



Give E-Checklists an A+

A finger on paper is no match for an insistent cursor.

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The scenario: You're taxiing to the active at Logan International Airport (BOS) with flaps up as required because of slush on the pavement. As is typical of busy hub airports, the taxi instructions and taxiway layout are complex and the ground control frequency jammed with jabber. Your concentration on your progress and the movement all around you is necessarily interrupted by additional requirements such as checklists and the departure briefing.

And then, of course, ATC calls with an amended clearance, changing your departure routing to a different runway, necessitating a grab for new runway charts, reconfirmation of takeoff performance

calculations, and application of any additional safety margins as required in the flight operations manual.

Many professional pilots agree that such terminal area operations are often the highest workload portion of the flight.

After you finally arrive at the departure end of the runway, ATC clears you into position and hold, and after a pause, there comes the magic words: "Cleared for takeoff." Time to go.

At V_1 you rotate the aircraft, but quickly sense something's wrong. The aircraft rocks left and right, can't seem to climb, and then the stick shaker activates. Whoa, what's going on here? You gingerly nurse the aircraft foot by foot away from the ground and eventually begin to accelerate, but you remain flummoxed about what just happened until you conduct the "After

Takeoff" checklist. That's when you realize you had failed to complete the taxi checklist and left the flaps in the "up" position. This and similar scenarios are favorites among simulator instructors, who employ them to induce such oversight errors in even the best flight crews on their sharpest days. The combination of high workload, multitasking, time pressure and distractions can be insurmountable.

For a recent NASA study, Dr. Key Dismukes, a well-known aviation human factors researcher and director of the human factors program at the NASA Ames Research Center, and Ben Berman, a former NTSB investigator and now an airline pilot, observed flight crew procedural, checklist and monitoring errors on 60 flights at three different air carriers. They found the crews averaged

3.2 checklist errors per flight (one of the observed flights had 14.)

The most-common checklist error involved the omission or deferral of an item, which was later forgotten. That finding confirmed the fact that the human brain is not well equipped to remember tasks that are interrupted, deferred or performed out of normal sequence. Sometimes the omitted item isn't critical to that phase of flight, but occasionally it is and the outcome is tragic.

On Aug. 20, 2008, the pilots of an MD-82 failed to position the flaps correctly for a takeoff from Madrid. Unfortunately, the takeoff configuration warning horn failed to sound, and the aircraft crashed shortly after lifting off. The results of the official investigation of the accident have yet to be published, but it's quite likely among the causes will be the crew's failure to configure the aircraft properly for the takeoff.

In the real world, we often get interrupted, and even though cockpit procedures are usually designed in a nice linear fashion, the truth is that many tasks often occur out of sequence, and new, unanticipated tasks pop up. The preflight phase is a prime time

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for these occurrences — the fueler arrives at the same time as the catering, just as you discover a malfunction that will require a phone call home and a decision on whether to MEL the item. And of course, this is about the time your cell phone sounds, alerting you that the passengers are 10 min. out. In fact, the NASA study found that pre-taxi was the third most error-prone phase of flight, only slightly behind descent and climb.

Checklists were originally developed to help pilots remember important tasks, but not all checklists are of equal quality. Over the decades checklists have grown in complexity, and now they come in two forms — paper and electronic.

As it turns out, paper checklists induce a higher workload because a pilot has to

physically hold the checklist — who hasn't dropped one at an inconvenient time? — keep track of the ever-changing place on the list, and turn or mark pages.

Printed checklists have secured the thumb's most important role of helping keep place on them. And that important job gets compromised when a checklist item can't be accomplished or a distraction occurs. The thumb moves on and often, so does our attention and the missed item goes unnoticed or gets forgotten. These are among the most-common errors involving paper checklists.

How often do they occur? According to findings in 2004 by the University of Texas Human Factors Research Project/The LOSA (Line Operations Safety Audit) Collaborative, 18% of the 7,000+ observed

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flights contained one or more checklist errors by flight crews; 13% of these were further mismanaged and allowed the aircraft to enter an “undesired aircraft state.”

Dr. Earl Wiener, co-author of “Human Factors of Flight-Deck Checklists,” found one of the largest weaknesses of paper checklists is the lack of a visual indication of the point where a checklist was interrupted. A paper checklist also fails to differentiate between accomplished and non-accomplished items. Since traditional paper checklists have no means of prompting the pilot about such unaccomplished items, the deferred item is stored in the pilot's short-term memory, which makes it vulnerable.

Unless actively rehearsed or aided by some reminder or memory jogger, information contained in the working memory will generally be forgotten in 10 to 20 sec.

Interference in the form of noise, conversation, ATC calls, etc. is the principal cause of loss of information from a pilot's working memory. In addition, an individual's emotional state, such as confusion or frustration, can negatively impact the ability to retain information. The net impact is a high probability that any deferred item from a paper checklist will be quickly forgotten.

One of the interesting observations from the recent NASA data is that many of the checklist errors occurred with flight crews using paper checklists. The researchers noticed that crews found using the paper lists to be slow and awkward, and thus performed the check items by memory instead, a decidedly flawed alternative.

Scroll-type checklists were created in the hope of preventing some of the endemic problems with paper lists. Many of you probably used a version of these at

some time in your previous career; they were commonly used in the previous generation of large military transports. The main advantage of the scroll checklist — generally, a strip of paper that moves vertically within a box fitted with a window and lubber line — is that it has a pointer system. One disadvantage is that, due to its relatively small size and placement on the copilot's and flight engineer's panels, it is difficult for the left seater to see. And, according to Wiener's interviews of flight crews using scrolling lists, another distinct disadvantage of the devices is their inability to highlight or call back unaccomplished items.

Dr. Alan Swain studied human reliability for many years while at the Sandia National Laboratories and found that nuclear power plant operators who used checklists without a check-off provision were more susceptible to errors of omission than those with access to that feature. According to his *Handbook of Human Reliability Analysis*, which is used by the Nuclear Regulatory Commission to help design procedures for nuclear reactor operators, the estimated probability of error per item for a checklist with no check-off

provision was one in 100, while the probability of error for a checklist with some kind of a check-off provision was three in 1,000. This fact has spurred development of “check off” devices.

While some mechanical checklists were developed to check off items by covering an accomplished item with a plastic slide, it was the digitization of cockpit instrumentation that changed the checklist function forever. With computerization, two distinct categories of checklists evolved. The first is merely a display and pointer system on the MFD, while the second is a pointer system that is part of the feedback loop. In the latter type, the computer senses the system’s status and feeds this information back to the screen.

Designers of electronic checklists have studied their paper counterparts extensively when creating features intended to decrease errors. For example, frequently during preflight, the check item, “Fuel,” is incomplete, and when using a paper checklist, the pilot usually skips that item intending to return to it later, but then forgets to do so.

However, electronic checklists cannot be closed out if any item is left incomplete. Rather, the cursor/indicator automatically returns to the incomplete item, highlighting it. The system will not allow the pilot to move to the next list of tasks until all of the items on the still-active checklist have been addressed. Had such a system existed in August 1987, the pilots on Northwest Flight 255 would have been blocked from proceeding to the next task list as they made their way to the active at Detroit Metropolitan Airport after inadvertently skipping the “Taxi” checklist and leaving their MD-82’s flaps and slats stowed.

As noted, terminal area operations are full of distractions and a pilot might need to attend to a radio call, ramp agent, flight attendant or passenger while preparing the aircraft for flight. It’s easy to lose one’s place on a checklist under such circumstances, but an electronic cursor or highlighted item is an automatic “place holder” bringing the pilot right back to the item waiting to be completed. It’s much more reliable than an imperfect memory or a misplaced thumb.

In addition, electronic checklists presented on MFDs are readable in any cockpit illumination level, never get dropped and are advanced with the flick of a finger.

Since computers monitor onboard systems, they can be programmed to alert the crew when certain configuration items have not been accomplished, or conversely, verify that certain items have been



accomplished and thereby substantially reduce the number of items on the pertinent checklist. This capability has impacted checklist philosophies. For example, the Boeing 757’s normal checklist philosophy states, “Only procedural steps, which if omitted, would have a direct and adverse impact on normal operation are included. Items annunciated by the Crew Alerting System are not included.” The Airbus A320 uses its Electronic Centralized Aircraft Monitoring (ECAM) computers to aid the crew. The critical items in the Takeoff and Landing task checklists appear on the CRT prior to those segments. In addition, the computer displays a pointer system to indicate accomplished items and informs the pilot about the status of each checklist item. Once items are accomplished, the computer clears them from the screen. The Boeing 777’s electronic checklist design will not allow critical line items to turn green unless the internal sensors detect the switch/item is in the proper position for that phase of flight.

With the advantages of electronic checklists so apparent, it’s surprising to learn that many pilots still eschew them in favor of paper lists. We queried several as to why they preferred paper and came away with a variety of reasons. It turns out that in some aircraft the MFD is rather small and the checklist consumes a lot of real estate on the face of it. Rather, some pilots would prefer the MFD display terrain, nav aids, route of flight and TCAS information to maintain a high level of situational awareness. In many aircraft the

checklist contained in the MFD is the same as that contained in the AFM and does not reflect the customized checklist approved for an operator by the FAA. Hence, pilots for the operator aren’t authorized to use the electronic checklist. At the Flight Safety Foundation’s October 2007 Corporate Advisory Committee meeting in Washington, attendees complained about the difficulty in altering electronic checklists any time their FAA-approved checklists gets amended. All these are valid issues that need to be resolved — and soon, since electronic lists work so well.

Daniel Boorman of the Boeing Commercial Airplane Group pointed out in an *ICAO Journal* article, “Today’s Electronic Checklists Reduce Likelihood of Crew Errors and Help Prevent Mishaps,” that simulator study of electronic checklist performance found a 46% decrease in errors compared to paper checklists.

The introduction of any new technology to a cockpit always carries the risks of unanticipated errors and unintended consequences. But electronic checklist technology has matured and proven itself and should be embraced. We need to learn from past checklist-related incidents and accidents and adapt electronic lists and presentations accordingly. Also, users should insist that manufacturers design electronic checklists so they can be easily modified to coincide with an operator’s FAA-approved checklists. It is time for this technology to be fully implemented to its maximum potential. It stops errors and can save lives. **BCA**