Context of Human Error in Commercial Aviation

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1 Introduction

11:08:25 Altitude alert horn sounds.
11:08:29 ***FO:*** *"...power on this [expletive]."*
Capt: *"Yeah, you got a high sink rate."*
Capt: *"You ought to see ground outside in just a minute. Hang in there, boy."*
11:08:57 Altitude alert horn sounds.
FO: *"Must have had a [expletive] of a downdraft."*
11:09:14 Radio altimeter warning horn sounds and stops.
FO: *"Boy!"*
11:09:20 ***Capt:*** *"Get some power on."*
Radio altimeter warning horn sounds again and stops.
At 11:09:22 TWA 514 struck the west slope of Mount Weather, about 25 nautical miles from Dulles at an elevation of about 1,670 feet. Seven crewmembers and 85 passengers perished in the crash. There were no survivors.

An international team of aviation experts was recently charged with exploring ways to dramatically reduce the incidence of catastrophic aviation accidents in the near future. Controlled flight into terrain (CFIT) continues to be a leading cause of airline tragedies and was the focus of a recent Joint Safety Analysis Team (JSAT) to demonstrate that “government and industry can work together on aviation safety issues” (JSAT, 1998). Dramatically reducing CFIT events is hoped to be the proof of concept of this effort.

CFIT is defined as “any collision with terrain or water in which the pilot was in control of the aircraft but was not aware of the airplane’s altitude, the terrain elevation or the airplane’s position in terms of latitude or longitude” (DOT/FAA/AAR-100-97-2, 1997) This report found that CFIT accidents accounted for 17% of general aviation fatalities and 32% of those in meteorological conditions. Instrument conditions and older pilots were well correlated with these fatalities suggesting that impaired or reduced sensory ability is an important factor in CFIT accidents. The consequences of CFIT are not isolated to general aviation. The majority of fatal accidents in turbofan and turboprop commercial aircraft, both abroad and in the US, over the last 10 years continues to be CFIT (JSAT, 1998).

The JSAT effort resulted in identification of the kinds of human errors that lead to CFIT. In addition, a Human Factors Analysis and Classification System (HFACS) was recently developed and further isolated the conditions of human aviation errors with the intent of suggesting remediation strategies (Wiegmann & Shappell, 2001). The research presented here attempts to modestly extend the efforts of JSAT, HFACS, and others by identifying and describing the dynamic context in which error occurs.

2 Objective

The objective of this research was to develop a working paper that would provide a catalogue for identifying and describing the context in which human error in commercial aviation occurs, based primarily on real world operational accidents and incidents. Because context is a dynamic matter, there was a need to include information about the source and time stamp and provide the setting in which human error occurs and unfolds over time based on the situation context.

In addition to the broad objective mentioned above, there was a specific request to provide the Human Performance Modeling Element of the Aviation Safety Program with accident and incidents corresponding to approach and landing phases of flight. The accidents and incidents can be utilized to create realistic scenarios for the FY02 human performance modeling effort. A further consideration was to emphasize accidents or incidents that could be potentially mitigated with the synthetic vision system (SVS).

3 Approach

The approach to fulfilling the objectives of this research involved collecting information from several different sources to define, describe, and categorize the *context of human error* (see Section 4) as it applies to the commercial aviation domain. Fortunately, the authors of this working paper had just recently performed a literature search in support of a NASA white paper on human error modeling (Leiden et al., 2001). Many of the findings from that literature search provided a solid foundation for the current round of research, particularly with respect to existing aviation taxonomies of human error.

The next step in the approach was to review aviation accidents and incidents to support the Aviation Safety Program's Human Performance Modeling Element by providing both interesting and representative vignettes of human error for CFIT and/or the approach/landing phases of flight. The sources include accidents compiled from various websites and incidents compiled from the NASA Aviation Safety Reporting System (ASRS). In addition, problem statement categories proposed by the government-sponsored Controlled Flight Into Terrain (CFIT) Joint Safety Analysis Team (JSAT) were attributed to each accident/incident. For each accident/incident selected for inclusion, information is described for initial conditions, sequence of events, and error analysis.

A brief discussion of how SVS could have averted the accident/incident is included in Appendix C.

4 Context of Human Error

One of the primary goals of this paper is to categorize the *context of human error*. First though, it is beneficial to define what is meant by the phrase *context of human error*. Webster's defines *context* as the parts of a sentence, paragraph, etc. that occur just before and after a specified word or passage, and determine its exact meaning. Using an analogy for the above definition, it would seem appropriate to suggest that the *context of human error is the understanding of human error based on the conditions surrounding the error, which includes both the conditions prior to and during the error*. This broad definition will be categorized more specifically later in this section after discussing applicable literature from human error research. In particular, a discussion of error chains and existing taxonomies of human error will be discussed so as to shed additional light on the meaning of the context of human error.

4.1 Error Chains

Research has shown that there are numerous causal factors behind any single aviation accident (Shappell & Wiegmann, 2000). These factors are often collectively referred to as an error chain. Each link in the chain corresponds to a failure in the system to some degree, although in some instances a single failure analyzed out of context might seem relatively benign. Often a *potential* error chain is broken by redundancy in the system (e.g., the pilot readback of a clearance gives the controller the opportunity to correct the clearance if 1) the pilot reads it back incorrectly or 2) the controller had issued the wrong clearance, but detects his/her error during the readback). Other times the only difference between an incident and a tragic accident is that the error chain was broken by lucky timing rather than any active correction by a human (e.g., an ill-timed runway incursion becomes a deadly accident if the taxiing aircraft crosses the path of a landing aircraft).

Also important to error chains is differentiating between commonly occurring human errors and what Reason (1990) refers to as *unsafe acts*. Reason defined unsafe acts to be human failures *committed in the presence of a potential hazard*. Unsafe acts are distinct from other human failures because the consequences are potentially severe. Figure 1 depicts human failures propagating through a system's defenses and redundancies. This depiction is often referred to as the Swiss Cheese model of human error causation.

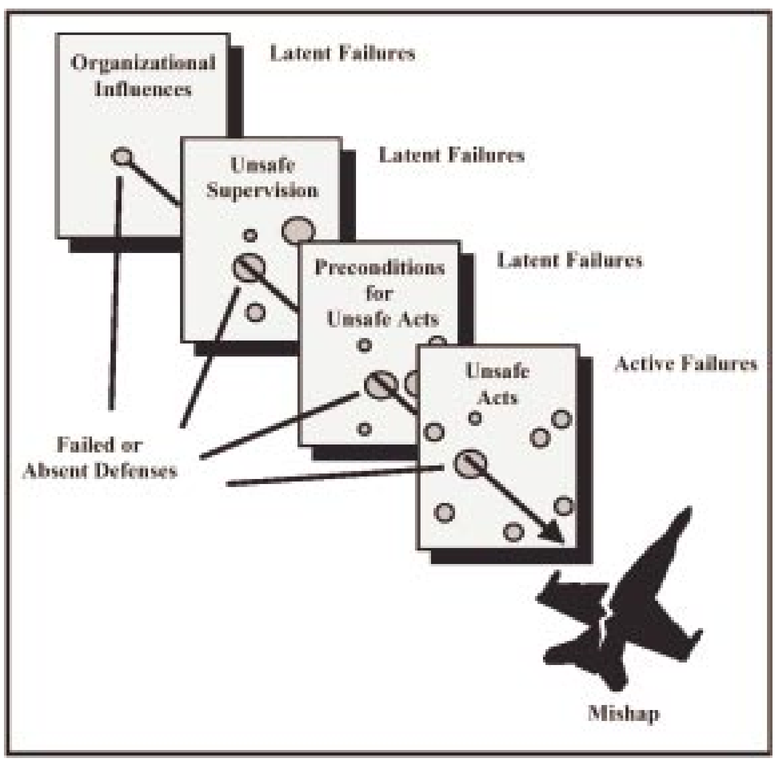

Figure 1. The Swiss Cheese model of human error causation [from Shappell & Wiegmann, (2000), adapted originally from Reason (1990)].

The Swiss Cheese model is important in categorizing the context of human error because it emphasizes the significance of latent failures in the error chain. Latent failures can lie dormant for hours, days, weeks, or longer (Shappell & Wiegmann, 2000) until at some point the right combination of conditions appear and the effect of the failure emerges. Because of the complex nature in which latent failures manifest themselves in error chains, latent failures can be difficult to detect. On the other hand, active failures result in consequences that are seen almost immediately, making the post-accident/incident cause-effect analysis easier to comprehend. In categorizing the context of human error, both active and latent failures must be addressed.

4.2 Taxonomies of Human Error

One of the primary goals of accident investigations is to understand the causal factors behind the accidents so as to prevent similar accidents in the future. The large corpus of aviation post-accident information has afforded both safety and human factors researchers with an opportunity to develop human error taxonomies that can be used to represent *and* quantify underlying causal factors. This approach enables researchers to focus firstly on the causal factors that are the most statistically relevant. The types of taxonomies that are most applicable to the context of human error are those taxonomies that are predominantly conceptual in nature. That is, they focus on understanding the cognitive process involved in the production of human error rather than describing the observable characteristic of the error. Five conceptual human error taxonomies applied specifically to aviation accidents and/or incidents were collected from the literature and reviewed. The names of the taxonomies and the researchers responsible for their development are listed below. In addition, a detailed description of each taxonomy is included in Appendix A.

- Situation Awareness Error Taxonomy (Endsley, 1999)
- Model of Internal Human Malfunction (Rasmussen, 1982, O'Hare et al., 1994)
- Model of Unsafe Acts (Reason, 1990)
- Information Processing Model (Wickens & Flach, 1988)
- Human Factors Analysis and Classification System (Shappell & Wiegmann, 2000)

These taxonomies represent a comprehensive view of the different types of human error that lead to unsafe acts. After reviewing the taxonomies, it was determined that the Human Factors Analysis and Classification System (HFACS) and the Situation Awareness Error Taxonomy would provide the greatest benefit in categorizing the context of human error. This was decided because in many instances there was considerable overlap in the classification of errors listed in the five taxonomies. Indeed, the most recent taxonomy, HFACS, was developed primarily from Reason's Model of Unsafe Acts while also considering the taxonomies of Internal Human Malfunction and Information Processing (Wiegmann & Shappell, 1997). HFACS, however, moves far beyond Reason's theoretical framework and is aimed specifically at the aviation domain. Also, no single taxonomy of human error had been generally accepted by accident investigators and human factors/aviation safety researchers for addressing all causal factors. Hence, it was Wiegmann and Shappell's goal for developing HFACS that it be utilized as a comprehensive framework to be used by both schools – the accident investigators would use it to identify human error while human factors and safety researchers would use it to analyze human error. Indeed, the second part of the equation has already occurred – HFACS has been applied with good success to real-world commercial aviation accidents (Wiegmann & Shappell, 2001).

HFACS contains four levels of latent and active failures:

1) Unsafe Acts
2) Preconditions for Unsafe Acts
3) Unsafe Supervision
4) Organizational Influences

These four levels are decomposed into 321 types of human causal conditions. Unfortunately, we have not yet obtained the full listing. The Shappell & Wiegmann (2000) paper has only a partial listing of the human causal conditions.

Although HFACS does indeed appear to be very comprehensive, it lists "loss of situation awareness" as a single human causal condition under the second level – Preconditions for Unsafe Acts. Given the research efforts to understand how and what is needed to improve situation awareness (SA), the single line item for "loss of SA" is too simplistic. (Note: without the full listing of the HFACS human causal conditions, we are assuming that SA is not discussed more fully. We may be way off the mark here.) Fortunately, the Endsley Situation Awareness Error Taxonomy provides the needed level of fidelity to fill this void. Though several definitions of SA exist, the definition used most often is that provided by Endsley (1988): "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Expanding upon this to describe pilot situation awareness, the following levels of SA were developed by Endsley (1999) and are presented here verbatim:

- **Level 1 SA – Perception of the elements in the environment -** The first step in achieving SA involves perceiving the status, attributes, and dynamics of relevant elements in the environment. The pilot needs to accurately perceive information about his/her aircraft and its systems (airspeed, position, altitude, route, direction of flight, etc.), as well as weather, air traffic control (ATC) clearances, emergency information, and other pertinent elements.

- **Level 2 SA – Comprehension of the current situation -** Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the pilot's goals. Based upon knowledge of Level 1 elements, particularly when put together to form patterns with the other elements, a holistic picture of the environment will be formed, including a comprehension of the significance of information and events. The pilot needs to put together disparate bits of data to determine the impact of a change in one system's status on another, or deviations in aircraft state from expected or allowable values. A novice pilot might be capable of achieving the same Level 1 SA as a more experienced one, but may fall short in the ability to integrate various data elements, along with pertinent goals to comprehend the situation as well.

- **Level 3 SA – Projection of future status -** It is the ability to project the future actions of the elements in the environment, at least in the near term, that forms the third and highest level of situation awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA). For example, the pilot must not only comprehend that a weather cell—given its position, movement and intensity—is likely to create a hazardous situation within a certain period of time, but s/he must also determine what airspace will be available for route diversions, and ascertain where other potential conflicts may develop. This ability gives the pilot the knowledge (and time) necessary to decide on the most favorable course of action.

A complete list of the errors associated with loss of, degraded, or insufficient SA is presented in Appendix A.

4.3 Categorizing the Context of Human Error

In this sub-section, a first cut at categorizing the context of human error will be presented. This is based heavily on the discussion of error chains, HFACS and the SA error taxonomy. Although it may appear that we are making a large leap to categorize the context of human error at this point in the paper, it is based largely on our understanding of HFACS and the SA error taxonomy listed in Appendix A. Figure 2 depicts the role of precursors and loss of or degraded SA on the emergence of unsafe acts. As depicted in Figure 2, degraded SA is not an unsafe act by itself, but rather an important precondition to error that is often influenced by other precursors. Although Figure 2 shows that the entire list of precursors contributes to the degradation of SA, in truth it is only a subset of the complete listing. Undetected or uncorrected human errors feedback into the precursors, which in turn may further degrade SA, until at some point, while in the presence of a potential hazard, an unsafe act is committed. Also, the feedback loop in Figure 2 is intended to convey the dynamic nature of the emerging errors – something that is missing from the more static-like representations of the error taxonomies in Appendix A.

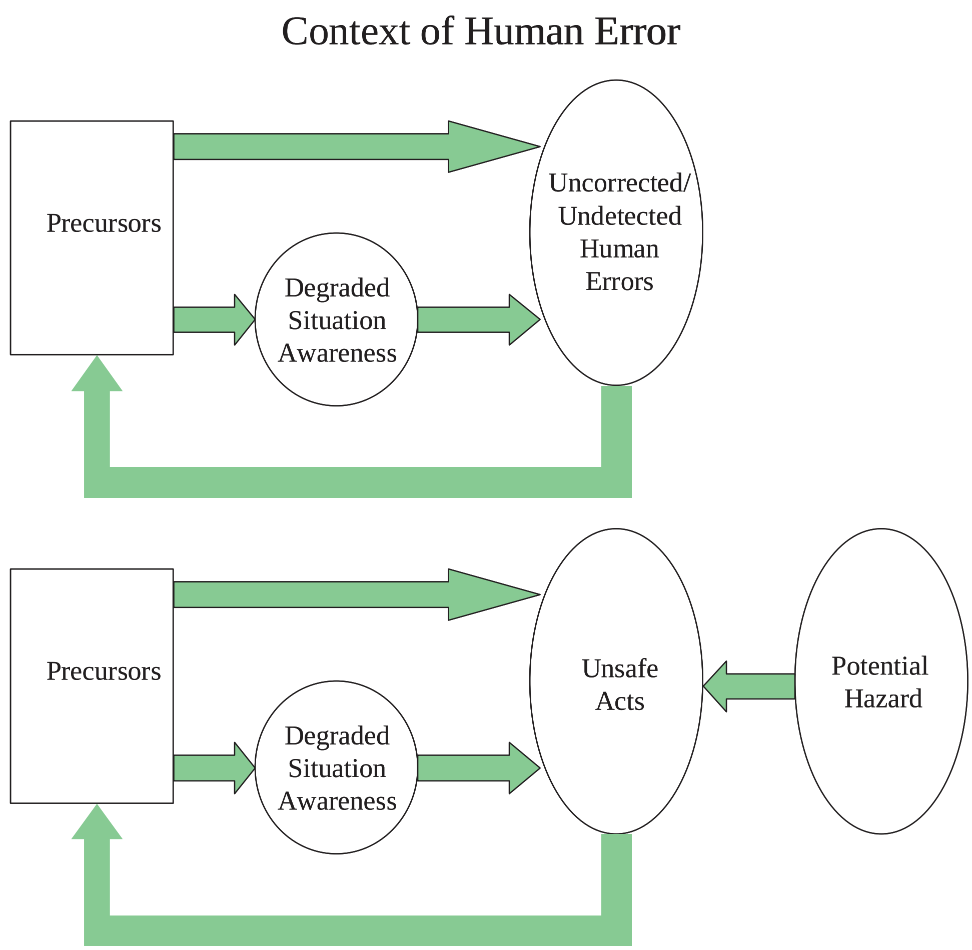

Figure 2. Context of human error in depicting the emergence of unsafe acts.

Degraded SA due to precursors is shown in Table 1. Degraded SA due to undetected/uncorrected human errors is shown in Table 2.

A first-cut at a Context of Human Error Matrix of precursors and root causes that result in human errors/unsafe acts is shown in Table 3. It is considered a first-cut because the categories of precursors and unsafe acts are defined at a rather high level. To provide practical insight into the context of human error, the categories would have to be decomposed into lower levels. Indeed, as mentioned earlier, the complete list of HFACS categories is 321. Using HFACS as a guideline, one could conjecture that a complete Context of Human Error Matrix would be roughly 75 x 250 – 75 categories of human errors/unsafe acts and 250 categories of precursors. Not all precursors/root causes would correlate to a specific human error/unsafe act category. In those cases, a "NA" (for not applicable) could be placed in the corresponding box in the matrix (e.g., degraded Level 3 SA is unlikely to be associated with skill-based technique errors).

To represent the dynamics of human error emergence, it is intended that the Context of Human Error Matrix be filled in for each human failure link in an error chain. For example, if an error chain consisted of five human failures – three latent and two active, then the Context of Human Error Matrix would be filled in five times starting with the last failure and working backward in time. In this way, the matrix has the potential to allow for a detailed correlation of precursors/root causes to unsafe acts.

Table 1. Degraded situation awareness due to precursors

Level 1: Failure to correctly perceive information
Data is not available due to failure of the system design to present it.
Data is not available due to failure in the communication process.
Data hard to discriminate or detect (e.g., poor runway markings, inadequate lighting, noise in the cockpit, or obstructions blocking view).
Failure to monitor or observe data due to high workload.
Level 2: Failure to correctly integrate or comprehend information
Poor mental model does not enable the combining of information needed to meet goals. Primarily associated with automated systems.
Level 3: Failure to project future actions or state of the system
Information of current state is correctly understood, but projection of that state into the future fails because of a poor mental model.

Table 2. Degraded situation awareness due to human failures

Level 1: Failure to correctly perceive information
Failure to monitor or observe data due to simple omission, attentional narrowing, or distractions due to multi-tasking or executing habitual schema.
Data is misperceived due to influence of prior expectations.
Data is misunderstood due to task distraction.
Forgetting information is due to disruptions in normal routine or high workload.
Level 2: Failure to correctly integrate or comprehend information
Interpretation of cues through an expected, but wrong, mental model of a system's behavior leads to the incorrect assessment of the situation.
Over-reliance on default values results in routine expectations of the system, even though conflicting information is available.
Information is not properly integrated or comprehended due to working memory lapses or other undetermined cognitive reasons.
Level 3: Failure to project future actions or state of the system
The current state is projected into the future correctly. However, it is projected further into the future than for which the data is realistically valid. This, combined with not updating the projections at appropriate intervals, can lead to incorrect plans for the future.
Projection of current state into the future fails because it is a demanding task that in a multi-tasking environment is not always performed. This is possibly due to the lower priority it is given or due to limits in cognitive resources.

Table 3. Context of Human Error Matrix

		Human Errors/Unsafe Acts									
		Skill-based errors			Decision errors			Perceptual errors		Violations	
		Attention failures	Memory failures	Technique errors	Procedural errors	Poor choices	Problem solving errors	Visual illusions	Spatial disorientation	Routine violations	Exceptional violations
Precursors and Root Causes	**Situation Awareness**										
	Degraded Level 1 SA										
	Degraded Level 2 SA										
	Degraded Level 3 SA										
	Preconditions for Unsafe Acts										
	Adverse mental states										
	Adverse physiological states										
	Physical / Mental limitations										
	Crew resource mismanagement										
	Personal readiness										
	Unsafe Supervision										
	Inadequate supervision										
	Planned inappropriate operations										
	Failure to correct a known problem										
	Supervisory violations										
	Organizational Influences										
	Resource management										
	Organizational climate										
	Operational processes										
	Environmental Conditions										
	Weather										
	Visibility										

5 Accidents and Incidents of Interest

5.1 Commercial Aviation CFIT Accidents

The incidence of CFIT accidents continues to be the leading cause of airline catastrophes. Figure 3 shows the frequency of CFIT accidents in commercial jet aircraft from 2000-1987 excerpted from a report by Honeywell (Bateman, 2000). The average accident frequency of CFIT considering international data is 4.3 per year (± 0.6 standard error of the mean). The CFIT accidents that were selected for this paper involved considerable loss of life and involved a large percent of the errors identified in the JSAT document. These were KAL Flight 801 in 1997 (Approach), TWA Flight 514 (Landing) in 1974, and TA Flight 655 in 1973 (Cruise). Additional details of the accidents can be obtained from primary NTSB reports (http://www.ntsb.gov/Publictn/A_Acc2.htm)

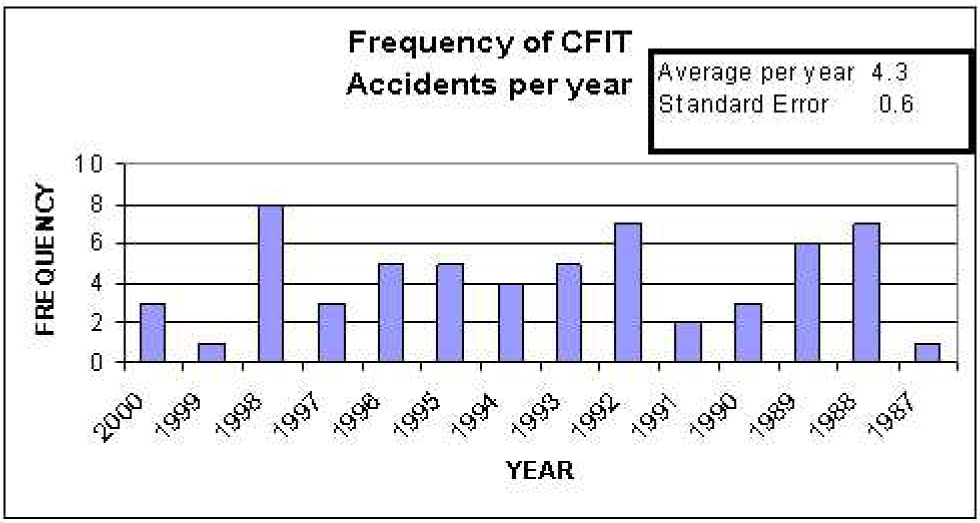

Figure 3. Frequency of CFIT Accidents

5.1.1 KAL Flight 801

Flight KAL 801 terminated as a CFIT into a hillside on approach to Guam. It is interesting because of the great number of errors made by ATC, by the airline operator and by the flight crew. It is also one of the world's greatest aviation tragedies with 228 fatalities. The accident occurred in the early morning hours compounding the fatigue of the captain which NTSB said was a contributing cause.

5.1.1.1 Initial Conditions

On August 6, 1997, about 01:42:26 Guam local time, Korean Air flight 801, a Boeing 747-3B5B (747-300), Korean registration HL7468, operated by Korean Air Company, Ltd., crashed at Nimitz Hill, Guam. Flight 801 departed from Kimpo International Airport, Seoul, Korea, with 2 pilots, 1 flight engineer, 14 flight attendants, and 237 passengers on board. The airplane had been cleared to land on runway 6 Left at A.B. Won Guam International Airport, Agana. After the flight crew made an initial sighting of Guam, Korean Air flight 801 encountered instrument meteorological conditions as the flight continued on its approach to Guam International Airport.

Initial Conditions Table

Aircraft Type	Large Transport
Crew Size	3
Flight Phase	Approach, Landing
Flight Conditions	Mixed_Conditions
Lighting	Night
Airport	Tower operating
Terrain	High peaks in vicinity
Elevation	298

5.1.1.2 Sequence of Events

About 4 minutes before the flight, the crew was advised by ground control that the glide slope landing system was inoperative, according to the flight data recorder. Poor visibility in the dark was compounded by the onset of heavy rains near the airport. One of the crew was heard to ask if the glide slope was working and the co-pilot replied that it was not. Soon thereafter the pilot was heard to ask if the glide slope indicator was working. The sound of the automated ground collision system was then heard indicating 1000 feet altitude. After cockpit alarms sounded, the captain cut off the autopilot and prepared to pull up. Seconds before the crash at 01:42, the automated voice calling to “go around” was heard just before impact. There were no lights on Nimitz Hill where the flight burst into flames. The crew apparently was relying on the localizer beacon to determine their distance from the runway. A survivor said there was no indication from the cockpit that anything was wrong. They crashed into the hillside with their landing gear extended. The tower allowed time for a go around to be executed, about 25 minutes, before calling crash equipment.

Sequence of Events Table

Situation	
Approach	Initially VFR became IFR due to weather; Non-precision

5.1.1.3 Error Analysis

The National Transportation Safety Board determined that the probable cause of the Korean Air flight 801 accident was the captain’s failure to adequately brief and execute the nonprecision approach and the first officer’s and flight engineer’s failure to effectively monitor and cross-check the captain’s execution of the approach. Contributing to these failures were the captain’s fatigue and Korean Air’s inadequate flight crew training. Contributing to the accident was the Federal Aviation Administration’s (FAA) intentional inhibition of the minimum safe altitude warning system (MSAW) at Guam and the agency’s failure to adequately manage the system.

The safety issues in this report focus on flight crew performance, approach procedures, and pilot training; air traffic control, including controller performance and the intentional inhibition of the MSAW system at Guam; emergency response; the adequacy of Korean Civil Aviation Bureau (KCAB) and FAA oversight; and flight data recorder documentation. Safety recommendations concerning these issues are addressed to the FAA, the Governor of the Territory of Guam, and the KCAB.

5.1.1.4 Application to CFIT JSAT Taxonomy

The tragedy of flight 801 is captured in many of the problem statements identified in the JSAT's Document.

CFIT JSAT Problem Statements relevant to this scenario

#	Problem Title	Category	Problem Statement
3	AIR TRAFFIC SYSTEM LACK OF STANDARDIZATION (APPROACH/DEPARTURE PLATES)	Equipment	Lack of standardized departure and approach plate depiction
5	ATC/FLIGHT CREW INADEQUATE COMMUNICATIONS	Communication	Inability of ATC and the flightcrew to communicate effectively
16	FLIGHTCREW – CRM FAILURE	Training	Lack of CRM training or failure to follow CRM practices.
20	AIRLINE OPERATIONS LACK OF TRAINING	Training	Airline/operator training failed to adequately address operational requirement
23	FLIGHTCREW –DISREGARD FLIGHTDECK WARNING	Procedures	Failure of flightcrew to respond to flightdeck warning

A number of other problems need to be considered in this analysis. The crew certainly lost their situational awareness of their vertical approach (problem 11). However the captain ignored the ground proximity alert (problem 23). This may have been related to his fatigue from a series of long flights (problem 24).

5.1.2 TWA Flight 514

As indicated in the Introduction, Flight 514 is a famous example of misunderstanding between flight crew and air traffic control. It is a CFIT during landing that resulted in the death of all 92 occupants - 85 passengers and 7 crewmembers.

5.1.2.1 Initial Conditions

At 11:10 am, December 1, 1974, Trans World Airlines, Inc., Flight 514, a Boeing 727-231, N54328, crashed about 25 nautical miles northwest of Dulles International Airport, Washington, D.C. The accident occurred while the flight was descending for a W R/DME approach to runway 12 at Dulles in instrument meteorological conditions.

Initial Conditions Table

Aircraft Type	Large Transport
Crew Size	3
Flight Phase	Approach, Landing
Flight Conditions	Thunderstorms mixed ice; high winds
Ceiling	2400 ft
Weather	Raining
Lighting	Night
Airport	Tower operating
Airport Elevation	146 MSL

5.1.2.2 Sequence of Events

FAA witnesses testified that Flight 514 was inbound to Armel by means of the pilot's own navigation, thereby relieving the controller of the responsibility cited above. Judging by the cockpit conversation in the introduction of this document, it appeared that the crew thought otherwise. The flight data recorder showed a continuous descent with little rate variation from 7,000 feet until about 1,750 feet. There were minor altitude excursions from 100 to 200 feet. Airspeed was fairly stable at 230 knots, with fluctuations between 222 knots and 248 knots. Gear, leading-edge devices, and flaps were up at the time of impact. The G-load was constant, ranging from plus or minus 0.2 G to 0.5 G until impact.

At the accident site, witnesses on the ground reported low ceilings with visibilities of 50 to 100 feet, drizzle, and wind estimated at 40 knots with stronger gusts. Possible altimeter errors caused by high wind speeds were calculated, with localized pressure changes, and the National Weather Service estimated that a worst-case scenario with 80-knot winds could result in an altitude indication 218 feet higher than the actual aircraft altitude.

Sequence of Events Table

Situation	700ft MSL Cleared to VOR/DME approach Rwy 12
Approach	VFR

5.1.2.3 Error Analysis

Testimony following the accident indicated that ATC frequently vectored aircraft off published routes and cleared them to descend below altitudes published on the charts. Pilots and controllers both had available published minimum sector altitudes (MSA) within 25 miles of the airport. MSAs provide 1,000-foot obstacle clearance within 25 miles of an airport and are considered emergency altitudes since they do not assure navigation signal coverage. Controllers also made use of minimum vectoring altitudes (MVA), which were not normally available to pilots.

The NTSB testimony also indicated that pilots had become so accustomed to receiving assistance from controllers that, unless advised by the controller, they did not know what type of ATC service they were receiving. Often they were unsure of their position relative to terrain. There was considerable debate as to whether the flight was being handled as "radar arrival," which could have put the burden for terrain separation on ATC. The National Transportation Safety Board determines that the probable cause of the accident was the crew's decision to descend to 1,800 feet before the aircraft had reached the approach segment where that minimum altitude applied. The crew's decision to descend was a result of inadequacies and lack of clarity in the air traffic control procedures which led to a misunderstanding on the part of the pilots and of the controllers regarding each other's responsibilities during operations in terminal areas under instrument meteorological conditions Nevertheless, the examination of the plan view of the approach chart should have disclosed to the captain that a minimum altitude of 1,800 feet was not a safe altitude. (Source: NTSB Report #NTSB-AAR-75-16.)

5.1.2.4 Application to CFIT JSAT Taxonomy

The tragedy of flight 514 is captured in the many of the problem statements identified in the JSAT’s Document.

CFIT JSAT Problem Statements relevant to this scenario

#	Problem Title	Category	Problem Statement
5	ATC/FLIGHT CREW INADEQUATE COMMUNICATIONS)	Communication	Inability of ATC and the flightcrew to effectively communicate
11	FLIGHTCREW - INADEQUATE SITUATION AWARENESS (VERTICAL)	Situation awareness	Failure of flight crew to correctly identify aircraft height above ground
14	AIRCRAFT EQUIPMENT FAILURE	Equipment	Failure of instrument and/or warning system during critical phase of flight.
18	AIR TRAFFIC SYSTEM - LIMITED NAVAID AVAILABILITY	Equipment	NAVAIDs not available, inadequate or out of service

A number of additional errors contributed to the demise of flight 514. For example, the ATC failed to follow standard procedures (problem 8). In the dark, high winds and icy weather conditions experienced by flight 514 synthetic vision systems should have dramatically improved the outcome.

5.1.3 TA Flight 655

TA Flight 655 is an example of CFIT during the cruise portion of flight. The Ouachita Mountains of Arkansas and Oklahoma have proven dangerous to many aircraft in the past, particularly in inclement weather. The worst of these claimed eleven lives on a stormy evening.

5.1.3.1 Initial Conditions

Texas International Airlines, Inc. was operating the Convair 600 N94230 on a flight between Memphis and Dallas with stops in Pine Bluff, El Dorado, and Texarkana, Arkansas. During the 1973 flight, a line of thunderstorms intersected the route between El Dorado and Texarkana. Although cleared by dispatch for an Instrument Flight Rules (IFR) trip, upon departure the crew contacted the FSS and informed the controller that the flight was proceeding visually to Texarkana.

Initial Conditions Table

Aircraft Type	Turboprop Cargo/Transport
Crew Size	2
Flight Phase	Cruise
Flight Conditions	Thunderstorms
Lighting	Night
Airport	Tower operating
Terrain	High peaks in vicinity
Elevation	389

5.1.3.2 Sequence of Events

After takeoff, Flight 655 turned northwest and followed various headings for the next thirty minutes. First Officer William Tumlinson was flying the aircraft, taking heading commands from Captain Ralph Crossman. Tumlinson soon became concerned about the airplane's track, that they really didn't know where they were.

Twenty-seven minutes into the flight, Crossman ordered a turn to 290 degrees and a descent to 2000 feet. Thirty seconds later, the plane began to receive the signal from the Page VOR (located in Oklahoma). The Convair then collided with Black Fork Mountain, nearly one hundred miles north of Texarkana.

The aircraft struck the mountain at 216 miles per hour and disintegrated.

Sequence of Events Table

Situation	
Cruise	Initially IFR clearance then alerted control proceeding VFR.

5.1.3.3 Error Analysis

The crew proceeded using visual flight rules (VFR) when conditions warranted instruments (IFR). They failed to maintain an adequate idea of their course and direction and descended without considering the elevation of the near-by terrain.

5.1.3.4 Application to CFIT JSAT Taxonomy

CFIT JSAT Problem Statements relevant to this scenario

#	Problem Title	Category	Problem Statement
5	ATC/FLIGHT CREW INADEQUATE COMMUNICATIONS	Communication	Inability of ATC and the flightcrew to communicate effectively
10	FLIGHTCREW - FAILURE TO FOLLOW PROCEDURES (SOP)	Procedures	Failure of flight crew to follow established procedures
11	FLIGHTCREW - INADEQUATE SITUATION AWARENESS (VERTICAL)	Situation awareness	Failure of flight crew to correctly identify aircraft height above ground
16	FLIGHTCREW - CRM FAILURE	Training	Lack of CRM training or failure to follow CRM practices.

The flight crew did not coordinate with center and could have requested flight following, problem 5. SOP during meteorological conditions warranted IFR flight and the crew failed to maintain their SA for the terrain.

5.2 Commercial Aviation CFIT Incidents from ASRS

5.2.1 Determining Incidents of Interest

The ASRS database contains information about more than 80,000 aviation incidents. This data represents the information collected through voluntary incident reports provided by pilots, air traffic controllers and others. The database contains over 70 searchable fields and can be searched using any combination of terms and fields.

Our goal for using the database was to find incidents related to CFIT and human error during approach/landing. Each report in the database includes a narrative written by the person(s) submitting the report that describes the sequence of events. Because this information is based on self-reports and does not require a specific format or content, the level of detail across the narratives varies greatly. To determine if a given report would be suitable as the basis for a scenario it became necessary to read the narratives. In an effort to focus on reports related to our area of interest a search criteria was developed to help reduce the number of reports to read through. Our search criteria are broken down into primary and secondary. The primary criteria are used to focus on only those reports from pilots of passenger jetliners. The results of a primary criteria search resulted in several thousand reports. The secondary criteria was used to reduce the number of reports to review based on specific visibility issues and/or specific problems that occurred.

The table below shows the primary and secondary search criteria. The search fields for the ASRS database are organized across a number of tabbed pages. Each page lists several properties of the reports that can be searched. A list of values is provided for each property. The table includes columns for the search tab, property and value. The search values listed as ‘Primary’ were used together. The secondary search values were used either singly or in combination to obtain more focused sets of reports from the results of the primary criteria search.

Primary and Secondary ASRS Database Search Values

Search Tab	Property	Value
Primary		
Aircraft	Mission	Passenger
	Operator Organization	Air_Carrier
	Number of Engines	2, 3 or 4
	Wing	Low_wing
	Gear	Retractable
	Operating Surface	Land_based
	Flight Phase	Approach or Landing
	Aircraft Type	Large_Transport or Med_Large_Transport
Personnel	Function Broad	Flight_Crew
Secondary		
Environment & Location	Visibility (miles) – Low	0 through 10
General	Anomalies Occurred	Alt Dev/Overshoot on CLB or DES
		Alt Dev/Undershoot on CLB or Des
		Alt Dev/Excursion From Assigned
		Conflict/Airborne Less Severe
		Controlled Flight Toward Terrain
		Less Than Legal Separation

The results of searches using combinations of the secondary criteria were lists of between 0 and 100 reports. From these shorter lists we began reading narratives to find incidents suitable for consideration. The focus was on scenarios that could be used to analyze how the human errors that occurred and might be reduced or eliminated through the use of synthetic vision. Such scenarios should include attributes associated with the benefits of using synthetic vision and limit those attributes that are not affected by its use. For the purposes of creating narrative selection criteria, we focused on the attributes of synthetic vision associated with replacing the 'out the window' view and the tunnel navigation. As such, the selection criterion includes incidents of low visibility and/or difficult approach and landing patterns. In addition, scenarios specifically related to equipment problems were excluded. Approximately 300 incidents were reviewed during our database familiarization process and the more directed search process.

This section describes three incidents from the ASRS database that were categorized as CFTT (Controlled Flight Towards Terrain) anomalies. For each incident, the summary and narrative text of the original report from the database are included in Appendix B. Each incident is presented in three sections. The first section describes the initial conditions of the incident. The second presents the sequence of events leading up to the point where things began to go wrong. The third section describes what actually happened as described in the ASRS report. This is followed by an analysis of the errors from this incident.

5.2.2 ASRS Incident #1

The following incident is based on report number 326787 from the ASRS database.

5.2.2.1 Initial Conditions

A crew of three is flying a large passenger jet with a full load of vacationers for the island and is on time for a 22:15 arrival. The captain was the Pilot Not Flying (PNF) while the First Officer (FO) was the Pilot Flying (PF). They were executing a non-directional beacon (NDB) / Distance Measuring Equipment (DME) approach to runway 9. There was no controller support at this airport at this time. They had overcast to broken cloud cover at approximately 1200ft with lots of rain. Having just flown the published DME arc transition arriving from the west, they turned north on the 12-mile arc and joined the 114 deg bearing inbound to the airport. At 700ft Mean Sea Level (MSL) Minimum Decision Altitude (MDA) at about 3 DME the runway lights and rotating beacon were in sight. There are cliffs at approximately ¾ of a mile final to runway 9 at 900ft MSL.

Aircraft Type	Large Transport
Crew Size	3
Flight Phase	Approach, Landing
Flight Conditions	Mixed_Conditions
Ceiling	1200 ft broken to overcast
Weather	Raining
Lighting	Night
Airport	Uncontrolled
Airport Elevation	10 ft MSL
Terrain	Cliff band ¾ mile final to runway at 90O ft MSL

Initial Conditions Table

5.2.2.2 Sequence of Events

They briefed to maintain 700ft MDA until approximately 2.5 DME in order to fly a 300ft per mile vertical profile and to augment this slope with the Visually Aided Slope Indicator (VASI). The 24-degree approach angle to the final approach course to the runway, used to avoid the cliffs, did not allow a view of VASI until aligned closer to final. They initiated a 700-foot per minute (FPM) descent rate at 2.5 DME and passed through 600 ft MSL at 2 DME. The PNF was spending his time looking outside to provide headings to the FO to place him on an approximate 1 mile final aligned with the runway centerline while avoiding the cliffs. His vectoring was conservative and they maintained a substantial angle to the centerline keeping the VASI out of view with the rain distorting the view through the cockpit windows.

Situation	700ft MSL MDA at 3 DME Runway lights and rotating beacon in sight Briefed to maintain 700ft MDA until 2.5 DME in order to fly a 300 ft per mile vertical profile and augment with VASI VASI not in site
Approach	24 deg angle of final approach to runway. Non-precision
	Initiated 700 fpm descent rate
	Xing 2 DME at 600 ft MSL
	PNF using outside visual cues to align 1 mile final with centerline
	VASI still not visible

Sequence of Events Table

5.2.2.3 Outcome

During the descent and maneuvering, the FO and second officer (SO) were apparently looking for outside visual cues. At some point the PNF thought the visual cues did not look right and that something felt wrong and looked at the instruments. They were at 1.5 NM passing 100ft MSL descending at about 1000 FPM! He commanded a GAR and a left turn once they were climbing. They over flew the airport, leveled at 1000ft MSL and flew a downwind base leg and final approach to a normal landing.

SA	PF and NPF both looking outside for visual cues
SA	PNF realizes visual cues not right and feels that something is wrong.
Incident	1.5 NM passing 100ft MSL at 1000 FPM descent rate!
Action	PNF commanded a GAR.

Actual Outcome Table

The report continues by stating that the captain suspects that while the FO was straining to look out the windshield that there may have been an inadvertent forward elevator pressure that increased the rate of descent and since they were all looking outside, there was no one to notice the problem via the instruments.

5.2.2.4 Error Analysis

The pilots in this scenario had a number of problems that combined to make this a difficult approach and landing. First, at the time of their arrival there was no tower support. As such, the pilots had to rely entirely on their own ability to maintain the approach and landing profiles. Second, the non-precision approach pattern requires a number of course and altitude changes due to terrain interference close to the final approach path. Indeed, the final approach was made at a large enough angle from the centerline of the runway that the Visually Assisted Slope Indicator (VASI) was not visible for most of the approach. Third, the rainy weather was distorting the view through the windows.

The important cues in this situation come from two sources. The first source is the flight instruments that indicate the aircrafts location relative to the ground and airport and the aircrafts attitude. The other source is the cues outside the cockpit that provide visual references for location and attitude. In this situation, these included the terrain, the runway and VASI lights. Due to the approach angle relative to the centerline, the VASI light cues were not available to help maintain the glide slope. Due to the rain, the other exterior visual cues were either distorted or difficult to locate.

All this combined to create a situation of increasing stress and high workload as the crew attempted to maintain a non-precision glide path and approach that avoided terrain without the cues provided by the external slope support and with reduced ability to obtain visual cues. Individually, increased workload and increased stress both increase the probability of human errors. When combined, the probability of error is multiplied making the likelihood of human errors very high for this situation. In this case, the errors that were made relates to a loss of cockpit resource management and the suspected, inadvertent forward elevator pressure by the PF. The captain did not confirm the roles of PF, PNF and SO and did not notice that all three of them were searching for visual cues outside the cockpit (maybe wanting to catch the first glimpse of the VASI lights came into view as they came closer to the centerline).

5.2.2.5 Application to CFIT JSAT Taxonomy

Problem statement 11 describes the result of the problems that the crew had in this scenario. They had lost awareness of how fast the aircraft was descending and how far above the ground they were. In general, problem statements 10, 16 and 22 describe the errors that occurred to cause them to loose their vertical awareness. It is clear that they failed to follow procedures that would have distributed the workload of the cockpit crew over the range of cues necessary. It is unclear if this was the result of a lack of CRM training or just a failure to follow CRM practices. Since the captain was the PNF, statement 22 isn't directly applicable. It would be more accurate to say that the captain did not organize the cockpit responsibilities adequately to obtain all the necessary cues. Finally, due to the approach angle relative to the centerline, the VASI NAVAID equipment wasn't available to the crew.

#	Problem Title	Category	Problem Statement
10	FLIGHTCREW – FAILURE TO FOLLOW PROCEDURES (SOP)	Procedures	Failure of flight crew to follow established procedures
11	FLIGHTCREW - INADEQUATE SITUATION AWARENESS (VERTICAL)	Situation awareness	Failure of flight crew to correctly identify aircraft height above ground
16	FLIGHTCREW – CRM FAILURE	Training	Lack of CRM training or failure to follow CRM practices.
18	AIR TRAFFIC SYSTEM - LIMITED NAVAID AVAILABILITY	Equipment	NAVAIDs not available, inadequate or out of service
22	FLIGHTCREW – PNF DUTIES NOT PERFORMED	Procedures	Pilot Not Flying (PNF) failed to perform monitoring function and other PNF responsibilities

CFIT JSAT Problem Statements relevant to this scenario

5.2.2.6 Situational Awareness Error Taxonomy

All the SA errors associated with this incident are Level 1 errors of failing to correctly perceive information. Most of the important visual cues outside the aircraft were distorted by the rain and hard to discriminate or detect. The VASI lights were also unavailable due to the approach angle. The relevant cues from inside the aircraft were available but were not being attended to as the entire flight crew looked for the outside cues.

SA Error Type	Error Description
Level 1: Failure to correctly perceive information.	
Data hard to discriminate or detect.	Outside cues of terrain obscured by rain. VASI lights unavailable due to approach angle.
Failure to monitor or observe data	The data provided by the aircraft instruments were not being attended to.

Related SA Error Taxonomy Statements

5.2.2.7 HFACS Error Taxonomy

The errors from this incident can be classified using HFACS as one Unsafe Act and one Precondition for Unsafe Acts. The Unsafe Act was a skill-based error and attention failure and is based on the captain's supposition that the FO was inadvertently applying forward elevator pressure that increased the rate of descent while they were all looking outside. The Precondition for the Unsafe Act is classified as a substandard practice of the operator related to crew resource mismanagement and occurred when the captain did not organize the cockpit duties or realize that both he and the FO were both looking outside for visual cues and nobody was observing the internal flight instruments.

HFACS Error Classification	Error Description
Unsafe Act	
Skill-based error: Attention failure	The FO (PF) applied forward elevator pressure without realizing it.
5.2.2.8 Precondition for Unsafe Acts	
Substandard practice of operators: Crew resource mismanagement	The captain did not organize cockpit duties on approach or realize that everyone was looking outside.

Related HFACS Error Taxonomy Statements

5.2.3 ASRS Incident #2

The following incident is based on report number 284260 from the ASRS database.

5.2.3.1 Initial Conditions

This B757 with a crew of two was on approach to Salt Lake City at night under good weather conditions. The captain was the PF and the co-pilot was the PNF. They had just been released from holding at FL210 over FFU VOR and ATC had instructed them to descend to 11,000 ft, maintain 250 kts or less and contact SLC approach control.

Aircraft Type	B757
Crew Size	2
Flight Phase	Approach, Go Around
Flight Conditions	VMC
Weather	Clear
Lighting	Night
Location	Salt Lake City, UT

Initial Conditions Table

5.2.3.2 Sequence of Events

Approach control cleared them to intercept RWY 34 LOC and to cross LUFCO intersection at 9000ft. Upon leveling at 9000ft, approach indicated a 727 at 8000ft at 12 o'clock and 1.5 miles their position. The pilots could not see the indicated aircraft due to high amount of ground lights that it was superimposed over. However, the TCASII display showed numerous targets including what the pilots believed with the indicated traffic. Approach then cleared them to 8500 ft and then to 7000 ft. They were still at 250 knots with a strong tail wind. They were high and fast nearing the OM (outer marker) and approach vectored them off the LOC to 310 deg. Descending to 7000 ft at about 240 kts when the controller asked them to visually acquire a south bound 757 at their 11 o'clock and 3 miles. The co-pilot indicated that he saw another aircraft near that location but the pilot could not see it. The radio traffic was very busy and when they got a chance the co-pilot told the controller that he could see two aircraft to their left. The controller indicated which one to follow then gave a turn to 260 deg and clearance to 6000ft, which the co-pilot read back. The controller asked if they still had the 757 to which the co-pilot answered no. The controller asked if they were still on 160 deg to which the co-pilot answered no, he had wanted 260 deg. The controller, sounding surprised, told them to turn to 160 deg and asked if they had the terrain in sight. The pilots responded that they could not see any terrain as it was dark.

Approach Control	Cleared to intercept RWY 34 LOC and cross LUFCO INTXN at 9000ft.
Traffic	Indicated a 727 at 8000ft at 12 o'clock and 1.5 miles Pilots could not see traffic due to high contrast ground lights of the city. TCASII display had numerous targets
Approach Control	Cleared to 8500 ft then to 7000 ft
Speed	250 knots with a strong tail wind
Location	High and fast coming up on the OM
Approach Control	Vectored them off the LOC to 310 deg and asked them to acquire a south bound 757 at their 11 o'clock and 3 miles Heavy radio traffic caused delay When he got through, co-pilot told control that they had two aircraft to their left. Control indicated which one to follow
Problem	Control gave them a turn to 260 and clearance to 6000ft which the co-pilot read back. The controller asked if they still had the 757. Co-pilot responds negative Controller asked if they were still on 160 deg Co-pilot responds negative they were given 260 deg Controller, surprised, gives them 160 deg and asked if they can see terrain. Co-pilot responds negative, it's dark.

Sequence of Events Table

5.2.3.3 Outcome

The controller told them to turn to 160 deg and climb to 7000 ft. Once done the controller asked again if they could see the terrain and then became very excited. He told them to turn quickly then to turn immediately to 090 deg and climb to 12000ft. After leveling at 12000 ft, the controller vectored them back to 160 deg and cleared to 7000ft. He then vectored them to 090 to intercept the 34 LOC then a tight turn to 340 to intercept. Although the strong tailwind pushed them through the LOC they were able to correct visually and made a safe landing.

Avoiding Terrain	Turn 160 deg and climb to 7000ft Turn immediately to 090 and climb to 12000ft
Redoing Approach	160 deg, cleared back to 7000ft 090 deg to intercept 34 LOC Tight turn to 340 to intercept
Visually adjust	Pilots had to visually adjust approach to runway as tailwind pushed them through LOC.
	Safe landing

Actual Outcome Table

5.2.3.4 Error Analysis

The results of the errors in this situation are the reduced spacing of aircraft and the controlled flight toward terrain. These problems seem to be the result of a combination of stressors during the approach and the reliance by the approach controller on the pilots ability to visually acquire targets in a visually limited environment. The stressors involve the apparent high workload of the controller and the time limitations imposed by the speed of the aircraft. Although the pilots made this ASRS report, they do mention that the radio traffic is quite high and that there are a number of aircraft in the area. It seems possible that the controller workload was high during the time period of this incident. In addition, the report mentions the speed of the aircraft combined with a tail wind and how that changed the dynamic of the approach. It seems possible that the approach instructions provided by the controller did not take the ground speed of the aircraft into account. This affect on the approach profile combined with the potential heavy workload of the controller may have prevented the controller from having a sufficient positional awareness of the aircraft over time.

Although the weather was not an issue, several of the visual tasks required of the pilots were either difficult or highly prone to error based on the situation and human visual limitations. As part of maintaining aircraft spacing and supporting the difficult approach profile, the controller repeatedly asked the pilots to visually acquire aircraft at lower altitudes. At night, pilots would have to acquire such targets based on the lights of the other aircraft but being over a large city the smaller aircraft lights were lost in the city light background. Although the TCASII system supported the pilots in terms of collision avoidance, it does not help in trying to follow another aircraft on an approach when that aircraft is difficult to visually detect. The controller also asked the pilots to visually acquire terrain in order to help avoid it. This task was not possible given the lighting conditions and was not supported by any of the aircraft systems. The controller seems to have an insufficient understanding of the pilot's situation and didn't realize that their ability to complete the tasks he needed them to do was limited.

5.2.3.5 Application to CFIT JSAT Taxonomy

The table below lists the subset of problem statements from the JSAT CFIT documents that describe limitations and errors from the incident. The first column lists the problem statement number from the CFIT document. The second column contains the title of the problem. The third column lists a categorization of the problem statement. The fourth column provides the text of the problem statement.

#	Problem Title	Category	Problem Statement
5	ATC / FLIGHTCREW INADEQUATE COMMUNICATIONS	Communications	Inability of ATC and the flight-crew to effectively communicate
7	ATC - INADEQUATE SITUATION AWARENESS (HORIZONTAL)	Situation awareness	Failure of ATC to correctly identify aircraft position over the ground

CFIT JSAT Problem Statements relevant to this scenario

Problem statement 5 relates specifically to the problem of the 160 deg versus 260 deg course provided by the controller during the approach sequence. Although reporting pilots stated that a read-back of the instructions did occur, it is clear that there was a communications breakdown between pilots and controller. Either the controller provided the wrong heading and did not catch the error from the read-back or the pilots understood the wrong number and the controller did not catch the error from the read-back. Problem statement 7 represents the seeming failure of the controller in keeping track of the horizontal location of the aircraft due to a combination of workload and the speed of the aircraft. It is apparent in at least two instances that the controller was surprised by the location of the aircraft. The first was early in the sequence when the controller vectored the aircraft off the locator as they were coming in too high and fast. The second was when the controller required a quick then immediate turn to avoid the terrain. This seems to indicate that the controller did have some difficulty in maintaining his situational awareness of the horizontal and, perhaps, vertical position of the aircraft relative to approach profile reference points, other aircraft and terrain.

5.2.3.6 Situational Awareness Error Taxonomy

This incident includes errors associated with all three levels of SA error types. The Level 1 errors of failing to correctly perceive information are all associated with trying to visually acquire cues or targets that are hard to discriminate or detect. These problems include trying to detect aircraft at night that are at lower altitudes and whose lights are lost in or obscured by the background lights of the city. They also include trying to detect terrain at night. The Level 2 and 3 errors are associated with the mental model used by the controller to generate his SA of the aircraft's location. It is possible that he was failing to correctly integrate or comprehend the effects of the aircrafts ground speed. This could have been the result of an over-reliance on default values related to how fast aircraft normally traverse the approach pattern versus how fast this aircraft was traveling. It is also possible that he was failing to project the future state of the system accurately. In either case, it led the controller to expect more time to maintain the aircraft's approach profile that was actually available.

SA Error Type	Error Description
Level 1: Failure to correctly perceive information.	
Data hard to discriminate or detect.	Aircraft lights obscured by background of city lights and unlit terrain at night.
Level 2: Failure to correctly integrate or comprehend information.	
Over-reliance on default values.	Normal time to traverse approach pattern versus accelerated approach of this aircraft.
Level 3: Failure to project future state of the system	
Other	Workload of controller may have affected his ability to accurately predict the position of the aircraft over time.

Related SA Error Taxonomy Statements

5.2.3.7 HFACS Error Taxonomy

The errors from this incident can be classified using HFACS as two Unsafe Acts both by the controller. The Unsafe Act is classified as a poor choice decision error and occurred repeatedly when he chose an interaction and approach methodology that required the crew to perform night time visual acquisition tasks that turned out to be difficult or impossible. The second Unsafe Act was a violation that may be routine. It occurred when the controller’s approach profile for the aircraft brought it with 1.5 miles of another aircraft thus violating spacing restrictions. This violation may be routine in that it may be common practice on approach and landing provided the pilots can visually acquire the aircraft.

HFACS Error Classification	Error Description
Unsafe Act	
Decision error: Poor choice	The controller’s choice of an approach profile and interaction that required difficult visual tasks from the pilots at night.
Violation: Routine	The approach required by the controller that reduced the spacing between aircraft.

Related HFACS Error Taxonomy Statements

5.2.4 ASRS Incident #3

The following incident is based on report number 253008 from the ASRS database.

5.2.4.1 Initial Conditions

This aircraft with a crew of 2 was on approach for the airport in Charlotte on a clear night. The captain was the PNF while the copilot was the PF.

Aircraft Type	Medium Large Transport
Crew Size	2
Flight Phase	Go Around
Flight Conditions	Visual Meteorological Conditions (VMC)
Lighting	Night
Airport	Charlotte, NC
Location	~5 miles downwind for runway 23
Visibility	The visibility was good but the brightness of the city lights masked the airport lights.

Initial Conditions Table

5.2.4.2 Sequence of Events

They were on an extended left downwind for runway 23 at approximately 5 miles out. The PF, in the right seat, did not have the airport in site as it was on their left. The captain (PNF) told control that he had the airport in site. The PF made the turn into the airport but could not locate it. The visibility was good but the airport lights did not stand out from the surrounding city lights. The captain provided a heading of 300 deg for the PF to follow for the approach. They continued to descend on 300 deg but the PF could still not see the airport.

Situation	Extended left downwind 5 miles out
Coms & Sequence	Captain reported airport in sight while PF could not see it. PF made turn into airport but could not locate it. Captain provided heading to fly for approach (300 deg). PF continued descent on heading

Sequence of Events Table

5.2.4.3 Outcome

They were continuing to descend on 300 deg when the captain suddenly told the PF to quickly turn to 230 deg and GAR. The PF briefly saw the airport directly under them as they turned and flew directly down the runway 23 centerline. They were handed off to departure control who had them circle and land on runway 18R.

Captain	Commanded a quick turn to 230 and GAR
PF	Briefly saw airport as they passed directly over it.
Control	Departure control had them circle and land on 18R.

Actual Outcome Table

The report continues by indicating that the captain thought he had identified the airport but was really looking at some other lights in the city. The reporting pilot indicates that it is an unwritten rule that they not tell controllers that the airport is in site until both pilots can see it. It was also stated that the pilots believed the controllers would have to sequence them farther out behind other aircraft if they couldn't accept a visual approach from their original position. Finally, no traffic conflicts occurred as a result of the GAR but the potential certainly existed.

5.2.4.4 Error Analysis

The errors in this incident are the captain erroneously identifying other city lights as the airport in a visually cluttered environment and the co-pilot believing that since the captain could see the airport that he would be able to see it after making a turn towards it. They also did not follow what the co-pilot describes as an unwritten rule of indicating visual contact with the airport to the tower only after both pilots can see it. On a clear night, the city lights create a visually cluttered environment in which to locate the airport lights. The captain indicated to the controller that he could see the airport before the co-pilot could thus eliminating the second person check and an opportunity to recover from the identification error. The co-pilot admits not questioning the captain and continuing to fly even though he couldn't see the airport. Their decision to continue may have been effected by the implied time pressure of having to wait for a later approach if they could not continue with the original visual approach.

5.2.4.5 Application to CFIT JSAT Taxonomy

Problem 10 is not directly applicable as the co-pilot indicates that they broke an 'unwritten' rule when they couldn't both see the airport. However, it does represent a failure to follow accepted operating practices. It is unclear from the report why the crew didn't want to take another approach later in the landing sequence. However, it is possible that an 'on-time' culture existed that pushed them to continue as represented by problem 15. It is also possible that the crew simply wanted to continue even though they knew things weren't ideal. Problem statement 21 represents this problem of 'pressing on'.

#	Problem Title	Category	Problem Statement
10	FLIGHTCREW - FAILURE TO FOLLOW PROCEDURES (SOP)	Procedures	Failure of flight-crew to follow established procedures
15	AIRLINE OPERATIONS - CORPORATE "ON-TIME" CULTURE	Culture	Airline/operator culture unduly emphasizes on-time performance
21	FLIGHTCREW - "PRESS-ON-ITUS"	Culture	Flight crew disregard of, or failure to recognize, cues to terminate current course of action or maneuver

CFIT JSAT Problem Statements relevant to this scenario

5.2.4.6 Situational Awareness Error Taxonomy

The SA errors in this incident are all related to Level 1 errors associated with failing to correctly perceive information. The captain erroneously identified lights he thought were the airport in a background of city lights that made the data hard to discriminate. The FO also failed to detect the airport following the turn. His SA prior to that is based on the erroneous information from the captain, which also represents a failure related to the cues for SA.

SA Error Type	Error Description
Level 1: Failure to correctly perceive information.	
Data hard to discriminate or detect.	The captain erroneously identified lights he thinks are the airport in the cluttered background. The FO is also unable to visually acquire the airport

Related SA Error Taxonomy Statements

5.2.4.7 HFACS Error Taxonomy

The errors in the incident can be classified using HFACS as two Unsafe Acts and one Precondition for Unsafe Acts by the pilots and a possible Organizational Influence. Both Unsafe Acts are decision errors. The first is a procedural error and occurred when the captain broke the unwritten rule of indicating to the controller that the airport was in site before both pilots could see it. The second was a poor choice when they chose to continue even though the PF couldn’t see the airport after turning towards it. The Precondition is classified as a substandard condition of operator based on a physical limitation. The error here was the action of continuing with a visual approach in a visually confusing environment. The possible Organization Influence was an ‘on-time’ climate that may have pushed the pilots to continue with the visual approach knowing that they would have to be sequenced behind other aircraft and land later if they did not continue.

HFACS Error Classification	Error Description
Unsafe Acts	
Decision error: Procedural	Breaking the unwritten rule of both pilots seeing the airport before reporting airport in site.
Decision error: Poor choice	Continuing the approach when both pilots could not see the airport.
Precondition for Unsafe Acts	
Substandard condition of operator: Physical limitation	Using a visual approach in a visually cluttered and confused environment.
Organization Influences	
Organizational climate	An 'on-time' climate may have existed that helped push the pilots to continue their approach.

Related HFACS Error Taxonomy Statements

6 CFIT Accident/Incident Summary

The CFIT accidents and incidents in this report are intended to provide insight into generating realistic scenarios that include error chains or sequences of events that could culminate in controlled flight into terrain. Such scenarios can be translated into scripts and programmed into high fidelity simulators to be used for finding ways to break these chains of events. Likewise, these simulations could be used to test the effectiveness of new support tools like the SVS. While it may be true that a single problem could theoretically cause a CFIT accident, realistic CFIT scenarios should include a sequence of problems similar to those described in the six accidents/incidents described in this report. This section will summarize some of the common errors associated with CFIT accidents and CFTT incidents and use them as the basis for components that could be used to generate realistic CFIT scenarios.

One important factor that has been identified in CFIT accidents and illustrated in several of the incidents and accidents described in this report is the increased risks associated with non-precision approaches (NPA) during the approach and landing phases of flight. A study by the Flight Safety Foundation found that 60% of the CFIT accidents clearly associated with pilot error between 1988-1994 involved NPA (Wiley, 1999). This study reported that the majority of these did not have significant high terrain features and were instead associated with landing short. NPA are associated with less situational awareness due to impoverished cue sets, increased workload and requires greater crew coordination than precision approaches. Crews are far less likely to train adequately on NPA and yet many commercially important airfields do not have PA capability. The JSAT document highlights NPA as an issue in reducing CFIT as well.

In addition to the problems associated with NPAs, the following table lists the combined CFIT JSAT problem statements from the six accidents/incidents analyzed in this document. While this list only represents the problems described in these six accidents/incidents and should not be considered representative of all CFIT problems, it does illustrate some of the common features of CFIT accidents that could be used to generate CFIT scenarios. The table lists the problem statements in the same format as the JSAT CFIT document. The first column lists the problem statement number from the CFIT document. The second column contains the title of the problem. The third column lists a categorization of the problem statement. The fourth column provides the text of the problem statement.

#	Problem Title	Category	Problem Statement
3	AIR TRAFFIC SYSTEM LACK OF STANDARDIZATION (APPROACH/DEPARTURE PLATES)	Equipment	Lack of standardized departure and approach plate depiction
5	ATC / FLIGHTCREW INADEQUATE COMMUNICATIONS	Communications	Inability of ATC and the flight-crew to effectively communicate
7	ATC - INADEQUATE SITUATION AWARENESS (HORIZONTAL)	Situation awareness	Failure of ATC to correctly identify aircraft position over the ground
10	FLIGHTCREW - FAILURE TO FOLLOW PROCEDURES (SOP)	Procedures	Failure of flight-crew to follow established procedures
11	FLIGHTCREW - INADEQUATE SITUATION AWARENESS (VERTICAL)	Situation awareness	Failure of flight crew to correctly identify aircraft height above ground
14	AIRCRAFT EQUIPMENT FAILURE	Equipment	Failure of instrument and/or warning system during critical phase of flight.
15	AIRLINE OPERATIONS - CORPORATE "ON-TIME" CULTURE	Culture	Airline/operator culture unduly emphasizes on-time performance
16	FLIGHTCREW - CRM FAILURE	Training	Lack of CRM training or failure to follow CRM practices.
18	AIR TRAFFIC SYSTEM - LIMITED NAVAID AVAILABILITY	Equipment	NAVAIDs not available, inadequate or out of service
20	AIRLINE OPERATIONS LACK OF TRAINING	Training	Airline/operator training failed to adequately address operational requirement
21	FLIGHTCREW - "PRESS-ON-ITUS"	Culture	Flight crew disregard of, or failure to recognize, cues to terminate current course of action or maneuver
22	FLIGHTCREW - PNF DUTIES NOT PERFORMED	Procedures	Pilot Not Flying (PNF) failed to perform monitoring function and other PNF responsibilities
23	FLIGHTCREW – DISREGARD FLIGHTDECK WARNING	Procedures	Failure of flight crew to respond to flight deck warning

Combined JSAT CFIT Problem Statements

The table describes common problems from CFIT accidents that include communication issues between controllers and the flight crew, loss of vertical and horizontal situation awareness, and crew resource management issues. Other problems include various types of equipment problems of the aircraft and navigation aids, safety culture of flight crew and the organization, and various types of procedural violations. Other common features not described in the table include limited or obscured visibility, high workload and stress that increase the likelihood of errors, terrain or structural features. Occurrences of CFIT type problems also seem to be more associated with the approach and landing phase of flight but do occur during other phases.

The incidents and accidents from this document can be used as scenarios without alteration. They can also be altered using other common CFIT problem components to vary the scenarios. Finally, the common problems and features listed here can be used to generate new scenarios. To generate realistic CFIT scenarios similar to those described in the incidents and accidents, the components should include some combination of events from these broad categories. The focus of the scenario should be to put the flight crew and/or controller in situations that lead to problems associated with unintentionally placing the aircraft in close proximity to the ground. The chosen components should include background information and features of the current situation, latent errors or problems, as well as timed events designed to create problems for the flight crew or controller. For example, a scenario of a non-precision approach with limited visibility combined with communications problems between the controller and the flight crew would lead to high workload and stress and increase the likelihood of errors. These errors might include CRM, SA, or procedural problems during the approach. Stress could also be applied to both controllers and flight crew by including increased air traffic or a terrain feature to avoid. The development of accurate situational awareness can be affected by equipment problems or distractions that prevent certain cues from being observed.

7 Conclusions and Recommendations

This paper served two functions. The first and more abstract function was to identify and describe the context of human error. We believe a meaningful first-cut of that was presented in Section 4 with the Context of Human Error Matrix. The matrix attempts to convey the dynamic nature of the emerging errors – something that we feel is missing from the more static-like representations of the error taxonomies in Appendix A. We believe a more thorough understanding of the context of error can occur when the matrix is mapped one-for-one with human failure links in an error chain. The matrix has the potential to allow for a detailed correlation of precursors/root causes to unsafe acts. As this is a working paper rather than a final report, we recommend that further development of the matrix be considered. In particular, we were unable to acquire the complete list (321) of HFACS categories in time to support this research. We believe that if the matrix contained a more detailed decomposition of the precursor and unsafe act categories, then it could be employed practically for post-accident/incident analysis to more fully understand the context in which errors are committed.

In addition, a high fidelity Context of Human Error Matrix could be used in reverse manner to play what-ifs. In other words, if a fictitious pilot was burdened with a group of precursors (e.g., poor training of NPA), what errors would he/she be most likely to make? This would be useful for developing mitigation strategies before a mishap would even occur. When considering new technology (e.g., flight deck decision aids), the matrix could be a useful evaluation tool for the human factors practitioner to predict and resolve potential errors during the design/development process.

The second and more tangible function was to provide the Human Performance Modeling Element of the Aviation Safety Program with accidents and incidents corresponding to approach and landing phases of flight and/or CFIT. Three accidents and three incidents were chosen and analyzed in detail. We believe this analyses will provide insight into generating realistic scenarios that could be programmed into high fidelity simulators for further research into human error and mitigation or potentially even pilot training.

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A Appendix A – Taxonomies of Human Error

A.1 Error Taxonomy for Situation Awareness

Table 4 – SA Error Taxonomy (Endsley, 1999)

Error Type	Error Description
Level 1: Failure to correctly perceive information	
Data not available	Data is not available due to failure of the system design to present it or failure in the communication process.
Data hard to discriminate or detect	Examples are poor runway markings or inadequate lighting, noise in the cockpit, or obstructions blocking view.
Failure to monitor or observe data	Data is available, but is not scanned due to simple omission, attentional narrowing, distractions due to multi-tasking, or high workload.
Misperception of data	Data is misperceived due to influence of prior expectations or misunderstood due to task distraction.
Memory loss	Forgetting information is due to disruptions in normal routine or high workload.
Level 2: Failure to correctly integrate or comprehend information	
Poor mental model	Poor mental model does not enable the combining of information needed to meet goals. Primarily associated with automated systems.
Use of incorrect mental model	Interpretation of cues through an expected, but wrong, mental model of a system's behavior leads to the incorrect assessment of the situation.
Over-reliance on default values	Routine expectations of the system is assumed even though conflicting information is available, but not accessed.
Other	Information is not properly integrated or comprehended due to working memory lapses or other undetermined cognitive reasons.
Level 3: Failure to project future actions or state of the system	
Poor mental model	Information of current state is correctly understood, but projection of that state into the future fails because of poor understanding of how to do so.
Over-projection of current trends	The current state is projected into the future correctly. However, it is projected further into the future than for which the data is realistically valid. This, combined with not updating the projections at appropriate intervals, can lead to incorrect plans for the future.
Other	Projection of current state into the future fails because it is a demanding task that in a multi-tasking environment is not always performed. This is possibly due to the lower priority it is given or due to limits in cognitive resources.
General	

Failure to maintain multiple goals	Failure to maintain multiple goals in memory degrades SA across all three levels.
Executing habitual schema	Performing task automatically can result in important system cues being overlooked.

Endsley (1995) applied the three-level SA error taxonomy to NTSB accident reports during a four year period. 71% of the accidents could be classified as having a substantial human error component. Of those accidents, 88% (32) involved degraded SA. Specifically, 72% were Level 1 errors, 22% were Level 2, and 6% were Level 3. In a much more detailed application of the SA error taxonomy, Jones and Endsley (1996) utilized voluntary reports from NASA's Aviation Safety Reporting System for 111 incidents involving pilots and 32 incidents involving controllers. The results are shown in Table 5.

Table 5 - SA Error Taxonomy:

Percentage of Incidents by Error Type

	Error Type	**Frequency (%)**
General	Failure to maintain multiple goals	0
	Executing habitual schema (less receptive to cues)	0
Level 1	Data not available	13
	Data hard to discriminate	11.1
	Failure to monitor data	35.1
	Misperception of data	8.7
	Memory loss	8.4
Level 2	Lack of poor mental model	6.9
	Use of incorrect mental model	6.5
	Over-reliance on default values	4.6
	Other	2.3
Level 3	Lack of poor mental model	0.4
	Over-projection of current trends	1.1
	Other	1.9

Although the percentages of Level 3 errors are quite low for the two studies mentioned above, its importance should not be undervalued. Level 3 errors are the leading cause of air traffic control operational errors for TRACON and Center operations at 29% and 32.8% respectively. Given that a controller manages and provides separation assurance for air traffic almost exclusively by propagating current states into the future, these statistics are no surprise. What is important to glean from this data is as the United States transitions to a Free Flight paradigm, pilots will become more responsible for their self-separation from other aircraft. In order to do this, pilots must understand how current or pending actions can affect their projected aircraft state relative to other air traffic. Although flight deck decision aids will assist the pilot, Level 3 SA of the pilot in a Free Flight paradigm will become paramount to aircraft safety.

A.2 Error Taxonomy from the Model of Internal Human Malfunction

Rasmussen (1982) outlined a decision-making process that led to the development of multi-step chain for diagnosing cognitive failure (O'Hare et al., 1994). The model assumes that information is processed beginning with the detection of cues in the environment and ending with action execution.

The types of error described by O'Hare can be summarized in Table 6as follows:

Table 6 - Error Taxonomy from Model of Internal Human Malfunction

Error Type	Error Description
Error other than human (structural, mechanical, electrical, etc.)	Pilot intervention could not prevent the accident/incident.
Information error	The pilot did not detect cues arising from the change in system states.
Diagnostic error	The pilot did not accurately diagnose the state of the system based on the information available.
Goal Setting error	The pilot did not choose a goal that was reasonable given the circumstances.
Strategy Selection error	The pilot did not choose a strategy that would achieve the intended goal.
Procedure error	The pilot did not execute procedures consistent with the strategy selected.
Action error	The pilot did not execute procedures as intended.

Using this model, Wiegmann and Shappell (1997) categorized flight related mishaps (Class A, B & C) for the US Navy and Marine Corps between 1977 and 1992. 91.3% (264) of the mishaps attributed to pilot causal factors fit this model. The results are shown in **Table 7**

Table 7 - Error Taxonomy from the Model of Internal Human Malfunction: Percentage of Mishaps by Error Type

Error Type	Frequency (%)
Information	6.1
Diagnostic	21.72
Goal Setting	11.55
Strategy Selection	12.95
Procedure	39.48
Action	8.19

A.3 Error Taxonomy from the Model of Unsafe Acts

Reason (1990) classifies human actions into three levels:

- **Skill-based** actions are routinely practiced and highly automatic (e.g., keeping a car in its lane on a windy mountain road). Conscious thought is used sporadically to verify progress.

- **Rule-based** actions are a combination of conscious and unconscious processes to determine responses for situations that have been encountered before, either through experience or training (e.g., routine takeoffs and landings). Unconscious pattern recognition matches the indicators of a problem to a potential solution. The mind then rationalizes consciously if the solution is appropriate. If it is not, then other stored rules are considered as solutions.

- **Knowledge-based** actions require slow, demanding, and highly-error prone conscious thought to determine a response when other methods have proven unsuccessful (e.g., multiple system failures). The broader and deeper the knowledge base, the more likely a good solution will be determined. Trial and error approaches can be successful if there is sufficient time.

The three levels of actions described above, if performed incorrectly, are categorized as either **errors** or **violations**. Errors differ from violations in that errors are unintended whereas violations are deliberate. Violations are deviations from normal operating procedures (e.g., cutting corners while performing a sequence of tasks), though in most instances the human committing the violation does not consider it an unsafe act. Another important difference between errors and violations is the means in which they are reduced. Whereas errors can be reduced by improving the quality of the information processed by the human, solutions to reduce violations require motivational, (e.g., enforcement of compliance, improved morale, show of concern), cultural, and organizational changes that are quite broad and far-reaching. Below we will discuss each of the three error types in the Reason taxonomy.

A.3.1 Error Types

When a **skill-based** action is not performed as intended, the result is a skill-based error that can be categorized as a slip, lapse or perceptual error:

- **Attentional slips** occur when we fail to monitor the progress of routine actions at some critical point, usually when our situation or intention has just changed. Then, actions of habit for the old situation or intention override the new actions.

- **Memory lapses** occur when we forget what we earlier intended to do or when we omit steps from a plan of action.

- **Perceptual errors** were later added to the model (Maurino, Reason, et al, 1995). They occur when we don't recognize some object or situation and is often based on either habit or expectation (e.g., Train conductor expecting a green light, but light is actually red)

When a rule-based action does not produce results as intended, the result is a **rule-based mistake** that can be categorized into one of two levels:

- **Misapplication of good rules** occur most often when several elements in a situation are familiar, but other aspects of the situation are distinctly different. The person applies a good rule for the familiar aspects of the situation, but overlooks the other critical aspects that make the good rule invalid. (e.g., braking on icy road for a pedestrian in the crosswalk)

- **Application of bad rules** occur when an incorrect rule has been used repeatedly in the past with no negative consequences. The repeated use of the bad rule reinforces the person's belief in the rule, but eventually a situation arises where something goes wrong (e.g., not wearing a seat belt and being involved in a car accident).

Lastly, a **knowledge-based mistake** occurs when a person is solving a unique problem that involves conscious reasoning. However, the solution is error-prone because of working memory limitations, inaccurate mental model of the situation, confirmation bias, frequency bias, similarity bias, and over-confidence.

A.3.2 Violation Types

- **Skill-based violations (i.e., routine violations)** are typically actions that cut corners due to an attitude of indifference about the environment (e.g., using the turn signal when changing lanes). The violator is rarely punished for incorrect actions or rewarded for correct actions.

- **Rule-based violations (i.e., situational violations)** are actions that assess the cost benefit trade-off of complying with proper rules and procedures vs. the time or effort saved by skipping steps. Although the person fully intends to violate the rules, they do so with the belief that nothing unsafe will happen in doing so.

- **Knowledge-based violations (i.e., exceptional violations)** in many cases occur when the situation preceding the violation was not covered by training or procedure. The violations can also occur in situations in which an unlikely combination of familiar aspects presents itself.

Wiegmann and Shappell (1997) again, like the Model of Internal Human Malfunction in Section 3.2, applied the Model of Unsafe Acts to flight related mishaps (Class A, B & C) for the US Navy and Marine Corps between 1977 and 1992. 91.3% (264) of the mishaps attributed to pilot causal factors fit this model. In this case, the taxonomy did not follow the Model of Unsafe Acts as rigorously – rule-based and knowledge-based mistakes were lumped together as were the three types of violations. The results are shown in **Table 8**.

Table 8 - Error Taxonomy from the Model of Unsafe Acts: Percentage of Mishaps by Error Type

Error Type	Frequency (%)
Slip	14.28
Lapse	11.18
Mistake	57.13
Violation	17.42

A.4 Error Taxonomy based on the Information Processing Model

Although not specifically developed to address human error, the classic Information Processing model (Wickens and Flach, 1988) provides another framework for classifying human error through a series of mental operations beginning with sensory stimuli and ending with response execution.

- **Sensory store** converts physical phenomena (e.g., light, sound) into neural manifestations. The information lasts briefly and does not require attention resources.

- **Pattern recognition** maps the physical codes of the sensory stores into meaningful elements (markings into letters, letters into words). This mapping is very complex and the least understood of the stages. Different physical memory codes may map to a single memory code, or conversely, a single physical code may map to several memory codes. Pattern recognition is strongly influenced by signal detection, data sampling, and linguistic factors.

- **Decision/response selection** is the next step and depends on the options available. The information can be stored in working memory to be used in the near future; the information can be combined with other information; or the information can initiate a decision process to immediately select a response. The information itself is often probabilistic so the consequences of the action for valid vs. invalid information needs to be considered. Cost benefit tradeoffs are often weighed in the decision making process.

- **Response execution** is initiated by the response selection. This stage takes the high level response and decomposes it into the required auditory, motor and cognitive steps. The execution of the response then becomes the feedback mechanism to the sensory stores.

- **Attention Resources** do not fit directly into the "sensory stimuli to response execution" sequence. Rather, attention resources can be viewed as a limiting factor for the last three stages – pattern recognition, response selection, and execution. For pattern recognition, attention resources may or may not limit perceptual processes (e.g., radio communication may be disregarded until the correct call sign is given or an inflection in voice captures the pilot's attention). Attention resources can delay or render the restart of both the response selection and response execution stages.

Wiegmann and Shappell (1997) again, like the Model of Unsafe Acts above, applied the Model of Information Processing to flight related mishaps (Class A, B & C) for the US Navy and Marine Corps between 1977 and 1992. 86.9% (251) of the mishaps attributed to pilot causal factors fit this model. The results are shown in Table 9.

Table 9 - Error Taxonomy from the Model of Information Processing: Percentage of Mishaps by Error Type	
Error Type	**Frequency (%)**
Sensory error	2.84
Pattern recognition error	14.87
Decision/response selection error	29.54
Response execution error	45.48
Attention resources error	7.28

A.5 Human Factors Analysis and Classification System – HFACS

A complete description in Acrobat format is available at:
http://www.cami.jccbi.gov/AAM-400A/Abstracts/2000/FULLTXT/00_07.pdf

- Unsafe Acts
  - Skill-based errors
    - Attention failures
    - Memory failures
    - Technique errors
  - Decision errors
    - Procedural errors
    - Poor choices
    - Problem solving errors
  - Perceptual errors
    - Visual illusions
    - Spatial disorientation
  - Violations
    - Routine violations
    - Exceptional violations
- Preconditions for Unsafe Acts
  - Substandard conditions of operators
    - Adverse mental states
    - Adverse physiological states
    - Physical / Mental limitations
  - Substandard practices of operators
    - Crew resource mismanagement
    - Personal readiness
- Unsafe Supervision
  - Inadequate supervision
  - Planned inappropriate operations
  - Failure to correct a known problem
  - Supervisory violations
- Organizational Influences
  - Resource management
  - Organizational climate
  - Operational processes

B Appendix B – ASRS Report Narratives

Appendix B contains the original text from the ASRS database for each of the three incidents analyzed in this document.

B.1 ASRS Incident # 1

Reference Number: 326787

B.1.1 Summary Text

ACR MAKING AN APCH INTO PTPN, THE CAROLINA ISLANDS, DSNDS TO 100 FT AGL AS ALL 4 CREW MEMBERS ARE 'OUTSIDE.' MAP.

B.1.2 Narrative Text

WE WERE EXECUTING THE NDB/DME RWY 9 AT PTPN, WX WAS APPROX 1200 BROKEN TO OVCST, VISIBILITY AT 75 MI WITH RAIN. FO WAS PF. I WAS PNF ALSO GIVING INITIAL OPERATING EXPERIENCE TO THE FO AS A CHK AIRMAN. WE FLEW THE PUBLISHED DME ARC TRANSITION ARRIVING FROM THE W ON R584 FROM TRUK. WE ARCED N ON THE 12 MI ARC AND JOINED THE 114 DEG BEARING INBOUND. AT THE 700 FT MSL MDA AND REACHING THE MAP AT 3 DME THE RWY LIGHTS AND THE ROTATING BEACON WERE IN SIGHT AND WE CONTINUED TO THE ARPT. THE SOKEH CLIFFS ARE LOCATED AT ABOUT A 3/4 MI FINAL TO RWY 9 AT 906 FT MSL. WE BRIEFED TO MAINTAIN 700 FT MDA UNTIL APPROX 2.5 DME IN ORDER TO FLY A 300 FT PER MI VERT PROFILE AND TO AUGMENT THAT WITH THE VASI. UNFORTUNATELY, THE 24 DEG ANGLE OF THE FINAL APCH COURSE TO THE RWY DOES NOT ALLOW A VIEW OF VASI UNTIL ALIGNED CLOSER TO FINAL. WE INITIATED A 700 FPM RATE OF DSCNT AT THE AGREED VDP. I RECALL XING 2 DME AT 600 FT MSL. FROM THEN ON, I SPENT CONSIDERABLE TIME LOOKING OUTSIDE TO PROVIDE HDGS TO THE FO TO PLACE HIM ON AN APPROX 1 MI FINAL ALIGNED WITH RWY CTRLINE. AWARE OF THE CLIFFS, MY 'VECTORING' WAS CONSERVATIVE AND WE MAINTAINED A SUBSTANTIAL ANGLE TO THE CTRLINE. THIS MADE THE VASI NOT VISIBLE, AS WELL AS THE TRAPEZOID VIEWING OF THE RWY. APPARENTLY DURING THE DSCNT AND MANEUVERING, THE FO WAS SPENDING MOST OF HIS TIME 'OUTSIDE.' IN ADDITION, OUR SO AND A FOURTH CREW MEMBER IN THE JUMP SEAT (GIVING SO IOE) ALSO WERE LOOKING FOR VISUAL CLUES IN THE RAIN DISTORTED VIEW OUT THE WINDSHIELD. AT SOME POINT THE VISUAL CLUES DID NOT LOOK RIGHT, AND AN 'INTERNAL ALARM' WENT OFF TELLING ME ALL WAS NOT RIGHT. LOOKING AT THE FLT/NAV INSTS WE WERE AT 1.5 NM PASSING 100 FT MSL DSCNT AT ABOUT 1000 FPM! I COMMANDED A GAR AND A L TURN ONCE WE WERE CLBING. WE OVER FLEW THE ARPT, LEVELED AT 1000 FT MSL, AND FLEW A DOWNWIND BASE AND FINAL TO A NORMAL LNDG. AFTER PARKING AT THE GATE, I POINTED OUT OUR NEAR 'SPLASH' TO THE OTHER 3 CREW MEMBERS AS I WAS NOT SURE THEY FULLY APPRECIATED WHAT HAD ALMOST OCCURRED. FROM MY THOUGHTS ON THE APCH, I SURMIZED THAT ALL 4 OF US WENT OUTSIDE LOOKING FOR VISUAL CLUES, WITH NOBODY MINDING THE STORE MONITORING THE FLT INSTS. I SUSPECT, AS THE FO STRAINED TO LOOK OUT THE WINDSHIELD, THAT THERE MAY HAVE BEEN AN INADVERTENT FORWARD ELEVATOR PRESSURE THAT INCREASED OUR RATE OF DSCNT. OUR TRAINING EMPHASIZES THE NEED TO MAINTAIN PROFILE AWARENESS DURING THESE NON PRECISION MANEUVERS, HOWEVER, WE ALL GOT LURED INTO FINDING THE VISUAL CLUES THAT RAINY NIGHT AT THE EXPENSE OF OUR DSCNT PROFILE. I HAVE ALWAYS BEEN CONSCIENTIOUS IN BRIEFING THE MDA, MAP, AND MISSED APCH PROC, AND MAKE SURE THE SO IS INVOLVED WITH THE GUYS UP FRONT. I SHALL FURTHER EMPHASIZE THE

NEED FOR SOMEONE STAYING INSIDE TO MONITOR THE AIRPLANE'S PROGRESS DURING THESE APCHS. PREVIOUS SIMULATOR TRAINING EMPHASIZED THAT, WHEN ONE PLT IS 'OUTSIDE,' THE OTHER SHOULD BE 'INSIDE.' I WILL BE SURE THAT WHEN I AM OUTSIDE THAT THE OTHER PLT WILL KEEP HIS ATTN MOSTLY INSIDE. WHEN THERE ARE SUFFICIENT VISUAL CLUES TO CONTINUE VISUAL AND HE CONFIRMS 'RWY IN SIGHT' OR 'I'M VISUAL' WE WILL THEN SWAP DUTIES WITH HE BEING MOSTLY OUTSIDE WITH ME GOING INSIDE. THERE NEEDS TO BE A DIALOGUE BACK AND FORTH BETWEEN THE 2 PLTS FOR THIS TO WORK. THE SO NEEDS TO BE THE BACKSTOP. FROM HIS POS HE CAN SEE THE APCH DEVELOP BEFORE HIM AND SHOULD BE ACTIVE IN CALLING OUT ANY DEVS THAT THE CAPT AND FO DON'T DETECT. SOMETIMES GOOD SOP'S ARE IN PLACE, THEY JUST NEED EMPHASIZING ON A REGULAR BASIS TO KEEP INCIDENTS LIKE THIS FROM OCCURRING.

B.1.3 Other Report Values

Flight Conditions:	Mixed_Conditions
Lighting	Night
Ceiling	1200 ft
Visibility	3 miles
Flight Phase	Approach, Landing
Flight Plan	IFR
Type	Large Transport
Engines	3
Ref Distance	2 miles
ALT_AGL	100 ft
Anomaly	Controlled Flight Toward Terrain

B.2 ASRS Incident # 2

Reference Number: 284260

B.2.1 Summary Text

CTLED FLT TOWARDS TERRAIN AFTER A HDG TRACK DEV DURING A MAP.

B.2.2 Narrative Text

THIS EVENT OCCURRED JUST AFTER RELEASE FROM HOLDING AT FL210 OVER FFU VOR. ATC INSTRUCTED US TO DSND TO 11000 FT, TO MAINTAIN 250 KTS OR LESS, AND TO CONTACT SLC APCH CTL. APCH CTL CLRED US TO INTERCEPT RWY 34 LOC AND TO CROSS LUFCO INTXN AT 9000 FT. AS WE WERE ABOUT TO LEVEL AT 9000 FT APCH POINTED OUT A 727 AT 8000 FT AT OUR 12 O'CLOCK POS, AND 1 1/2 MI. WE DID NOT SEE THIS TFC VISUALLY DUE TO THE MASSIVE AMOUNT OF GND LIGHTS OVER WHICH IT WAS SUPERIMPOSED. THE TCASII DISPLAY SHOWED NUMEROUS TARGETS INCLUDING WHAT WE BELIEVED TO BE THIS TFC BELOW AND SLIGHTLY TO THE FRONT OF US. APCH INDICATED THAT THIS 727 WAS BEING CLRED BELOW US TO RWY 35 AND AT THIS TIME CLRED US TO 8500 FT AND THEN TO 7000 FT. WE WERE STILL AT 250 KTS AND WERE COVERING GND RAPIDLY DUE TO A STRONG TAILWIND. AT ABOUT THIS TIME WE WERE NEARING THE FINAL APCH FIX (OM) STILL HIGH AND FAST AND APCH CTL, REALIZING THIS, VECTORED US OFF THE LOC ON A 310 DEG HDG. WE WERE STILL ON A 310 DEG HDG AND ABOUT 240 KTS AND STILL DSNDING TO 7000 FT WHEN THE CTLR ASKED US TO VISUALLY ACQUIRE A SBOUND 757 AT OUR 11 O'CLOCK AND 3 MI. MY COPLT SAID THAT HE SAW ANOTHER ACFT AT OUR 11-12 O'CLOCK SLIGHTLY BELOW US AND PROBABLY 5 OR 6 MI AWAY. I DID NOT SEE THIS PARTICULAR TFC AT THAT TIME AS I WAS MANUALLY FLYING THE AIRPLANE. THE RADIO WAS REALLY BUSY AT THIS TIME AND WHEN HE GOT A CHANCE MY COPLT RPTED TO THE CTLR THAT WE SAW 2 ACFT TO OUR L AND THE CTLR REPLIED THAT WE WOULD FOLLOW THE ONE AT 11-12 O'CLOCK. HE THEN GAVE US A TURN TO 260 DEGS AND CLRED US TO 6000 FT

AND MY COPLT REPEATED THIS BACK TO HIM. THE CTLR ASKED 'DO YOU STILL HAVE THE 757 TFC IN SIGHT?' MY COPLT REPLIED 'NO' AND THEN THE CTLR ASKED IF WE WERE ON A 160 DEG HDG AND MY COPLT RESPONDED 'NO, YOU TOLD US 260 DEGS' AND THE CTLR THEN SAID 'NO -- I GAVE YOU 160 DEGS -- WE CAN TALK ABOUT THIS LATER -- TURN TO 160 DEGS.' HE THEN ASKED US IF WE HAD THE TERRAIN IN SIGHT. MY COPLT RESPONDED 'NO, IT'S DARK!' THE CTLR THEN SAID TURN TO 160 DEGS AND CLB TO 7000 FT AND WE TURNED TO 160 DEGS. AGAIN THE CTLR ASKED US IF WE SEE THE TERRAIN, AT WHICH TIME HE SEEMED TO GET QUITE EXCITED. HE SAID 'TURN QUICKLY,' AND ADDED 'TURN IMMEDIATELY TO 090 AND CLB TO 12000 FT.' AFTER WE LEVELED AT 12000 FT HE VECTORED US TO 160 DEGS AND AGAIN CLRED US TO 7000 FT. THEN HE VECTORED US 090 TO INTERCEPT 34 LOC THEN 'A TIGHT TURN' TO 340 TO INTERCEPT. A STRONG TAILWIND AT THIS ALT PUSHED US THROUGH THE LOC BUT WE CORRECTED BACK VISUALLY AND FROM THAT POINT OF THE LNDG WAS NORMAL.SUPPLEMENTAL INFO FROM ACN 284331: ATC RPTED 727 TFC AT 8000 FT, 12 O'CLOCK, 1.5 MI, WHICH WE NEVER SAW VISUALLY, BUT HAD ON TCASII.

B.2.3 Other Report Values

Make	B757
Lighting	Night
Time	1800-2400
Flight Conditions	VMC
Location	Salt Lake City, UT
Crew Size	2
Number of Engines	2
Flight Phase	Go Around
Anomalies	NON ADHERENCE LEGAL RQMT/FAR TRACK OR HDG DEVIATION CONTROLLED FLT TOWARD TERRAIN NON ADHERENCE LEGAL RQMT/PUBLISHED PROC NON ADHERENCE LEGAL RQMT/CLNC

B.3 ASRS Incident #3

Reference Number: 253008

B.3.1 Summary Text

AN ACR MLG MADE AN APCH TO SOMETHING THAT LOOKED LIKE CLT ARPT.

B.3.2 Narrative Text

WE WERE ON AN EXTENDED L DOWNWIND FOR RWY 23 AT CLT. SINCE I SIT IN THE R SEAT AND THE ARPT WAS TO OUR L, I DIDN'T HAVE THE ARPT IN SIGHT. WHILE ON APPROX 5 MI DOWNWIND, THE CAPT TOLD THE APCH CTLR THAT WE HAD THE ARPT IN SIGHT. WHILE I COULDN'T ACTUALLY SEE THE ARPT FROM WHERE I WAS SITTING, I WAS QUITE SURE I WOULD BE ABLE TO PICK UP THE ARPT VISUALLY ONCE WE TURNED IN TOWARDS THE ARPT. I TURNED IN, I COULDN'T PICK OUT THE ARPT AS EASILY AS I FIGURED AND THE CAPT GAVE ME A HDG TO FLY. THE VISIBILITY ON THIS PARTICULAR EVENING WAS EXCEPTIONAL, AND ON THESE OCCASIONS ARPT LIGHTS ARE OFTEN HARD TO PICK UP BECAUSE THE SURROUNDING CITY LIGHTS APPEAR SO BRIGHT. I FLEW THE 300 DEG HDG BUT STILL HAD NO LUCK SEEING THE ARPT AS WE DSNDED. THE CAPT SUDDENLY TOLD ME TO QUICKLY TURN TO A 230 DEG HDG AND INITIATE A GAR AT ABOUT 2500 FT MSL. I BRIEFLY SAW THE ARPT PASS DIRECTLY UNDERNEATH US AS WE FLEW DOWN THE RWY 23 CTRLINE. TWR HANDED US OFF TO DEP AND WE CIRCLED AND LANDED UNEVENTFULLY ON RWY 18R. THE CAPT HAD ALL ALONG BEEN LOOKING AT OTHER LIGHTS OFF IN THE DISTANCE, AND HADN'T SEEN THE ARPT UNTIL WE WENT AROUND. THERE WERE NO TFC CONFLICTS, AS OUR GAR TOOK US DIRECTLY DOWN THE CTRLINE OF RWY 23. THERE HAS ALWAYS BEEN SORT OF AN UNWRITTEN LAW THAT SAYS YOU DON'T CALL THE ARPT IN SIGHT UNTIL BOTH CREW MEMBERS CAN SEE IT. WHEN THE CTLR

INITIALLY ASKED US IF WE HAD THE ARPT IN SIGHT, HE INFERRED THAT IF WE COULDN'T TAKE A VISUAL APCH FROM OUR PRESENT POS, HE WOULD HAVE TO TAKE US FURTHER OUT TO SEQUENCE US BEHIND OTHER TFC. IN THE FUTURE I WILL TRY TO DISSUADE CAPTS FROM CALLING THE FIELD IN SIGHT WHEN I CAN'T OR DON'T SEE IT YET. I WILL NOT ACCEPT VISUAL APCHS UNLESS THE PF ALSO SEES THE ARPT.

B.3.3 Other Report Values

Lighting	Night
Time	1800-2400
Location	North Carolina
Crew Size	2
Number of Engines	2
Flight Phase	Go Around
Anomalies	CONFLICT/GROUND LESS SEVERE CONTROLLED FLT TOWARD TERRAIN TRACK OR HDG DEVIATION

C Appendix C: Synthetic Vision Affects on Incidents and Accidents

The synthetic Vision System (SVS) that is current under development a research has the potential to eliminate or reduce the occurrences of CFIT type errors. This section includes brief descriptions of how SVS might affect some of the incidents and accidents analyzed in this document.

C.1 ASRS Incident #1 (Ref 326787)

The main cause of error in this scenario is the increased stress level and workload. The captain knew how things should have been done but got too focused on obtaining visual cues and didn’t maintain good cockpit resource management. The increases in both stress and workload are caused by a combination of a difficult approach and weather conditions and darkness that made it difficult to obtain visual cues. The use of synthetic vision would reduce the workload and provide many of the cues that were either difficult to obtain due to weather and darkness or unavailable due to approach characteristics and equipment limitations.

The synthetic vision would provide a clear visual representation of the terrain including the cliff band. This would allow the pilots to obtain visual terrain reference cues independent of darkness or weather. The tunnel navigation function of synthetic vision would aid the pilots by providing them a visual approach corridor that takes the terrain and approach angles into account. This would allow the pilots to have all the necessary cues easily visible within the cockpit and provide a clear indication of any deviations from the approach and landing profiles. This reduction in workload and addition of other cues would reduce the stress level and therefore probability for human error related to controlled flight into terrain.

C.2 ASRS Incident #2 (Ref 284260)

The use of the SVS would be able to support the tasks required of the pilots but would not affect the SA problems of the controller. The target acquisition tasks required of the pilots would be much easier to perform using the SVS. They would easily be able to detect nearby aircraft to either avoid or follow and the terrain would be clearly represented. The system might also be able to help recover quickly from the direction communication error. Even after the read-back of the heading failed to help catch the 160 versus 260 deg discrepancy, the use of the SVS may have allowed the pilots to see that the 260 deg heading was incorrect and allow them to query the controller.

The SVS does not do anything to support the SA of the controller in this incident. There is nothing about SVS that would help the controller maintain his control of the approach profile as the aircraft’s speed moves it along faster than he expects. However, in adding to the information provided to the pilots it may reduce the workload of the controller by requiring less controller support of the pilots.

C.3 ASRS Incident #3 (Ref 253008)

The SVS would provide a representation of the airport that eliminates the problem of identifying it in a cluttered background of light. Even though the weather is not an issue, the ability to obtain the required visual cues, the airport in this case, is seriously degraded. The SVS would allow the pilots to continue the approach without having to visually acquire the airport.