Increasing Learning from Accidents
A Systems Approach illustrated by the UPS Flight 1354 CFIT Accident

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Introduction

Most accident analyses are based on *ad hoc* approaches. Many formal analysis techniques have been proposed, but few are widely used. This case study shows how a structured process called CAST (Causal Analysis based on Systems Theory), based on a more powerful model of accident causation, can improve the results of accident investigation. The case study used is a CFIT (controlled flight into terrain) accident involving a UPS A300-600 aircraft while landing at the Birmingham-Shuttlesworth International Airport on August 14, 2013. The results are compared with the official NTSB accident report. The NTSB process is usually considered the "gold standard" in accident investigations, and indeed, they do an excellent job. Therefore, a comparison of the results is informative about how accident investigation and analysis might be improved beyond the standard approach used by the NTSB and most others.

The structured analysis method used, called CAST[6] (Causal Analysis based on System Theory), is based on an expanded accident model called STAMP (Systems-Theoretic Accident Model and Processes) [Leveson, 2012]. Traditionally, accidents have been thought of as resulting from a chain of failure events, each event directly related to the event that precedes it in the chain. For example, the baggage door is not completely closed, the aircraft climbs to a level where unequal pressure between the cargo compartment and the passenger cabin causes the cabin floor to collapse, the cables to the control surfaces (which run through the floor) are severed, the pilots cannot control the aircraft, and the plane crashes. The biggest problem with such a chain-of-events model is what it omits. For example, why did the design of the baggage door closure mechanism made it difficult to determine whether it was effectively sealed? Why did the pilots not detect that the door was not shut correctly? Why did the engineers create a design with a single point failure mode by running all the cables through the cabin floor? Why did the FAA certification process allow such designs to be used? And so on. While these additional factors can be included in accident investigation and analysis, there is no structured process for making sure that "systemic" causal factors are not missed.

STAMP extends the traditional model of accident causation to include the chain-of-events model as one subcase but includes the causes of accidents that do not fit within this model, particularly those that occur in the complex sociotechnical systems common today. These causes (in addition to component failure) include system design errors, unintended and unplanned interactions among system components (none of which may have failed), flawed safety culture and human decision making, inadequate controls and oversight, and flawed organizational design. In STAMP, accidents are treated as more complex processes than simple chains of failure events. The focus is not simply on the events that led to the accident, but ***why*** those events occurred.

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[6] Unfortunately, the acronym CAST for this accident analysis approach has an important conflict in the aviation community. CAST has been used as an accident analysis technique for close to 20 years in the safety community and for about the same time in aviation to denote Commercial Aviation Safety Team, without either group being aware of the conflict. In this paper, CAST appears only as a reference to the accident analysis technique

The other significant difference is that, instead of focusing on failures, STAMP assumes that accidents are caused by a lack of effective enforcement of safety constraints on the system behavior to prevent hazardous states or conditions. Thus, safety becomes a control problem, not a failure problem. Controls are created to prevent hazards, such as CFIT. Such controls clearly include pilot knowledge, but they also include ILS and PAPI, ATC and MSAW (Minimum Safe Altitude Warning), procedures and training, ground proximity warning systems, standards, government regulation and oversight, etc. Theoretically, the extensive controls that have been introduced to eliminate CFIT should have prevented the accident. Why didn't they? How can we learn from the accident to improve those controls?

Because individual controls and controllers may not be adequate or effective, there are almost always many types of controls used. The goal of accident analysis should be not to identify someone to blame (in practice this is usually the flight crew) because they did not satisfy their particular role in preventing a hazard such as CFIT but to identify all the flaws in the safety controls that allowed the events to occur, to understand why each of these controls was not effective, and to learn how to strengthen the controls and the design of the safety control system in general to prevent similar losses from occurring in the future.

In this paper, CAST is demonstrated with a case study of a CFIT accident at the Birmingham-Shuttlesworth International Airport. The official NTSB accident report [AAR-1402-2] summarizes the accident (the chain of events) in the following way:

> On August 14, 2013, about 0447 central daylight time (CDT), UPS flight 1354, an Airbus A300-600, N155UP, crashed short of runway 18 during a localizer nonprecision approach to runway 18 at Birmingham-Shuttlesworth International Airport (BHM), Birmingham, Alabama. The captain and first officer were fatally injured, and the airplane was destroyed by impact forces and postcrash fire. The scheduled cargo flight was operating under the provisions of 14 *Code of Federal Regulations* Part 121 on an instrument flight rules flight plan, and dark night visual flight rules conditions prevailed at the airport; variable instrument meteorological conditions with a variable ceiling were present north of the airport on the approach course at the time of the accident. The flight originated from Louisville International Airport-Standiford Field, Louisville, Kentucky, about 0503 eastern daylight time.
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> A notice to airmen in effect at the time of the accident indicated that runway 06/24, the longest runway available at the airport and the one with a precision approach, would be closed from 0400 to 0500 CDT. Because the flight's scheduled arrival time was 0451, only the shorter runway 18 with a nonprecision approach was available to the crew. Forecasted weather at BHM indicated that the low ceilings upon arrival required an alternate airport, but the dispatcher did not discuss the low ceilings, the single-approach option to the airport, or the reopening of runway 06/24 about 0500 with the flight crew. Further, during the flight, information about variable ceilings at the airport was not provided to the flight crew.
>
> The captain was the pilot flying, and the first officer was the pilot monitoring. Before descent, while on the direct-to-KBHM leg of the flight, the captain briefed the localizer runway 18 nonprecision profile approach, and the first officer entered the approach into the airplane's flight management computer (FMS). The intended method of descent (a "profile approach") used a glidepath generated by the FMS to provide vertical path guidance to the crew during the descent from the final approach fix (FAF) to the decision altitude, as opposed to the step-down method ("dive and drive") that did not provide vertical guidance and required the crew to refer to the altimeter to ensure that the airplane remained above the minimum crossing altitude at each of the approach fixes. When flown as a profile approach, the localizer approach to runway 18 had a decision altitude of 1,200 ft mean sea level (msl), which required the pilots to decide at that point to continue descending to the runway if the runway was in sight or execute a missed approach.

> As the airplane neared the FAF, the air traffic controller cleared the flight for the localizer 18 approach. However, although the flight plan for the approach had already been entered in the FMS, the captain did not request and the first officer did not verify that the flight plan reflected only the approach fixes; therefore, the direct-to-KBHM1 [The Birmingham airport waypoint] leg that had been set up during the flight from Louisville remained in the FMS. This caused a flight plan discontinuity message to remain in the FMS, which rendered the glideslope generated for the profile approach meaningless. The controller then cleared the pilots to land on runway 18, and the first officer performed the Before Landing checklist. The airplane approached the FAF at an altitude of 2,500 ft msl, which was 200 ft higher than the published minimum crossing altitude of 2,300 ft.
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> Neither pilot noticed that the flight plan was not verified nor that the meaningless glideslope information even though they knew they were above the glideslope at the FAF. When the autopilot did not engage in profile mode, the captain changed the autopilot mode to the vertical speed mode, but he did not brief the first officer of the autopilot mode change.
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> About 7 seconds after the first officer completed the Before Landing checklist, the first officer noted that the captain had switched the autopilot to vertical speed mode; shortly thereafter, the captain increased the vertical descent rate to 1,500 feet per minute (fpm). The first officer made the required 1,000-ft above-airport-elevation callout, and the captain noted that the decision altitude was 1,200 ft msl but maintained the 1,500 fpm descent rate. Although the approach violated the stabilized approach criteria defined in the UPS flight operations manual, they did not perform a go-around. As the airplane descended to the minimum descent altitude, the first officer did not make the required callouts regarding approaching and reaching the minimum descent altitude, and the captain did not arrest the descent at the minimum descent altitude.
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> The airplane continued to descend, and at 1,000 ft msl (about 250 ft above ground level), an enhanced ground proximity warning system (EGPWS)3 "sink rate" caution alert was triggered. The captain began to adjust the vertical speed in accordance with UPS's trained procedure, and he reported the runway in sight about 3.5 seconds after the "sink rate" caution alert. The airplane continued to descend at a rate of about 1,000 fpm. The first officer then confirmed that she also had the runway in sight. About 2 seconds after reporting the runway in sight, the captain further reduced the commanded vertical speed, but the airplane was still descending rapidly on a trajectory that was about 1 nautical mile short of the runway. The cockpit voice recorder then recorded the sound of the airplane contacting trees followed by an EGPWS "too low terrain" caution alert.

The National Transportation Safety Board determined that "the probable cause of this accident was the flight crew's continuation of an unstabilized approach and their failure to monitor the aircraft's altitude during the approach, which led to an inadvertent descent below the minimum approach altitude and subsequently into terrain [AAR-1402-2].

The report also concludes that contributing to the accident were (1) the flight crew's failure to properly configure and verify the flight management computer for the profile approach; (2) the captain's failure to communicate his intentions to the first officer once it became apparent the vertical profile was not captured; (3) the flight crew's expectation that they would break out of the clouds at 1,000 feet above ground level due to incomplete weather information; (4) the first officer's failure to make the required minimums callouts; (5) the captain's performance deficiencies likely due to factors including, but not limited to, fatigue, distraction, or confusion, consistent with performance deficiencies exhibited during training; and (6) the first officer's fatigue due to acute sleep loss resulting from her ineffective off-duty time management and circadian factors.

Note that the probable cause and the contributing factors identified focus only on the flight crew behavior and the events in the event chain reflecting flight crew "failures." Alternatively, a system's approach looks not only at what human operators (such as pilots) did that contributed to the accident but, more important, *why* they believed it was the right thing to do at that time. In addition, the entire system for preventing CFIT is examined and not just the pilot behavior. How did the system design influence the events and the flight crew's behavior? Why were the design controls to prevent CFIT not effective in this case?

In this approach, safety is treated as a *control* problem, not a *failure* problem. Commercial aviation has many controls to prevent CFIT. To maximize learning from the events, focus in CAST is on why the controls were not effective in this case and how they can be improved for the future.

The rest of this section shows the CAST analysis of the accident causes. As will be seen, most of the emphasis is on explaining why the flight crew and others behaved as they did, i.e., why it made sense to them to do what they did [Dekker, 2017], and why the controls to prevent such behavior were not effective.

CAST tries to avoid *hindsight bias* by assuming that the humans involved (absent any contradictory information) were trying to do the right thing and did not purposely engage in behavior that they thought would lead to an accident. After an accident, it is easy to see where people went wrong, to determine what they should have done or not done, to judge people for missing a piece of information that turned out to be critical, and to blame them for not foreseeing or preventing the consequences [Dekker, 2017]. Before the event, such insight is difficult and, usually, impossible. The Clapham Junction railway accident in Britain concluded: "There is almost no human action or decision that cannot be made to look flawed and less than sensible in the misleading light of hindsight" [Hidden 1990]. CAST attempts to eliminate hindsight bias as much as possible from accident analysis. Simply listing what people did wrong provides very little useful information about how to eliminate or mitigate that behavior.

The next section describes CAST using UPS Flight 1354 as an example. The full analysis is contained in Appendix A and only examples are provided in the main part of the paper.

In the last section, the NTSB findings and recommendations are compared to the CAST findings and recommendations. This section contains some general thoughts about the concept of "probable cause" and of accident analysis in general.

There was no opportunity to do additional investigation for the CAST analysis, so the only things used were the NTSB findings (which are usually very comprehensive) and the basic knowledge of the authors of this report about aircraft safety and airline operations. The difference is not in the facts but in their interpretation.

CAST is most effective when used during an investigation to generate the questions that should be answered. Many of the questions generated during the CAST analysis are not answered in the NTSB report and are therefore left as questions in the CAST analysis. Even without answers to these questions, additional conclusions and recommendations are derived from the CAST analysis than are provided in the NTSB report on this accident.

CAST Analysis of the Loss of UPS Flight 1354

In a systems approach to safety, the role of the system as a whole to ensure constraints on behavior (i.e., prevention of hazards) is emphasized, not individual failures. Commercial aviation has introduced many controls to prevent CFIT. To maximize learning from the events, focus in CAST is on *why* the controls were not effective in this case and how they can be improved for the future.

CAST has three main components: identifying the system-level hazard involved in the loss (usually easy), modeling the control structure involved in the accident, and analyzing the control structure to identify why the existing controls were unable to prevent the accident. The results are then used to generate recommendations to improve the controls and control structure in order to prevent future accidents.

Identifying System-Level Hazard Leading to the Loss

The first step in the CAST analysis is identification of the hazard involved. In this case it was *Controlled Flight into Terrain* or CFIT. The constraint that must be enforced by the controllers and controls is that aircraft must not experience controlled flight into terrain.

The next step is to build a model of the safety control structure. The safety control structure is the controls that existed at the time of the accident to prevent the hazard. That control structure will in subsequent steps be used to analyze why it was not effective in this case.

Modeling the Safety Control Structure Created to Prevent CFIT (the Hazard)

Aviation has an excellent safety record and learning from past events has led to many controls being introduced into the system. The goal of the CAST analysis is to determine why the controls (as a whole) were ineffective in preventing the current loss. To accomplish this goal, a model is first created of the current controls and overall control structure. This model then becomes the focus of the analysis.

The control structure uses the basic engineering concept of feedback control. Figure 1 shows a simple feedback control loop. The usual requirements for effective management—assignment of responsibility, authority, and accountability—are mapped onto this control loop. The controller has responsibilities assigned to it with respect to enforcing the system safety constraints. It satisfies these responsibilities by issuing control actions on the process it is controlling (representing its authority). The controller can determine what type of control actions are required to satisfy its responsibilities for preventing hazards given the current state of the controlled process, as identified through feedback from the controlled process.

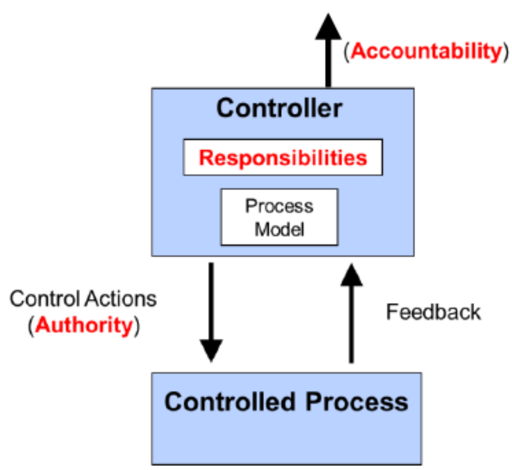

Figure 1: A Simple feedback control loop showing the relationship to standard Management concepts of responsibility, authority, and accountability

As an example, The FAA has responsibilities related to overseeing the safety of flight in the U.S. They have various types of control actions to carry out their responsibilities, such as airworthiness circulars and directives, FAA regulations, handbooks and manuals, Notices to Airmen (NOTAMs), policy and guidance, etc. Feedback comes in the form of reporting systems, accident and incident analyses, audits and inspections, etc. to determine the current state of safety of the air transportation system.

Ultimately, they are accountable to the U.S. Dept. of Transportation, Congress, and the executive branch.

Feedback information is incorporated into the controller's model of the controlled process, called the *process model* or, if the controller is a human, it may be called the *mental model*. Accidents often result when the controller's process model becomes inconsistent with the actual state of the process and the controller provides unsafe control as a result. For example, the air traffic controller thinks that two aircraft are not on a collision course and does not change the course of one or both. Other examples are that the manager of an airline believes the pilots have adequate training and expertise to perform a particular maneuver safely when they do not or a pilot thinks that de-icing has been accomplished when it has not.

There are four general types of unsafe control actions:

1. A provided control action leads to a hazard: e.g., two aircraft are not on a collision course but ATC issues control actions that put them on one.
2. Not providing a necessary control action leads to a hazard: e.g., two aircraft are on a collision course but one or both are not diverted.
3. A control action provided with wrong timing (early, late) or control actions in the wrong order leads to a hazard: a change of course is issued, but too late to avoid the collision.
4. A continuous control action provided for too long or too short a time leads to a hazard: e.g., the pilot is told to go up to 30,000 feet but instead levels off at 25,000 feet.

These four types of unsafe control actions, along with the hierarchical safety control structure, can be used after an accident to generate the causal scenarios that led to the loss or to identify future potential accident scenarios so they can be eliminated or mitigated in the system design.

Problems can occur not just because of inconsistency between the controller's process model and the state of the controlled process but also when different controllers, all involved in the same general task—particularly under safety-critical or emergency conditions—are operating with different mental models of either (a) what the system is currently doing, or (b) what should be done to control it. Process models are kept up to date, as stated, through feedback or from information received externally. A common factor in accidents is that appropriate feedback or other information about the state of the controlled process is incorrect, missing, or delayed.

The use of the process model concept is a much better way to understand why humans or software may have done the wrong thing and how to prevent such events in the future than simply saying the human or software or organization "failed," which only attaches a pejorative word without providing any insight about *why* the person or software did something dangerous.

The basic control loop shown in Figure 1 is combined with others to create the more complex control structure in real safety control systems. Figure 2 shows a generic example of a safety control structure. The controls related to development are shown on the left and those relating to operations on the right. The downward arrows represent control actions while the upward arrows show feedback. Each level of the control structure controls the components at the level below.

There is usually interaction between parallel control structures. Manufacturers must communicate to their customers the assumptions about the operational environment in which the original safety analysis was based, e.g., maintenance quality and procedures, as well as information about safe operating procedures. The operational environment, in turn, provides feedback to the manufacturer about the performance of the system during operations. Each component in the hierarchical safety control structure has responsibilities for enforcing the safety constraints appropriate for that component. Taken together, the entire control structure should prevent or mitigate hazardous system behavior.

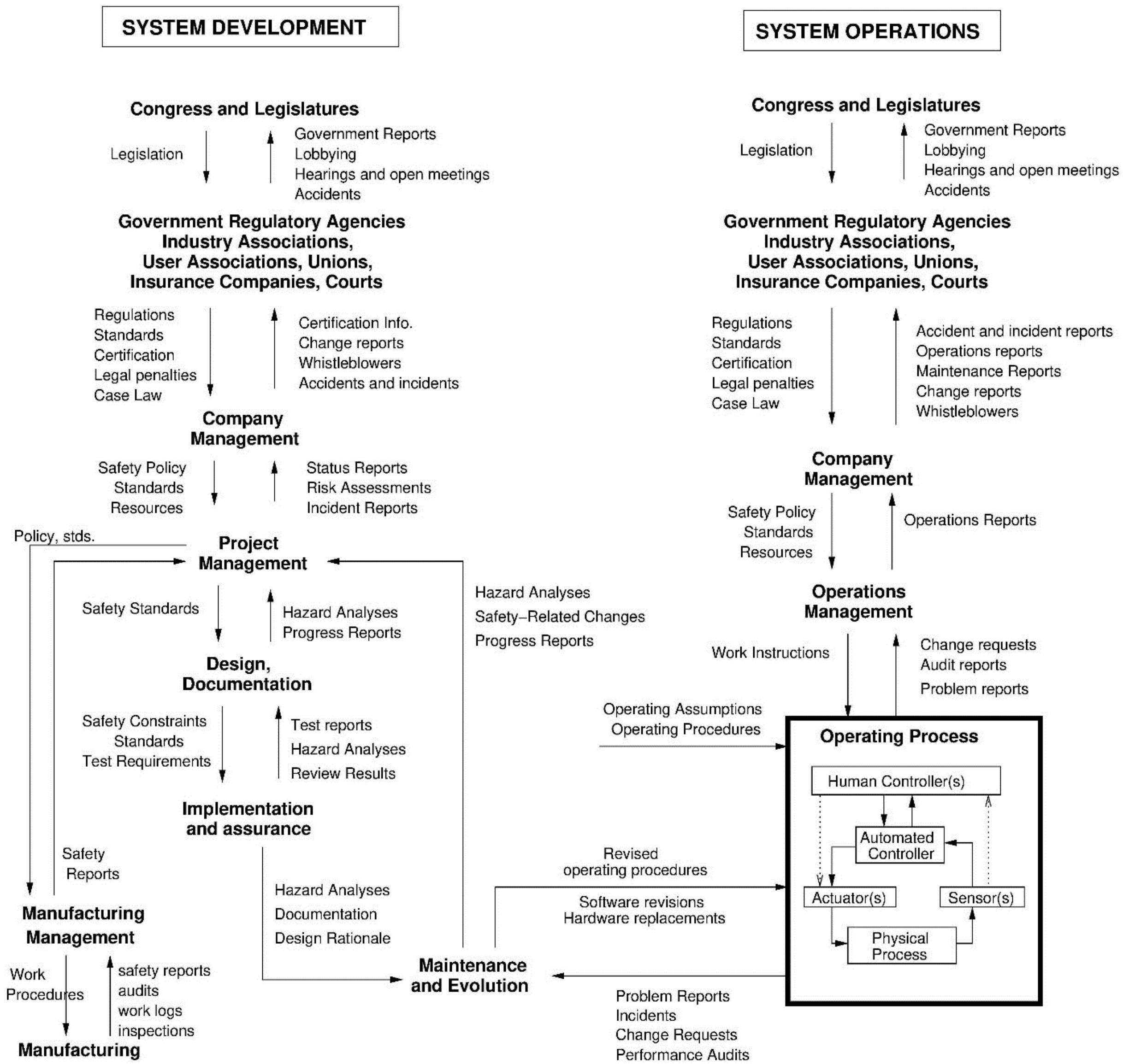

Figure 2: A generic example safety control structure

Note that the use of the term “control” does not imply a rigid command and control structure. Behavior is controlled not only by engineered systems and direct management intervention, but also indirectly by policies, procedures, shared value systems, and other aspects of the organizational culture. All behavior is influenced and at least partially “controlled” by the social and organizational context in which the behavior occurs. Engineering (i.e., designing) this context can be an effective way to create and change a safety culture, i.e., the subset of organizational culture that reflects the general attitude about and approaches to safety by the participants in the organization or industry [Shein 1986].

Now we are ready to start the UPS 1354 causal analysis. The control structure in Figure 3 shows the controls and controllers to prevent CFIT at the time of the accident. Only some of the control actions and feedback are labeled here to avoid clutter in the diagram, but they will be identified during the causal analysis process.

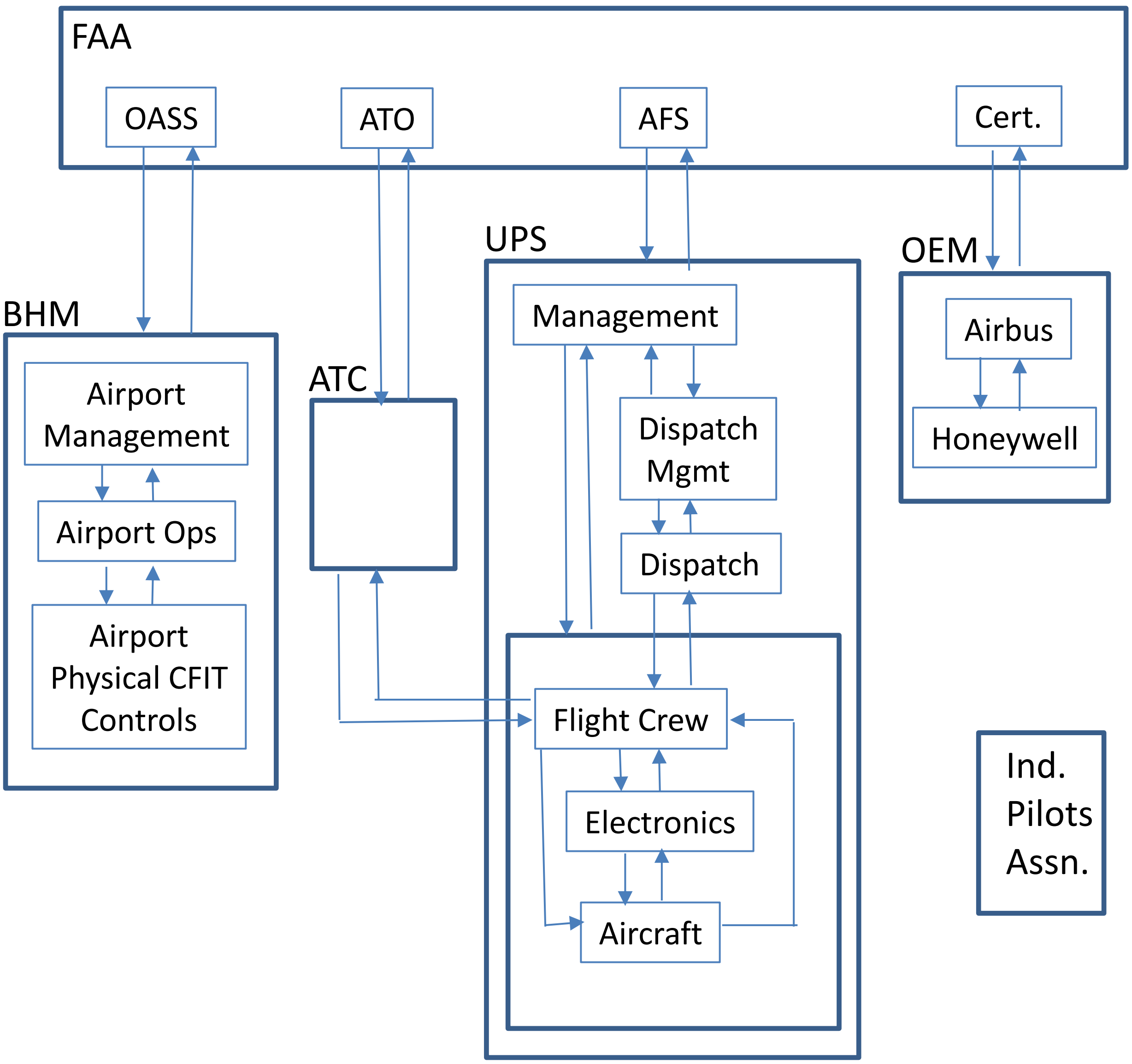

Figure 3: Control Structure for Preventing CFIT at BHM airport
(Note that this control structure is relevant to preventing CFIT at most airports)

The aircraft was designed and built by Airbus (Original Equipment Manufacturer – OEM), and the vendor for the avionics (flight instruments, autopilot, FMS), was Honeywell. Airbus is, in turn, regulated by the Federal Aviation Administration (FAA) in the United States, and must comply with the policies, regulations and guidelines imposed by the FAA.

The pilots receive inputs and guidance from quite a few sources. Air Traffic Control (ATC) provides the clearances for the aircraft and determines the routes and altitudes the aircraft must fly until it joins a published segment of an instrument approach. ATC monitors and receives alerts from the Minimum Safe Altitude Warning (MSAW) if an aircraft is dangerously low. The parameters for MSAW are established by FAA. The FAA also determines the policies and procedures for ATC, as well as ensuring air traffic controllers are provided with Notices to Airmen (NOTAMs) and are trained (in the case of the control tower) as weather observers. NOTAMs include physical changes to the environment such as runway and taxiway closures, nearby cranes operating, inoperative navigational aids and other items that may impact flight safety, airport suitability for a particular operation, or flight planning. NOTAMs are often reported by the airport operator, but there are other authorized sources. Air Traffic Controllers can initiate NOTAMs through input to the FAA NOTAM system. The Automatic Terminal Information Service, or ATIS, is a continuous recorded broadcast from ATC of essential information, such as weather information, active runways, available approaches, NOTAMs, and any other information required by the pilots. In the United States ATIS is normally updated every hour unless a change is reported that meets specific criteria.

There are two physical airport controls pertinent to this accident used to assist in maintaining a proper glideslope during landing. The ILS (Instrument Landing System) is a ground-based instrument approach system that provides precision lateral and vertical guidance to an aircraft approaching and landing on a runway. It uses a combination of radio signals and, in many cases, high-intensity lighting arrays to enable a safe landing during instrument meteorological conditions (IMC), such as low ceilings or reduced visibility due to fog, rain, or blowing snow.

Another physical CFIP control, PAPI (Precision Approach Path Indicator), is a visual aid that provides guidance information to the pilot to help acquire and maintain the correct approach (in the vertical plane) to an airport or an aerodrome in place of or in addition to an ILS. Both the PAPI and ILS are built to FAA specifications and are maintained by the FAA. The FAA and the airport authority control their installation.

Dispatchers at airline company operations centers provide flight planning and enroute flight following. Dispatchers hold legal joint authority and responsibility for the safety of the flight, such that if there is a safety concern, the dispatcher is required to take the steps necessary to ensure the flight can be operated safely. The dispatcher and the flight crew independently receive weather information and a NOTAM package via the airline's (in this case UPS) system. NOTAMs are disseminated via the FAA NOTAM system where they are then included with the current weather and forecasts for the flight's departure, destination and alternate airports. UPS is responsible for training, policies and procedures, pertinent manuals, etc. for both the dispatchers and the pilots. In turn, UPS receives manuals and guidance on operating the Airbus A300 from Airbus, while both Airbus and UPS are regulated by the FAA.

The airport authority must follow the regulations as set by the FAA, and they, in turn, must provide information on maintenance and inoperative components to the FAA NOTAM system, as well as communicate it directly to ATC.

Completing the CFIT control structure requires specifying the responsibilities of each control structure component with respect to preventing CFIT during approach and landing. The components will have other responsibilities, but they are not included. The CAST analysis identifies which responsibilities were not fulfilled and why.

<u>Instrument Landing System (ILS)</u>: Present accurate location and guidance information to the aircraft, allowing for safe descent in bad weather.

<u>Precision Approach Path Indicators (PAPI)</u>: Provide guidance information to help a pilot acquire and maintain the correct approach in the vertical plane.

<u>Birmingham Airport Authority</u>:

- Install and maintain safety-related controls so they are effective in preventing losses
- Ensure safety of operations at airport when outages of physical controls are necessary (planning for outages). More generally, developing and following Management of Change (MoC) procedures for airport operations.

Minimum Safe Altitude Warning (MSAW) Radar: Provide air traffic controllers, in a timely manner, with an alert about aircraft proximity to terrain or obstacles.

Air Traffic Controller:

- Ensure traffic separation
- Monitor aircraft flight path and provide vectors to approach
- Clear aircraft for the type of instrument approach the flight crew desires or requests
- Provide current weather observations verbally and via ATIS

Aircraft Electronics:

Flight Management System:

- Provide database of navigation waypoints with associated altitude/speed constraints
- Provide data to NAV and PFD display
- Provide guidance to AFDS when engaged by pilots

Enhanced Ground Proximity Warning System (EGPWS):

- Provide terrain awareness and warning to the flight crew.
- Clearly indicate when the aircraft needs to execute an escape maneuver due to proximity to ground contact.
- Provide oral height alerts when function is activated by airline

Autopilot (AFDS): Control the elevators

Pilot-Vehicle Interface: Navigation Display:

- Provide easily interpreted visual presentation of aircraft position relative to runway location
- Indicate when display is not presenting safe information
- Clearly show discontinuity or programing errors

Captain Flying:

- Operate the aircraft in accordance with company policies
- Direct first officer (PM) in duties
- Operate autopilot or flight controls to manage the airplane descent profile
- Monitor PM inputs into FMS
- Monitor aircraft position and altitude
- Ensure PM/FO is aware of intentions and plans
- Call for aircraft configuration changes as appropriate
- Climb to MSA in the event continued safe operation cannot be assured.
- Make decisions about landing vs. diverting

Pilot Monitoring:

- Perform duties at direction of captain/PF, including configuration changes, etc
- Make entries/changes to FMS
- Monitor aircraft flight path, altitude, configuration, performance and position
- Back up captain in decision making
- Verbalize any concerns
- Make call-outs as required by company procedures

UPS Dispatcher:

- Assist in planning flight paths, while taking into account all conditions potentially affecting flight
- Provide a flight following service. During flight, monitor and advise crew of changes affecting safety of flight

- Advise pilots if conditions change
- Share responsibility for exercise of operational control (joint control), which gives them the authority to divert, delay, or cancel a flight. 50% legally responsible for safety of every flight they dispatch (PIC has other 50%)
- Analyze and evaluate meteorological information to determine potential hazards to safety of flight
- Prepare flight plans containing information such as weather conditions, field conditions, NOTAMs, etc.
- Monitor weather conditions, aircraft position reports, and navigation charts to evaluate progress of flight
- Update PIC of significant changes to weather or flight plan and recommend flight plan alternates, such as changing course, altitude, etc.

<u>UPS Dispatch Management</u>

- Provide procedures, equipment, and training for dispatchers
- Provide oversight of flight dispatch and ensure policies and procedures lead to safe operations.

<u>UPS Management</u>:

- Ensure aircraft equipment for prevention of CFIT (including updates to EGPWS) is installed and maintained.
- Ensure that procedures require that an approach not be continued if it is not stable and pilots have not confirmed that the mode is correct by the final approach fix.
- Ensure pilots are trained to fully understand the system operation [that pilots have required process models (understanding) of the automation and the safety controls to avoid unstable approaches (CFIT)
- Ensure that flight operations follow best practices and that pilots have all the information needed for good decision making, including weather information.
- Provide oversight and training to flight dispatchers and ensure policies and procedures lead to safe operations.

<u>Airbus/Honeywell</u>:

- Design an aircraft that is safe during approach and landing
- Provide documentation and training materials to customers

<u>Independent Pilots Association</u>:

- Promote the non-punitive use of fatigue calls
- Promote mitigations to reduce fatigue risk
- Ensure pilot community is safety rather than mission oriented. [Promote pilot independence and speaking up when making safety vs. efficiency or productivity decisions.]

<u>FAA Aviation Flight Standards (AFS)</u>: Provide oversight of airlines with respect to training, procedures, and software updates that relate to approach and landing.

<u>FAA Office of Airport Safety and Standards</u>:

- Provide oversight and guidance to ensure that airports are operated in a safe manner.
- Establish airport design, construction, maintenance, operational and safety standards and issue operational certificates accordingly.
- Perform airport inspections and surveillance. Enforce compliance if problems found.

<u>FAA Air Traffic Operations</u>

- Oversee use and effectiveness of safety controls such as the use of MSAW
- Ensure airports have adequate controls for aircraft approach and landing
- Provide adequate policy, guidance, and oversight of NOTAM and ATIS process

The crux of the CAST analysis is to determine why this extensive control structure was not effective on August 14, 2013 at Birmingham in preventing the CFIT accident. STAMP assumes that accidents are the result of inadequate control over the system hazards, in this case CFIT. Three things need to be controlled in order to enforce the safety constraint (1) physical component failures, (2) individual system component behavior, and (3) interactions among system components that contribute to CFIT. Such interactions include, for example, the flight crew not getting important information from the UPS dispatcher or the FAA not providing control over the closing of runways for maintenance when there are aircraft scheduled to arrive. To analyze the cause of a particular accident, then, involves identifying these three types of causal factors in the events that occurred:

1. Starting at the bottom of this structure (the physical process involving the loss), identify the failures and unsafe interactions involved in the physical loss events (e.g., impact with terrain) as well as any physical controls that were designed to prevent the specific loss events that occurred. Why were they not effective?
2. Next, starting with the controller(s) immediately above the physical process and moving in turn upward in the control structure, identify
    a. The controller's responsibilities related to preventing the loss
    b. Their Contributory Control Actions or lack of actions
    c. Why they behaved unsafely
        i. Process model flaws
        ii. Contextual factors
3. Identify other factors that affected the behavior and interactions among the safety control structure components as a whole including
    a. Industry and organizational safety culture
    b. Safety information system
    c. Communication and coordination among controllers
    d. Dynamics and changes over time
4. Generate recommendations that will eliminate or reduce the unsafe behavior. These will often involve missing feedback.

The complete CAST analysis results are shown in the Appendix. This section provides examples of these analysis steps for the UPS 1354 accident. The next section contains a summary of the contribution of the role of each of the safety (CFIT) control structure components in the accident.

The analysis starts with the physical process at the bottom of the control structure, in this case the aircraft and the airport terrain.

AIRCRAFT PHYSICAL COMPONENTS

Physical control systems

- Aircraft control surfaces
- Engines

Failures and Unsafe Interactions

- No physical component failures on the aircraft contributed to the CFIT
- The aircraft impacted the terrain 1 nautical mile short of the runway

- The elevators were in a position that would cause the aircraft to impact the terrain short of the runway. Pitch was too low to intercept the runway at the proper point.

Context:

- Elevators were following guidance from the MCP.
- Autothrottles were following the MCP selected airspeed.

Recommendations: None

Clearly, the reason for this loss is not understood from just examining the physical components involved, as is true for most accidents. There are also some questions raised, such as why the MCP gave incorrect guidance to the elevators and autothrottles. These questions would, of course, be raised in any analysis of the accident.

While there is no required order in which the controls are examined, there are advantages in starting at the bottom and working one's way up the control structure to answer questions that are generated at the lower levels.

Our CAST proceeds by analyzing each of the controls and alerting mechanisms at the airport that were created to prevent CFIT. The goal is to determine why the CFIT controls (all the components in Figure 3 both individually and working together) were ineffective in this case in preventing the loss.

In CAST, four things are considered when examining the behavior of controllers and controls:

- The responsibilities of the component with respect to the particular hazard
- The unsafe (inadequate) control provided by the component
- The component's presumed process or mental model existing at the time. If the flaws that contributed to the loss are understood, then it may be possible to change training or feedback to maintain the accuracy of the model with the actual state of the controlled process.
- The context in which the behavior occurred and the contextual factors that influenced the unsafe behavior. Some of these are very specific to particular Contributory Control Actions while others are more general and affect indirectly many or most of the Contributory Control Actions.

As an example, consider the physical controls and alerting mechanisms installed at the airport, starting with the instrument landing system.

INSTRUMENT LANDING SYSTEM (ILS)

Responsibility related to CFIT during approach:

- Present accurate location and guidance information to the aircraft, allowing for safe descent in bad weather.

Contributory Factor: The runway on which the pilots were landing did not have ILS.

Why?	Questions Raised
Unknown	*Why was there ILS only on one runway? Was the decision a financial one or related to something else (e.g., terrain and physical constraints)? What rules or guidance does the FAA have about installing ILS on airport runways? Are there rules about what airports must provide in terms of ILS?*

	Also see section on Dynamics and Changes over Time

Contributory Factor: The runway with ILS was shut down for maintenance. It was scheduled to reopen 10 minutes after the UPS aircraft arrived.

Why?	Questions Raised
The primary runway with ILS glideslope control was closed at the time. The other available runway did not have an ILS.	*Are there rules and guidance about ILS maintenance during airport operations? Why did the Captain decide to land on a runway without ILS instead of delaying (as a FedEx pilot did around the same time)?*

Recommendations: None but there are recommendations related to ILS that are shown for the FAA and Airport Authority)

The analysis of the ILS contributions to the loss raises a slew of questions that need to be answered to understand why the accident occurred. Some of these questions were answered in the NTSB report while others were not. An important set of questions arises about why a decision was made to land on the runway without ILS instead of delaying. These questions lead to questions about the role that the flight crew, UPS dispatch, UPS rules, the NOTAM system, etc. played in this decision.

Another set of questions needing to be answered involves why the airport authority decided to perform ILS maintenance at a time that an aircraft was scheduled to arrive. Was there a reason that the maintenance could not be shifted 10-15 minutes earlier? Was the airline scheduled to land at that time (i.e., UPS) informed about the maintenance activity earlier so that they could strategize about their options? Management of change (MoC) policies should include the procedures for analyzing any hazards involved in changes to the controlled processes, including maintenance outages. Did the BHM airport authority have a MoC policy and did it cover maintenance outages? Are there FAA rules and guidance about maintenance decisions, or more generally, MoC policies?

Other questions include why the airport authority decided not to put ILS on all runways. There was almost surely a good reason. Was the decision a financial one or related to something else (e.g., terrain and physical constraints)? What rules or guidance does the FAA have about installing ILS on airport runways? Questions will be naturally raised during the CAST process in order to explain why the decisions involved in the loss occurred.

Answering these questions will require examining the controllers of the ILS installation and maintenance, in this case the Birmingham Airport Authority and the FAA. Unfortunately, the official accident report did not include answers to these questions so we could not include them in our CAST analysis (beyond raising the questions). If the questions had been considered during the official investigation, they could have been answered and the contextual reasons included in the CAST analysis results.

Without answers, it is not possible to identify recommendations related to ILS and this accident. With answers to these questions, it would be straightforward to generate recommendations related to ILS and CFIT accidents, both at this airport and at airports in general, if they were appropriate.

PAPI (Precision Approach Path Indicators) are another example of an airport physical control to prevent CFIT. The runway on which the aircraft was scheduled did have PAPI.

Precision Approach Path Indicators (PAPI)

Responsibility related to CFIT during approach:

- Provide visual guidance information to help a pilot acquire and maintain the correct approach in the vertical plane. [The ratio of white to red lights is dependent on the angle of approach to the runway. If the aircraft is above the designated glide slope, a pilot will see more white lights than red. On approaches below the ideal angle, more red lights than white will be seen. PAPI are generally located beside the runway approximately 300 meters beyond the landing threshold of the runway.]

Contributory control action: The PAPI did not provide guidance information that was capable of preventing the CFIT.

Why?	Questions Raised
The PAPI were operational on the runway that was used and they operated as designed. However, they were not visible to the pilots due to a combination of the aircraft height and low cloud ceilings. The NTSB report states on page 36: A post-accident airplane performance study showed that, because the pilots did not report the runway in sight until they were descending through about 900 ft msl (250 ft above airport elevation), the PAPI indications would have been visible for less than 1 second before becoming obscured by rising terrain.	*Could this have contributed to the pilot impression that they were not too low?*
According to the NTSB Survival Factors factual report, the PAPI for runway 18 was designed for height group 3 aircraft. The A300 is a height group 4 aircraft. Despite this, the FAA does not require any aircraft restrictions due to this factor nor is there any requirement to notify pilots of the issue, even though this does put the aircraft lower than optimal.	*Why does the FAA not make restrictions relative to aircraft height?*

Conclusions and Recommendations: It is not clear that this was a factor in this accident from the available evidence. However, one possible recommendation might be to examine the FAA rules for aircraft height restrictions on runways with PAPI but no ILS.

In order to answer the questions raised in the ILS CAST analysis, the role played by the Birmingham Airport Authority in the loss must be examined:

Birmingham Airport Authority

Responsibilities related to CFIT during approach:

- Install and maintain safety-related controls so they are effective in preventing losses
- Ensure safety of operations at airport when outages of physical controls are necessary (planning for outages). More generally, developing and following Management of Change (MoC) procedures for airport operations.

Contributory Control Action**:** Did not have ILS on all runways

Why?

Process Model Flaws	Questions Raised
Believed that large aircraft operations were safe without ILS.	
Believed possibly that runway 18 would not be utilized by larger aircraft?	

Context	Questions Raised
Cost of an ILS system is high and is weighted against traffic volume and other considerations, plus terrain for runway 18 may not have complied with criteria for an ILS.	*Why was the decision made not to have ILS on runway 18 in this case?*

<u>Contributory Control Action</u>: Performed maintenance on primary runway when large aircraft operations were scheduled to commence.

Why?

Process Model Flaws	Questions Raised
Believed that risk was low enough that the ILS maintenance did not need to be completed 10 minutes earlier to accommodate scheduled arrival times	*Why were airline schedules not given more consideration? If only one hour was required, why was it not done when no arrivals were scheduled, such as 0200?*
Thought that decisions about landing during ILS maintenance outages was the responsibility of the airlines and maybe ATC	

Context	Questions Raised
Low traffic time	
Airport maintenance is required to maintain safety of the airport	*What constraints are the airports under in scheduling maintenance outage times?*
Possibly did not put as much weight on cargo aircraft safety as passenger aircraft. Historical assumptions for times to conduct maintenance have been in place since prior to the advent of overnight delivery. System changes have invalidated these assumptions.	*Are there pressures that lead to the decisions about maintenance times that are not mentioned in the accident report?*
	Is there adequate consideration given to the risks for pilots of large aircraft operating in the early morning hours in darkness with fatigue? Is there more concern for safety in daylight (passenger) operations than night time cargo operations? Does ATC and the airport management have a similar level of risk standards for

	operators of both passenger and cargo aircraft?
	Why was no consideration given to the schedules of large widebody aircraft arriving in the early morning hours?
	What information about the maintenance that night was provided to the airlines (AOC?) using the airport at that time? When was it provided? To what extent does the airport coordinate with operators for outages?
	See section on Changes and Dynamics over Time

Recommendations:

- Review criteria for when scheduled maintenance is performed with consideration given to scheduled arrival times for air carrier operations.
- Review policies to conduct maintenance at night that compromises the arrivals for flights that are scheduled due to overnight delivery needs. Current policies were implemented prior to the time where such flights became routine for most U.S. domestic airports. Current policies compromise safety for large aircraft arrivals when flight crews are most likely to be fatigued, whereas the risk during other times of day may be lower.
- Review criteria for installing precision approach equipment if there was not a good reason for this decision.

As another example of CAST analysis, consider the role of the pilot flying in the accident. The same format is used as for other control structure components. Questions are inserted where appropriate. Note that if one stops after simply listing all the contributory control actions of the pilot flying, one can certainly "blame" the accident on the him (if blame is the goal), but not much is learned about why the pilot behaved in this way and how to prevent similar mistakes in the future. The goal in CAST is to understand why this behavior occurred without hindsight bias. The first step is to identify the Captain's mental model flaws at the time. Then contextual factors are examined that might explain the behavior. Only a few contributory control actions are included here. The rest can be found in the appendix.

Captain: Pilot Flying

Responsibilities Related to CFIT:

- Operate the aircraft in accordance with company policies
- Direct the first officer (PM) in duties
- Operate the autopilot or flight controls to manage the airplane descent profile
- Monitor the PM inputs into FMS
- Monitor aircraft position and altitude
- Ensure the PM/FO is aware of intentions and plans

- Call for aircraft configuration changes as appropriate
- Climb to a minimum safe altitude (MSA) in the event continued safe operation cannot be assured.
- Make decisions about landing vs. diverting

Contributory Control Action: Did not monitor the altitude, which led to an inadvertent descent below the minimum descent altitude when the runway was not in sight. Continued below minimum descent altitude prior to visually acquiring the runway.

Contributory Control Action: Did not monitor descent rate (or alternatively was not aware that the selected descent rate was too high).

Why?

Process Model Flaws	Questions Raised
Expected they would break out at 1000' because of incorrect weather report.	*Why did they get an incorrect weather report?*
Thought they were higher than they were on the final approach segment	*What led them to believe this?*
Did not realize that ceilings were variable down to 300 feet (as reported by FedEx captain in interview).	
Did not realize that they were descending below minimums prior to visually acquiring the runway environment.	*What CRM factors allowed the altitude not to be monitored? Was pilot aware that aircraft descended below MDA? Why did no other controls or alerts prevent this? Did they believe they had it in sight? Did they believe they would see the runway due to the reported weather on the ATIS?*
Did not know about the variable ceilings at the airport.	
Was not aware of uneven terrain prior to the runway on the approach.	*Why is this information not more readily available in a clear way?*

Context	Questions Raised
During flight, information about variable ceilings at airport by both their request for weather via the UPS system (ACARS) or the ATIS was not provided to flight crew. Actual ceilings were as low as 300 feet, which would have affected the expectations of the pilot. [Would it have made a difference in the outcome?]	
ATC kept aircraft high so they were initially above the nominal profile. Aircraft was still high and fast passing the final approach fix.	
Weather information for the actual approach is rarely available absent pilot reports or in unusual	

circumstances. There is no direct measurement of weather during the approach itself.	

Contributory Control Action: Did not delay arrival in order to have a precision approach (ILS). Did not appear to see or recall the NOTAM on the runway closure.

Why?

Mental Model Flaws	Questions Raised
Did not know that the other runway would open soon once they discovered the runway was closed.	*Why did they miss the NOTAM? Why did they not communicate with Dispatch to get this information?*

Context	Questions Raised
The weather reported on their preflight package as well as the enroute weather they received while they were flying (both digitally and via the ATIS) indicated good visibility and ceilings (cloud heights) of at least 1,000 feet. As a result, the crew may not have been concerned about the NOTAM about the runway. The forecast essentially indicated visual flight rule (VFR) weather.	
There are so many NOTAMs, many of which are not pertinent to a particular flight, that pilots can easily miss important information, particularly time blocks. The likelihood increases when pilots are fatigued. They may depend on ATIS or ATC to prevent problems; the most important NOTAMs are generally available on the ATIS. These pilots did not see the NOTAM so they did not know to even inquire about when the primary runway might open.	*Why did the dispatcher not communicate this information to the crew? Why do dispatchers not ensure that critical NOTAMS are discussed with the crew before departure or added to the remarks on the flight plan/release that they provide to the crew? Were the crew aware that another approach would be available? Were they anxious to get on the ground due to fatigue? Were there other pressures to just "get the job done"? Did they check NOTAMs? Why did the dispatcher not delay the arrival? Why did this crew not decide to delay the approach as another crew did? Did fatigue and wanting to get to the hotel play a part in this? Is the NOTAM system adequate? How often do pilots miss a NOTAM during flight preparation? Are NOTAMS and ATC comms sufficient for the PF to build a mental model of the approach and form a viable hazard and risk analysis?*

Contributory Control Action: Did not follow sterile cockpit rules. Inappropriate talk in cockpit while approaching.

Why?

Mental Model Flaws	Questions Raised
Believed that discussion of non-pertinent items would not detract from attention to the approach.	

Context	Questions Raised
When very tired, conversation is one of the most effective ways to stay alert. The loss of concentration from the talking can be much less than the loss due to sleep pressure. A jovial attitude is common when people are tired and trying to stay awake.	*Did the conversation lead to missing the lack of sequencing the waypoints? Did the conversation actually create this problem? Is there actual evidence that the conversation resulted in missing the waypoint sequencing issue?*

Contributory Control Action: Flew when fatigued.

Why?

Mental Model Flaws	Questions Raised
Apparently believed that they could safely operate despite the fatigue they openly discussed.	

Context	Questions Raised
Pilots, particularly in night cargo operations, commonly fly when very tired. After many years of doing this with no potentially harmful outcomes, it becomes routine and the risk is less apparent.	*Why did nobody do anything about the pilots flying fatigued? Why is there not a formal pre-departure briefing item on fatigue mitigation strategies?*

General Question: Are NOTAMS and ATC communications sufficient for the PF to build a mental model of the approach and form a viable hazard and risk analysis?

As a final example of the detailed analysis of contributory control actions by individual controllers, consider one by the UPS Dispatcher. The other UPS Dispatcher contributory control action analyses are in the Appendix.

UPS Dispatcher

Responsibilities Related to CFIT:

- Assist in planning flight paths, while taking into account all conditions potentially affecting flight
- Provide a flight following service. During flight, monitor and advise crew of changes affecting safety of flight
- Advise pilots if conditions change

- Share responsibility for exercise of operational control (joint control), which gives them the authority to divert, delay, or cancel a flight. 50% legally responsible for safety of every flight they dispatch (PIC has other 50%)
- Analyze and evaluate meteorological information to determine potential hazards to safety of flight
- Prepare flight plans containing information such as weather conditions, field conditions, NOTAMs, etc.
- Monitor weather conditions, aircraft position reports, and navigation charts to evaluate progress of flight
- Update PIC of significant changes to weather or flight plan and recommend flight plan alternates, such as changing course, altitude, etc.

Contributory Control Action: Forecasted weather at BHM indicated that low ceilings upon arrival required an alternate airport, but dispatcher did not discuss with the flight crew the low ceilings, the single approach option, or the reopening of runway 6/24 about 0500 that had precision landing equipment. Did not discuss possibility of landing at an alternate airport or waiting until 0500. Did not consider delaying the flight until the opening of the primary runway equipped with an ILS.

Why?

Process Model Flaws	Questions Raised
Was not aware of the observation remarks for variable ceilings as it was not contained in the UPS weather package.	*Why was it not contained in the weather package? (see UPS and ATC)*

Context	Questions Raised
The dispatcher stated he was not aware that the crew did not have the information about variable ceilings, as the dispatcher also did not have the remarks, according to the interview factual.	
Dispatchers provide what is legal (performed all the expected duties according to the NTSB report), but the “joint authority” in this case appeared to not be “joint” at all	*Why is this the case? How common is it?*
Joint authority is not well defined by UPS or by the FAA.	
Dispatcher was working many flights and so may not have had time to explore nuances for each flight, despite sharing (having joint) responsibility.	*Is the workload too high for dispatchers?*
Dispatchers may be under pressure to ensure on-time departures. It is not known if there are incentives or penalties assigned to flight dispatchers at UPS regarding flights departing on time.	*Are there incentives or penalties assigned to flight dispatchers at UPS (or elsewhere) regarding flights departing on time?*
UPS’s vendor had removed the remarks at the request of dispatch management to stop a duplication issue. The weather package provided to the dispatcher was the same as the flight	*Why did UPS allow this decision to be made? Who in UPS is ultimately responsible*

crew. Like most of UPS management (including dispatch management), the dispatcher was not aware of it. The only way for the dispatcher to obtain the remarks would have been to pull them up via a different system and that only occurred when a pilot would specifically ask for it. It is unlikely a pilot would ask for this if they did not know it was missing	*for this type of information, was it the director of operations? Why was he not informed [per Ops Group interview])? (see UPS)*
According to the ops group interviews, the dispatcher enters the flight information and the computer (Lido system) checks for legality and if legal, provides that information to the dispatcher. The dispatcher only then checks it to ensure it is actually legal and nothing is missed, and if so, releases the flight. The automated system does not look for aspects such as a better situation becoming available with a short delay (e.g. the runway opening just after scheduled arrival). Rather, the system just confirms that it is legal as scheduled. If it is legal, there is a strong incentive for the dispatcher not to look further as the system just guides the dispatcher through the steps and humans tend not to question whether computer-guided steps are appropriate. UPS could not legally dispatch a flight without the Lido system and according to the FAA inspector, they were dependent on the automation [ops group interview, other interviews]. There has, perhaps, been an overreliance on computers and the errant belief that they are better at humans in all cases, ignoring the often superior decision-making ability of humans.	*Are dispatchers questioning computer outputs?*

Besides an analysis of the role played by the individual safety control structure components in the accident, a CAST analysis includes identifying factors that affected the behavior and interactions of the safety control structure components as a whole including industry and organizational safety culture, the safety information system (one of the most important factors in preventing accidents), communication and coordination among controllers, and the impact of dynamics and changes over time. Again, the complete analysis is in the Appendix, but a few examples are included here.

In this accident (as in most accidents), problems in communication and coordination played an important role. Some examples are the lack of ensuring the pilots were actually aware of the runway closure; the information on the company chart regarding ATC keeping aircraft high, which contributed to an expectation bias; inadequate communication in the NOTAM about runway closures and updated weather information; and inadequate communication between the dispatcher and the pilots about weather and landing decisions and between the pilots themselves.

With respect to the dispatcher–pilot communication, for example, the FAA defines the pilot and dispatcher as being held “jointly responsible” for the safety of the flight. The definition of this shared responsibility and how decision-making will be coordinated, however, is only vaguely defined. In any control system, the potential for safety problems increases when there are two controllers and the responsibilities for each are not clearly defined. At one extreme, both controllers think the other one is making the necessary decisions (and thus nobody does) and at the other extreme conflicting control actions may be issued. In this case, it appears that the inadequate definition of responsibility has led to the pilots assuming much of the supposed joint responsibility, with flawed communication being the result. Responsibility cannot be assigned as "50-50" (as currently defined by the FAA) without a careful definition of how this equal responsibility division will operate in practice.

Example recommendations might include:

- The FAA should consider evaluating the communications and coordination deficiencies implicated in this loss and whether they are more widespread than they are believed to be.
- The roles of dispatch and pilots and how they interact need to be clarified. "Joint responsibility" is not adequately defined.

Another systemic factor is changes and dynamics over time. Accidents usually occur after some type of change. The change(s) may be in the physical process, the operating procedures, the safety procedures, the management process, or in the oversight (both internal and external). CFIT has been a major cause of accidents for a while and many controls were installed to prevent such losses. Have they degraded over time or have changes in commercial aviation made them less effective?

In general, changes may be planned or unplanned. Both types need to be controlled.

If the changes are planned, a strong management of change policy that is enforced and followed can be effective. In this accident, the management of change procedures appear to have been neither enforced nor effective. Examples include the closure of the runway without an analysis of what hazards were involved nor consideration of the alternatives to closing it at that time. In addition, the airline and dispatchers did not seem to consider any modifications to procedures based on the closure.

Changes may also be unplanned and must therefore be detected. There needs to be a way to detect unplanned changes that affect safety or prevent them from occurring. Detection may be accomplished by using leading indicators and safety-focused audits. There may also be periodic planned re-evaluation of assumptions underlying the original safety-related design features and management procedures.

Complicating the problem is the fact that changes may occur slowly over time, such as the removal of the remarks in the weather data, which appear to have been implemented without consequence up until this accident, which is often the case with changes over time. In addition, the industry trend away from pilots directly interacting with dispatchers (and meteorologists) has led to a reliance on providing data to pilots via printed form, often without discussion or providing context as would occur with an actual interaction/discussion. Changes such as these do not appear to have been reviewed by experts, but if they were, then the review process was flawed.

Changes may be known and planned in one system component but appear as unplanned and unknown to others, as was the case here. The runway closure was certainly entered as a NOTAM well in advance, and known to the airport as well as the local ATC controllers, but the UPS dispatcher may not have been aware until just prior to the flight, and it is clear that the pilots were not aware until they were preparing for the approach itself. This leaves little time to fully evaluate the risks.

Another, more subtle long-term change was the increase in night cargo operations. Questions have been raised by cargo pilots about whether there is as much weight placed on cargo aircraft safety as passenger aircraft and whether more concern is shown for daylight operations than in the early morning in darkness with fatigue. Historical assumptions about airport operations may need to be revisited in the light of changes in airline traffic and operations.

Recommendations:

- The FAA should ensure that airline safety management systems as well as those at airports have adequate change management procedures, have ways to ensure they are followed, and create ways to identify when risk is increasing because of unplanned changes over time.

- The FAA and cargo aircraft pilot associations should institute a study of whether cargo aircraft are treated differently by airports and whether any differences result in higher risk for cargo aircraft.

The following is a summary of all the contributions of the components to the loss in this accident.

Aircraft Physical Components	**Role:** The physical aircraft components all operated as commanded. There were no failures. The elevators were in a position that would cause the aircraft to impact the terrain short of the runway. Pitch was too low to intercept runway at proper point. **Recommendations**: None
AIRPORT PHYSICAL CFIT CONTROLS	
Instrument Landing System (ILS)	**Role:** The runway on which the aircraft was landing did not have ILS installed. The runway with ILS glideslope control was closed for maintenance at the time and was scheduled to reopen 10 minutes after the UPS aircraft was scheduled to arrive. **Recommendations**: None but see related recommendations for the Airport Authority and the FAA.
PAPI	**Role**: The PAPI were operational and operated as designed. However, they were not visible to the pilots due to a combination of aircraft height and low cloud ceilings. The PAPI were designed for height group 3 aircraft but the A300 is a height group 4 aircraft. The PAPI indications would have been visible for less than 1 second before being obscured by rising terrain. **Recommendations**: None but see FAA recommendations.
Birmingham Airport Authority	**Role**: Did not have ILS on all runways, probably for cost or feasibility reasons. Performed maintenance on the primary runway when large aircraft operations were scheduled. **Open Questions**: Why was ILS maintenance scheduled during scheduled arrival times for large aircraft? Is as much weight put on cargo aircraft safety as passenger aircraft? When and what type of information was provided to the scheduled airlines about maintenance that night? What type of constraints are airports under in scheduling maintenance outage times? **Recommendations**: Review criteria for scheduling maintenance and notifying airline dispatchers. Review criteria for installing precision approach equipment if there was not a good reason for the decision to omit it from the secondary runway.

FAA Office of Airport Safety and Standards	**Role**: Did not provide oversight on (1) the use of runways with navigational aids that are not appropriate for larger aircraft (2) the scheduling of maintenance on navigational aids during periods of scheduled arrivals, and (3) did not require methods in additional to NOTAMs to assure safety during maintenance outages. Large cargo operations at night are a relatively new practice. **Recommendations**: (1) Review criteria for installation of precision approach guidance at runways that are used for jet transport aircraft. (2) Review criteria allowing the flying of approaches to runways that use aids not designed for that size/type of aircraft.
AIR TRAFFIC CONTROL	
ATC: MSAW (Minimum Safe Altitude Warning) Radar	**Role**: Did not provide an alert to the controllers about the early descent of the aircraft because the MSAW was configured such that the aircraft never entered the warning zone. MSAW has been implicated in several recent accidents. **Recommendations**: Evaluate the role of MSAW in recent accidents and determine whether changes may be useful, including an evaluation of the tradeoffs made in the design between too many false alerts and omitting an alert when needed.
ATC: Air Traffic Controller	**Role:** (1) Offered a LOC landing on the non-ILS runway and did not mention the availability of another approach (RNAV). ATC procedures do not require the controller to offer every approach available. The LOC approach likely appears to be more precise than the RNAV. ATC at Birmingham may be more used to the performance capabilities and limitations of smaller aircraft as they do not work many widebody aircraft at Birmingham. (2) Did not include weather information about variable ceilings in ATIS nor update the weather after ASOS issued a "special observation." He was trying to leave a margin of safety for the pilots as the special observation was an improvement over the previous weather reported on ATIS. It is unclear why the remarks about a variable ceiling were not appended on the ATIS. An earlier flight had been visible from outside the final approach fix to runway 18. (3) Provided a late descent clearance, putting the aircraft well above a normal descent profile to intercept the final approach course. The final controller was working both tower and approach control, but provided descent vectors immediately when contacted. The aircraft had been held high by Atlanta and then Memphis ARTCC due to air traffic control factors (W*hy?).* (4) Did not detect and warn the crew about early descent. Did not know the aircraft was on too low an approach path and did not receive an MSAW. **Open Questions**: There are unanswered questions here about why the weather information received by the A300 crew was incorrect, why the aircraft was held high by Atlanta and Memphis, and why the air traffic controller did not detect the unsafe descent path.

	Recommendations: See recommendations for FAA ATO
FAA Air Traffic Operations (ATO)	**Role**: (1) Has not reviewed MSAW criteria despite several recent CFIT accidents where the MSAW had significant gaps in protection areas. (2) Did not update procedures for ATC with the advent of RNAV-type approaches and improved capability or provide ATC training that includes types of available approaches and the risks involved with specific types. Changing technology has led to a situation where newer procedures (e.g., GPS/RNP approaches) can be more precise than older technology but are still not believed to be better or necessary by many. (3) Despite many known problems with the NOTAM system, significant changes have not been made. Upgrading the system is complicated, with many competing factors to consider. **Recommendations**: (1) Review the MSAW criteria. Review guidance for ATC to monitor aircraft altitude and position and ensure that controllers are not depending on MSAW alone. (2) Review criteria for holding aircraft high due to traffic constraints (3) Ensure controllers are familiar with the different needs for larger widebody aircraft at airports that only serve these types of aircraft on a limited basis (4) Review training for ATC to ensure that ATC understands the advantages and disadvantages of a LOC vs. a RNAV approach within the context of the advantage of RNAV approaches for preventing this type of accident (5) Ensure that controllers append any remarks to reported weather on ATIS and that they know to update the weather even if they believe it has not changed. (6) Work with other FAA offices to upgrade the NOTAM system. (6) Ensure that at least two air traffic controllers are on duty at all times.
AIRCRAFT CONTROLS AND CONTROLLERS	
Flight Management System (FMS)	**Role**: Provided incorrect altitude data to pilots. The FMS "believed" that it was below the programmed path due to the actual routing being shorter than the programmed routing (i.e., the FMS assumed that it was flying a longer routing so therefore thought it should still be at a higher altitude as it was further from the airport). FMS is not designed to know the routing, but is dependent on pilot actions. Pilot did not sequence the waypoints correctly. **Recommendations**: None but see recommendations for Airbus/Honeywell
Enhanced Ground Proximity Warning System (EGPWS)	**Role**: (1) The EGPWS did not alert until there was not enough time to avoid the accident. The alerts did not escalate per design due to the close proximity of the airport and terrain on this approach. Using the software version on the aircraft at the time of the accident, the software calculated that the aircraft would be able to safely execute an escape maneuver in the time left. The EGPWS on the aircraft did not contain the latest software enhancements, which were free but needed to be installed. However, to trigger alerts that would require immediate aggressive enough action from the pilots to avert this accident, the software would have had to be

	enhanced beyond the latest software version, which would be outside the design specifications of the FAA. (2) Call outs for 1,000 feet, 500 ft, and minimum were not provided because they were not enabled by UPS. (3) Did not provide clear visual depiction of terrain on the approach path **Recommendations**: See recommendations for UPS and FAA. • Review alerting criteria for EGPWS. Several CFIT accidents have occurred due to proximity of runways. Criteria must allow adequate time for a response. • Add warning criteria to EGPWS to alert pilots that descent rate is exceeding criteria to ensure stabilized approach criteria to runway. • Add a depiction in profile view to the Nav Display that portrays the terrain along the intended flight path.
Autopilot (AFDS)	**Role**: Because the FMS had not been properly sequenced and the profile approach selected, the autopilot began a descent on the glidepath to the runway. It commanded the elevators to control pitch and approach speed using the autothrottles in vertical speed mode and continued the descent below minimum descent altitude (MDA). Vertical speed mode was commanded by the pilots, but that does not provide protection against too steep a glidepath. The procedures, as designed, offers no protection against descending below MDA in vertical speed mode. The autopilot will not normally fly past an altitude selected on the MCP. If the minimum descent altitude were entered on the MCP, the autopilot would "capture" that selected altitude. However, the published procedures call for the pilots to instead set the missed approach altitude on their MCP. The missed approach altitude is normally above the final approach fix altitude. As the autopilot now has no constraints on the descent, it will not stop without pilot intervention. No other mechanism aside from selecting an altitude will stop the descent at MDA as the system is designed. It would be possible to create alternative programming to force a disconnect to descend below MDA absent direct pilot action, even allowing for a slight excursion of 50 feet below MDA at intercept, however with the current system design, the only way to create this feature would limit a full constant angle descent procedure and would not allow for the setting of the missed approach altitude. , **Recommendations**: Add controls that would prevent the aircraft from descending below minimums absent direct pilot intervention while preserving the aspects of constant descent path and the setting of a missed approach altitude
Navigation Display (Pilot-Vehicle Interface)	**Role**: (1) The vertical deviation indicator provided anomalous (unhelpful) information, i.e., it was pegged at the top of the scale, indicating the aircraft was more than 200 ft. below the glidepath. PVI programming is based on the assumption that the aircraft is at the same point in space the FMS shows based on leg sequencing and navigation signals (e.g. GPS, IRS, radio). The software believed it was not on the approach so was providing indications accordingly. To provide correct glideslope information, proper sequencing of points was required but was not done. As the LOC was

	providing lateral guidance, the aircraft could still track the displayed final approach track despite the lack of waypoint sequencing. (2) The navigation display showed the aircraft on route even though the points had not actually been sequenced. At lower range scales, the "extra routing" would not be visible in the VDI or, if visible, would not be salient on the navigation display. Thus, the cues for inadequate programming required interpretation by the flight crew. The design cues were standard for the time the system was designed and continue to be widely utilized by industry. The functionality to conduct profile mode approaches was an addition/modification to an existing system requiring the OEM to work around constraints. The system was created at the request of customers who were, in turn, working to comply with changes in industry practice implemented by regulators. **Recommendations**: • Review Nav display functionality and consider adding a feature that would clearly denote that the waypoints have not sequenced even if the aircraft is on the path (magenta line). • Consider whether to add more clear guidance on path deviation indicator, e.g. an automatic go-around if the indicator is not indicating aircraft is on path when passing the FAF. • Ensure that flight below MDA and segment altitudes is clearly presented to pilots. System should be designed such that pilots are alerted if they are below a safe altitude for a particular segment. • Design future displays such that they clearly delineate the relative position to the runway at all times, and/or highlight prominently when the information does not match the path, i.e., when the aircraft is not actually on the route segment, the vertical information clearly shows that it is in error by changing color or another prominent way. • Consider increasing the size of the font on the display to make a cross track error more prominent.
Pilot Flying	**Role**: Did not confirm waypoints were not sequenced, allowed aircraft to descend below the approach profile by changing modes to a one that was too high of a descent angle. Did not notice NOTAM regarding runway closure. Flew the LOC approach rather than RNAV approach, diverted attention to outside when approaching minimums. Flew when fatigued. **Recommendations**: All recommendations go to UPS, Airbus, Honeywell and FAA.

Pilot Monitoring	**Role**: Improperly entered the clearance into the FMS, did not make the required callouts, did not challenge the captain's selection of 1,500 feet per minute of vertical speed, and did not properly monitor aircraft position, including altitude. Fatigue and the pace of activity was high at the time. Because the LOC approach was used, the aircraft intercepted the course as expected so the lack of proper programming was not apparent. Time compression due to the pace of events and other responsibilities, such as checklists, etc., made the callout easy to miss. There are a great many callouts and not all are helpful to increase situational awareness. **Recommendations**: All recommendations go to UPS, Airbus, Honeywell and FAA.
Airbus, Honeywell	**Role**: Created a design that could contribute to confusion on a nonprecision approach. It relied on pilot knowledge and procedures. It also created a design where the aircraft would continue to descend below minimums in a vertical speed approach with the recommended procedures. These procedures are standard in the industry. Also, profile mode was not an initial function in the electronics and required several steps to accomplish. An assumption was made that humans would reliably follow the procedures. **Recommendations**: (1) Ensure that assumptions in design are provided to the carriers so they may better understand and train the basis for the procedures. (2) Communicate all aspects of any software changes to the carriers so the carrier can include and monitor the changes as part of their SMS. (3) Review Nav display functionality and consider adding a feature that would clearly denote that the waypoints have not sequenced even if the aircraft is on the path (magenta line). (4) Consider whether to add more clear guidance on path deviation indicator, e.g. an automatic go-around if the indicator is not indicating aircraft is on path when passing the FAF. (5) Ensure that flight below MDA and segment altitudes is clearly presented to pilots. System should be designed such that pilots are alerted if they are below a safe altitude for a particular segment. (6) Design future displays such that they clearly delineate the relative position to the runway at all times, and/or highlight prominently when the information does not match the path, i.e., when the aircraft is not actually on the route segment, the vertical information clearly shows that it is in error by changing color or another prominent way.
AIRLINE OPERATIONS	

UPS Dispatcher	**Role**: (1) The weather forecast at BHM indicated low ceilings upon arrival but the dispatcher did not discuss with the flight crew the low ceiling, the single approach option, delaying the flight until 0500 for the reopening of the primary runway equipped with an ILS, or the possibility of landing at an alternate airport. Why? (a) The dispatcher was not aware the crew did not have the information about variable ceilings as the dispatcher also did not have that information. The weather package provided to the dispatcher was the same as the flight crew. The NOTAM remarks section with that weather information had been removed (see Dispatch Management) but neither the dispatcher nor pilot was aware that it had been removed. The only way for the dispatcher to get the remarks would have been to pull them up via a different computer system and that only occurred when a pilot would specifically ask for it. It is unlikely a pilot would ask for this information if they did not know it was missing. (b) Dispatchers and pilots have "joint authority" for operational control but joint authority is not well defined by UPS or by the FAA and in this case was not "50-50" as required by the FAA (see communication and coordination). (c) The dispatcher was working many flights and so may not have had time to explore the details for each flight, despite having joint authority (d) Dispatchers may be under pressure to ensure on-time departures. Are there penalties or incentives at UPS for flight dispatchers regarding flights departing on time? (e) The dispatcher enters the flight information and the computer (Lido system) checks for legality. The automated system does not look for aspects such as a better situation becoming available with a short delay (e.g., the runway opening just after scheduled arrival). If the computer tells the dispatcher that the flight information is legal, there is strong incentive for the dispatcher not to look further as the system simply guides the dispatcher through the steps and humans tend not to question whether computer guided steps are appropriate. UPS could not legally dispatch a flight without the Lido system and, according to the FAA inspector, they were dependent on the automation. Overreliance on computers and beliefs that they are better than humans in all cases (ignoring the often superior decision-making ability of humans, is common. (2) Did not communicate to the crew that only one approach (RNAV 18) was available based on his review of the approach charts and the LOC NA note. It was also not listed on the flight release. Why? The dispatcher believed the crew was aware of the LOC NA note. When asked why he did not mention it, he cited professional courtesy and was afraid the crew would be insulted. (3) The dispatcher did not account for fatigue on the ability of the flight crew to safely conduct the flight. Dispatchers assume that pilots will handle any fatigue issues and they are not trained to be part of the mitigation for pilot fatigue unless the pilot raises the issue. Even then, the dispatcher is normally only minimally involved.

	Recommendations: 1. Dispatchers must a. Mutually work with the flight crew regarding NOTAMS and weather that involve closures of primary runways, approaches and similar safety of flight aspects, to include the times of those events. b. Proactively provide information to flight crews regarding the status of approaches and why a particular runway and approach is listed in the flight plan c. Notify pilots of what approaches are considered for planning purposes and the reasons for that approach if not a primary approach for the airport. **2.** Captain and dispatcher must mutually agree as to the safety of flight while considering airline scheduling needs. Flight should operate only if both agree that the flight can be operated safely under the circumstances. This recommendation contemplates an active discussion and not just a pilot signing a flight release.
Dispatch Management	**Role**: Removed remarks from the weather information provided to pilots either through dispatch paperwork or via weather requests on ACARS. Specifically, requested that UPS's vendor remove the weather remarks from the NOTAM to avoid a duplication problem. The removal of the weather remarks was required to solve a technical issue of duplicate information by the IT department working with the dispatch office. As remarks are not "controlling," it probably made sense to the dispatch office to conclude they were not necessary. The information that this was done was not shared with the flight operations department. It is likely that the absence of the weather information was less of a problem, however, than the absence of remarks on the ATIS. The NOTAM provides more information than the flight crew is able to process. In general, removing non-critical information can be positive. Did not have policies and procedures in place that would require the dispatcher to proactively communicate with pilots (e.g., provide information that the runway would be opening soon) in order to fully share responsibility for safety with the flight crew. The roles of the dispatcher and flight crew in the "joint control" process are only vaguely specified by the FAA and many airlines. **Recommendations**: 1. Require dispatchers mutually work with the flight crew and flight operations regarding NOTAMS and weather that involve closures of primary runways, approaches and similar safety of flight aspects. Dispatchers should proactively provide information to flight crews regarding the status of approaches and why a particular runway and approach is listed in flight plan. Captain and dispatcher must mutually agree as to the safety of flight while considering airline scheduling needs. Flight should operate only if both agree that the flight can be

	operated safely under the circumstances. This recommendation contemplates an active discussion and not just a pilot signing a flight release. 2. Ensure that dispatchers are provided with all weather information including all remarks and that they, in turn, ensure pilots are aware of (not just provided with) the information that might impact the safety of the flight. 3. Ensure that dispatchers consider if a crew might be fatigued and how that might impact the pilot's cognitive processes so dispatcher can act proactively accordingly. 4. Review workload for dispatchers to ensure they can provide actual joint authority for individual flights. Current workload does not allow for the individualized attention to details that can prevent accidents. 5. Provide computer assistance that does not encourage reliance and unquestioning acceptance of outputs.
UPS [Not divided into more detailed roles due to lack of information]	**Role**: (1) Did not create effective procedures to mitigate the risk of fatigue (such as briefings and protocols with dispatchers) beyond flight and duty rules. The industry as a whole has not created well-specified protocols nor enforced fatigue standards. (2) Did not upgrade EGPWS software to more recent versions that would have provided an earlier alert and did not activate a variety of automatic callouts and alerts but instead relied on the pilots to make callouts. The upgrade was not required by the FAA and assumed that compliance with FAA guidelines was enough to ensure safety (3) Implemented procedures that would not prevent the autopilot from descending below minimums on a vertical speed approach. Such procedures were not required by Airbus or FAA guidance. (4) Did not ensure that pilots had a complete mental model of how the system performed a profile approach and what requirements needed to be met. (5) Did not enforce a requirement that an approach be immediately abandoned if the aircraft is not stable on the vertical path in the correct mode by the final approach fix. (a) The industry generally confuses safety constraints developed to mitigate the hazard of runway excursions with those developed to mitigate against the hazard of CFIT. The 500ft VMC /1000ft IMC safety constraints are to protect against runway excursions. The FAA recommendation to be stable by the FAF is a safety constraint intended to prevent CFIT but not generally enforced by U.S. carriers (see FAA AC 120-108). While desirable to require abandoning the approach should it not be stable, this is not industry standard practice for most U.S. carriers. (b) OEMs and Airlines have not kept up their NPA guidance. Many airlines flight operations manuals are not using the latest industry approach terminology, e.g. PA, APV, NPA, and so it is easy to see how the associated guidance can be lost. (c) UPS procedures on nonprecision approaches matched the Airbus flight manuals in regards to vertical speed approaches.

	(d) Pilot training met regulatory requirements. Numerous constraints to training exist such that there is not time to spend a lot of time on a procedure that is deemed to be rarely used. (e) Best practices in terms of safety constraints to prevent CFIT exist in FAA and other leading industry guidance, but the exact definition is left with the operator. Also, there is little guidance as to crew actions required if the safety constraint is not met. (6) Relied on historical data for safety decisions. The use of statistics is widely accepted and expected, but the use of statistical data may provide a false sense of security as a low rate may be due to many factors, such as lack of reporting or monitoring the wrong thing. Furthermore, even in the best case, statistics only reflect historical situations and not new combinations of factors that can lead to an accident **Recommendations**: • Activate current software updates and automatic call-outs for EGPWS. • Add a "fatigue briefing" item to the pre-flight procedures. Create fatigue mitigation measures that also include dispatchers so that dispatchers can help mitigate risks by providing extra support to crews who may be more fatigued based on established metrics. Ensure that the company and managers are actually following the written guidance and stated policies regarding fatigue so that line pilots do not feel that it is "all talk" and are not reticent to report fatigue or call in "fatigued" on a trip, regardless of reasons. • Require dispatchers to proactively communicate to pilots on NOTAM issues that directly affect the approach capabilities at airports. Ensure pilots are aware of effective times for NOTAMs through secondary means, and not just assume they are aware because they have received the information. Provide pilots with extra time (to be determined) to allow for adequate review of NOTAMs, e.g., add one minute to the preflight time allowed for each NOTAM. Such time shall be considered a part of flight duty for regulatory duty time limitations. • Require that all operational and informational changes impacting the dispatchers and pilots, such as removing weather remarks from NOTAMs, are done in close coordination with flight operations and are fully vetted through the Change Management Procedures in the SMS. • Ensure that dispatchers are provided with all weather information including all remarks and that they, in turn, ensure pilots are aware (not just provided) with those aspects that might impact the safety of the flight. • Ensure that dispatchers are actually sharing responsibility for the safety of the flight. This may require reducing the number of flights a dispatcher is working so that they can actually monitor each flight rather than only being brought into the loop when the flight crew contacts the dispatcher. Ensure that dispatchers are not under undue time pressure to provide on-time flights that degrades from safety and their joint responsibility role. • Review dispatcher use of automated computer systems to release flights. Automated systems may result in a legal flight without considering small changes

	that can have a large impact on safety (such as the 10-minute delay for the ILS runway opening on this accident flight). While automated systems can reduce the workload, the ability of humans to make sense of all of the information still exceeds computer capabilities (see Hoffman et al, 2017). • Ensure that all airline-produced manuals contain consistent guidance. • Change procedures and training with respect to: approach procedures in general, including communication between pilots about any change in approach and the selection of approaches other than the one being suggested by ATC or ATIS; conditions requiring a go-around; rules for changing autopilot modes and required call-outs for an intentional change of modes; secondary cues that waypoints are not sequenced; announcement of passing MDA; what to do if automation is not working as expected; conditions that must be brought to the attention of the other pilot so both pilots can agree on the problem and a strategy to manage it; and minimizing “black-hole illusion.” Review procedures to identify where workload can be reduced without affecting safety. • Consider adding a procedure to ensure flight plan is on the correct page and a mandatory call-out that a pilot is feeling behind or rushed rather than left as a vague “should do.” Specific language that is trained is more likely to overcome psychological hurdles. At the same time, consider removing callouts that are not actually beneficial or that may easily and more reliably be replaced by automated systems (such as EDPWS). Research whether pilots are actually distracted from other duties by making very routine callouts (such as 1,000 feet). • Make sure training of pilots includes the reason procedures are designed a certain way in order to reduce instances of pilots modifying or attempting to work around a seemingly cumbersome procedure due to lack of understanding the reasons for the procedural steps. If there are no good reasons, simplify the procedures.
FAA Aeronautical Information Services	**Role:** Did not consider the effect of the order of charts on pilot and ATC decision making. Did not include a profile view of terrain on aeronautical charts to aid pilot in determining risk of CFIT during the approach itself. **Recommendations:** • Consider the order of charts in the sequence and study whether there is a human factor aspect that might lead a pilot to choose a “lower numbered” chart under the premise the approach is safer. This accident would not have occurred if they had been flying the RNAV approach as the aircraft would not have tracked the course due to the lack of waypoint sequencing. • Add terrain to the profile view of approach charts so pilots can have a visual representation of the terrain on the approach that does not require interpretation that might absorb cognitive resources during busy phases of flight, particularly when fatigued.

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Role: Allowed (or at least did not detect) removal of weather information from the NOTAM by UPS. Criticism of the NOTAM format has been around for a long time but nothing has been done by the FAA to fix it. Ability to enhance presentation of NOTAM information is very tightly regulated by the FAA.
Recommendations:
General:

Provide oversight and review manuals to ensure consistent guidance.
Create a method to monitor for safety of changes such as the removal of weather remarks. Ensure any changes to information supplied to pilots and dispatchers are fully vetted through the carrier’s SMS Management of Change process.
Improve NOTAM system so pertinent NOTAMs are more prominent (see also ATO recommendations).
Review whether so-called “non-pertinent” conversation can improve crew alertness and the degree that it actually distracts crews, particular in light of pilots not knowing the context for required callouts. Do required callouts where pilots are not aware of the reason behind them lead to a compliance without improving situational awareness?
Reassess the data rates for accidents and incidents plus other event reporting in consideration of the actual practices of industry. Should the base regulation and compliance standards be increased to match industry practice? This might result in industry moving to an even higher safety level, and thus reduce accidents.

Enhanced Ground Proximity Warning System (EGPWS).

Ensure operators install and do not defer software updates and that alerts are activated.
Ensure operators activate automated callouts in software to enhance crew awareness. At the same time, review the use of callouts and evaluate which callouts are actually beneficial. It appears that callouts are being added after events as a way to appear that “something was done” rather than to actually prevent a problem. FAA should ensure that pilots are trained to understand why the callout was implemented and also review if there is a better way to prevent an accident or mitigate an issue that does not increase pilot workload during critical phases of flight. Do the callouts actually improve situational awareness or just protect the operator and FAA by shifting responsibility to fight crew for any problems encountered if they are missed? Are the callouts just done absent mindedly like pushing a switch can be impacted by automaticity?
Review alerting criteria for EGPWS. Several CFIT accidents have occurred due to proximity of runways. Criteria must allow adequate time for a response.
Add warning criteria to EGPWS to alert pilots that descent rate is exceeding criteria to ensure stabilized approach criteria to runway.

Dispatch:

Ensure that dispatchers are provided with all weather information including all remarks and that they, in turn, ensure pilots are aware (not just provided) with those aspects that might impact the safety of the flight.

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	2. Ensure dispatchers and ATC are clearly provide information to pilots that an improved situation will be available very shortly, e.g. a runway that is closed (and preferred) will be open soon. Currently there is no policy on this aspect. Revise both dispatcher as well as ATC rules to ensure that pilots are proactively notified so can make an informed decision. 3. Ensure that dispatchers are proactive in communicating to pilots any aspects that are not entirely routine. 4. Clarify what “joint authority” actually means in practice and ensure that it is being effectively implemented in practice (see Communication and Coordination in Systemic Factors) 5. Review dispatcher use of automated computer systems to release flights. Automated systems may result in a legal flight without considering small changes that can have a large impact on safety (such as the 10-minute delay for the ILS runway opening on this accident flight). While automated systems can reduce the workload, the ability of humans to make sense of all of the information still exceeds computer capabilities (see Hoffman et al, 2017). 6. Review dispatcher workload (number of flights each dispatcher can operate) to include the need to provide actual “joint authority” to individual flights. Current workload does not allow for the individualized attention to details that can prevent accidents. 7. Investigate and ensure that dispatchers do not have Fatigue: 1. Study additional protocols to mitigate fatigue risk beyond flight and duty regulations. 2. Ensure that pilots are aware that decision making when fatigued is compromised. Ensure that dispatcher and ATC are trained to provide backup to pilots in scenarios that may be expected to lead to fatigue. Approach Procedures: 1. Review airline approach procedures. Study changing nonprecision approach procedures to require that pilots set the minimums in the altitude window. Review the implications of mixing RNAV and LOC procedures. Review charting order to reduce possibility that pilots will believe that the next chart in sequence is the best available choice. 2. Require more opportunities for nonprecision approaches in training, particularly with scenarios that may present unusual situations such as LOC or BC. Require operators to train pilots that abandoning an approach is mandatory should it not be stable on glide path in the correct mode passing the final approach fix. Ensure that pilots are tested on determining their current position (height and distance relative to ideal 3:1 GS) during recurrent training scenarios. Monitor proficiency for less-used procedures such as nonprecision approaches.

Independent Pilots Association	**Role**: Did not create a fatigue mitigation strategy beyond work rules. The industry has not considered a formal fatigue mitigation brief for pilots nor utilized dispatchers in a more proactive way to mitigate fatigued pilots missing important things. **Recommendations**: 1. Encourage pilots to be proactive in speaking up when they are "behind" the aircraft. 2. Work with companies to create a "fatigue brief" item that would include aspects such as choices of types of approaches, etc. 3. Work with company dispatchers to create a mutual platform to assist dispatchers in aiding pilots in mitigating fatigue. 4. Train pilots on fatigue risk mitigation including recommending only precision approaches to longer runways. Recognize that pilots will try to "get the job done" and also try to "get to the hotel" when tired so proactively train and implement methods that mitigate this. **5.** Work with UPS to improve the communication to pilots as to the actual intent of the safety culture and that the company means what it says it means.

SYSTEMIC FACTORS SPANNING COMPONENTS

INDUSTRY AND ORGANIZATIONAL SAFETY CULTURE
There is some suspicion among cargo aircraft pilot associations that cargo aircraft are treated differently by airports, with more risk allowed. Did this influence the decision to perform maintenance early in the morning when cargo operations when scheduled cargo operations at the airport had started? Was there any analysis of the hazards involved in closing the primary runway for maintenance during scheduled arrivals? Do airlines and dispatchers consider modifications to procedures based on runway closures or other conditions that raise risk? Questions have been raised by cargo pilots about whether there is as much weight placed on cargo aircraft safety as passenger aircraft and whether more concern is shown for daylight operations than in the early morning in darkness with fatigue. Because of the position most cargo airlines have taken very publicly arguing against the "same standards" for cargo aircraft pilots as passenger pilots, it is also possible that cargo aircraft pilots are more suspicious of the motives and intents of their companies, which may impede communication and working together on problems. **Recommendations**: 1. FAA and cargo aircraft pilot associations should investigate whether the actions of the cargo operator industry have led to more suspicion and less trust by the pilots of those carriers. 2. The FAA and cargo aircraft pilot associations should institute a study of whether cargo aircraft are treated differently by airports and whether any differences result in higher risk for cargo aircraft.
SAFETY INFORMATION SYSTEM

Remarks were removed from weather reports without an adequate assessment of the consequences and assurance that critical weather information was available to the pilots. The industry trend away from pilot directly interacting with dispatchers (and meteorologists) has led to a reliance on providing data to pilots via printed form, often without discussion or providing context as would occur with a direct interaction and discussion. **Recommendations**: Identify and implement changes to the information system to ensure that accurate weather information is available when needed and to those who need it. Subject changes in the provision of critical information to a hazard analysis.
DYNAMICS AND CHANGES OVER TIME
Night cargo operations are increasing. Historical assumptions about airport operations may need to be revisited in the light of changes in airline traffic and operations. **Recommendation**: 1. The FAA should ensure that airline SMS's as well as those at airports have adequate change management procedures, have ways to ensure they are being followed, and create ways to identify when risk is increasing because of unplanned changes over time. 2. The FAA and other industry groups should study whether the increase in cargo operations has changed or increased the level or types of hazards such that they are no longer adequately mitigated by current procedures and controls.
COMMUNICATION AND COORDINATION AMONG CONTROLLERS
• The runway closure was entered as a NOTAM well in advance, and known to the airport as well as the local ATC controllers, but the UPS dispatcher does not seem to have been aware until just prior to the flight, and it is clear that the pilots were not aware until they were preparing for the approach itself. This leaves little time to fully evaluate the risks. • There was inadequate communication of updated weather information between the pilots, ATC, and dispatch as well as between the dispatcher and pilots about landing and routing decisions. • "Joint responsibility" of the pilots and dispatchers is not adequately defined nor is there oversight by the FAA or UPS of how it is working in practice. • When the autopilot did not engage in profile mode, the captain changed the autopilot mode to the vertical speed mode, but did not brief the pilot monitoring on the autopilot mode change. He appeared to assume the PM would see the change, or, conversely, considered it normal procedure that did not require discussion. Why did both the PF and PM miss that the computer had not been sequenced correctly? When changes are made in automation, are CRM procedures adequately re-evaluated for their ability to synchronize the pilots' mental models? **Recommendations**: 1. The FAA should consider evaluating the communications and coordination deficiencies implicated in this loss and whether they are more widespread than they are believed to be. Was

this just a one-time event or are communication and coordination deficiencies more wide-spread than believed?

2. The roles of dispatch and pilots and how they interact need to be clarified. "Joint responsibility" is not adequately defined nor is there oversight by the FAA or UPS of how it is working in practice.

Comparison of the NTSB Results and the CAST Results

The NTSB report divides its results into *probable cause*, *contributory causes*, and *findings* along with *recommendations* stemming from these three. Given the ubiquity of this division into these factors and the requirement that the NTSB identify a probable cause, it is surprising that we could find no definition of a probable cause in any official NTSB document. And the difference between contributory causes and findings are also not carefully defined. Some of this opacity may arise from the way that "cause" and, in particular "root cause," are traditionally conceived.

In the past and still almost universally today, accident causation is conceived as a series of events (usually failures or errors) in a direct causal chain:

$$\boxed{E_1} \rightarrow \boxed{E_2} \rightarrow \boxed{E_3} \rightarrow \boxed{E_4} \rightarrow \boxed{E_5}$$

where each event is the direct result of the preceding event. This traditional model of causation goes back several hundred years to the definition by philosophers of cause and effect and of "necessary and sufficient" causes. In effect, a "counterfactual argument" is applied to each link in the chain that says:

If cause A results in effect B then the absence of cause A will result in the absence of effect B.

To test whether something is a cause, one removes A and sees if B still occurs. If not, then A cannot be the cause of B. This simple rule of direct causality and the counterfactual argument, however, eliminates much of indirect causality that is important in a complex world. For example, the statement "smoking causes lung cancer" cannot be made (which was the argument by the tobacco lobby for decades against regulating tobacco use) because some people get lung cancer who do not smoke and many people smoke and never get lung cancer. There clearly is a connection between the two and most people accept this connection today, but it is indirect and complex and involves factors that are not all currently understood, although science is slowly explaining the physical links. By limiting ourselves only to direct, counterfactual causation, we reduce our ability to prevent accidents (and effects like lung cancer).

While traditional approaches to accident analysis are based on this simple model of direct chains of failure events, CAST is based on the formal foundation of an extended model of causation that assumes that accidents (losses) are the result of a complex process involving interactions among hardware, humans, software, and social systems. This new extended definition of causality is based on Systems Theory, which was created after World War II to deal with complex systems that do not follow the simple and limited rules of traditional causality, including biological and modern engineered systems. In today's world, the simple chain of failure events from 400 years ago no longer provides the power to explain why accidents occur, including not only the technical and human operator factors but also the software, management and social factors.

As Rimson points out [Rimson 1998], statements like the probable cause was "the flight crew's failure to properly configure and verify the flight management computer for the profile approach" (as in the UPS Flight 1354 accident report) is not a cause or explanation at all; it is simply a description of a behavior involved, called the Contributory Control Action in CAST. It does not provide information about *why* the flight crew behaved in this fashion. Understanding why the behavior occurred is required to design controls or make changes that will prevent or mitigate such behavior in the future, i.e., to get beyond blame and take effective actions for prevention.

In the case of UPS Flight 1354, the probable cause and contributory causes identified in the NTSB report all involve flight crew "failure" or flight crew physical state (e.g., fatigue), which is common in accident reports. Factors not related directly to the flight crew are relegated to the list of findings. In contrast, CAST considers all accidents to have the same "root cause," namely the weaknesses in the safety control structure (controls) that allowed the loss to occur. In the analysis of accidents, then, the goal is to determine why the safety controls existing at that time were unable to prevent the loss. Recommendations focus on how to strengthen the controls, in this case, the controls used to prevent CFIT.

Loss of life in aircraft accidents is tragic. But even more tragic is not maximizing the learning that can be derived from such losses in preventing future accidents. Ignoring what could be learned from an accident simply because it does not fit some narrow definition of causality is counterproductive. We must maximize what we learn from loss events and even incidents (where no losses occur but might have occurred given different circumstances) in order to most aggressively and effectively prevent future losses. If it could contribute to an accident in the future (either directly or indirectly), then it should be included in the analysis of the events that occurred and the lessons to be learned.

In the end, everything found by CAST could potentially be sorted into NTSB probable cause, contributory causes, and findings. The CAST analysis provides a framework for identifying these things—indeed all the factors related to the events—and showing how they together contributed to the loss. How the results are presented in an accident report, given that nothing is left out, is less important.

With this background, the two analyses of this accident (the NTSB analysis and the CAST analysis) can be compared. Again, the CAST analysis uses information in the NTSB report, so the fact that something appears in both does not provide comparative information: The CAST contributory control actions include all the behavior noted in the NTSB probable cause, contributory causes, and findings. The most important comparison is what is in the CAST analysis and not in the NTSB final report. In order to avoid arguments about definitions of categories, anything that appears as a probable cause, contributory cause, or finding in the NTSB report is included in the comparison below.

The primary difference to be noted is that the NTSB almost exclusively includes what in CAST is an control action, but (at least in the probable cause, contributory causes, and findings parts of the report) not the reason why those control actions occurred; the latter is the primary findings in the CAST analysis. The NTSB report does include a few of the reasons in the "findings" section and there may be others distributed throughout the full report, but the emphasis in the conclusions of the report is on all the things that the flight crew did wrong (at least in hindsight) and not an in-depth investigation of why they did them.

Table 1: Comparison of factors identified by both methods

CFIT Controls	Included by NTSB in Probable Cause or in Findings?	Included by CAST?	Comparison
ILS	No	Yes	The CAST analysis generates questions (not answered in the NTSB report) about why the maintenance was performed at a time when large aircraft were scheduled to arrive, why ILS was not installed on the second runway (e.g., was the decision financial or related to physical constraints at BHM), are there rules about what airports must

			provide in terms of ILS, and was this decision making related to changes over time involving increasing night operations by cargo carriers?
PAPI	No	Yes	The CAST analysis notes that the PAPI on runway 18 was designed for height group 3 aircraft while the A300 is a height group 4 aircraft. The PAPI would have been visible for less than 1 second in this case before being obscured by terrain.
Birmingham Airport Authority (BAA)	No	Yes	CAST identifies questions about the BAA decision making involved in installing ILS on only one runway and performing ILS maintenance on the primary runway when large aircraft operations were scheduled to commence (and not performed earlier).
Minimum Safe Altitude Warning (MSAW) radar	No	Yes	CAST asks why the MSAW did not alert ATC to the early descent of the aircraft (which seems to be a factor in several recent accidents).
Air Traffic Controller	Partial	Yes	The CAST analysis asks why ATC did not mention the availability of an RNAV approach instead of a LOC on runway 18, why important weather information was not included in the ATIS or updated through an ASOS "special observation," why a late descent clearance was given, and why ATC did not warn the crew about early descent. The NTSB reports mentions in the findings that the weather information was removed from the remarks section of METAR reports and that the ATIS broadcast did not include current weather ceiling information. No information about why is included in the findings or causes section.
FMS	No	Yes	CAST points out the reasons why the points were not sequenced and the visual depiction on the NAV display showed the aircraft on track.
EGPWS	Partial	Yes	The NTSB report does not ask why UPS did not update the software (it was free so the answer is not direct cost, although there may be indirect costs). CAST generates questions to determine why the alert occurred too late to avoid the accident and why EGPWS did not provide automated call outs for 1,000 feet, 500 feet, and minimums. The CAST analysis generates questions about why the UPS aircraft software was not updated. The NTSB report notes the lack of updated software and the absence of warning call outs and escalating terrain alerts. NTSB does not

			reference the need for terrain display in profile mode.
Autopilot (AFDS)	No	Yes	The CAST analysis raises a question about why the AP does not provide protection against descending below minimums if pilots do not intervene.
Pilot-Vehicle Interface: NAV display	Yes	Yes	CAST analysis asks why the vertical deviation indicator provided anomalous information and depicted the aircraft on route even though the points had not been properly sequenced. The NTSB report notes that the crew could have been confused by the anomalous information provided by the vertical deviation indicator.
Pilot Flying	Yes	Yes	To a large degree, the two reports agree on the role of pilot behavior in the accident, although the NTSB characterizes these as “failures” while CAST looks at them as providing inadequate control of the aircraft and includes much more analysis of why it occurred.
Pilot Monitoring	Yes	Yes	Basically, the two analyses are in agreement about what the PM did wrong, but the CAST analysis looks more deeply at why than just distraction by looking out the window and fatigue.
UPS Dispatcher	Partial	Yes	The inadequate assistance provided to the pilots is highlighted in the CAST analysis and why. The NTSB report says that the dispatcher should have alerted the flight crew to the limited options for arrival at BHM and notes unclear communication between them but omits other more subtle problems and explanations for the inadequate behavior such as those created by the software used by the dispatchers.
UPS	Partial	Yes	The CAST analysis points out the large role played by the airline in not providing adequate controls to prevent the accident. The NTSB report notes a subset of these, including the removal of the weather information from the NOTAM, the inadequate amount of practice of nonprecision approaches, the lack of standardization and inconsistency among UPS documents, and not providing adequate fatigue counseling and briefing before flights.
Airbus/Honeywell	No	Yes	CAST identifies some design features of the aircraft that contributed to the confusion and loss.

Independent Pilots Association	Yes	Yes	Both reports note that the IPA (along with the FAA and UPS) did not create a fatigue mitigation strategy beyond work rules.
FAA Aviation Flight Standards	Yes	Yes	Limitations in the FAA flight standards oversight are identified in the CAST analysis and some reasons why these limitations might exist. The NTSB report notes the lack of adequate review by the FAA of UPS manuals, the lack of standardized guidance, and oversight of pilot training.
FAA Office of Airport Safety and Standards	No	Yes	CAST points out limitations in the oversight provided by the FAA for airports.
FAA Air Traffic Operations	Partial	Yes	CAST notes limitations of the MSAW (a common factor in many recent accidents), problems in the provision of information in the NOTAMs and ATIS, and limitations in the guidance about approach procedures provided to the pilots. The NTSB report notes the role of a lack of accurate weather information on the behavior of the pilot flying and its non-inclusion in the ATIS report.
FAA Aeronautical Information Services	No	Yes	CAST captures the problems with charting orders as well as the need for a profile depiction of terrain on the approach chart.
System Issues			
Communication and Coordination	Yes	Yes	Both call out problems in communication between the pilots and between the pilots and dispatch. Both analyses point out the contribution of the lack of accurate weather information on the loss.
Safety Culture	No	Yes	Very little information is provided in the report. The CAST analysis raises questions about safety culture with respect to how airports treat cargo carriers and whether
Fatigue Management	Yes	Yes	Both reports raise similar questions about fatigue management in the industry.
Safety Information System	No (?)	Yes	CAST raises questions about removal of information from what is provided to the pilots. It also questions whether the data-driven approach in the industry misses important leading indicators of increasing risk.
Dynamics and Changes over Time	No	Yes	The CAST analysis identifies both planned and unplanned changes that were not adequately

			handled in terms of risk analysis and identifying when risk was increasing.

In summary, with a couple of exceptions, the NTSB Probable Cause, Contributory Causes, and Findings correspond to the CAST Contributory Control Actions. While some of the reasons why these contributory control actions occurred might be contained in the full NTSB report, only a few are called out in the summary of the causes of the accident (e.g., lack of opportunity to practice nonprecision approaches). In contrast, CAST emphasizes understanding the reasons for any unsafe behavior in order to identify ways to improve CFIT controls. An important difference is that the accident model used by the NTSB stresses the role of failures in accidents while CAST uses a more general cause of inadequate control (which could include failures, at least at the hardware level).

The two reports (the official NTSB report and the unofficial CAST analysis) can also be compared with respect to the recommendations that were provided.

The NTSB report and CAST analysis contain similar recommendations with respect to:

- Fatigue management,
- EGPWS software updates and callouts,
- Providing a cue to pilots when they program the FMC incorrectly and waypoints have not been sequenced (even if the aircraft is on the path),
- Improving dispatcher resource management and communication with pilots,
- Prohibiting “dive and drive” nonprecision approaches,
- Fixing problems in providing weather information to pilots,
- Providing more opportunities for pilots to practice nonprecision approaches
- Requiring operators to train pilots that abandoning an approach is mandatory should it not be stable on glide path in the correct mode passing the final approach fix
- Ensuring operating procedures require rebriefing changes to an approach, and
- Improving pilot manuals with respect to critical approach procedures.

The CAST analysis resulted in additional recommendations. Some of these are similar to the NTSB recommendations but are more detailed because of the more extensive CAST causal analysis about why contributory control actions occurred. Other CAST recommendations raise totally different issues such as decisions about scheduling ILS maintenance when large aircraft were scheduled to arrive; the design of the PAPI for aircraft types that were landing on that runway; the design of MSAW; actions of the air traffic controller not included in the official report; the design of the FMS and the autopilot; subtle problems related to the dispatcher and the inadequate definition of “joint” responsibility for safety with the pilot; additional flaws in UPS controls; design features of the aircraft that contributed to flight crew confusion; limitations in the oversight provided by the FAA offices of Airport Safety and Standards, Aircraft Flight Standards, Air Traffic Operations, and Aeronautical Information Services; and systemic factors such as airport safety culture and dynamics and changes over time in cargo operations.

Summary and Conclusions

This report has described a new method to provide a structured approach to accident causal analysis called CAST. The new approach is based on a more inclusive model of accident causation that focuses on more than failures but instead generalizes from failures to look at inadequate control. An example is provided by applying CAST to the CFIT of UPS Flight 1354 at Birmingham-Shuttlesworth International Airport in 2013.

The results of the case study are compared to the official NTSB report on this accident. In general, CAST goes beyond just stating what failures occurred and focuses more on why the events occurred. The findings of both are compared. There are many more recommendations that are generated by the CAST analysis. Some are simply more detailed because using the extra information generated by looking more carefully at "why." Others are related to factors that are left out of the NTSB findings.

References:

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: an ERP study. *Cognitive brain research*, *25*(1), 107-116.

Dekker, S. (2017). *The field guide to understanding'human error'*. CRC press..

FAA (2006). *Advisory Circular 120-90*. Retrieved from: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/22478

FAA. (2002) *Advisory Circular 120-66B*. Retrieved from https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/23207

FAA. (2011) *AC 120-108*. Retrieved from: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/877339

Hoffman, R. R., LaDue, D. S., Mogil, H. M., Trafton, J. G., & Roebber, P. J. (2017). *Minding the weather: How expert forecasters think*. MIT Press.

Nancy G. Leveson, Engineering a Safer World, MIT Press, 2012.

Nancy G. Leveson, A systems approach to risk management through leading safety indicators, *Reliability Engineering and System Safety*, 136: 17-34, April, 2015.

NTSB (2014) *Asiana 214 AAR-14/01* Retrieved from: https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1401.pdf

NTSB (2015). *UPS 1354 DCA13MA133.* Retrieved from: https://www.ntsb.gov/investigations/Pages/2014-Birmingham-AL.aspx

NTSB (2014) *Operations Group Chairman's Report.* Retrieved from: https://dms.ntsb.gov/pubdms/search/hitlist.cfm?docketID=55307&CFID=343107&CFTOKEN=51723048

NTSB (2014) *Operations Group Chairman's Report attachment 1.* Retrieved from: https://dms.ntsb.gov/pubdms/search/hitlist.cfm?docketID=55307&CFID=343107&CFTOKEN=51723048

NTSB (2014) *Operations Group Chairman's Report attachment* 2. Retrieved from: https://dms.ntsb.gov/pubdms/search/hitlist.cfm?docketID=55307&CFID=343107&CFTOKEN=51723048

Rimson, Ira (1998), Investigating 'Causes,' *Int. Soc. Of Air Safety Investigators International Seminar*, Barcelona Spain, Oct. 20.

Appendix: Full CAST Analysis

AIRCRAFT PHYSICAL COMPONENTS

Physical control systems

- Aircraft control surfaces
- Engines

Failures and Unsafe Interactions

- No physical component failures on the aircraft contributed to the CFIT
- The aircraft impacted the terrain 1 nautical mile short of the runway
- The elevators were in a position that would cause the aircraft to impact the terrain short of the runway. Pitch was too low to intercept runway at proper point.

Context:

- Elevators were following guidance from the MCP.
- Autothrottles were following the MCP selected airspeed.

Recommendations: None

AIRPORT PHYSICAL CONTROLS

Instrument Landing System

Responsibility related to CFIT during approach:

- Present accurate location and guidance information to the aircraft, allowing for safe descent in bad weather.

Contributory Factor: The runway on which the pilots were landing did not have ILS.

Context	Questions Raised
Unknown	*Why was there ILS only on one runway? Was the decision a financial one or related to something else (e.g., terrain and physical constraints)? What rules or guidance does the FAA have about installing ILS on airport runways? Are there rules about what airports must provide in terms of ILS?*

	Also see section on Dynamics and Changes over Time

<u>Contributory Factor</u>: The runway with ILS was shut down for maintenance. It was scheduled to reopen 10 minutes after the UPS aircraft arrived.

Context	Questions Raised
The primary runway with ILS glideslope control was closed at the time. The other available runway did not have an ILS.	*Are there rules and guidance about ILS maintenance during airport operations? Why did the Captain decide to land on a runway without ILS instead of delaying (as a FedEx pilot did around the same time)?*

<u>Recommendations</u>: None (but there are recommendations related to ILS that are shown for the FAA and the Airport Authority)

Precision Approach Path Indicators (PAPI)

<u>Responsibility related to CFIT during approach</u>:

Provide visual guidance information to help a pilot acquire and maintain the correct approach in the vertical plane. [The ratio of white to red lights is dependent on the angle approach to the runway. Above the designated glide slope a pilot will see more white lights than red. On approaches below the ideal angle, more red lights than white will be seen. PAPI are generally located beside the runway approximately 300 meters beyond the landing threshold of the runway (figure 5).

<u>Contributory Factor</u>: **The PAPI did not provide guidance information that was capable of preventing the CFIT.**

Context	Questions Raised
The PAPI were operational on the runway that was used and they operated as designed. However, they were not visible to the pilots due to a combination of the aircraft height and low cloud ceilings. The NTSB report states on page 36: A post-accident airplane performance study showed that, because the pilots did not report the runway in sight until they were descending through about 900 ft msl (250 ft above airport elevation), the PAPI indications would have been visible for less than 1 second before becoming obscured by rising terrain.	*Could this have contributed to the pilot impression that they were not too low?*
According to the NTSB Survival Factors factual report, the PAPI for runway 18 was designed for height group 3 aircraft. The A300 is a height group 4 aircraft (figure 4). Despite this, the FAA does not require any aircraft restriction due to this factor nor is there any	*Why does the FAA not make restrictions relative to aircraft height?*

requirement to notify pilots of the issue, even though this does put the aircraft lower than optimal.	

Representative Aircraft Type	Approximate Cockpit-to-Wheel Height	Visual Threshold Crossing	Remarks
Height Group 1 General aviation Small commuters Corporate turbo jets	10 feet (3m) or less	40 feet (+5, -20) 12 m (+2, -6)	Many runways less than 6,000 feet (1829 m) long with reduced widths and/or restricted weight bearing that would normally prohibit landing by larger aircraft.
Height Group 2 F-28, CV-340/440/580 B-737, DC-9, DC-8	15 ft. (4.5 m)	45 ft. (+5, -20) 14 m (+2, -6)	Regional airport with limited air carrier service
Height Group 3 B-727/707/720/757	20 ft. (6 m)	50 ft. (+5,-15) 15 m (+2, -6)	Primary runways not normally used by aircraft with ILS glide- path-to-wheel heights exceeding 20 ft. (6 m).
Height Group 4 B-747/767, L-1011, DC-10, A-300	Over 25 ft. (7.6 m)	75 ft. (+5, -15) 23 m (+2, -4)	Most primary runways at major airports.

Figure 4

Precision Approach Path Indicator (PAPI)

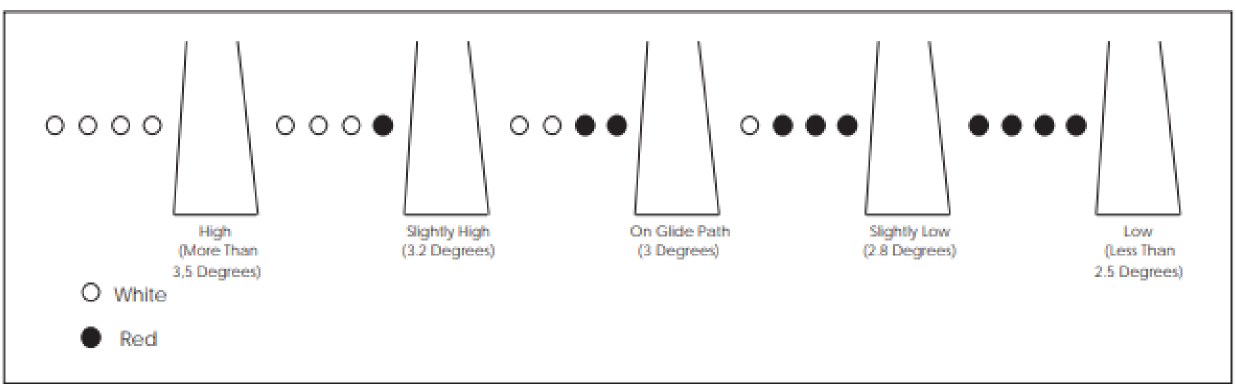

Figure 5

<u>Conclusions and Recommendations</u>: It is not clear that this was a factor in this accident from the available evidence. However, one possible recommendation might be to examine the FAA rules for aircraft height restrictions on runways with PAPI but no ILS.

In order to answer the questions raised in the ILS CAST analysis, the role played by the Birmingham Airport Authority in the loss must be examined:

Birmingham Airport Authority

<u>Responsibilities related to CFIT during approach</u>

- Install and maintain safety-related controls so they are effective in preventing losses

- Ensure safety of operations at airport when outages of physical controls are necessary (planning for outages). More generally, developing and following Management of Change (MoC) procedures for airport operations.

Contributory Control Action: Did not have ILS on all runways

Why?

Process Model Flaws	Questions Raised
Believed that large aircraft operations were safe without ILS.	
Believed possibly that runway 18 would not be utilized by larger aircraft?	

Context	Questions Raised
Cost of an ILS system is high and is weighted against traffic volume and other considerations, plus terrain for runway 18 may not have complied with criteria for an ILS.	*Why was the decision made not to have ILS on runway 18 in this case?*

Contributory Control Action: Performed maintenance on primary runway when large aircraft operations were scheduled to commence.

Why?

Process Model Flaws	Questions Raised
Believed that risk was low enough that the ILS maintenance did not need to be completed 10 minutes earlier to accommodate scheduled arrival times	*Why were airline schedules not given more consideration? If only one hour was required, why was it not done when no arrivals were scheduled, such as 0200?*
Thought that decisions about landing during ILS maintenance outages was the responsibility of the airlines and maybe ATC	

Context	Questions Raised
Low traffic time	
Airport maintenance is required to maintain safety of the airport	*What constraints are the airports under in scheduling maintenance outage times?*
Possibly did not put as much weight on cargo aircraft safety as passenger aircraft. Historical assumptions for times to conduct maintenance have been in place since prior to the advent of overnight delivery. System changes have invalidated these assumptions.	*Are there pressures that lead to the decisions about maintenance times that are not mentioned in the accident report?*
	Is there adequate consideration given to the risks for pilots of large

	aircraft operating in the early morning hours in darkness with fatigue? Is there more concern for safety in daylight (passenger) operations than night time cargo operations? Does ATC and the airport management have a similar level of risk standards for operators of both passenger and cargo aircraft?
	Why was no consideration given to the schedules of large widebody aircraft arriving in the early morning hours?
	What information about the maintenance that night was provided to the airlines (AOC?) using the airport at that time? When was it provided? To what extent does the airport coordinate with operators for outages?
	See section on Changes and Dynamics over Time

Recommendations:

- Review criteria for when scheduled maintenance is performed with consideration given to scheduled arrival times for air carrier operations.
- Review policies to conduct maintenance at night that compromises the arrivals for flights that are scheduled due to overnight delivery needs. Current policies were implemented prior to the time where such flights became routine for most U.S. domestic airports. Current policies compromise safety for large aircraft arrivals when flight crews are most likely to be fatigued, whereas the risk during other times of day may be lower.
- Review criteria for installing precision approach equipment if there was not a good reason for this decision.

Minimum Safe Altitude Warning (MSAW) Radar

Responsibilities related to CFIT during approach: Provide air traffic controllers, in a timely manner, with an alert of aircraft proximity to terrain or obstacles.

Contributory Control Action: Did not alert ATC to the early descent of the aircraft.

Context	Questions Raised
The MSAW was configured such that the aircraft never entered the warning zone (see FAA ATC Factual below).	*Many accidents seem to implicate MSAW [see Asiana accident report, AAR-14/01, 2014]. There is a tradeoff between too many false alarms and omitting an alert when it is needed. Does this tradeoff need to be reconsidered? FAA stated [ATC factual]) that the MSAW configuration for runway 18 at BHM was not being considered for modification. Why not? Are there other airports that should be reconsidered?*

According to the FAA ATC Factual report for this accident (ATC Factual Report DCA13MA133):

> Approach path monitoring occurs in defined areas along the runway and the extended runway centerline. A rectangle known as a “Type 1 area” encompasses the runway and extends to a defined distance, typically 1 to 2 miles, from the threshold outward along the final approach course. All MSAW alerts are suppressed within Type 1 areas. Type 2 areas extend from the end of the associated Type 1 area outward to a variable distance depending on the requirements of the particular airport and approach procedures. The specific boundaries of these areas are ait unique and configured according to various parameters such as topography, nuisance alert mitigation, etc.
>
> MSAW Vertical: The MSAW current initiate monitor altitude, also referred to as the warning slope, begins where the type I and type II areas intersect at an altitude based on the airfield elevation plus 500 feet plus the distance from the runway end to the beginning of the warning slope in nautical miles time 100 feet. The predicted initiate monitor altitude, also known as the predicted slope, is nominally set 100 feet below the warning slope. If the slope created by this equation exceeds 100 feet per NM, the current initiate altitude may be lowered to obtain any slope of at least 100 feet per NM. All obstacles and terrain must be at least 200 feet below the adapted current warning slope generated by the beginning and ending of the current warning slope settings.
>
> The current initiate monitor altitude was a two part adaptation configuration. with the first starting at 1084 feet MSL 1.99 NM from the approach end of runway 18 extending to 1170 feet MSL 3.0 NM from the approach end of runway 18 with the second portion beginning at 1200 feet MSL 2.99 NM from the approach end of runway 18 extending to 1202 feet MSL 5.9 NM from the approach end of runway 18. The predicted monitor altitude is 100 feet below the current initiate monitor altitude for both segments. (See figure 6).
>
> The final radar return for UPS1354 was at 04:47:34 at 900 feet MSL approximately 1.3 NM from the approach end of runway 18. (See figure 6) UPS1354's altitude profile on approach to runway 18 did not result in an MSAW alert. The flight path of the aircraft was above the current initiate monitor slope until intercepting the type I area.
>
> According to the FAA MSAW Board, there is currently no plan to modify the existing parameters for the MSAW configuration for runway 18 at BHM.

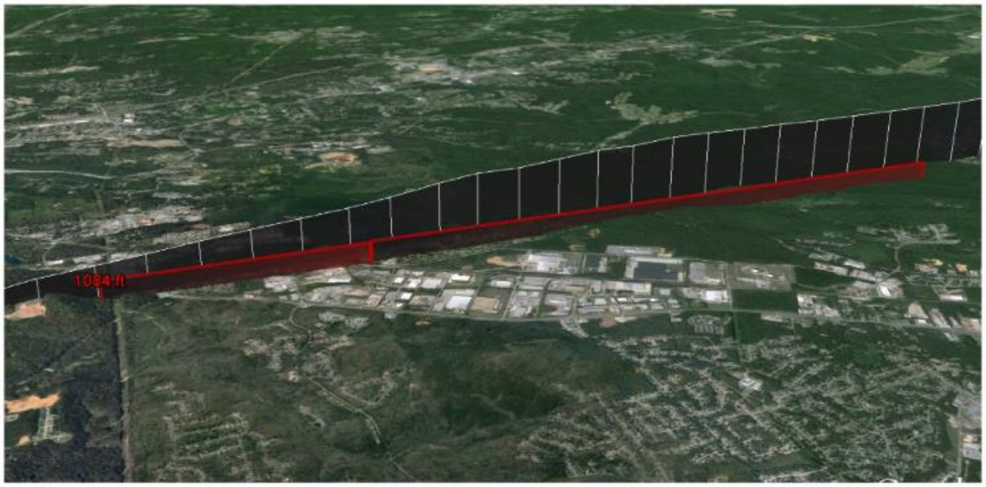

Figure 6 – The UPS1354 radar flight path is indicated by the white line and the 2 segment MSAW type II area current initiate monitor altitude is indicated by a red line.

Recommendations:

- Evaluate the role of MSAW in recent accidents and determine whether changes may be useful.

Air Traffic Controller

Responsibilities related to approaching aircraft:

- Ensure traffic separation
- Monitor aircraft flight path and provide vectors to approach
- Clear aircraft for the type of instrument approach the flight crew desires or requests
- Provide current weather observations verbally and via ATIS

Contributory Control Action: Offered flight the LOC runway 18 and did not mention the availability of another approach (RNAV).

Why?

Context	Questions Raised
ATC procedures do not require the controller to offer every type of approach available. The LOC likely appears to be more precise than the RNAV.	
ATC at Birmingham may be more used to the performance capabilities of smaller aircraft as they do not work that many widebody aircraft at Birmingham and therefore may not be familiar with their limitations.	

Contributory Control Action: Did not include important weather information (variable ceiling) in ATIS. Did not update the weather although the ASOS issued a “special observation.”

Why?

Process Model Flaws	Questions Raised
Did not know the actual weather was below what he put on the ATIS.	*Why not?*

Context	Questions Raised
Weather observations were obtained from the automated surface observing system (ASOS) but the controller did not append the remarks of the ceiling being variable between 600 and 1300 from the observation onto the ATIS The special observation was an improvement over the previous weather, which stated that the ceiling was 1,000 feet. Decided to leave the worse conditions on the ATIS rather than the improved report in order to provide a margin of safety to pilots. The controller stated that an earlier flight was visible from outside the final approach fix to runway 18 so he had no reason to suspect that the weather was worse than what was reported on the ATIS, although he stated in his interview that the aircraft had stated it was "between layers". From the ATC factual: BHM tower had a manual system where controllers were required to make a new ATIS recording when needed. The ASOS provided an audible alarm at 47 minutes after the hour advising that a new observation was pending and at 53 minutes after the hour a new weather sequence was posted. Mr. Brown assumed that as a LAWRS observer, he had the option to leave a previous observation on the ATIS even if a new observation had been posted. This was the case on the evening of August 14. ATIS information "Papa" reflected the 0353 ASOS observation, and the new 0404 observation showed improved weather and cloud conditions. Because the weather was clearing, he felt it was more favorable to leave the worse conditions on the ATIS rather than broadcast the improved report. He elected to keep the more restrictive observation on the ATIS to provide a margin of safety to pilots.	*Why not? Should ATC procedures be reviewed?*

<u>Contributory Control Action</u>: Provided late descent clearance putting aircraft well above a normal descent profile to intercept the final approach course (10,000 feet at 20 miles vs. a normal profile of about 7,000 feet at 20 miles for a 3° descent path).

Why?

Process Model Flaws	Questions Raised

Believed that the flight crew could descend easily from their position.	

Context	Questions Raised
The final controller was working both tower and approach control. As soon as the UPS 1354 contacted him they requested a descent, which was provided immediately. The aircraft had been held high by Atlanta and then Memphis ARTCC due to ATC.	*Why did Atlanta and Memphis hold the aircraft high? What constraints exist that would lead to this situation?*

<u>Contributory Control Action</u>: Did not detect and warn crew about early descent.

Why?

Process Model Flaws	Questions Raised
Did not know the aircraft was on too low an approach path.	

Context	Questions Raised
The air traffic controller did not receive an MSAW, i.e., the equipment to see an unsafe descent did not indicate any alerts due to airport proximity.	*The ATC displays contain at least the following information: callsign, speed, altitude, assigned altitude. Why did they not detect the low approach even without an MSAW? Have they become complacent because they depend on MSAW? Were they busy with other activities or is the information display not salient enough to trigger their attention?*

<u>Contributory Control Action</u>: Kept aircraft high during the approach.

Why?

Process Model Flaws	Questions Raised
Believed that keeping aircraft high is not a safety risk.	*Why was this not considered a safety risk considering it adds workload to the pilots, particularly when fatigued?*

Context	Questions Raised

FAA ATC procedures are long standing and the higher angle of descent was due to other airspace constraints, and was known to the airline and flight crews.	*Was it assumed that if the pilots had the information that they would be held high that would be adequate for safety?*

Recommendations: The related recommendations are associated with the FAA ATO

AIRCRAFT ELECTRONICS

The physical components of the aircraft can be controlled directly by the pilots or by the automation. A more detailed control structure for just this part of the overall CFIT control structure shown below is in Figure 7.

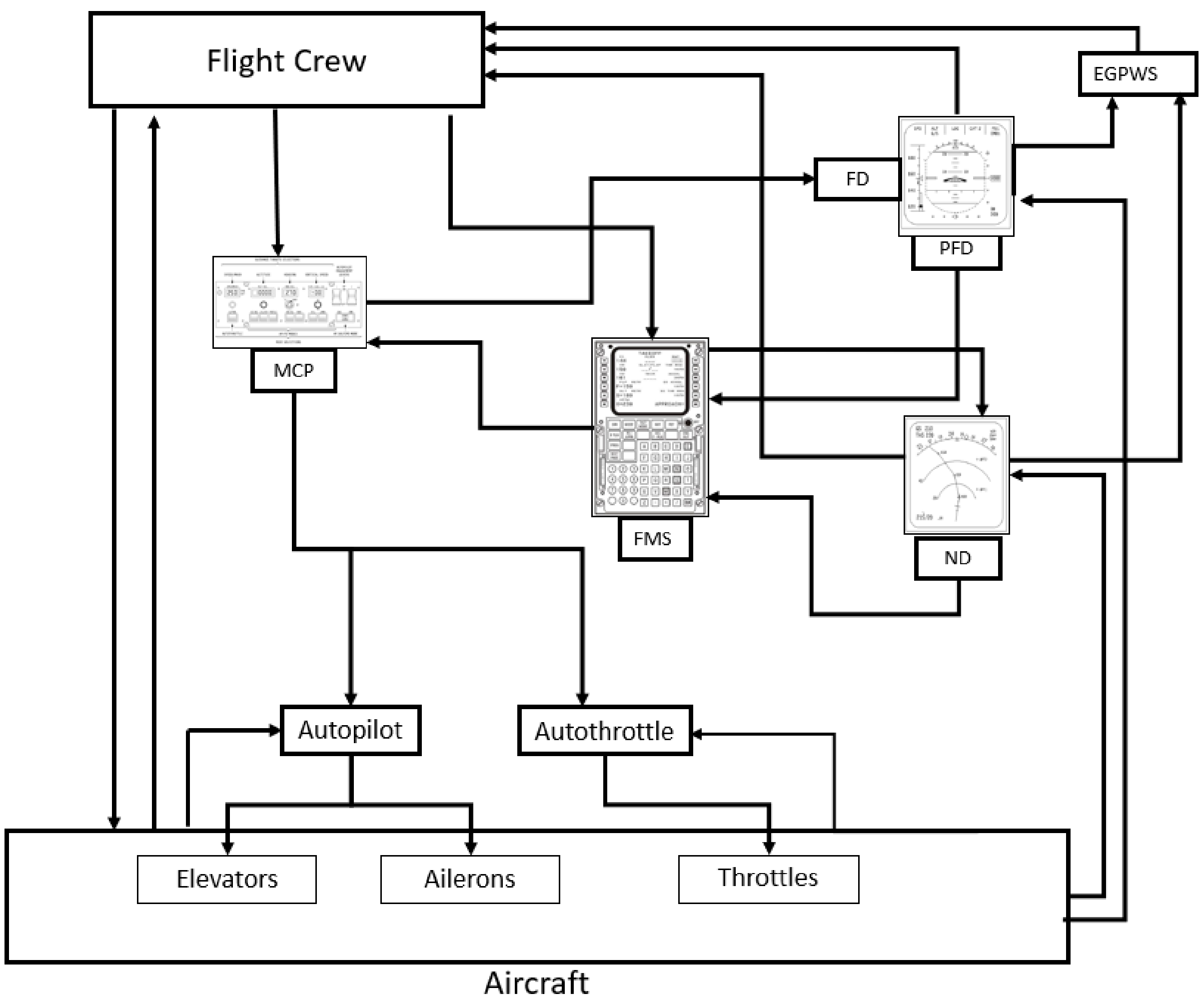

Figure 7

For the purposes of this accident, the primary control of the aircraft path is via the elevators, ailerons and throttles. The elevators control the pitch of the aircraft, which is how high or low the nose of the aircraft is pointed relative to the horizon, and the ailerons control the bank angle, enabling the aircraft to turn. The throttles control the speed if the pitch is not changed. For the purposes of this accident we will simplify the interactions to state that the elevators control the aircraft altitude and the throttles control the aircraft speed, as this is how the automation controls the flight path. Other components, such as spoilers, rudders, landing gear, brakes and reverse thrust have been excluded here as they were not pertinent in this case. As can be seen in figure 7, the pilot has direct control over these items, but the elevators and ailerons can also be controlled by the autopilot, while the throttles can also be controlled by the autothrottle.

The autopilot and autothrottles are controlled by the Mode Control Panel (MCP), which in turn can be controlled by the Flight Management System[7] (FMS)or by the pilot making changes to the MCP, or a combination of both. The MCP allows the pilot to choose the airspeed, lateral guidance or vertical guidance and based on those commands the MCP will control the autopilot, which in turn will control the elevators and ailerons. The Airbus A300 MCP is shown in figure 8. The MCP allows the pilot to select the modes. A pilot can choose, for example, (1) to allow the FMS to control the vertical profile while manually commanding the autopilot to fly a certain airspeed or a heading, (2) set the system to follow a localizer signal (a ground based radio course), while allowing the FMS to control the airspeed and vertical profile, (3) manually just control the vertical profile via the vertical speed window, or many other combinations.

The mode the aircraft is in is based on these control commands and is displayed to the pilots on their Primary Flight Display (PFD), which incorporates heading (HDG), altitude (ALT), vertical speed (V/S), localizer (LOC), glideslope and flight director (FD) See figure 9. The flight director displays the computer recommended pitch and roll to stay on the selected path. This same information is also provided to the autopilot, if engaged. The other primary tool for the pilot to gain information on the aircraft state is the navigation display, or ND. The ND provides a graphical display of the aircraft position. Using the FMS database, it can also display things such as airports, navigation aids and points as well as weather radar. If there is a route programmed into the FMS (by the pilots) it will display the aircraft position relative to that route. If the FMS also has altitudes associated with the various points on the route, the ND can also display the aircraft position relative to the computed flight path of the aircraft.

The pilots program the FMS via two control display units (CDU) which allow for the pilots to insert points, along with altitude and airspeed constraints. The airline can choose approaches to load into the FMS database. When an approach is selected, it generally includes the routing as well as the altitude and airspeed constraints that are published for that approach.

An important consideration is that the waypoints are displayed only on the F PLN (Flight Plan) or DIR (Direct to) pages. If the pilots have a different page displayed, then they would not see these points. Furthermore, on the ND, how much of the routing is displayed is dependent on the range selected. On an approach the range is normally selected down to the lowest range that will depict the necessary information. In the case of an approach, that would normally be (on the A300) the 15 mile scale.

[7] The term FMS is often used synonymously with FMS. Technically there are two FMSs which work in conjunction with other aspects of the automation

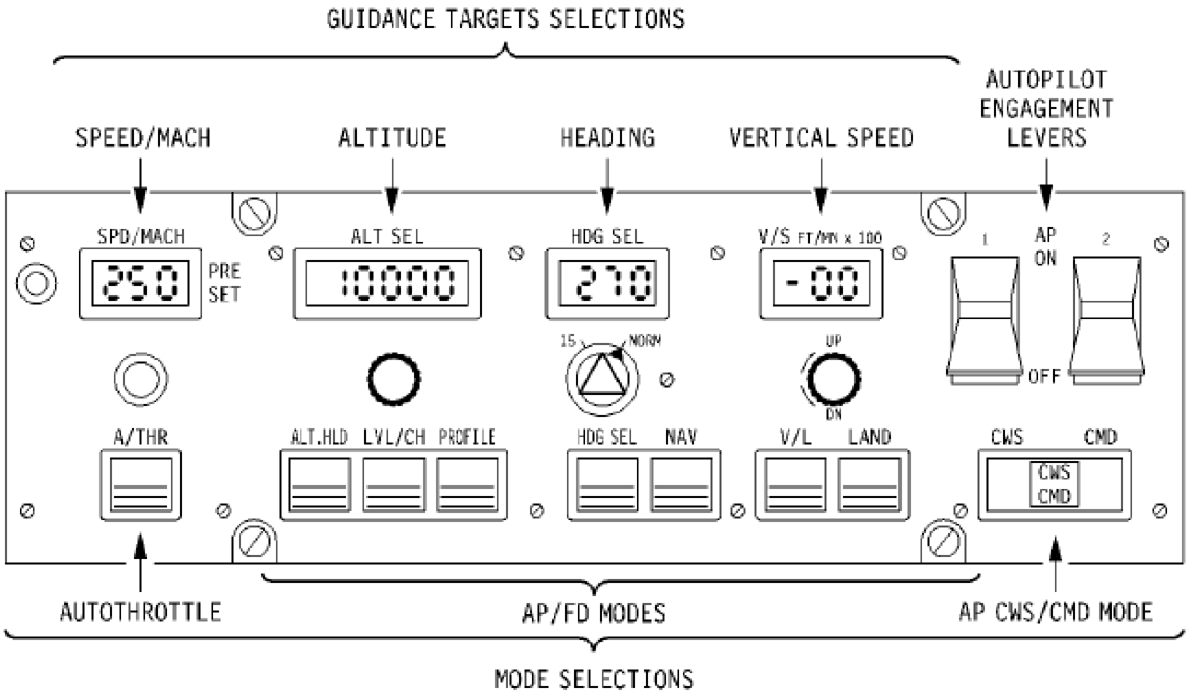

Figure 8

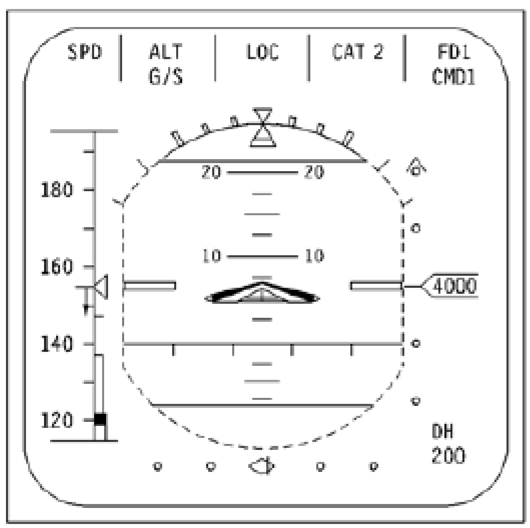

Figure 9

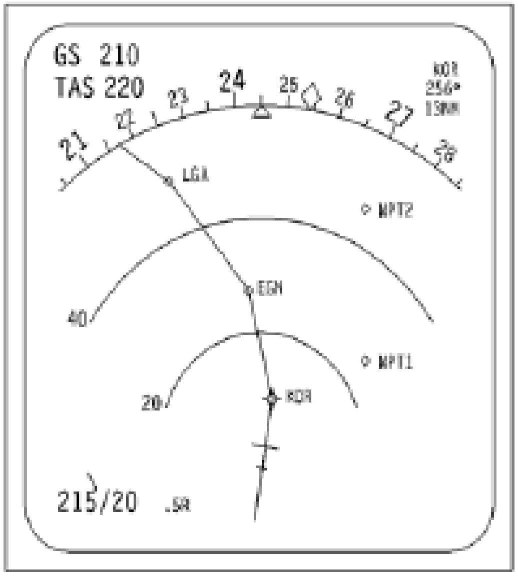

Figure 11

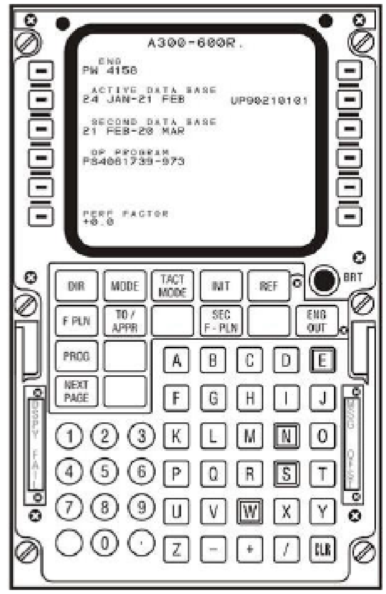

Figure 12

Figure 13

Figure 14

The final item on the control diagram is the Enhanced Ground Proximity Warning System (EGPWS). The EGPWS includes a database of terrain information and receives information from the aircraft position, the radio altitude, vertical speed and other information to warn the pilots if impact with terrain is imminent.

On an approach to land, there are several controls that are designed to prevent CFIT at the most basic level. The pilots are one control. If the pilots are aware of their altitude and position (have accurate feedback) then they will do what is necessary to stay away from terrain prior to the runway. The pilots gain their information primarily from the ND as well as the PFD, or they can look out the window if conditions are appropriate. A normal approach is designed to be a 3° "glidepath" (the angle the aircraft descends towards the ground). While the approximate height that the aircraft should be at can be determined by a combination of the ND's display of distance to the runway to a reasonable approximation, most approaches for air carriers are done utilizing the Instrument Landing System (ILS). The ILS consists of both lateral (localizer and vertical) and (the glideslope) signals. If the glideslope is not available, the approach can still be flown using the localizer signal and a secondary method of determining a safe height.

There are two primary ways the approach may be flown in the absence of the ILS glideslope. One is to allow the FMS to determine a correct computed path, while the other method is to manually control the path. If the autopilot is engaged, the path can be manually controlled with the vertical speed selection, where the pilot sets the desired vertical speed to maintain the path. For the FMS to be able to correctly calculate the vertical path, the route on the FMS must match what the aircraft is actually flying, and the aircraft position must remain on that path. If the path is different, then the assumptions are no longer valid. In the case of this accident, as previously described, the routing was not correct. This led to the FMS having a longer routing than they were actually following. A longer distance equates to the need to be higher up to remain on the proper path. Figure 13 shows the FMS routing that existed and Figure 14 shows the displays that resulted. The larger control diagram (Figure 7), shows the PAPI (described earlier) feedback to the pilot. Of course, for pilots to use the PAPI, they must be able to see it. Pilots also receive information from the ILS (if available).

Source: FAA Aeronautical Information Manual, p. 2.1.4.

Flight Management System (FMS)

Responsibilities Related to CFIT:

- Provide database of navigation waypoints with associated altitude/speed constraints
- Provide data to NAV and PFD display
- Provide guidance to AFDS when engaged by pilots

Contributory Control Action: Did not sequence points on approach so provided incorrect altitude data.

Why?

Process Model Flaws	Questions Raised
Believed it had not passed airport, which was part of its programmed route	
The FMS "believed" that it was below the programmed path due to the actual routing being shorter than the programmed routing (i.e., the FMS assumed that it was flying a longer routing so therefore	

thought it should still be at a higher altitude as it was further from the airport).	

Context	Questions Raised
FMS is not designed to know the routing, but is dependent on pilot actions. Pilot did not sequence the waypoints correctly.	

Contributory Control Action: Provided visual depiction on NAV display that showed aircraft on track.

Why?

Process Model Flaws	
Believed it had not passed airport, which was part of its programmed route	
Believed that it was below the programmed path due to the actual routing being shorter than the programmed routing (i.e., the FMS assumed that it was flying a longer routing so therefore thought it should still be at a higher altitude as it was further from the airport)..	
Context	Questions Raised
FMS is not designed to know the routing, but is dependent on pilot actions. Pilot did not sequence the waypoints correctly	

Recommendations: none but see the recommendations for Airbus/Honeywell.

Enhanced Ground Proximity Warning System (EGPWS)

Responsibilities Related to CFIT:

- Provide terrain awareness and warning to the flight crew.
- Clearly indicate when the aircraft needs to execute an escape maneuver due to proximity to ground contact.
- Provide oral height alerts when function is activated by airline

Contributory Control Action: Did not alert until there was not enough time to avoid the accident.

Why?

Process Model Flaws	Questions Raised
Before the warning, the software calculated that the aircraft would be able to safely execute an escape maneuver in the time left.	

Context	Questions Raised
The EGPWS on the aircraft did not contain the latest software enhancements (which were free, but needed to be installed on the aircraft).	*Why did UPS not install them? (see UPS)? What oversight does the FAA provide with respect to updates and maintenance?*
EGPWS alerts did not escalate per design due to the close proximity of the airport and terrain on this approach.	*What assumptions are being used in the design of the alerting system? What factors drive the design for false alerts and are these parameters affecting flight safety?*
The EGPWS operated as designed, but the approach did not meet the criteria to trigger EGPWS alerts in the software version operational at the time of the accident.	*FAA provides standards for EGPWS. Did the system on the UPS aircraft meet those standards?*
In order to trigger alerts that would require immediate aggressive enough action from the pilots to avert this accident, the software would have to be enhanced beyond the latest software version, which would be outside the design specifications of the FAA.	*Why did the design specifications not require this? (See FAA)*

<u>Contributory Control Action</u>:
Did not provide automated call-outs for 1,000 feet, 500 feet, and minimums

Why?

Process Model Flaws	
Context	Questions Raised
The callouts for 1,000 feet, 500 feet and minimums were not enabled by UPS.	*Why not?*

<u>Contributory Control Action</u>: Did not provide clear visual depiction of terrain on the approach path.

Why?

Process Model Flaws	Questions Raised
Believed that such depiction, such as vertical profile, did not need to be retrofitted into earlier aircraft.	*Why was this not done considering that it is available on the latest generation?*

Context	Questions Raised
Changes to depictions can lead to additional training requirements and may require upgrades to hardware and software.	*What is the incentive to not make these changes?*

Recommendations: (See recommendations for UPS/Airlines and FAA]
Most of the deficiencies here are the responsibility of higher levels in the control structure. There are some questions remaining (but not answered in the accident report) about the design of EGPWS, such as the parameters for false alerts and triggering alerts that would require aggressive enough action from the pilots to avert the accident.

- Review alerting criteria for EGPWS. Several CFIT accidents have occurred due to proximity of runways. Criteria must allow adequate time for a response.
- Add warning criteria to EGPWS to alert pilots that descent rate is exceeding criteria to ensure stabilized approach criteria to runway.
- Add a depiction in profile view to the Nav Display that portrays the terrain along the intended flight path.

Autopilot (AFDS)

Responsibilities Related to CFIT:

- Control the elevators.

Contributory Control Action: Commanded elevators to control pitch and approach speed using the autothrottles in vertical speed mode and continued descent below minimum descent altitude (MDA)

Why?

Process Model Flaws	Questions Raised
The autopilot thought that vertical speed mode was to be used as it was the mode commanded by the pilots.	

Context	Questions Raised
Vertical speed mode does not provide protection for too steep a glidepath.	
The procedures, as designed, offers no protection against descending below MDA in vertical speed mode. The autopilot will not normally fly past an altitude selected on the MCP. If the minimum descent altitude were entered on the MCP, the autopilot would "capture" that selected altitude. However, the published procedures call for the pilots to instead set the missed approach altitude on their MCP. The missed approach altitude is normally above the final approach fix altitude. As the autopilot now has no constraints on the descent, it will not stop without pilot	

intervention. No other mechanism aside from selecting an altitude will stop the descent at MDA as the system is designed. It would be possible to create alternative programming to force a disconnect to descend below MDA absent direct pilot action, even allowing for a slight excursion of 50 feet below MDA at intercept, however with the current system design, the only way to create this feature would limit a full constant angle descent procedure and would not allow for the setting of the missed approach altitude.	
NTSB report says: Had the FMS been properly sequenced and the profile approach selected, the autopilot would have begun a descent on the glidepath to the runway.	*Why was the FMS not properly sequenced? (See FMS and Pilots)*

Recommendations:

- Add controls that would prevent the aircraft from descending below minimums absent direct pilot intervention while preserving the aspects of constant descent path and the setting of a missed approach altitude.
- See also recommendations for pilot, UPS/Airlines and Airbus/Honeywell

Pilot-Vehicle Interface (PVI): Navigation Display (Honeywell)

Responsibilities Related to CFIT during approach:

- Provide easily interpreted visual presentation of aircraft position relative to runway location
- Indicate when display is not presenting safe information
- Clearly show discontinuity or programing errors

Contributory Control Action: Vertical deviation indicator provided anomalous (unhelpful) information, i.e., full-up scale deflection.

Why?

Process Model Flaws	Questions Raised
PVI programming is based on the assumption that the aircraft is at the same point in space the FMS shows based on leg sequencing and navigation signals (e.g. GPS, IRS, radio). The software "believed" it was not on the approach so was providing indications accordingly.	

Context	Questions Raised
To provide correct glideslope information, proper sequencing of points was required but was not done. As the LOC was providing lateral guidance the aircraft could still track the displayed final approach track despite the lack of waypoint sequencing.	

Contributory Control Action: ND depiction showed aircraft on route even though points had not actually been sequenced.

Why?

Process Model Flaws	
Thought the aircraft was in the position it displayed	
Context	Questions Raised
The vertical deviation indicator is the primary source of vertical path correction information At lower range scales the “extra routing” would not be visible or, if visible, not be salient on the navigation display. The design cues are standard for the time the system was designed and continue to be widely utilized by industry. The functionality to conduct profile mode approaches was an addition/modification to an existing system requiring the OEM to work around constraints. The system was created at the request of customers who were, in turn, working to comply with changes in industry practice implemented by regulators. The OEM interface satisfied the acceptable industry standard, which was adequate at the time of the design. The cues for inadequate programming require interpretation by the flight crew. VDI was pegged at top of scale, indicating the airplane was more than 200 ft. below the glidepath, because of meaningless information provided by the FMS. Nav display of cross-track error is very small (10 point) font so not very salient.	*On a profile approach the crew will select profile and get a Pdecent on the FMA. In a descent to an altitude (e.g. the FAF crossing altitude) the FMA’s go for ALT* (altitude capture) to ALT (altitude hold). Pdescent FMA will go away once the ALT* transitions to ALT (normally about 1/10th of a second). Sometimes ALT* will last 10 to 15 seconds so the aircraft does not descend because it is in ALT hold and profile is no longer armed. Pilots will then use vertical speed to recapture the profile. Is this what happened? There is no evidence that this factor was investigated (author J. Perry personal experience).*

Recommendations: (also to FAA)

6. Review Nav display functionality and consider adding a feature that would clearly denote that the waypoints have not sequenced even if the aircraft is on the path (magenta line).
7. Consider whether to add more clear guidance on path deviation indicator, e.g. an automatic go-around if the indicator is not indicating aircraft is on path when passing the FAF.

8. Ensure that flight below MDA and segment altitudes is clearly presented to pilots. System should be designed such that pilots are alerted if they are below a safe altitude for a particular segment.
9. Design future displays such that they clearly delineate the relative position to the runway at all times, and/or highlight prominently when the information does not match the path, i.e., when the aircraft is not actually on the route segment, the vertical information clearly shows that it is in error by changing color or another prominent way.
10. Consider increasing the size of the font on the display to make a cross track error more prominent.

Captain: Pilot Flying

Responsibilities Related to CFIT:

- Operate the aircraft in accordance with company policies
- Direct first officer (PM) in duties
- Operate autopilot or flight controls to manage the airplane descent profile
- Monitor PM inputs into FMS
- Monitor aircraft position and altitude
- Ensure PM/FO is aware of intentions and plans
- Call for aircraft configuration changes as appropriate
- Climb to MSA in the event continued safe operation cannot be assured.
- Make decisions about landing vs. diverting

Contributory Control Action: Continued an unstabilized approach into BHM. [This was the probable cause identified in the accident report] Descended at a rate violating UPS's stabilized approach criteria. Did not go around at 1000' when unstable in accordance with UPS approach criteria. Continued to descend once they stated the airport was in sight.

Why?

Process Model Flaws	Questions Raised
Appeared to have believed that the erroneous glidepath indication from the FMS was due to some factor other than the fact that they were not sequenced [the transcript implies that the reason that he and PM thought this was they were still too high].	*How common is this perception among other pilots? Did fatigue play a role here? According to research, when stimulus is received, the brain uses these relevancy filters to disregard information that is not relevant to solving the current problem. Mental fatigue has been shown to degrade the effectiveness of relevancy filters. This allows irrelevant information in to the processing chain at a time when it is already overloaded, resulting in greater performance error potential. (Boksem, Meijman & Lorist, 2005)*
Did not recognize meaningless information in the vertical path indicator	*Did they assume that the path information was not correct due to a different reason? Did they notice that*

	the indication was not correct and chose to disregard it?

Context	Questions Raised
Possibly had a visual illusion with minimal ground contact. Visual environment of the runway was very dark on the approach end, but the lights on the runway and around the airport, coupled with a steeper than normal glidepath (to avoid terrain) and terrain just off the end of the runway may have led to black-hole illusion.	*Was "black hole" illusion part of this, making it appear that they were on a normal glidepath? Was the crew aware the aircraft was unstabilized? What factors influenced the decision if the crew was aware it was unstabilized?*
Many pilots appeared to lack understanding of the automation functionality (based on the interviews). If a person does not understand the automation design, they might just assume that an errant indication is due to a problem in the programming and ignore the invalid information.	
May have not realized that they were unstable.	*Did they realize they were not stable? Did they understand the reason behind the procedures? What factors may have influenced the decision by the PF to continue an unstabilized approach? Why did the PM not call out minimums for unstable approach? Why did they look out the window? What expectations did they have on looking out the window? Did the expectation of getting important visual information conflict with the requirement to monitor the aircraft descent*
The tailored chart provided to the crew indicated that keeping flights high going into BHM was a common problem.	*Did this contribute to their belief that they were high late in the approach? ATC did keep them high prior to that time.*

<u>Contributory Control Action</u>: Did not properly configure (program) the FMC for a profile approach. Did not call for pilot monitoring to verify the flight plan in the FMS.

Why?

Process Model Flaws	Questions Raised
Apparently thought the waypoints had been sequenced.	*Why would the PF not catch this mistake?*
Appeared to have believed that the erroneous glidepath indication from the FMS was due to some	*How common is this perception among other pilots? Did fatigue play a role*

factor other than the fact that they were not sequenced [the transcript implies that the reason that he and PM thought this was that they were still too high].	*here? According to research, when stimulus is received, the brain uses these relevancy filters to disregard information that is not relevant to solving the current problem. Mental fatigue has been shown to degrade the effectiveness of relevancy filters. This allows irrelevant information in to the processing chain at a time when it is already overloaded, resulting in greater performance error potential. (Boksem, Meijman & Lorist, 2005)*
Did not recognize that the flight plan was not verified	

Context	Questions Raised
Pilots do not normally have the page that displays the sequence displayed during the approach. While the F-PLN page would have showed this information normally, if the page were slewed to look at the approach itself it would be masked. There is a DSPY annunciator to advise of the F PLN not being on the beginning of the page but it would be possible to miss this on an busy approach, assuming it was functioning. Furthermore, many pilots choose or are advised to use the TACT and PROG page once on the approach. Neither of these pages would show that the waypoints had not sequenced. Also, the navigation display (ND) would likely be selected to the lowest (15 mile) range so the "extra routing" would not be displayed.	*Were there other distractions involved? Did it appear sequenced? What procedural controls are in place to ensure this is accomplished, is there a formal announcement or statement?*
The use of tracking the LOC results in the aircraft staying on "the magenta line" path even though the waypoints are not sequenced.	

<u>Contributory Control Action</u>: Did not monitor the altitude, which lead to an inadvertent descent below the minimum descent altitude when runway was not in sight. Continued below minimum descent altitude prior to visually acquiring the runway.

<u>Contributory Control Action</u>: Did not monitor descent rate (or alternatively was not aware that the selected descent rate was too high).

Why?

Process Model Flaws	Questions Raised
Expected they would break out at 1000' because of incorrect weather report.	*Why did they get an incorrect weather report?*

Thought they were higher than they were on the final approach segment	*What led them to believe this?*
Did not realize that ceilings were variable down to 300 feet (as reported by FedEx captain in ops group interview).	
Did not realize that they were descending below minimums prior to visually acquiring the runway environment.	*What CRM factors allowed the altitude not to be monitored? Was pilot aware that aircraft descended below MDA? Why did no other controls or alerts prevent this? Did they believe they had it in sight? Did they believe they would see the runway due to the reported weather on the ATIS?*
Did not know about the variable ceilings at the airport.	
Was not aware of uneven terrain prior to the runway on the approach.	*Why is this information not more readily available in a clear way?*

Context	Questions Raised
During flight, information about variable ceilings at airport by both their request for weather via the UPS system (ACARS) or the ATIS was not provided to flight crew. Actual ceilings were as low as 300 feet, which would have affected the expectations of the pilot. [Would it have made a difference in the outcome?]	
ATC kept the aircraft high so they were initially above the nominal profile. Aircraft was still high and fast passing the final approach fix.	
Weather information for the actual approach is rarely available absent pilot reports or in unusual circumstances. There is no direct measurement of weather during the approach itself.	

<u>Contributory Control Action</u>: Changed to vertical speed approach after not capturing the profile path without communicating the change to the pilot monitoring. [When the autopilot did not engage in profile mode, the captain changed the autopilot mode to the vertical speed mode, but did not brief the pilot monitoring on the autopilot mode change.]

Why?

Mental Model Flaws	Questions Raised
Appeared to assume PM would see the change, or, conversely, considered it normal procedure which did not require discussion.	*Are such changes a common occurrence? Is it common to ignore the procedures? If they knew them why*

	would they purposely violate them? Did they understand the reason behind the procedures? Did they believe they would soon visually acquire the runway? Was this a result of an expectation that they would soon see the runway or were they just not aware of it? Was it an intentional violation?

Context	Questions Raised
Pilot was concerned about being too high. While PF did not state the change, it should be noted that she was making a required callout at the time. PM did notice it almost immediately, so the first assumption would be valid. Based on interviews it appears that adjusting the method was a common process. Humans will commonly take the actions they deem necessary to "make the system work" (Dekker, 2017).	*Why was this common? What is lacking in the understanding of the system that lends to this? Did the change appear to be implicit? Was changing modes so common to not appear to need announcement?*
Even the UPS chief pilot stated that the use of vertical speed on LOC approach is what he would do (p. 6 of factual interviews). PF may have believed that the profile mode did not capture due to being too high or being in altitude hold mode and that the system would capture from above with the use of vertical speed. They were still initially above glidepath attempting to slow down passing the final approach fix	*Why is it so common to need to work around the system design to "make it work"?*
Some pilots were not familiar with why profile/VNAV mode would not work [from NTSB interviews and factual attachments in the accident report] and so a common "work around" was to continue in another mode, visually or with VS. There are several procedural steps to get the vertical profile to work properly, resulting in workarounds.	*Why was this common? Was there a training issue? Do pilots actually understand the functionality or are they just trained to follow procedures without deeper understanding? Are decisions based on "work-arounds" the result of the known slow processing of the early generation FMS that are installed on the A300? Why is the procedure so cumbersome? Is that necessary? Do pilots really understand the design of the automation so they can know when it is giving them bad information?*

<u>Contributory Control Action</u>: Did not delay arrival in order to have a precision approach (ILS). Did not appear to see or recall the NOTAM on the runway closure.

Why?

Mental Model Flaws	Questions Raised

Did not know that the other runway would open soon once they discovered the runway was closed.	*Why did they miss the NOTAM? Why did they not communicate with Dispatch to get this information?*

Context	Questions Raised
The weather reported on their preflight package as well as the enroute weather they received while they were flying (both digitally and via the ATIS) indicated good visibility and ceilings (cloud heights) of at least 1,000 feet. As a result, the crew may not have been concerned about NOTAM about the runway. The forecast essentially indicated visual flight rule (VFR) weather.	
There are so many NOTAMs, many of which are not pertinent to a particular flight, that pilots can easily miss important information, particularly time blocks. The likelihood increases when pilots are fatigued. They may depend on ATIS or ATC to prevent problems; the most important NOTAMs are generally available on the ATIS. These pilots did not see the NOTAM so they did not know to even inquire about when the primary runway might open.	*Why did the dispatcher not communicate this information to the crew? Why do dispatchers not ensure that critical NOTAMS are discussed with the crew before departure or added to the remarks on the flight plan/release that they provide to the crew? Were they aware that another approach would be available? Were they anxious to get on the ground due to fatigue? Were there other pressures to just "get the job done"? Did they check NOTAMs? Why did the dispatcher not delay the arrival? Why did this crew not decide to delay the approach as another crew did? Did fatigue and wanting to get to the hotel play a part in this? Is the NOTAM system adequate? How often do pilots miss a NOTAM during flight preparation? Are NOTAMS and ATC comms sufficient for the PF to build a mental model of the approach and form a viable hazard and risk analysis?*

Contributory Control Action: Flew LOC approach rather than an RNAV GPS approach. Did not consider using RNAV GPS, missed notice on chart about LOC not being available at night.

Why?

Mental Model Flaws	Questions Raised
Did not know that LOC was not available at night.	*Why did they not notice the note? How many other pilots would make a similar error?*

Context	Questions Raised
Pilots have traditionally chosen the approach that provides the most accuracy: first the ILS, then LOC, and then various other types of approaches. Until recently, with the advent of GPS, the LOC approach was always more accurate than the others, with the exception of an ILS.	*Why have pilots not been trained to understand the limitations of the different approaches?*
ATIS and ATC both stated that the LOC 18 was in use with no mention of other approaches. Pilots likely ignored the note of the approach being NA at night (assuming they saw it) as ATC was clearly using it. The dispatcher stated in his interview that he did not discuss the issue with the pilots as it might "insult" them.	*Did they believe the LOC approach was more accurate or did they even consider the question? Did ATC influence them or confirm their belief that the LOC was the correct procedure or "best available" procedure? Did the ATIS stating that the LOC 18 approach was in use influence their decision? Did the chart order (i.e., the sequence of charts starts with the ILS and then LOC before going to the RNAV GPS) influence their decision? Were they using an EFB or paper charts?* *Why did the dispatcher assume that this would insult the crew? Was there a rule that required the dispatcher to communicate this information? Was there a bias towards flying LOC vs. the RNAV? Why did the FAA not have more oversight of this? Why did ATIS only state the one type of approach? Does ATC give priority to LOC approaches even when the minimums for it are the same as the RNAV GPS?*

<u>Contributory Control Action</u>: Diverted attention outside when approaching minimums.

Why?

Mental Model Flaws	Questions Raised
Believed runway would be visible at that point.	

Context	Questions Raised
Ceiling was lower than they expected due to the lack of weather reporting during the approach itself as well as the removal of the weather remarks from the NOTAM.	*Should airports install ceilometers or LIDAR to accurate measure the cloud base at critical points on instrument approaches, particularly nonprecision approaches?*

Contributory Control Action: Did not follow sterile cockpit rules. Inappropriate talk in cockpit while approaching.

Why?

Mental Model Flaws	Questions Raised
Believed that discussion of non-pertinent items would not detract from attention to the approach.	

Context	Questions Raised
When very tired, conversation is one of the most effective ways to stay alert. The loss of concentration from the talking can be much less than the loss due to sleep pressure. A jovial attitude is common when people are tired and trying to stay awake.	*Did the conversation lead to missing the lack of sequencing the waypoints? Did the conversation actually create this problem? Is there actual evidence that the conversation resulted in missing the waypoint sequencing issue?*

Contributory Control Action: Flew when fatigued.

Why?

Mental Model Flaws	Questions Raised
Apparently believed that they could safely operate despite the fatigue they openly discussed.	

Context	Questions Raised
Pilots, particularly in night cargo operations, commonly fly when very tired. After many years of doing this with no potentially harmful outcomes, it becomes routine and the risk is less apparent.	*Why did nobody do anything about the pilots flying fatigued? Why is there not a formal pre-departure briefing item on fatigue mitigation strategies?*

General Question: Are NOTAMS and ATC communications sufficient for the PF to build a mental model of the approach and form a viable hazard and risk analysis?

Recommendations: The recommendations related to the pilot's behavior appear in the recommendations for the airline (UPS training and policy) and for the FAA oversight office.

Pilot Monitoring

Responsibilities Related to CFIT:

- Perform duties at direction of captain/PF, including configuration changes, etc
- Make entries/changes to FMS
- Monitor aircraft flight path, altitude, configuration, performance and position
- Back up captain in decision making
- Verbalize any concerns
- Make call-outs as required by company procedures

Contributory Control Action: Improperly entered clearance into FMS

Why?

Mental Model Flaws	Questions Raised
Believed FMS was properly programmed.	

Context	Questions Raised
Fatigue and the pace of activity was high at the time. As the LOC approach was used the aircraft intercepted the course as expected so the lack of proper programming was not apparent.	*Were they aware that it was not properly programmed? Was this a slip or a mistake?*

<u>Contributory Control Action</u>: Did not make required callouts

Why?

Context	Questions Raised
Time compression due to pace of events and other responsibilities, such as checklists, etc., made the callouts easy to miss. There are a great many callouts and not all are beneficial to increase situational awareness. Pilots need to choose between various responsibilities and choose the one that appears most critical.	

<u>Contributory Control Action</u>: Did not challenge captain's selection of 1,500 feet per minute of vertical speed.

Why?

Mental Model Flaws	Questions Raised
May have believed that the vertical speed was necessary.	

Context	Questions Raised
As PM, she may not have been able to keep up with all aspects with the PM duties. Pilot monitoring still must complete checklists, move landing gear and flaps and a number of basic tasks. While the term has been changed to "pilot monitoring" from "pilot not flying", the reality is that the tasking has not changed. If the PM were primarily "monitoring" when checklists, flaps and gear needed to be accomplished then those items would be missed and the aircraft would be in a risky state, too low and not configured, etc.	

<u>Contributory Control Action</u>: Did not properly monitor aircraft position, including altitude

Why?

Mental Model Flaws	Questions Raised
Did not notice that flight had descended below minimums prior to acquiring runway. (Or did not think that flight was below minimums or thought they were higher than they were)	
Did not notice that aircraft was still descending well before the runway.	

Context	Questions Raised
See contextual factors for previous Contributory Control Action.	

Recommendations: As with the PF, the recommendations are associated with UPS training and policy and with FAA oversight.

UPS Dispatcher

Responsibilities Related to CFIT:

- Assist in planning flight paths, while taking into account all conditions potentially affecting flight
- Provide a flight following service. During flight, monitor and advise crew of changes affecting safety of flight
- Advise pilots if conditions change
- Share responsibility for exercise of operational control (joint control), which gives them the authority to divert, delay, or cancel a flight. Dispatch has 50% legally responsible for safety of every flight they dispatch (PIC has other 50%).
- Analyze and evaluate meteorological information to determine potential hazards to safety of flight
- Prepare flight plans containing information such as weather conditions, field conditions, NOTAMs, etc.
- Monitor weather conditions, aircraft position reports, and navigation charts to evaluate progress of flight. Update PIC of significant changes to weather or flight plan and recommend flight plan alternates, such as changing course, altitude, etc.

Contributory Control Action: Forecasted weather at BHM indicated that low ceilings upon arrival required an alternate airport, but dispatcher did not discuss with the flight crew the low ceilings, the single approach option, or the reopening of runway 6/24 about 0500 that had precision landing equipment. Did not discuss possibility of landing at an alternate airport or waiting until 0500. Did not consider delaying the flight until the opening of the primary runway equipped with an ILS.

Why?

Process Model Flaws	Questions Raised
Was not aware of the observation remarks for variable ceilings as it was not contained in the UPS weather package.	*Why was it not contained in the weather package? (see UPS and ATC)*

Context	Questions Raised
The dispatcher stated he was not aware that the crew did not have the information about variable ceilings, as the dispatcher	

also did not have the remarks, according to the interview factual.	
Dispatchers provide what is legal (performed all the expected duties according to the NTSB report), but the "joint authority" in this case appeared to not be "joint" at all	*Why is this the case? How common is it?*
Joint authority is not well defined by UPS or by the FAA.	
Dispatcher was working many flights and so may not have had time to explore nuances for each flight, despite sharing (having joint) responsibility.	*Is the workload too high for dispatchers?*
Dispatchers may be under pressure to ensure on-time departures. It is not known if there are incentives or penalties assigned to flight dispatchers at UPS regarding flights departing on time.	*Are there incentives or penalties assigned to flight dispatchers at UPS (or elsewhere) regarding flights departing on time?*
UPS's vendor had removed the remarks at the request of dispatch management to stop a duplication issue. The weather package provided to the dispatcher was the same as the flight crew. Like most of UPS management (including dispatch management), the dispatcher was not aware of it. The only way for the dispatcher to obtain the remarks would have been to pull them up via a different system and that only occurred when a pilot would specifically ask for it. It is unlikely a pilot would ask for this if they did not know it was missing	*Why did UPS allow this decision to be made? Who in UPS is ultimately responsible for this type of information, was it the director of operations? Why was he not informed [per Ops Group interview])? (see UPS)*
According to the ops group interviews, the dispatcher enters the flight information and the computer (Lido system) checks for legality and if legal, provides that information to the dispatcher. The dispatcher only then checks it to ensure it is actually legal and nothing is missed, and if so, releases the flight. The automated system does not look for aspects such as a better situation becoming available with a short delay (e.g. the runway opening just after scheduled arrival). Rather, the system just confirms that it is legal as scheduled. If it is legal, there is a strong incentive for the dispatcher not to look further as the system just guides the dispatcher through the steps and humans tend not to question whether computer-guided steps are appropriate. UPS could not legally dispatch a flight without the Lido system and according to the FAA inspector, they were dependent on the automation [ops group interview, other interviews]. There has, perhaps, been an overreliance on computers and the errant belief that they are better at humans in all cases, ignoring the often superior decision-making ability of humans.	*Are dispatchers questioning computer outputs?*

Contributory Control Action: Did not communicate to crew that based on his review of the approach charts and issue of LOC NA note, that only one approach (RNAV 18) was available, nor was it listed on the flight release.

Why?

Process Model Flaws	Questions Raised
Believed the crew was aware of the LOC NA note	
Thought the crew would be insulted if he told them that.	

Context	Questions Raised
In the accident report, the dispatcher explained his actions by citing professional courtesy and not wanting to insult the crew	*How often do dispatchers communicate with pilots what runways and approaches the dispatcher chose and the reasons why?*

Contributory Control Action: Did not account for fatigue on ability of flight crew to be aware of various issues.

Why?

Process Model Flaws	Questions Raised
Assumed pilots would handle any fatigue issues.	*Did the dispatcher know the crew were fatigued?*

Context	Questions Raised
Dispatchers are not currently trained to be part of the mitigation for fatigue for pilots unless the pilot raises the issue. Even then the dispatcher is minimally involved normally.	*Are dispatchers trained to understand how fatigue might impact inflight decision making?* *Does the dispatcher have access to information about crew fatigue?*

Recommendations:

- Dispatchers must
  a. Mutually work with the flight crew regarding NOTAMS and weather that involve closures of primary runways, approaches and similar safety of flight aspects, to include the times of those events.
  b. Proactively provide information to flight crews regarding the status of approaches and why a particular runway and approach is listed in the flight plan
  c. Notify pilots of what approaches are considered for planning purposes and the reasons for that approach if not a primary approach for the airport.

- Captain and dispatcher must mutually agree as to the safety of flight while considering airline scheduling needs. Flight should operate only if both agree that the flight can be operated safely under the circumstances. This recommendation contemplates an active discussion and not just a pilot signing a flight release.

UPS

[We did not divide this section into specific UPS decision-making components, including the operations manager, because the report does not differentiate and contains little information about the assignment of decision-making responsibilities within UPS.]

Responsibilities Related to CFIT during approach and landing:

- Ensure aircraft equipment for prevention of CFIT (including updates to EGPWS) is installed and maintained.
- Ensure that procedures require that an approach not be continued if it is not stable and pilots have not confirmed that the mode is correct by the final approach fix.
- Ensure pilots are trained to fully understand the system operation [that pilots have required process models (understanding) of the automation and the safety controls to avoid unstable approaches (CFIT)
- Ensure that flight operations follow best practices and that pilots have all the information needed for good decision making, including weather information.
- Provide oversight and training to flight dispatchers and ensure policies and procedures are safe.

Contributory Control Action: Did not ensure that there were procedures to mitigate the risk of fatigue, such as briefings, protocols with dispatchers, i.e., items beyond flight and duty rules.

Why?

Process Model Flaws	Questions Raised
Believed that industry standard practice regarding fatigue was adequate to maintain safety.	

Context	Questions Raised
The industry as a whole has not well specified protocols nor enforced fatigue standards.	

Contributory Control Action: Did not upgrade EGPWS software to more recent versions that would have provided an earlier alert.

Why?

Process Model Flaws	Questions Raised
Believed that not upgrading to the newest version would have no impact on safety.	

Context	Questions Raised

Upgrade was not required by the FAA. Assumed that compliance with FAA guidelines was enough to ensure safety.	*Why was it not required? What factors (operational, commercial, or practical) influenced the decision not to upgrade the EGPWS software?*

Contributory Control Action: Did not activate a variety of alerts on EGPWS (1000, 500, minimums). Relied on pilots to make callouts rather than implement automatic callouts from the EGPWS.

Why?

Process Model Flaws	Questions Raised
Believed that mandating callouts was not required for safety.	

Context	Questions Raised
Adding EGPWS callouts was not mandatory by regulation. Assumed that compliance with FAA guidelines was enough to ensure safety.	*Why not? These callouts can serve to increase crew awareness as the timing/pacing of the callouts can provide pilots a significant cue when descent rates are not nominal. Requiring the PM to make these callouts both increases PM workload and also diminishes the potential for crew awareness due to pacing as the callouts may be missed, late or lack the same salience.*

Contributory Control Action: Did not have policies and procedures in place that would require dispatcher to proactively communicate with pilots (e.g., provide information that runway would be opening soon) in order to fully share responsibility for safety with flight crew.

Why?

Process Model Flaws	Questions Raised
Did not believe such policy was needed?	

Context	Questions Raised
The roles of the dispatcher and flight crew in the "joint control" paradigm are only vaguely specified by the FAA and many airlines.	*Is staffing adequate to allow for dispatchers to engage at the level implied by the regulation?*

Contributory Control Action: Removed remarks from weather information provided to pilots either through dispatch paperwork or via weather requests on ACARS.

Contributory Control Action: Did not update NOTAM presentation to ensure pilots would not miss pertinent information for their particular flight.

Why?

Process Model Flaws	Questions Raised
Personnel in the Flight Control Dispatch Office believed that weather remarks were not necessary for safety.	*Why?*

Context	Questions Raised
The removal of the weather remarks was required to solve a technical issue of duplicate information by the IT department working with the dispatch office. As remarks are not "controlling," it probably made sense to the dispatch office to conclude they were not necessary. The information that this was done was not shared with the flight operations department.	*Why was a risk assessment of some type not completed when this change was made, and if it was, why did it not capture the safety and regulatory problem with the change?*
This was likely less of a problem than the absence of remarks on the ATIS. The NOTAM provides a lot of information, and the flight crew are unable to process it all. In general, removing information that is not critical is a good idea.	
Criticism of the NOTAM format has been around for a long time but nothing has been done by the FAA to fix it. Ability to enhance presentation of NOTAM information is very tightly regulated by the FAA.	*Why are carriers limited? Why has this not been tackled by the FAA and industry previously?*

Contributory Control Action: Implemented procedures that would not prevent the autopilot from descending below minimums on a vertical speed approach.

Why?

Process Model Flaws	Questions Raised
Did not believe such procedures were needed?	

Context	Questions Raised
Such procedures were not required by airbus or FAA guidance.	*Is the industry moving towards constant angle descents, not considering secondary problems that can be a consequence of the changes?*

Contributory Control Action: Did not ensure that pilots had a complete mental model of how the system performed a profile approach and what requirements needed to be met.

Contributory Control Action: Did not enforce a requirement that an approach be immediately abandoned if the aircraft is not stable on the vertical path in the correct mode by the final approach fix.

Why?

Process Model Flaws	Questions Raised
Believed that current requirements were adequate to prevent such behavior.	

Context	Questions Raised
The industry generally confuses safety constraints developed to mitigate the hazard of runway excursions with those developed to mitigate against the hazard of CFIT. The 500ft VMC /1000ft IMC safety constraints are to protect against runway excursions. The FAA recommendation to be stable by the FAF is a safety constraint intended to prevent CFIT but not generally enforced by U.S. carriers (see FAA AC 120-108). While desirable to require abandoning the approach should it not be stable, this is not industry standard practice for most U.S. carriers.	*Why is this not standard practice? Is the fact that there are not many non-ILS approaches flown lead to missing the significance of this type of problem?*
OEMs and Airlines have not kept up their NPA guidance. Many airlines flight operations manuals are not using the latest industry approach terminology, e.g. PA, APV, NPA, and so it is easy to see how the associated guidance can be lost.	*Why has this guidance not been updated? Simply because rarely used by large aircraft?*
UPS procedures on nonprecision approaches matched the Airbus flight manuals in regards to vertical speed approaches.	
Pilot training met regulatory requirements. Numerous constraints to training exist such that there is not time to spend a lot of time on a procedure that is deemed to be rarely used	*How is the determination made as to where to put emphasis in training? Where is the oversight on training and why did the regulator not deem this an issue?*
Best practices in terms of safety constraints to prevent CFIT exist in FAA and other leading industry guidance, but the exact definition is left with the operator. Also, there is little guidance as to crew actions required if the safety constraint is not met.	

Contributory Control Action: Relied on historical data for safety decisions

Why?

Process Model Flaws	Questions Raised
Believing that statistical data is a valid method to predict future problems.	

Context	Questions Raised
The use of statistics is widely accepted and expected.	*Why are these assumptions not challenged?*
The use of statistical data may provide a false sense of security as a low rate may be due to many factors, such as lack of reporting or monitoring the wrong thing. Furthermore, even in the best case, statistics only reflect historical situations and not new combinations of factors that can lead to an accident	

Recommendations: [Most of these apply to all airlines]

- Activate current software updates and automatic call-outs for EGPWS.
- Add a "fatigue briefing" item to the pre-flight procedures. Create fatigue mitigation measures that also include dispatchers so that dispatchers can help mitigate risks by providing extra support to crews who may be more fatigued based on established metrics. Ensure that the company and managers are actually following the written guidance and stated policies regarding fatigue so that line pilots do not feel that it is "all talk" and are not reticent to report fatigue or call in "fatigued" on a trip, regardless of reasons.
- Require dispatchers to proactively communicate to pilots on NOTAM issues that directly affect the approach capabilities at airports. Ensure pilots are aware of effective times for NOTAMs through secondary means, and not just assume they are aware because they have received the information. Provide pilots with extra time (to be determined) to allow for adequate review of NOTAMs, e.g., add one minute to the preflight time allowed for each NOTAM. Such time shall be considered a part of flight duty for regulatory duty time limitations.
- Require that all operational and informational changes impacting the dispatchers and pilots, such as removing weather remarks from NOTAMs, are done in close coordination with flight operations and are fully vetted through the Change Management Procedures in the SMS.
- Ensure that dispatchers are provided with all weather information including all remarks and that they, in turn, ensure pilots are aware (not just provided) with those aspects that might impact the safety of the flight.
- Ensure that dispatchers are actually sharing responsibility for the safety of the flight. This may require reducing the number of flights a dispatcher is working so that they can actually monitor each flight rather than only being brought into the loop when the flight crew contacts the dispatcher. Ensure that dispatchers are not under undue time pressure to provide on-time flights that degrades from safety and their joint responsibility role.
- Review dispatcher use of automated computer systems to release flights. Automated systems may result in a legal flight without considering small changes that can have a large impact on safety (such as the 10-minute delay for the ILS runway opening on this accident flight). While automated systems can reduce the workload, the ability of humans to make sense of all of the information still exceeds computer capabilities (see Hoffman et al, 2017).
- Ensure that all airline-produced manuals contain consistent guidance.

- Change procedures and training with respect to: approach procedures in general, including communication between pilots about any change in approach and the selection of approaches other than the one being suggested by ATC or ATIS; conditions requiring a go-around; rules for changing autopilot modes and required call-outs for an intentional change of modes; secondary cues that waypoints are not sequenced; announcement of passing MDA; what to do if automation is not working as expected; conditions that must be brought to the attention of the other pilot so both pilots can agree on the problem and a strategy to manage it; and minimizing "black-hole illusion." Review procedures to identify where workload can be reduced without affecting safety.
- Consider adding a procedure to ensure flight plan is on the correct page and a mandatory call-out that a pilot is feeling behind or rushed rather than left as a vague "should do." Specific language that is trained is more likely to overcome psychological hurdles. At the same time, consider removing callouts that are not actually beneficial or that may easily and more reliably be replaced by automated systems (such as EDPWS). Research whether pilots are actually distracted from other duties by making very routine callouts (such as 1,000 feet).
- Make sure training of pilots includes the reason procedures are designed a certain way in order to reduce instances of pilots modifying or attempting to work around a seemingly cumbersome procedure due to lack of understanding the reasons for the procedural steps. If there are no good reasons, simplify the procedures.

Airbus/Honeywell

<u>Responsibilities Related to CFIT during approach</u>:

- Design an aircraft that is safe during approach and landing

<u>Contributory Control Action</u>: Created a design that could contribute to confusion on a nonprecision approach that was overly reliant on pilot knowledge and procedures.

<u>Contributory Control Action</u>: Allowed a design where the aircraft would continue descent below minimums in a vertical speed approach with the procedures recommended

Why?

Process Model Flaws	Questions Raised
Assumed humans would reliably follow procedures.	

Context	Questions Raised
System for profile mode was not an initial functionality so required several steps to accomplish.	*After an aircraft is certified for operation, are the continued airworthiness requirements adequate for the monitoring of safe operations?*
Procedures for the approach are standard in the industry. There are no other current designs that prevent descending below minimums with the autopilot using the standard procedures	*Why was this never considered?* *Are the airlines provided with adequate information about*

	the safe operation of the aircraft? *What were the aircraft design and operational assumptions contributing to the accident?*

Recommendations:

- Ensure that assumptions in design are provided to carriers so that they may better understand and train the basis of procedures.
- Communicate all aspects of any software changes to carriers so carrier can include and monitor the changes as part of their SMS.
- [*Are there design changes that would have helped besides those listed under the PVI?]*

Independent Pilots Association

Responsibilities:

- Promote the non-punitive use of fatigue calls
- Promote mitigations to reduce fatigue risk
- Ensure pilot community is safety rather than mission oriented. [Promote pilot independence and speaking up when making safety vs. efficiency or productivity decisions.]

Contributory Control Action: Did not create a fatigue mitigation strategy beyond work rules.

Why?

Process Model Flaws	Questions Raised
Believed that this was the responsibility of management?	

Context	Questions Raised
Industry has not considered a formal fatigue mitigation brief for pilots.	*Why not?*
Industry has not utilized dispatchers in a more proactive way to mitigate fatigued pilots missing important things	

Recommendations:

- Encourage pilots to be proactive in speaking up when they are “behind” the aircraft.
- Work with company to create a “fatigue brief” item that would include aspects such as choices of types of approaches, etc.
- Work with company dispatchers to create a mutual platform to assist dispatchers in aiding pilots in mitigating fatigue.
- Train pilots on fatigue risk mitigation including recommending only precision approaches to longer runways. Recognize that pilots will try to “get the job done” and also try to “get to the hotel” when tired so proactively train and implement methods that mitigate this.

- Work with UPS to improve the communication to pilots as to the actual intent of the safety culture and that the company means what it says it means.

FAA Aviation Flight Standards (AFS)

Responsibilities Related to CFIT during Approach and Landing:

- Provide oversight of airlines with respect to training, procedures, and software updates that relate to approach and landing.

Contributory Control Action: Did not ensure or encourage UPS to implement most recent software and database for EGPWS, i.e., oversee process of keeping EGPWS software up to date. Did not ensure consistent guidance in manuals for EGPWD alerts.

Why?

Process Model Flaws	Questions Raised
Believed that the airline would implement the most recent software?	*Did they believe that airlines would install most recent software or did they think it was not important to do so?*

Context	Questions Raised
FAA personnel were not aware that EGPWS software was not updated.	*What types of feedback are required?*
FAA staffing does not provide for the ability to keep up with all of the changes in software or the need, so this is often left to the carriers	
The FAA may be lulled into a false sense of security because most of the industry exceeds required standards by a large margin. While this is a positive thing, it may leave the false impression that oversight and regulation do not need to be improved.	

Contributory Control Action: Did not require UPS to activate EPGWS callouts.

Why?

Process Model Flaws	Questions Raised
Did not think that callouts were important? Thought airlines were doing it themselves?	

Context	Questions Raised
Implementing callouts is usually left to the discretion of the carriers.	

Contributory Control Action: Did not provide oversight of pilot/dispatch communications or carefully define shared authority (i.e., who is in charge?).

Why?

Process Model Flaws	Questions Raised
Thought the pilot/dispatch guidance provided was adequate.	*Did they assume that airlines would clarify roles themselves?*

Context	Questions Raised
This is an industry-wide issue. Shared responsibility is not actually shared, pilots are responsible for more than 50% partially due to the number of flights dispatchers normally work.	

<u>Contributory Control Action</u>: Did not ensure proficiency requirements for nonprecision approaches.

Why?

Context	Questions Raised
FAA tends to rely on carriers for training and the metrics are based on training records, which may or may not reflect actual safety. As an example, if pilots know what to expect in a training session, they will then "study for the test," leading to very good optics for the training department and lower costs for training (but perhaps not the best training).	
LOC approaches with vertical FMS guidance creates a scenario where a pilot may miss the fact that waypoints have not sequenced because the lateral guidance is not dependent on the correct flight plan. This potential problem is not one that has been considered by the industry at all.	

<u>Contributory Control Action</u>: Allowed UPS to remove remarks from pilot-provided weather. Has not improved the NOTAM system to ensure pilots do not easily miss important items.

Why?

Process Model Flaws	Questions Raised
The FAA was apparently not aware of remarks being removed from weather.	

Context	Questions Raised
The FAA has been attempting to update the NOTAM system, but the process requires coordination between many users and ICAO.	
Remarks are not always provided unless warranted, so their omission would not stand out.	

<u>Contributory Control Action</u>: Did not provide oversight of airline procedures/training for pilots and dispatchers necessary to prevent this accident (see Pilots and UPS)

Why?

Process Model Flaws	Questions Raised
Thought procedures and training was adequate.	

Context	Questions Raised
Company manuals are large, and it can be difficult to ensure each section is in compliance other manuals, particularly training guides that are not required.	
FAA tends to rely on carriers for training and the metrics are based on training records, which may or may not reflect actual safety. As an example, if pilots know what to expect in a training session, they will then "study for the test," leading to very good optics for the training department and lower costs for training (but perhaps not the best training).	

<u>Contributory Control Action</u>: Did not provide protocols to mitigate fatigue risk beyond crew rest requirements.

Why?

Context	Questions Raised
Fatigue management has been mostly limited to flight and duty regulations and has not considered other controls that might reduce risk when other uncontrolled factors are involved.	

<u>Recommendations:</u>

General:

- Provide oversight and review manuals to ensure consistent guidance.
- Create a method to monitor for safety of changes such as the removal of weather remarks. Ensure any changes to information supplied to pilots and dispatchers are fully vetted through the carrier's SMS Management of Change process.
- Improve NOTAM system so pertinent NOTAMs are more prominent (see also ATO recommendations).
- Review whether so-called "non-pertinent" conversation can improve crew alertness and the degree that it actually distracts crews, particular in light of pilots not knowing the context for required callouts. Do required callouts where pilots are not aware of the reason behind them lead to a compliance without improving situational awareness?
- Reassess the data rates for accidents and incidents plus other event reporting in consideration of the actual practices of industry. Should the base regulation and compliance standards be increased to match industry practice? This might result in industry moving to an even higher safety level, and thus reduce accidents.

Enhanced Ground Proximity Warning System (EGPWS).

- Ensure operators install and do not defer software updates and that alerts are activated.
- Ensure operators activate automated callouts in software to enhance crew awareness. At the same time, review the use of callouts and evaluate which callouts are actually beneficial. It appears that

callouts are being added after events as a way to appear that "something was done" rather than to actually prevent a problem. FAA should ensure that pilots are trained to understand why the callout was implemented and also review if there is a better way to prevent an accident or mitigate an issue that does not increase pilot workload during critical phases of flight. *Do the callouts actually improve situational awareness or just protect the operator and FAA by shifting responsibility to fight crew for any problems encountered if they are missed? Are the callouts just done absent mindedly like pushing a switch can be impacted by automaticity?*

- Review alerting criteria for EGPWS. Several CFIT accidents have occurred due to proximity of runways. Criteria must allow adequate time for a response.
- Add warning criteria to EGPWS to alert pilots that descent rate is exceeding criteria to ensure stabilized approach criteria to runway.

Dispatch:

- Ensure that dispatchers are provided with all weather information including all remarks and that they, in turn, ensure pilots are aware (not just provided) with those aspects that might impact the safety of the flight.
- Ensure dispatchers and ATC are clearly provide information to pilots that an improved situation will be available very shortly, e.g. a runway that is closed (and preferred) will be open soon. Currently there is no policy on this aspect. Revise both dispatcher as well as ATC rules to ensure that pilots are proactively notified so can make an informed decision.
- Ensure that dispatchers are proactive in communicating to pilots any aspects that are not entirely routine.
- Clarify what "joint authority" actually means in practice and ensure that it is being effectively implemented in practice (see Communication and Coordination in Systemic Factors)
- Review dispatcher use of automated computer systems to release flights. Automated systems may result in a legal flight without considering small changes that can have a large impact on safety (such as the 10-minute delay for the ILS runway opening on this accident flight). While automated systems can reduce the workload, the ability of humans to make sense of all of the information still exceeds computer capabilities (see Hoffman et al, 2017).
- Review dispatcher workload (number of flights each dispatcher can operate) to include the need to provide actual "joint authority" to individual flights. Current workload does not allow for the individualized attention to details that can prevent accidents.
- Investigate and ensure that dispatchers do not have undue pressure to provide on-time flights.

Fatigue:

- Study additional protocols to mitigate fatigue risk beyond flight and duty regulations.
- Ensure that pilots are aware that decision making when fatigued is compromised. Ensure that dispatcher and ATC are trained to provide backup to pilots in scenarios that may be expected to lead to fatigue.

Approach Procedures:

- Review airline approach procedures. Study changing nonprecision approach procedures to require that pilots set the minimums in the altitude window. Review the implications of mixing RNAV and LOC procedures. Review charting order to reduce possibility that pilots will believe that the next chart in sequence is the best available choice.
- Require more opportunities for nonprecision approaches in training, particularly with scenarios that may present unusual situations such as LOC or BC. Require operators to train pilots that abandoning an approach is mandatory should it not be stable on glide path in the correct mode passing the final approach fix. Ensure that pilots are tested on determining their current position (height and distance

relative to ideal 3:1 GS) during recurrent training scenarios. Monitor proficiency for less-used procedures such as nonprecision approaches.

FAA Office of Airport Safety and Standards

Responsibilities Related to CFIT:

- Provide oversight and guidance to ensure that airports are operated in a safe manner.
- Establish airport design, construction, maintenance, operational and safety standards and issue operational certificates accordingly.
- Perform airport inspections and surveillance. Enforce compliance if problems found.

Contributory Control Action: Did not require airport authorities and operators to prohibit approaches to a runway using aids that are not appropriate for the size and type of aircraft.

Why?

Process Model Flaws	Questions Raised
Believed that their airport oversight was sufficient to maintain safe operations.	

Context	Questions Raised
???	

Contributory Control Action: Did not require installation of precision approach guidance for runways that are utilized for large jet transport aircraft.

Why?

Process Model Flaws	Questions Raised
Believed that their airport oversight was sufficient to maintain safe operations.	

Context	Questions Raised
???	

Contributory Control Action: Did not require scheduling of ILS maintenance in periods when there were no scheduled arrivals

Why?

Process Model Flaws	Questions Raised
Believed that their airport oversight was sufficient to maintain safe operations.	

Context	Questions Raised
Large cargo aircraft operations at night are a relatively new practice.	

Contributory Control Action: Did not require methods in addition to NOTAMs to assure safety during maintenance outages

Why?

Process Model Flaws	Questions Raised
Believed that the accepted practice of using NOTAMs to advise crew of maintenance outages was sufficient for safety.	

Context	Questions Raised
???	

Recommendations:

- Review criteria for installation of precision approach guidance at runways that are utilized for jet transport aircraft.
- Review criteria allowing operators to fly approaches to a runway using aids that are not designed for that size/type of aircraft, e.g., runway 18 PAPI was set for a Group 3 aircraft, yet the Airbus A300 is a Group 4 aircraft. Even if the PAPI is available, that puts the aircraft lower than the specifications.

FAA Air Traffic Operations (ATO)

Responsibilities Related to CFIT:

- Oversee use and effectiveness of safety controls such as the use of MSAW
- Ensure airports have adequate controls for aircraft approach and landing
- Provide adequate policy, guidance, and oversight of NOTAM and ATIS process

Contributory Control Action: Created/used an MSAW that has significant gaps in protection areas

Why?

Process Model Flaws	Questions Raised
Believed MSAW was adequate	

Context	Questions Raised
There are many constraints involved in designing MSAW, it is not considered the primary terrain avoidance tool.	

Contributory Control Action: Has not updated the NOTAM system

Why?

Context	Questions Raised
NOTAM system upgrade problem is complex due to many users and inputs around the world and the need to ensure a common framework.	

Contributory Control Action: Did not provide ATC training that includes types of available approaches and the risk of suggesting a specific type.

Contributory Control Action: Did not update procedures for ATC with the advent of RNAV-type approaches and improved capability.

Why?

Process Model Flaws	Questions Raised
Believe training is adequate	
Believe ATO procedures regarding approaches are adequate.	

Context	Questions Raised
FAA ATC procedures are long standing. Controllers tend to offer what they consider the “highest level”. Changing technology has led to a situation where newer procedures (e.g., GPS/RNP approaches) can be more precise than older technology, yet are still [“not”?] believed to be higher by many.	

Contributory Control Action: Provided only one air traffic controller at time of accident.

Why?

Process Model Flaws	Questions Raised
Believe policy for the number of controllers is adequate.	

Context	Questions Raised
Policy has been in place a number of years. Is ATO aware that only one controller is sometimes in the tower?	*Why is this still the case after several accidents and near accidents due to a single controller not being able to adequately monitor air traffic?*

Recommendations: (Some of these may be the responsibility of the local ATC manager).

- Review criteria for Minimum Safe Altitude Warning (MSAW) in light of the fact that it has been implicated in several CFIT accidents in the last few years. Review guidance for ATC to monitor aircraft altitude and position and ensure that controllers are not depending on MSAW alone.
- Review criteria for when aircraft may be held high due to other traffic constraints. (see Air Traffic Controller CAST analysis)
- Ensure that controllers are familiar with the different needs for larger widebody aircraft at airports that only serve these types of aircraft on a limited basis and review the types of changes that may be needed with the increasing cargo aircraft operations.
- Review training for ATC to ensure that ATC understands the advantages and disadvantages of a LOC vs. a RNAV approach within the context of the advantage of RNAV approaches for preventing this type of accident.

- Ensure that controllers append any remarks to reported weather on ATIS and that they know to update the weather even if they believe it has not changed (see Air Traffic Controller CAST analysis).
- Work with other FAA offices and stakeholders to upgrade the NOTAM system.
- Ensure that at least two air traffic controllers are on duty at all times.

FAA Aeronautical Information Services

Responsibilities Related to CFIT:

- Ensure that aeronautical charts provide adequate guidance.
- Establish charts, charting order and design of instrument approach charts.
- Perform oversight on commercial vendors of aeronautical charts. Enforce compliance if problems found.

Contributory Control Action: Did not consider the effect of the order of charts on pilot and ATC decision making.

Why?

Process Model Flaws	Questions Raised
Believed that their charting oversight was sufficient to maintain safe operations.	*Why was there not consideration to the changes in approach capabilities and how that might impact the ideal charting order?*

Context	Questions Raised
Traditionally the charts are listed in the order of the lowest minimums. In the past this was the ILS, LOC, VOR, then NDB. With the advent of RNAV/GPS and RNP approaches the minimums have changed in sequence and in certain cases the RNAV approach is desirable over the LOC approach, for example.	*Why were the changes in technology not tracked and monitored for their assumptions?*

Contributory Control Action: Did not include a profile view of terrain on aeronautical charts to aid pilot in determining risk of CFIT during the approach itself.

Why?

Process Model Flaws	Questions Raised
Believed that their charting was sufficient to maintain safe operations.	

Context	Questions Raised

Charts have not had this data, although some charting companies do provide a portion of it, they do not provide it in profile to make it very clear to the pilots.	

Recommendations:

- Consider the order of charts in the sequence and study whether there is a human factor aspect that might lead a pilot to choose a "lower numbered" chart under the premise the approach is safer. This accident would not have occurred if they had been flying the RNAV approach as the aircraft would not have tracked the course due to the lack of waypoint sequencing.
- Add terrain to the profile view of approach charts so pilots can have a visual representation of the terrain on the approach that does not require interpretation that might absorb cognitive resources during busy phases of flight, particularly when fatigued.

SYSTEMIC FACTORS AFFECTING MORE THAN ONE CONTROLLER

Industry and Organizational Safety Culture

There was little information provided in the report as to the details of the safety culture involved in this accident. UPS does have an SMS implemented (as do all airlines), but the accident report and other docket entries did not include very much information about it. From the Operations Group Chairman's report (p. 42):

> UPS was an International Air Transport Association (IATA) Operational Safety Audit (IOSA) registered airline. According to the UPS Director of Safety, UPS had completed an IATA LOSA[8] and DOD audit in 2013 year and "scored very well." A Flight Operations Safety Action Group monitored trend data from ASAP[9] and FOQA[10] (85-88% of all UPS flights were covered by FOQA) to recommend changes to policy and procedures.

The official policy stated that the airline had a culture to "speak up" with concerns and there was a proactive emphasis on implementing changes based on ASAP and FOQA data. However, the interview summaries do include some statements that are concerning. For example:

- The accident F/O spoke of feeling pressure of managing safety with the company's profitability. Capt. Gresham spoke of working for the company and that they had a profit

[8] Line Operations Safety Audit. For more information, see FAA Advisory Circular 120-90 "Line Operations Safety Audit."

[9] Aviation Safety Action Program. According to the FAA Advisory Circular 120-66B "Aviation Safety Action Program (ASAP)", the objective of the ASAP is to encourage air carrier and repair station employees to voluntarily report safety information that may be critical to identifying potential precursors to accidents. The Federal Aviation Administration (FAA) has determined that identifying these precursors is essential to further reducing the already low accident rate. Under an ASAP, safety issues are resolved through corrective action rather than through punishment or discipline. The ASAP provides for the collection, analysis, and retention of the safety data that is obtained. ASAP safety data, much of which would otherwise be unobtainable, is used to develop corrective actions for identified safety concerns, and to educate the appropriate parties to prevent a reoccurrence of the same type of safety event.

[10] Flight Operational Quality Assurance (FOQA) is a voluntary safety program designed to improve aviation safety through the proactive use of flight recorded data. Source: FAA.

margin to maintain but the pilots were flying an airplane and had safety to maintain (Operations Group attachment 1, p. 22).

- He had not made a fatigue call before. The line pilot group had a general culture of skepticism that they would be met with resistance (Operations Group attachment 2, p. 66).

Safety programs like ASAP and FOQA were very good programs; they had buy in and stakeholders (UPS, IPA and FAA) were involved. Dealing with fatigue was a little different. Fatigue crisscrossed into the industrial. Hours of service, duty periods and rest periods were all negotiated so they "kind of got tangled up in that sometimes." She wished safety could be kept separate. There was a kind of crisscross in that a pairing met the contractual requirement, it was legal, and it was safe (p. 72).

This was contradicted by some of the FAA CMO inspectors: He thought the safety culture at UPS was "fine." They did not have any problems. There were always safety improvements that could be made and it was an ongoing process (p. 106).

It is not unusual for there to be a disparity in perception between a company and its employees. It is entirely possible (and even likely) that the company means what it says but that information is not being assimilated by the pilots. More proactive efforts between the company and the pilots' association may help mitigate this. Due to the position most cargo airlines have taken very publicly arguing against the "same standards" for cargo aircraft pilots as passenger pilots, it is also possible that cargo aircraft pilots are more suspicious of the motives and intents from their companies, which may impede communication and working together on solutions to problems.

Recommendations:
- The FAA and cargo aircraft pilot associations should institute a study of whether cargo aircraft are treated differently by airports and whether any differences result in higher risk for cargo aircraft.
- FAA and cargo aircraft pilot associations should investigate whether the actions of the cargo operator industry have led to more suspicion and less trust by the pilots of those carriers.
- The FAA should, in concert with other aviation groups, initiate a study on fatigue management in aviation.

Safety Information System

In a study of the safety information systems of various companies, Kjellan found that the quality of the safety information system was the second most important factor in discriminating between companies with high and low accident rates [Kjellan 1982].[14] Uses for a safety information system include storing and passing on information about hazards, detecting trends and deviations that portend an accident, evaluating the effectiveness of safety controls and standards, comparing models and risk assessments with actual behavior, identifying and controlling hazards to improve designs and standards, etc.

In general, the aviation industry provides an excellent example of how safety information systems should be designed. The accident report did, however, identify a deficiency in the safety information system, specifically, the removal of the remarks from the weather reports, which was apparently not adequately assessed by an appropriate component of the safety management system.

The Director of Safety stated he was "very data driven" (p. 21). This has been a trend and even a push in the aviation industry. However, we are concerned that seeking action only on data may lead to missing safety-critical problems. The very low event rates inherent in aviation result in such low statistical variation that it can be difficult or even impossible to discern the difference between a statistically significant event and just random variation. Furthermore, there is no evidence that finding a small variation in the data is a leading indicator for an accident. While this is industry standard practice, there are more effective ways to identify risk [Leveson, 20XX].

Recommendations: The industry might consider a study of whether the current focus on FOQA data is adequate to ensure identifying leading indicators of increasing risk or if new approaches are needed.

Dynamics and Changes over Time

Accidents usually occur after some type of change. The change(s) may be in the physical process, the operating procedures, the safety procedures, the management process, or in oversight (both internal and external). CFIT has been a major cause of accidents for a while and many controls were installed to prevent such losses. Have they degraded over time or have changes in commercial aviation made them less effective? In general, changes may be planned or unplanned. Both types need to be controlled.

If the changes are planned, a strong management of change policy that is enforced and followed can be effective. In this accident, the management of change procedures appear to have been neither enforced nor effective. Examples include the closure of the runway for maintenance without an analysis of what hazards were involved nor consideration of the alternatives to closing it at that time. In addition, the airline and dispatchers did not seem to consider any modifications to procedures based on the closure.

Changes may also be unplanned and must therefore be detected. There needs to be a way to detect unplanned changes that affect safety or prevent them from occurring. Detection may be accomplished by using leading indicators and safety-focused audits. There may also be periodic planned re-evaluation of assumptions underlying the original safety-related design features and management procedures. In this accident, the leading indicators chosen in the evaluation of the ASAP and FOQA data did not capture the potential accident.

Complicating the problem is the fact that changes may occur slowly over time, such as the removal of the remarks in the weather data, which appear to have been implemented without consequence up until this accident. In addition, the industry trend away from pilot directly interacting with dispatchers (and meteorologists) has led to a reliance on providing data to pilots via printed form, often without discussion or providing context as would occur with an actual interaction/discussion. Changes such as these do not appear to have been reviewed by experts, but if they were, then the review process was flawed.

Changes may be known and planned in one system component but appear as unplanned and unknown to others, as was the case here. The runway closure was certainly entered as a NOTAM well in advance, and known to the airport as well as the local ATC controllers, but the UPS dispatcher may not have been aware until just prior to the flight, and it is clear that the pilots were not aware until they were preparing for the approach itself. This leaves little time to fully evaluate the risks.

Another, more subtle long-term change has been the increase in night cargo operations. Questions have been raised by cargo pilots about whether there is as much weight placed on cargo aircraft safety as passenger aircraft and whether more concern is shown for daylight operations than in the early morning in darkness with fatigue. Historical assumptions about airport operations may need to be revisited in the light of changes in airline traffic and operations.

Recommendations:

- The FAA should ensure that airline SMS's as well as those at airports have adequate change management procedures, have ways to ensure they are being followed, and create ways to identify when risk is increasing because of unplanned changes over time.
- The FAA and other industry groups should study whether the increase in cargo operations has changed or increased the level of hazards such that they are no longer adequately mitigated by current procedures.

Communication and Coordination Among Controllers

There are many aspects of this accident that reflect problems in communication and coordination among components in the control structure. Some examples are the lack of ensuring the pilots were actually aware of the runway closure; the information on the company chart regarding ATC keeping aircraft high, which contributed to an expectation bias; inadequate communication in the NOTAM about runway closures and updated weather information; inadequate communication between the dispatcher and the pilots about weather and landing decisions; and flawed communication between the two pilots.

<u>**PF and PM**</u>

To coordinate their actions, the mental models of the pilots in the cockpit must be consistent. CRM procedures were introduced to assist in ensuring this consistency. With the advent of class cockpits, where the PF and the PM may be provided with different information, these procedures become even more important and difficult to implement. In addition, CRM may over time be losing adherence and effectiveness.

In this loss, for example, when the autopilot did not engage in profile mode, the captain changed the autopilot mode to the vertical speed mode, but did not brief the pilot monitoring on the autopilot mode change. He appeared to assume the PM would see the change, or, conversely, considered it normal procedure that did not require discussion. Why did both the PF and PM miss that the computer had not been sequenced correctly?

[When changes are made in aircraft automation, are CRM procedures adequately re-evaluated for their ability to synchronize the pilots' mental models?]

<u>**Pilots and UPS Dispatch**</u>

The FAA defines the pilot and dispatcher as being held "jointly responsible" for the safety of the flight. The definition of this shared responsibility and how decision-making will be coordinated, however, is only vaguely defined. In any control system, the potential for safety problems increases when there are two controllers and the responsibilities of each are not clearly defined. At one extreme, both controllers think the other one is making the necessary decisions (and thus nobody does) and at the other extreme conflicting control actions may be issued. In this case, it appears that the inadequate definition of responsibility has led to the pilots assuming many of the assumed joint responsibilities, with flawed communication being the result. Responsibility cannot be assigned as "50-50" without a careful definition of how this equal responsibility will operate in practice.

<u>Recommendations</u>:

- The FAA should consider evaluating the communications and coordination deficiencies implicated in this loss and whether they are more widespread than they are believed to be. Was this just a one-time event or are communication and coordination deficiencies more wide-spread than believed?

- The roles of dispatch and pilots and how they interact need to be clarified. “Joint responsibility” is not adequately defined nor is there oversight by the FAA or UPS of how it is working in practice.