The Human Factors Funnel Model (HFFM): Another Window on Error Causation

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Abstract

Over the last few decades there has been a noticeable shift in the error causation paradigm. Not long ago blame was typically relegated to the person who committed the "active error." Over the years, however, there has been a shift to the organization itself as being complicit in the active errors that individuals commit. While acknowledging that the propagation of errors can certainly begin with the upper levels of the organization, it appears that the pendulum may now have swung too far in that direction. The author proposes the Human Factors Funnel Model (HFFM) in an effort to balance this disparity. The HFFM's conceptual framework is introduced and its component parts are elucidated in detail. It is hoped that the HFFM will be used by academia and practitioners alike for another window on error causation.

Keywords: human factors funnel model, HFFM, human error, human factors

The Human Factors Funnel Model (HFFM): Another Window on Error Causation

The Human Factors Funnel Model (HFFM) is a new conceptual framework that can be used in various settings with the utility of both proactive and reactive applications. In its broadest concept, the HFFM is analogous to how a funnel works. The opening is fairly wide which depicts the Atmosphere (organization). As the funnel tapers down there are various individual factors that mix together. The combined influences of the Atmosphere and individual factors then flow down to Outcomes (or what pours out the bottom). The outcomes are color coded in red and green. Red indicates unsuccessful outcomes while green indicates successful outcomes. The HFFM conceptual model is depicted in Figure 1 which is followed by an elucidation of its component parts.

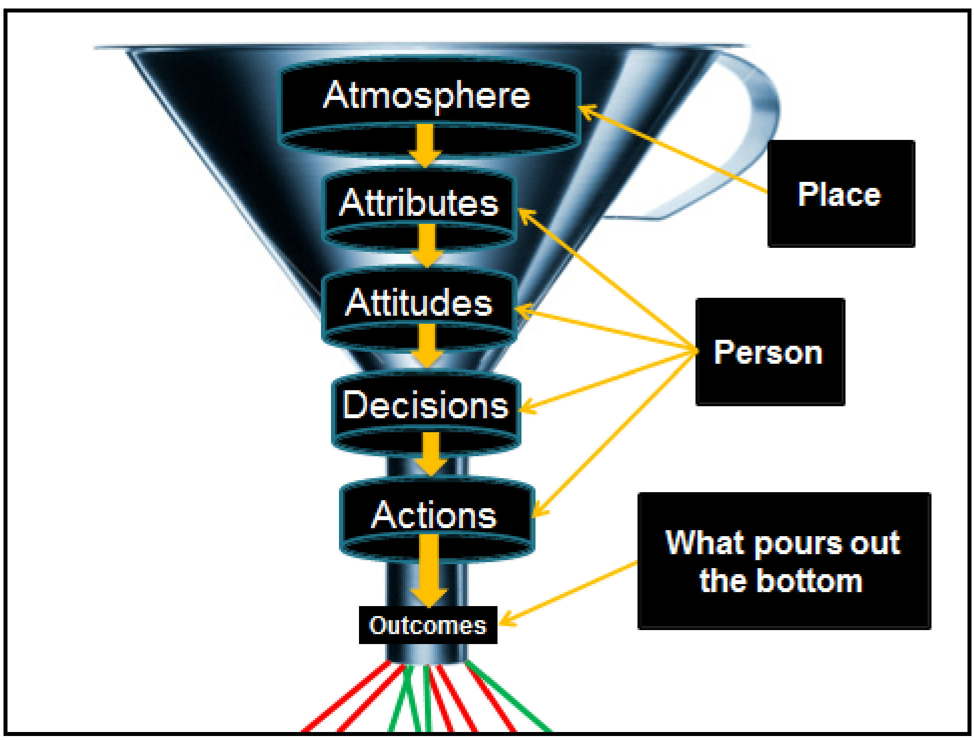


Figure 1. The Human Factors Funnel Model. ©2011 Robert I. Baron.

The Atmosphere (or organization) is at the top of the funnel. This location makes sense in that the organization, and corresponding culture, has an overarching effect on the rest of the funnel elements. The organizational culture can, and will, affect the overall performance of employees by setting the precedents of behavior. For example, if the organization has a poor safety culture and managers are modeling inappropriate behaviors then invariably some of these behaviors will wear off on lower-level employees. In fact, some of the most dangerous company-wide negative norms may be propagated by the highest levels of the organization (Baron, 2009).

Ajzen's (1988, 1991) theory of planned behavior (TPB) provides a good fit to this concept. TPB suggests that “intentions to perform behaviors of different kinds can be predicted with high accuracy from attitudes toward the behavior, subjective norms, and perceived behavioral control; and these intentions, together with perceptions of behavioral control, account for considerable variance in actual behavior” (Ajzen, 1991, p. 179). Unlike other theories that have low empirical relations between attitudes and prediction of behavior (e.g., dispositional predictions; Wicker, 1969), TPB has been found to be well supported by empirical evidence (Ajzen, 1991, p. 185). Figure 2 shows the TPB model using an example from the aircraft maintenance domain. In this case an aircraft maintenance technician (AMT) chooses not to use safety goggles. The antecedents that affect the AMTs decision are his or her Intentions and Subjective Norms. It is at the Subjective Norms level where negative transfer occurs. Also notice that Attitudes, which are included in the HFFM, appear in the TPB framework as well.

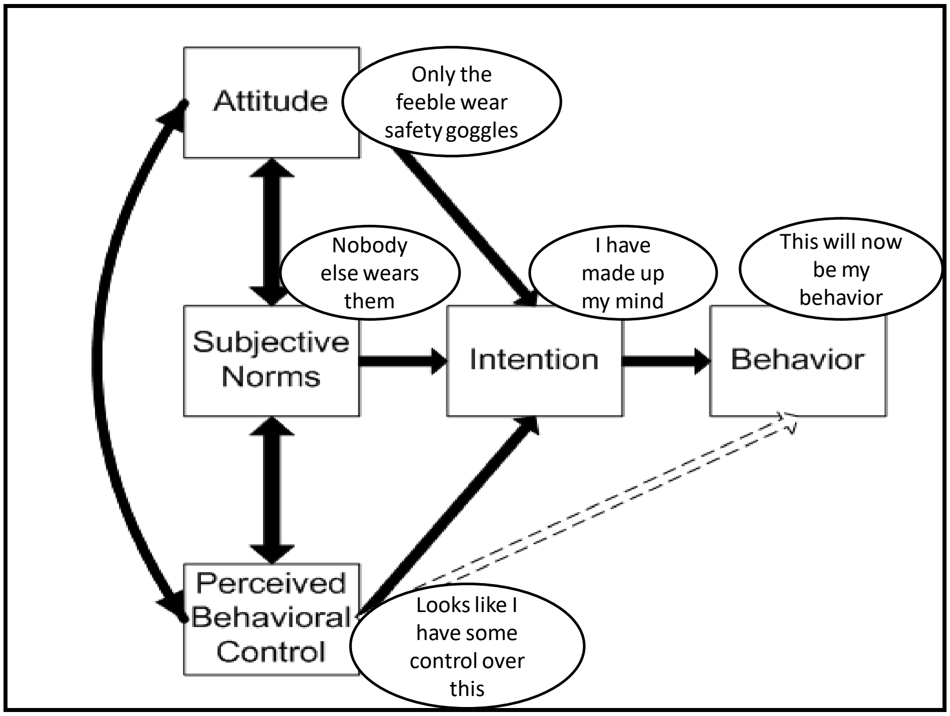


Figure 2. The Theory of Planned Behavior with Example (Adapted from Ajzen, 1991).

Invariably, perturbations in the organizational culture can filter down to the front-line employees. Latent conditions at the organizational level, which may lie dormant for lengthy periods of time, can be triggered by employees at the "sharp end." However, it should be noted that the highest performance organizational cultures with the best policies and procedures still cannot fully protect against the innate, and sometimes very dynamic, characteristics of individual performance. Individual performance, which can mix with, and be influenced by, the organization, is discussed next.

Attributes can best be described as the innate qualities a person possesses as part of his or her personality. Attributes are more or less ingrained in a person and resistant to change. Typically, when describing someone, we use one or more adjectives to sum up a person's attributes. While there are numerous adjectives to describe someone's attributes, here are just a few examples:

- Dependability (are they dependable?)
- Aggressiveness (are they aggressive?)
- Control needs (do they have a need to be in control?)
- Fairness (are they fair?)
- Leadership (do they act as leaders?)
- Egocentrism (are they egotistical?)
- Team spirit (do they work well with others?)

These types of attributes can have a significant impact on individual and/or team performance. For instance, if a maintenance shift supervisor is deficient in leadership skills there may a lack of direction for the line mechanics which in turn can lead to errors and omissions. Or, in flight operations, a Captain with excessive control needs may have a hard time delegating tasks to the First Officer.

Attributes may be difficult to screen for in the pre-employment process. While there are many tests that can identify various dimensions of a person's personality it is still very difficult to obtain a complete picture in the limited time the interview process affords. Many traits can be easily identified but others may go undetected due to “best behavior syndrome” during the interview process. This is an important concept to fully understand and the case study at the end of this paper demonstrates how negative attributes can have consequential effects on the safety of flight.

Attitudes can be described as the way somebody feels about someone or something, which in turn may guide that person’s behavior. Unlike attributes, attitudes are a bit more dynamic and easier to change. In other words, a change in attitude can be the result of something positive occurring (such as management unveiling a new safety plan) or something negative occurring (an accident).

In fact, there has been considerable research conducted in flight operations regarding the “Five Hazardous Attitudes” (Federal Aviation Administration, 1991). In its Aeronautical Decision Making Advisory Circular AC60-22, the FAA describes the most commonly identified hazardous attitudes displayed by pilots. They are:

- Antiauthority (don’t tell me)
- Impulsivity (do something quickly)
- Invulnerability (it won’t happen to me)
- Macho (I can do it)
- Resignation (what’s the use?)

In many accident investigations one or more of these hazardous attitudes have been identified in the overall human performance aspect. Most of the time they are not explicitly labeled but rather they are implicit in the way the pilot performed, and the decisions that were made, during the events leading to the accident.

Decisions can be described as the choice that we make based on multiple alternative solutions. Similar to hazardous attitudes, poor decision skills continue to be cited in a multitude of aircraft accidents. Most of these flawed decisions occur in the general aviation realm, however there have been, and still continue to be, consequential decision errors occurring in the air carrier domain as well.

Similar to attributes, decision making skills may be difficult to fully evaluate in the interview process. Additionally, decision making is a very dynamic and fluid process. Pilots are presented with a myriad of decisions that must be made during the course of a flight. These decisions are more proximal than attributes or attitudes which tend to be more distal in the accident chain. In other words, the decision that a pilot makes at one particular moment could have immediate and consequential effects on the safety of flight. However, the distal effects of attributes and attitudes should not be discounted since these may also influence the decision making process.

Weather-related decision making appears to be most problematic. In general aviation many decision errors occur because pilots continue VFR flight into IMC conditions. In air carrier operations decision making errors are occurring at a high rate during the approach and landing phase in less than optimal weather conditions. Specifically, a large number of runway excursions are occurring due to pilots attempting to land in conditions that exceed the aircraft's limitations. The following psychological decision factors must be considered as part of the causal factors in these types of accidents:

Hindsight Bias

According to Plous (1993), "Hindsight bias is the tendency to view what has already happened as relatively inevitable and obvious—without realizing that retrospective knowledge of the outcome is influencing one's judgments." Hindsight bias breeds complacency and may result in losing focus of the big picture. The pilot must understand that although he or she has landed successfully in "similar" adverse weather situations in the past that does not guarantee that this particular landing will yield the same outcome.

Sunk Cost Effect

The sunk-cost effect specifies that if more has been invested in a certain course of action, the less likely this course of action will be abandoned than if less were invested (Kahneman & Tversky, 1982). Decision frames may be induced by the proximity of the pilots' goals, such as the destination airport. As goal achievement gets closer the "sunk cost" effect might be more likely (O'Hare & Smitheram, 1995).

Bounded Rationality

In the decision making process people tend to be only partly rational, and are in fact emotional or irrational in the remaining part of their actions. Aviation is a skilled domain and pilots are considered experts when they apply their knowledge to decision situations (Orasanu & Martin, 1998). Humans are simply not capable of processing large amounts of information at once, so this becomes known as bounded rationality. People may try to rationalize decisions by

Satisficing which is a behavior that attempts to achieve at least some minimum level of a particular variable, but which does not strive to achieve its maximum possible value (Simon, 1957).

The implications of bounded rationality in aviation decision making can be clearly articulated when pilots are confronted with, for example, a landing in extreme weather conditions. In these cases, the pilot might make a decision, albeit not the best decision, based strictly on an on-time arrival and personal pride. All of the conflicting information for a safe landing tends to be minimized or excluded from the decision process.

Cognitive Dissonance

Pairs of cognitions can be relevant or irrelevant to one another (Festinger, 1957). If two cognitions are relevant to one another, they are either consonant or dissonant. The existence of dissonance, being psychologically uncomfortable, motivates the person to reduce the dissonance and leads to avoidance of information likely to increase the dissonance.

Conflicting cognitions may be apparent when making the decision, for instance, to land in a thunderstorm with windshear. The dissonance manifests as a conflict between *arriving successfully at the destination airport* and the *possibility of having to go missed approach (*the least preferred choice). In an attempt to lessen the dissonance between these two cognitions the pilot may use the rationale that the landing will ultimately be successful, and the chance of a missed approach is minute. This type of thinking can create tunnel vision and can significantly affect good decision making at critical times.

Plan Continuation Error

Pilots may choose a course of action and stay with it regardless of the consequences or rule violations simply because they have "made a plan and they are going to stick to it." Plan

Continuation Error (PCE) is a term developed by Burian, Orasanu, and Hitt (2000) who found that a large number of general aviation accidents that involved flight from VFR into IMC involved a plan continuation error. While the crux of their study focused on general aviation and enroute weather situations, PCE can be easily applied to landing decisions in commercial air transport operations. There is a tremendous amount of pressure for a pilot to complete a trip as planned and because of this there may be a degradation of rational decision making towards the end of a flight.

Complacency

Complacency is a feeling of well-being, contentment, and invulnerability and can be associated with performing the same task over and over again with the same predictable outcome. Pilots perform landings thousands of times in their careers under varying levels of complexity and weather conditions. Once the pilot has hundreds or thousands of landings under his or her belt a certain level of complacency may develop. A complacent mindset may cause the pilot to believe that all landings will be successful which in turn may cause him or her to push more limits and boundaries. It must be kept in mind that every landing is somewhat different and a pilot should never let his or her guard down during the landing process. The option to go-around remains viable during the approach and up to a certain point during touchdown.

Although the above list is not exhaustive, it does include some of the most common psychological factors that can affect landing decisions. To put all this in perspective I have created a graphic of what I term the Landing Decision Danger Zone (LDDZ) (Figure 3). The LDDZ begins at the final approach fix (FAF) and terminates at the touchdown zone. In between these two points is the “decision zone” where all of the previously discussed factors may affect the landing decision. It should be noted that most of the recent weather-related runway excursions occurred because the pilot attempted to land when a missed approach should have been conducted instead.

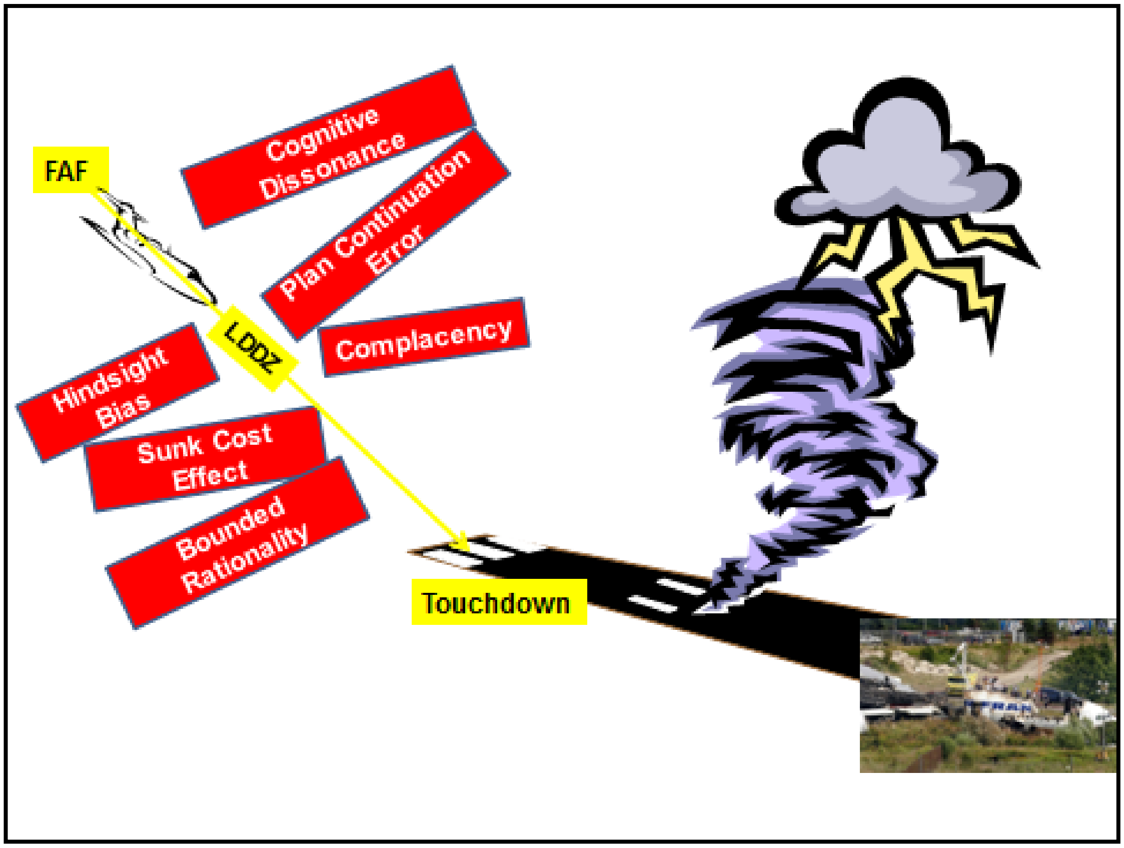
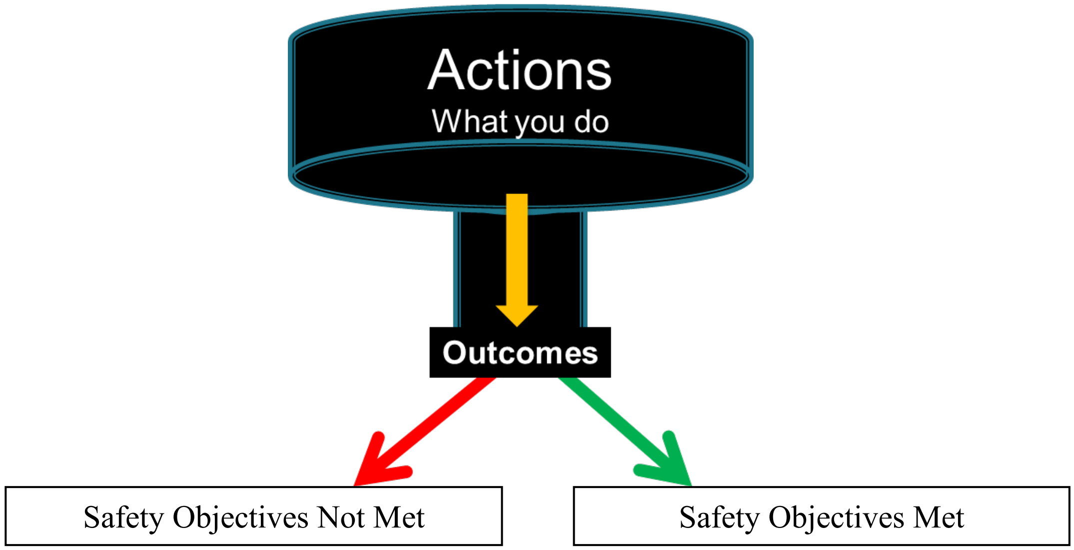


Figure 3. The “Landing Decision Danger Zone.” ©2011 Robert I. Baron.

While the discussion about decision making could go on considerably longer, that is not the intent of this paper. There are numerous, external sources for additional information on this topic. However, it should be noted that there was quite a bit more emphasis put on the Decisions component of the HFFM compared to the other components. This was done because the Decisions component may very well be the most important part of the model. It also lays the foundation for the next component, Actions, and their corresponding Outcomes, discussed next.



Now that all of the components have mixed together in the funnel, a person's Actions at this point will set the stage for the final Outcomes. Actions are simply "what you do" and the resultant outcomes of these actions will either meet, or not meet, the safety objectives. Some of the overarching reasons why safety objectives may not be met include:

- Not doing something when it should be done
- Doing the right thing at the wrong time
- Doing the wrong thing at the right time
- Shortcutting procedures
- Doing something out of sequence
- "Clustering" workload
- Violating rules or procedures

It is at this particular juncture that it should be pointed out that the front-line employee may very well be the trigger puller for an organizational failure. Or, this may be the point where a single, errant, erroneous, careless act by the front-line employee may be the reason there is a failure to meet the safety objective.

To further delineate these two concepts, an example of an organizational failure and an individual failure will be presented. The first example, an organizational failure, is the Continental Express Flight 2574 accident in 1991. During a routine maintenance shift turnover the outgoing crew failed to inform the incoming crew that 47 screws needed to be reinstalled on the horizontal stabilizer of an Embraer 120. Consequently, the aircraft was dispatched without the screws installed and experienced a catastrophic inflight structural failure. The National Transportation Safety Board (1992) issued the Probable Cause as follows:

> …(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…(National Transportation Safety Board, 1992, p. 54)

Continental Express Flight 2574 *was* a quintessential organizational failure. In this particular case there were widespread failures throughout the organizational hierarchy, from those tasked with management and oversight all the way down to the line mechanics. There were approved procedures in place; they were just not being used. But the reason they were not being used was not because of one or two careless individuals. It was a company norm or “the way business was being done,” which became tacitly endorsed at all levels of the organization. In other words, slack turnovers became the way business was conducted in the time period leading up to this accident. Thus, it would be unjustifiable to ascribe blame to just one or two individuals. The entire organization was complicit.

The second example, an individual failure, is a Gulfstream III accident that occurred in 2004. The aircraft, with just the pilots and flight attendant aboard, were repositioning to pick up former president George H. W. Bush at William P. Hobby Airport (HOU) in Houston, TX. The automatic terminal information service (ATIS) was reporting calm winds with a visibility of 1/8 statute miles in fog, the runway visual range (RVR) for runway 4 was variable between 1,600 and 2,400 feet, and the clouds were broken at 100 feet and overcast at 9,000 feet (National Transportation Safety Board, 2006). On approach the airplane struck a light pole and crashed about three miles short of runway 4 at HOU. The National Transportation Safety Board (2006) issued the Probable Cause as follows:

> …the flight crew's failure to adequately monitor and cross-check the flight instruments during the approach. Contributing to the accident was the flight crew's failure to select the instrument landing system frequency in a timely manner and to adhere to approved company approach procedures, including the stabilized approach criteria. (National Transportation Safety Board, 2006, p. 21)

In this particular accident, unlike the previous accident, it would be very difficult to categorically term this as a failure of the organization. In this case, similar to the previous case, there were policies and procedures in place to effectively mitigate this type of an accident. However, in this case the highly experienced Captain and First Officer (with more than 33,000 total flight hours combined) committed a situational violation due to specific circumstances. The crew's actions were not necessarily part of a poor organizational culture or a widespread norm of descending below minimums without adequate visual reference. These violations were of the crew's own volition and the flawed decision to attempt a landing at the time of the accident was invariably reflective of some of the previously discussed Decisions component in the model. This accident clearly demonstrates that no matter how effective the organization is in providing training, developing procedures and policies, and fostering a relatively healthy safety culture, there may always be unmitigated aberrations of individual behavior at any given time.

Kenya Airways Flight 507 and the Human Factors Funnel Model

The Kenya Airways Flight 507 accident provides a good fit to demonstrate the practical application of the HFFM. Shortly after takeoff from Douala, Cameroon, on a dark night with convective activity in the area, the pilots lost control of the aircraft. The Captain, while trying to manually recover, experienced confusion and spatial disorientation. His inputs greatly exacerbated the bank angle and the aircraft entered an unrecoverable spiral dive. There were organizational as well as individual factors that significantly contributed to the accident. Specifically, there were numerous distal (latent) and proximal (active errors) that were identified in the chain of events that precipitated the accident. The Cameroon Civil Aviation Authority (n.d.) issued the Probable Cause as follows:

> …loss of control of the aircraft as a result of spatial disorientation...after a long slow roll, during which no instrument scanning was done, and in the absence of external visual references in a dark night. Inadequate operational control, lack of crew coordination, coupled with the non-adherence to procedures of flight monitoring, confusion in the utilization of the [autopilot], have also contributed to cause this situation. (Cameroon Civil Aviation Authority, n.d., p. 57)

Space does not allow for a full review of the accident details (see Lacagnina, 2010) but there are a few significant findings that will be discussed here. Of interest, but tangential to the discussion, is the similarity of this accident to the Tenerife disaster some 30 years earlier. Although the Kenya Airways accident occurred in flight and the Tenerife accident occurred on the ground, there were still a number of related factors. These factors included:

- Weather conditions (low visibility)
- Took off without a clearance (a clearance was neither requested, or received, from ATC)
- CA’s known psychological traits:
    - Strong character and heightened ego
    - Authoritative and domineering with subordinates
    - Paternalistic attitude towards FO on accident trip
- FO’s known psychological traits:
    - Was intimidated by the weather but did not question the decision to depart
    - Reserved and non-assertive
    - Subdued by the strong personality of the CA

Additional factors included:

- Documented deficiencies in the Captain’s upgrade training which included CRM, adherence to standard procedures, cockpit scan and situation awareness.
- Captain was known to have a “touch of arrogance” and “insufficient flight discipline.”
- Numerous recommendations for the Captain to attend remedial training for deficiencies related to systems knowledge, procedures, and briefings, command ability and teamwork.

*Note: Sources for the bullet list were Lacagnina (2010) and Cameroon Civil Aviation Authority (n.d.).

The factors and events that precipitated the Kenya Airways accident are transposed onto the HFFM in Figure 4. This allows the reader to view a practical application of the model. Shown are the influences of the Atmosphere (organization) as well as Attributes, Attitudes, Decisions, Actions, and Outcomes. This example does a good job depicting the distal errors (Captain's personality and training issues) as well as the proximal errors (the events that occurred the day of the accident).

In this particular accident it became very clear where the organizational and individual deficiencies were occurring. Kenya Airways could have been more proactive in identifying and mitigating the antecedent factors that led up to the accident. However, it is not in the scope of this paper to delve deeper into the accident itself. The reader can draw his or her own conclusions based on the facts that have been presented.

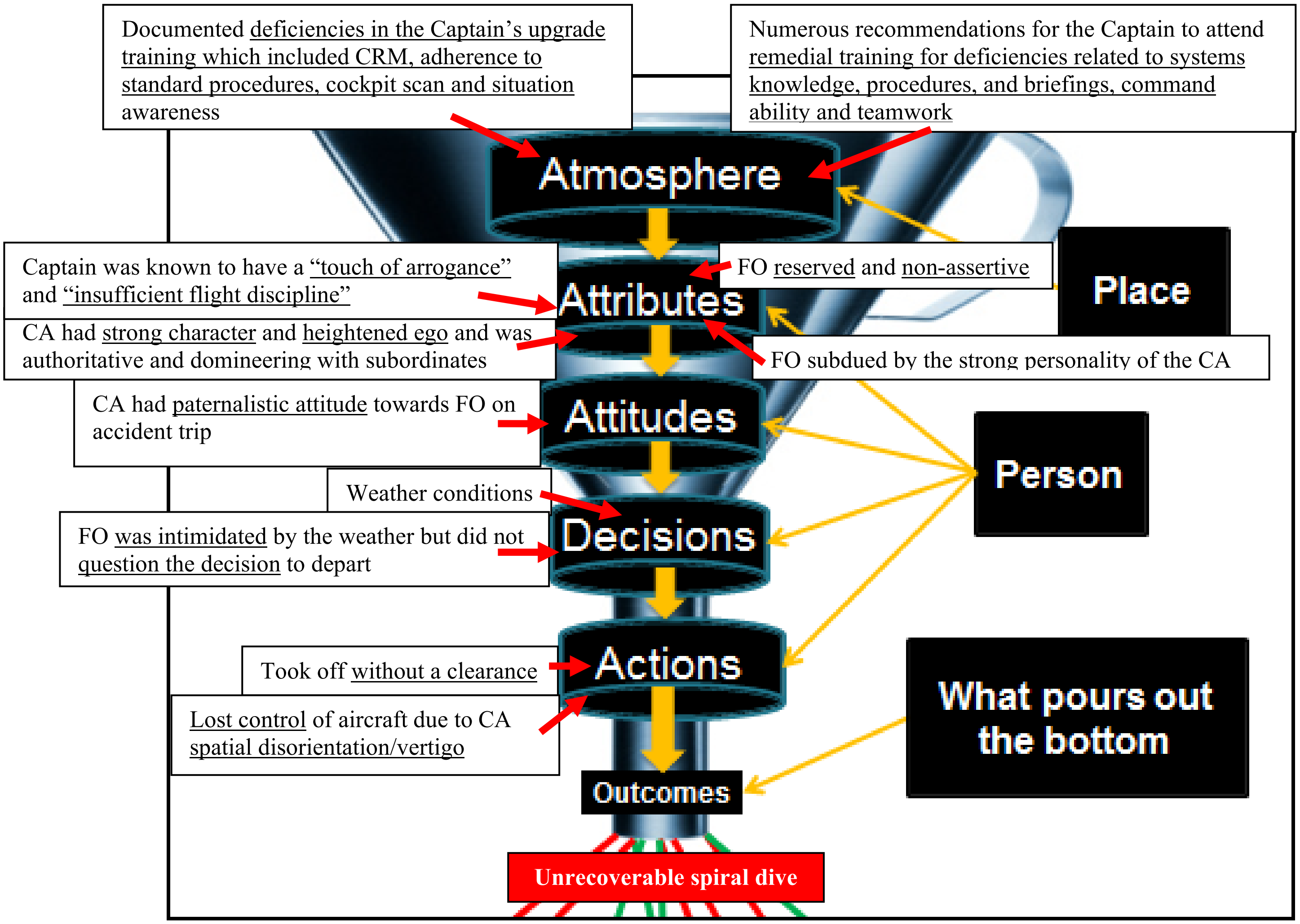


Figure 4. Full Human Factors Funnel Model With Kenya Airways Flight 507 as an Example.

Summary

This paper introduced the conceptual framework of the Human Factors Funnel Model. The framework for the HFFM builds on the concept of a funnel. At the top of the funnel is the Atmosphere (or the overarching organizational inputs). The Atmosphere then flows down into Attributes, Attitudes, Decisions, and Actions by employees. Based on the "mixture of these ingredients," the Outcomes will either meet, or not meet, the intended safety objectives.

Since the HFFM is not domain-specific, examples were incorporated from both the maintenance and flight operations domains. The Continental Express Flight 2574 accident exemplified a true organizational failure from the maintenance perspective. The Gulfstream III accident exemplified an individual failure that had no discernable connection to a broad organizational failure. Finally, the Kenya Airways Flight 507 accident showed how the HFFM can be used in the practical analysis of an accident. In fact, the HFFM is well-suited as a reactive, as well as proactive, investigation model. To that end it is hoped that the HFFM will be used by academia and practitioners alike for another window on error causation.

References

Ajzen, I. (1988). *Attitudes, personality, and behavior.* Chicago, IL: Dorsey.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes. 50,* 179-211.

Baron, R. (2009, March). The human factors ladder still needs to extend higher. *Aviation Maintenance Magazine.* Retrieved from http://www.aviationtoday.com/am/categories/commercial/30009.html

Burian, B., Orasanu, J., & Hitt, J. (2000). Weather-related decision errors: Differences across flight types. *Proceedings of the 14thIEA Triennial Congress of the International Ergonomics Association/44thAnnual Meeting of the Human Factors and Ergonomics Society* (pp. 22-24). Santa Monica, CA: Human Factors and Ergonomics Society.

Cameroon Civil Aviation Authority. (n.d.). *Technical investigation into the accident of Kenya Airways B737-800.* Retrieved from http://www.ccaa.aero/images/blogs/d033e22ae348aeb5660fc2140aec35850c4da99744f683a84163b3523afe57c2e008bc8c/rapport%20kenya.pdf

Federal Aviation Administration. (1991). Advisory Circular 60-22. Retrieved from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/CCDD54376BFDF5FD862569D100733983?OpenDocument

Festinger, L. (1957). *A theory of cognitive dissonance*. Evanston, IL: Row, Peterson.

Kahneman, D., & Tversky, A. (1982). Choices, values, and frames. *American Psychologist, 39*(4), 341-350.

Lacagnina, M. (2010, August). Beyond redemption: Spatial disorientation turned a minor upset into a major accident. *AeroSafety World, 5*(7), 24-27. Retrieved from http://flightsafety.org/asw/aug10/asw_aug10.pdf

National Transportation Safety Board. (1992). *Continental Express Flight 2574 in-flight structural breakup.* NTSB/AAR-92/04. Retrieved from http://libraryonline.erau.edu/online-full-text/ntsb/aircraft-accident-reports/AAR92-04.pdf

National Transportation Safety Board. (2006). *Crash during approach to landing.* NTSB/AAB-06/06. Retrieved from http://www.ntsb.gov/publictn/2006/AAB0606.htm

O'Hare, D., & Smitheram, T. (1995). "Pressing on" into deteriorating conditions: An application of behavioral decision theory to pilot decision making. *The International Journal of Aviation Psychology, 5*(4), 351-370.

Orasanu, J., & Martin, L. (1998). Errors in aviation decision making: A factor in accidents and incidents. Retrieved from http://www.dcs.gla.ac.uk/~johnson/papers/seattle_hessd/judithlynne-p.pdf

Plous, S. (1993). *The psychology of judgment and decision making.* New York: McGraw-Hill.

Simon, H. A. (1957). *Models of man*. New York: Wiley.

Wicker, A. W. (1969). Attitudes versus actions: The relationship of verbal and overt behavioral responses to attitude objects. *Journal of Social Issues, 25,* 41-78.