tone of speech. Such phrasing and tone is not available in printed CVR transcripts, and the unavailability of such information is not consistent with national safety goals. There seem to be multiple ways of providing such valuable phrasing and tone information while meeting traditional privacy goals.

Behavior refers to both the decisions and actions of the protagonist.

During the course of an accident progression, the protagonist may make a number of decisions. These decisions may result in a deliberate action at either an abstract level (e.g., starting an approach) or at a lower level (e.g., calling for the landing gear to be lowered.) Decisions may result in a set of actions to be undertaken, such as performing a checklist. Thus, decisions and actions are modeled in PEEMBO as closely linked, and are thus grouped into "behavior."

A property of "behaviors" in the PEEMBO sense is that a time, or a start time before a relatively short time interval, is associated with each behavior.

Not all actions will be the result of conscious decision, however. For example, a skilled pilot will perform may perform tracking tasks without conscious deliberation of each correction.

As actions are taken, those actions affect the state of the aircraft in the control theoretic sense. The state of the aircraft is best described as part of the environment, so behavior feeds back into the environment, then through the mindset, and back to behavior. This loops nicely models relationships between behaviors and subsequent behaviors.

Reason's error model of slip, lapse, violation, and mistake is split in the PEEMBO model: slip, violation, and mistake are considered behaviors, and a lapse is considered a missed opportunity, described below.

Missed opportunities are actions that the protagonist could have been taken to reduce risk or severity but did not. Missed opportunities also include decisions that were not made, said decisions establishing the framework for the actions not taken. Missed opportunities in the context of incidents and accidents may be defenses not employed in Reason's model.

Examples of missed opportunities include going around; proceeding to the alternate; being more clear in communications; and asking for clarification of communications from others.

It seems clear that a flight crew will not employ defenses when they believe that the flight can be safely concluded. An interesting hypothesis is that the crew's mindset causes them to ignore cues and misinterpret events, as hinted at by Monan (1986), as mentioned above.

Missed opportunities are most interesting when they could have prevented the accident, but missed opportunities may be mitigating as well. Missed opportunities may or may not be associated with a specific point in time, and may or may not be repeatable. Useful classifications of missed opportunities include:

- Preventing – taking this course of action or making this decision would have prevented the accident
- Supporting – although this course of action not taken would not have prevented the accident, it supports observations about the mindset of the flight crew.

Causality

In our society, we tend to look for direct causes of accidents. Certainly this phenomenon is observable in the press, sometimes in politicians, sometimes in legal proceedings, and sometimes in the military. Indeed, the idea that retribution will re-establish the world order is traceable at least as far back as Shakespearean times.

Particularly in aviation accidents, such direct causality is rare. More common, and more difficult to analyze are events in which improper motivation(s) were the "direct cause." For such psychological phenomena, it seems more appropriate to use terms that reflect such motivations than to use terms of formal logic.

In the PEEMBO model, the following non-exclusive terms are used to describe the causality of a phenomenon contributing to an accident:

- Necessary – if this one phenomenon were not present, the accident would not have occurred, even if all other phenomena were still present.
- Sufficient – this phenomenon would cause the accident all by itself, even if all other factors were absent. Sufficient phenomena are rare in aviation, with the most common occurrences being irrecoverable mechanical problems.
- Continuing – this phenomenon is a direct consequence of a previous behavior (action or decision). Because it is a consequence, it adds little if anything to the discussion of "causality." For example, high airspeed on final approach following a late descent is not considered an independent phenomenon, but is considered to be a continuation of the late descent.
- Irrelevant – this phenomenon has nothing to do with the causality of the accident. It is worth noting that phenomena may be irrelevant because they had nothing to do with the accident, or because the model has no way to handle that phenomenon. Most accident analysis models will not be able to properly accommodate all phenomena of an accident, so within the context of each accident analysis model, some factors will be irrelevant.
- Motivating – explains why the crew made the choices they did. Such motivations would include corporate culture, schedule pressure, and how each crew member wanted to be perceived by others.
- Contributing – while this phenomenon was neither necessary nor sufficient, it contributed to the evolution of the scenario being studied, particularly to the severity of the scenario or to the difficulty in returning to a more normal state of operation. Speculation is that many contributing factors may be motivating factors.
- Supporting – gives useful insight into the environment or the crew's mindset, although it had nothing to do with the accident causality in a strict sense. Thus, a supporting factor cannot be necessary. For example, in the case of a runway overrun accident, an ignored GPWS warning on short final might provide insights on the mindset and mental condition of the crew but, strictly speaking, would be irrelevant to a taxi error made once off the runway. (This is similar to the epidemiological concept of "confounding.")

Temporal Analysis

The PEEMBO model not only groups factors by control and influence, but by time. There are three time spans shared between the six boxes:

- Observed consistently before and during the scenario – Predispositions only
- Observed during the course of the scenario, but may change at specific times – Mindset / mental condition, and Environment
- Observed at specific points in time during the course of the scenario – Events, Behaviors, and Missed Opportunities

These time spans help clarify in which boxes specific observed phenomena should be grouped.

Conclusions

A direct focus on pilot mindset, as embodied in the PEEMBO model, has been shown in the classroom to be a valuable tool for analyzing airline accidents and events. A preliminary review of ASRS events suggests that mindset is an identifiable, addressable, and significant contributor to unstable approach events.

Acknowledgements

The PEEMBO model was developed to support a Special Projects course in Flight Safety taught in the Master of Science in Safety Science program at Embry-Riddle Aeronautical University, Prescott, AZ. Student feedback, especially from the second year, has greatly improved this work.

References

Bruseberg, A and Johnson, P (2003) "Understanding human error in context: approaches to support interaction design using air accident reports." In: Jensen R (ed.): *Proceedings of the 12th International Symposium on Aviation Psychology*, 14-17 April 2003, Dayton, Ohio, USA, pp 166-171. (http://www.cs.bath.ac.uk/~anneb/humanErr.pdf)

Leveson, N. (2001). *Evaluating Accident Models Using Recent Aerospace Accidents*: NASA Internal Study, avail. http://sunnyday.mit.edu/accidents.

Monan, W. P. (1986) *Addressee problems in ATC communications: The call sign problem*. NASA Contractor Report 166462. Moffett Field, CA: NASA-Ames Research Center.

Reason, James. Human Error. Cambridge University Press, 1990.

Tillyard, Eustace M. Elizabethan World Picture, Vintage/Ebury (A Division of Random House Group), 1975

Wiener, Earl L., and Nagel, David C. Human Factors in Aviation, Academic Press, Inc. 1988. San Diego, etc.

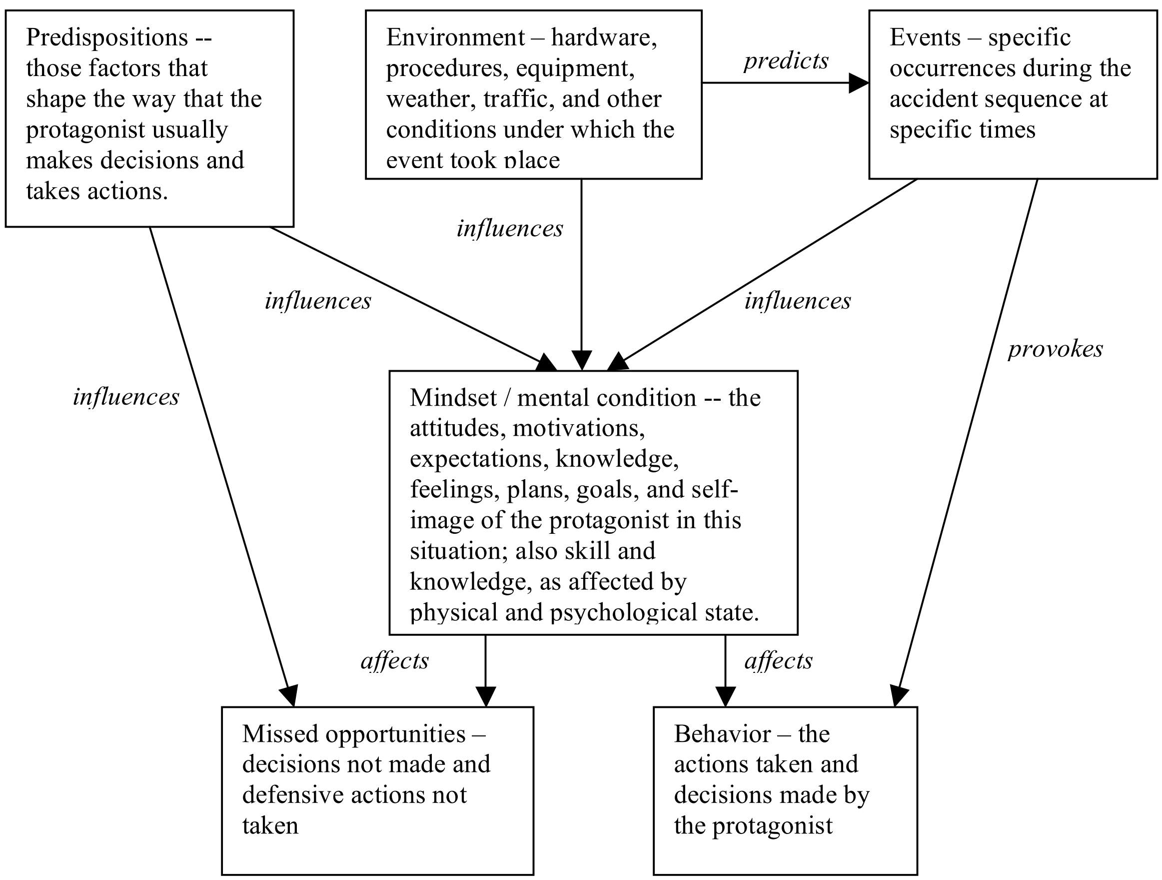

Figure 1. Elements of the PEEMBO model