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PRESSING THE

BY BENJAMIN A. BERMAN AND R. KEY DISMUKES, PH.D.

June 1, 1999 — American Airlines Flight 1420 was seconds from landing at Little Rock, Arkansas, U.S., when the captain's view of the runway was obscured by heavy rain lashing the windshield. "I can't see it," he said, but the runway quickly reappeared. From 200 ft to the ground, he struggled against the thunderstorm's crosswinds to align the McDonnell Douglas MD-82 with the centerline, and the ground-proximity warning system (GPWS) produced two warnings of excessive sink rate. The first officer thought about telling the captain to go around, but if he spoke, his voice was too soft to be heard. Saturated with high workload during the last stages of the approach, the crew had forgotten to arm the jet's ground spoilers for automatic deployment and had not completed the last steps of the landing checklist, which included verification of the spoilers; consequently, braking performance was greatly degraded. During the landing rollout, the airplane veered left and right by as much as 16 degrees before departing the left side of the runway at high speed. The crash into the approach light stanchions at the far end of Runway 04R destroyed the airplane and killed 11 people, including the captain.[1]

March 5, 2000 — Runway 08 at Burbank, California, U.S., would have appeared very short and very far beneath the airplane as the captain nosed Southwest Airlines Flight 1455 down at a steep angle to try to land near the beginning of the 6,032-ft (1,840-m) strip. Air traffic control (ATC) had brought the Boeing 737-300 in high and fast, and there was a shearing tailwind aloft. As the captain looked at the situation on final approach, he thought he could make it; in quick succession, he called for gear and flaps to try to slow the 737. The first officer could see that the airplane was exceeding the limits for a stabilized approach. However, he said nothing because he could see that the captain was doing all he could to correct it. The jet landed near the normal touchdown point — but at 182 kt, the airspeed was more than 40 kt faster than the computed target speed. The pilots were unable to stop the airplane, and it crashed through a blast fence at the end of the runway, crossed a street and came to a stop near a service station. Two passengers were seriously injured, and the airplane was substantially damaged.[2]

Why did these experienced professional pilots make these errors? The U.S. National Transportation Safety Board (NTSB) concluded that the crews caused both accidents. It's true that the pilots' actions and errors led to the accidents — and that in the final moments they were in a position to prevent the crashes but did not. However, our recently completed U.S. National Aeronautics and Space Administration (NASA) study of these and 17 other recent accidents gives a different perspective on pilot error, and this perspective holds keys to making flights safer in the future.[3]

Our analysis suggests that almost all experienced pilots operating in the same environment in which the accident crews were operating, and knowing only what the accident crews knew at each moment of the flight, would be vulnerable to making similar decisions and errors. Our study draws upon growing scientific understanding of how the skilled performance of experts, such as airline pilots, is driven by the interaction of moment-to-moment task demands, the availability of information and social/organizational factors with the inherent characteristics and limitations of human cognitive processes. Whether a particular crew in a given situation makes errors depends as much, or more, on this somewhat random interaction of factors as it does on the individual characteristics of the pilots.

Flights 1420 and 1455 came to grief, in part, because of two of the most common themes in the 19 accidents studied: plan continuation bias — a deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan — and snowballing workload — workload that builds on itself and increases at an accelerating rate. Although other factors not

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APPROACH

A NASA study of 19 recent accidents yields a new perspective on pilot error.

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discussed here played roles in these accidents, the problems encountered by the crews seem to have centered on these two themes.

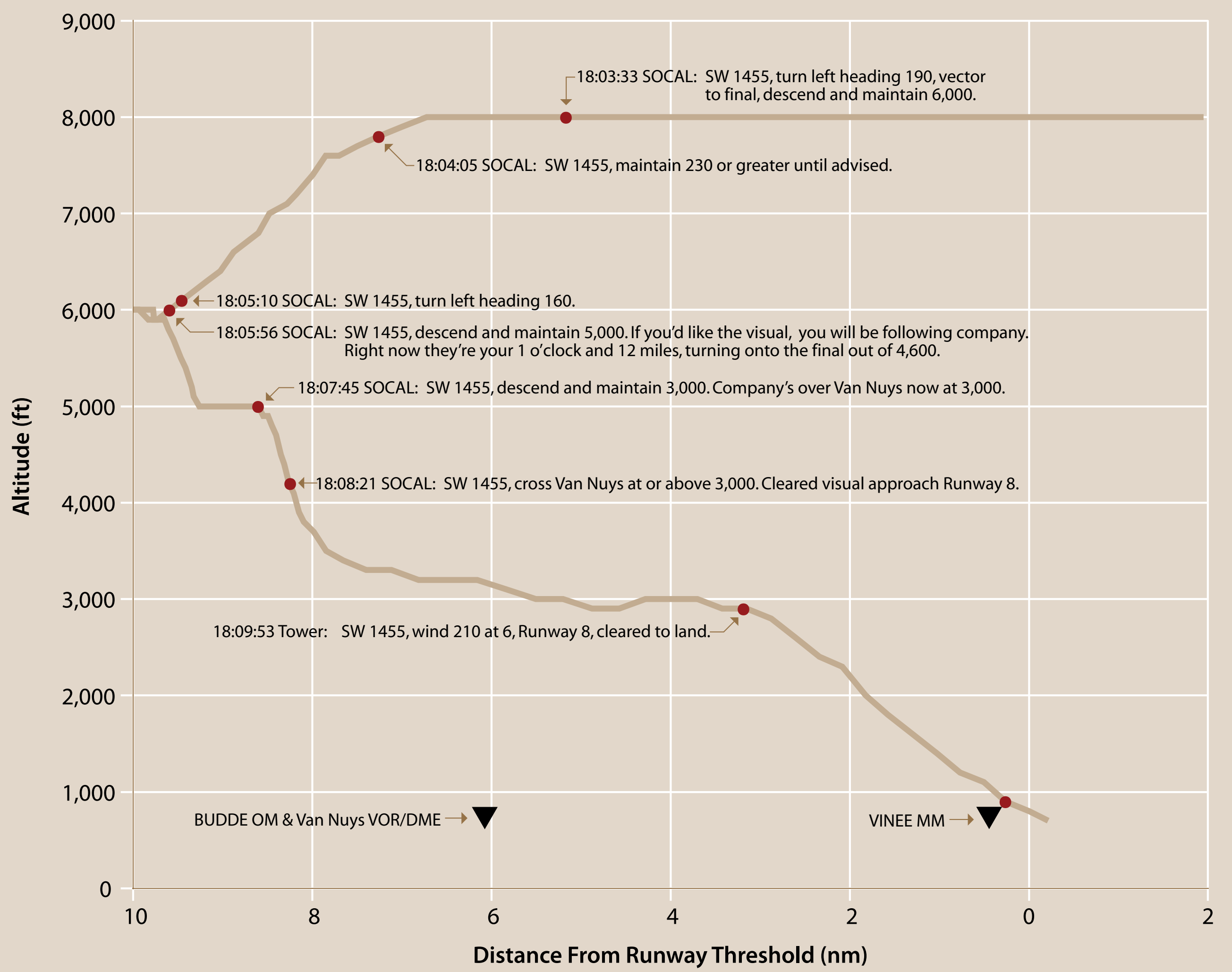
Plan Continuation Bias

The pilots of Flight 1420 were aware from the outset that thunderstorms could affect their approach to Little Rock. Before beginning the approach, they saw lightning and rain near the airport, and they used on-board weather radar to identify a thunderstorm cell northwest of the field. At that point, the crew had no way of knowing whether they could land before the thunderstorm arrived.

Later, as Flight 1420 continued its approach, the pilots received a series of ATC radio transmissions suggesting that the thunderstorm was beginning to affect the airport: reports of shifting winds, gusts, heavy rain and low visibility. In hindsight, assembling all the cues that were available to the crew, one can readily infer that the thunderstorm had arrived at the airport. Yet the crew of Flight 1420 persevered, accepting a change of runways to better accommodate the winds, attempting a close-in visual approach to expedite their arrival, and then, as conditions continued to deteriorate, changing to an instrument landing system (ILS) approach and

Radar Data and Partial Air Traffic Communication

Southwest Airlines Flight 1455, March 5, 2000, Burbank, California, U.S.



MM = Middle marker OM = Outer marker SOCAL = Southern California Approach Control

Source: U.S. National Transportation Safety Board

Figure 1

pressing that approach to a landing instead of executing a missed approach.

Similarly, the pilots of Flight 1455 tried to cope in a situation in which their airplane was obviously high and fast, and they continued their approach despite numerous cues that landing safely would be challenging (Figure 1). For example, 1,000 ft above touchdown elevation, where company operating procedures specified that flights should be stabilized, this flight was unstabilized, far above the glide path, more than 50 kt too fast and descending at more than three times the desired rate; flaps were at the approach setting because of excessive airspeed, and idle thrust was set. Below 1,000 ft, the GPWS repeatedly annunciated "SINK RATE" and "PULL UP," and the approach remained highly unstabilized through touchdown.

Too often, pressing an approach in these circumstances is attributed to complacency or an intentional deviation from standards, but these terms are labels, not explanations. To understand why experienced pilots sometimes continue ill-advised approaches, we must examine the insidious nature of plan continuation bias.

Plan continuation bias appears to underlie what pilots call "press-on-itis," which a Flight Safety Foundation task force found to be involved in 42 percent of accidents and incidents they reviewed.[4] Similarly, this bias was apparent in at least nine of the 19 accidents in our study. Our analysis suggests that this bias results from the interaction of three major components: social/organizational influences, the inherent characteristics and limitations of human cognition, and incomplete or ambiguous information.

Safety is the highest priority in commercial flight operations, but there is an inevitable trade-off between safety and the competing goals of schedule reliability and cost effectiveness. To ensure conservative margins of safety, airlines establish written guidelines and standard procedures for most aspects of operations, including specifications for minimum clearance from thunderstorms and criteria for stabilized approaches. Yet considerable evidence exists that the norms for actual flight operations often deviate considerably from these ideals, in ways that are strikingly similar to Flights 1420 and 1455.[5,6,7]

Our study suggests that, when standard operating procedures are phrased not as requirements but as strong suggestions that may appear to tacitly approve of bending the rules, pilots may — perhaps without realizing it — place too much importance on schedule and cost when making safety/schedule/cost tradeoffs. Also, pilots may not fully understand why guidance should be conservative; that is, they may not recognize that the cognitive demands of recovering an airplane from an unstabilized approach severely impair their ability to assess whether the approach will work out. For all these reasons, many pilots, not just the few who have accidents, may deviate from procedures that the industry has set up to build extra safety into flight operations. Most of the time, the result of these deviations is a successful landing, which further reinforces deviant norms.

Our study suggests that as pilots amass experience in successfully deviating from procedures, they unconsciously recalibrate their assessment of risk toward taking greater chances. This recalibration is abetted by a general tendency of individuals to risk a severe negative outcome of very low probability — such as the very small risk of an accident — to avoid the certainty of a much less serious negative outcome — such as the inconvenience and the loss of time and expense associated with a go-around.

Another inherent and powerful human cognitive bias in judgment and decision making is expectation bias — when someone expects one situation, he or she is less likely to notice cues indicating that the situation is not quite what it seems. Having developed expectations that the thunderstorm had not yet reached the airport (Flight 1420) and that the descent and approach profile was manageable (Flight 1455), the crews in these accidents may have become less sensitive to cues that reality was deviating from their mental models of the situation.

Expectation bias is worsened when crews are required to integrate new information that arrives piecemeal over time in incomplete, sometimes ambiguous, fragments. Human working

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memory has extremely limited capacity to hold individual chunks of information, and each piece of information decays rapidly from working memory. Further, the cognitive effort required to interpret and integrate these fragments can reach the limits of human capacity to process information under the competing workload of flying an approach.

The crew of Flight 1420 had to make inferences about the position of the thunderstorm and the threat it presented by using information obtained from their view through the windshield, cockpit radar, automatic terminal information service (ATIS) information and a series of wind reports from ATC spread over time. The information available from these sources was incomplete and ambiguous; for example, the weather radar was pointed away from the thunderstorm for several minutes while the flight was being vectored, and in any case, this radar does not delineate the wind field extending from a thunderstorm.

The situation facing the crew of Flight 1455 may seem to have been obvious from several miles before touchdown, as the 737 joined the final approach course above the glideslope at a very fast airspeed. But although the excess energy — in the form of altitude and speed — was apparent, it was not at all clear that the approach could not be stabilized in time for a safe landing. No display in any airline cockpit directly indicates or projects the energy status of the aircraft all the way to the stopping point on the runway; thus, the pilots had to continuously observe cues about the gradient path to the runway, airspeed, pitch attitude, altitude and thrust, and integrate them with other factors that were not displayed — lift, drag and braking performance — to update their understanding of the situation.

Snowballing Workload

Errors that are inconsequential in themselves have a way of increasing crews' vulnerability to further errors and combining with happenstance events — with fatal results. By continuing the unstabilized approach, the captain of Flight 1455 increased the crew's workload substantially. Getting the aircraft configured and down to the glideslope made strong demands on the pilots' attention — a very limited cognitive resource. The high speed of the aircraft (197 kt), with a 2,624 foot-per-minute descent rate, increased the rate of events and reduced the time available for responding. This situation would produce stress, and acute stress narrows the field of attention ("tunneling") and reduces working memory capacity.

An airplane that landed ahead of Flight 1455 was slow clearing the runway — another development that placed demands on the crew's attention. These factors combined to impair the crew's ability to monitor all relevant flight parameters and to determine whether they could land the airplane safely. In post-accident interviews, the captain said that he had no idea the airspeed was so fast. Also, the snowballing workload made it less likely that the pilots would remember that the assigned runway was considerably shorter than the runways they were accustomed to and recognize the implications.

Similarly, the decision of the crew of Flight 1420 to continue the approach in the face of challenging weather substantially increased their workload. After the accident, the first officer told investigators, "I remember that around the time of making the base-to-final turn, how fast and compressed everything seemed to happen." Undoubtedly, this time compression and the high demands on the crew's attention contributed to their forgetting to arm the spoilers and to complete the landing checklist. Also, the pilots had been awake more than 16 hours at the time of this approach, and they were flying at a time of day when they were accustomed to sleeping. Among the effects of fatigue are slowing of information processing and narrowing of attention. The combination of fatigue, the stress of a challenging approach and heavy workload can severely undermine cognitive performance.

A particularly insidious manifestation of snowballing workload is that it pushes crews into a reactive, rather than proactive, stance. Overloaded crews often abandon efforts to think ahead of the situation strategically, instead simply responding to events as they occur and failing to ask, "Is this going to work out?"

Implications and Countermeasures

Simply labeling crew errors as "failure to follow procedures" misses the essence of the problem. All experts, no matter how conscientious and skilled, are vulnerable to inadvertent errors. To develop measures to reduce this vulnerability, we first must understand its basis in the interaction of task demands, limited availability of information, sometimes conflicting organizational goals and random events with the inherent characteristics and limitations of human cognitive processes. Even actions that are not inadvertent, such as continuing an unstabilized approach, must be understood in this context.

Almost all airline accidents are system accidents. Human reliability in the system can be improved — if pilots, instructors, check pilots, managers and the designers of aircraft equipment and procedures understand the nature of vulnerability to error. For example, monitoring and checklists are essential defenses, but in snowballing-workload situations, when these defenses are most needed, they are most likely to be shed in favor of flying the airplane, managing systems and communicating. Monitoring can be made more reliable, though, by designing procedures that accommodate the workload and by training and checking monitoring as an essential task, rather than as a secondary task.[8] Checklist use can be improved by explaining the cognitive reasons that effectiveness declines with extensive repetition and showing how this can be countered by slowing the pace of execution to be more deliberate, and by pointing to or touching items being checked.

We also must accept that some variability in skilled human performance is inevitable and put aside the myth that because skilled pilots normally perform a task without difficulty, they should be able to perform that task without error 100 percent of the time.

Although plan continuation bias is powerful, it can be countered once acknowledged. One countermeasure is to analyze situations more explicitly than is common among crews. This would include explicitly stating the nature of the threat, the observable indications of the threat and the initial plan for dealing with the threat. Crews then should explicitly ask, "What if our assumptions are wrong? How will we know? Will we know in time?" These questions are the basis for forming realistic backup plans and implementing them in time, but they must be asked before snowballing workload limits the pilots' ability to think ahead.

Airlines should periodically review normal and non-normal procedures and checklists for design features that invite errors. Examples of correctable design flaws are checklists conducted during periods of high interruptions, critical items that are permitted to "float" in time (e.g., setting takeoff flaps at an unspecified time during taxi) and actions that require the monitoring pilot to go "head-down" during critical periods, such as when a taxiing airplane nears a runway intersection.

Operators should carefully examine whether they are unintentionally giving pilots mixed messages about competing goals such as stabilized approaches versus on-time performance and fuel costs. For example, if a company is serious about compliance with stabilized approach criteria, it should publish, train and check those criteria as hard-and-fast rules rather than as guidelines. Further, it is crucial to collect data about deviations from those criteria — using flight operational quality assurance (FOQA) and line operations safety audits (LOSA) — and to look for organizational factors that tolerate or even encourage those deviations.

These are some of the ways to increase the reliability of human performance on the flight deck, making errors less likely and helping the system recover from the errors that inevitably occur. This is hard work, but it is the way to prevent accidents. In comparison, blaming flight crews for making errors is easy, but ultimately ineffective. ●

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