Checklist Discipline: Against the Flow

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When it comes to checklists, I think you can divide the pilot world into two distinct categories and a third, secret, grouping.

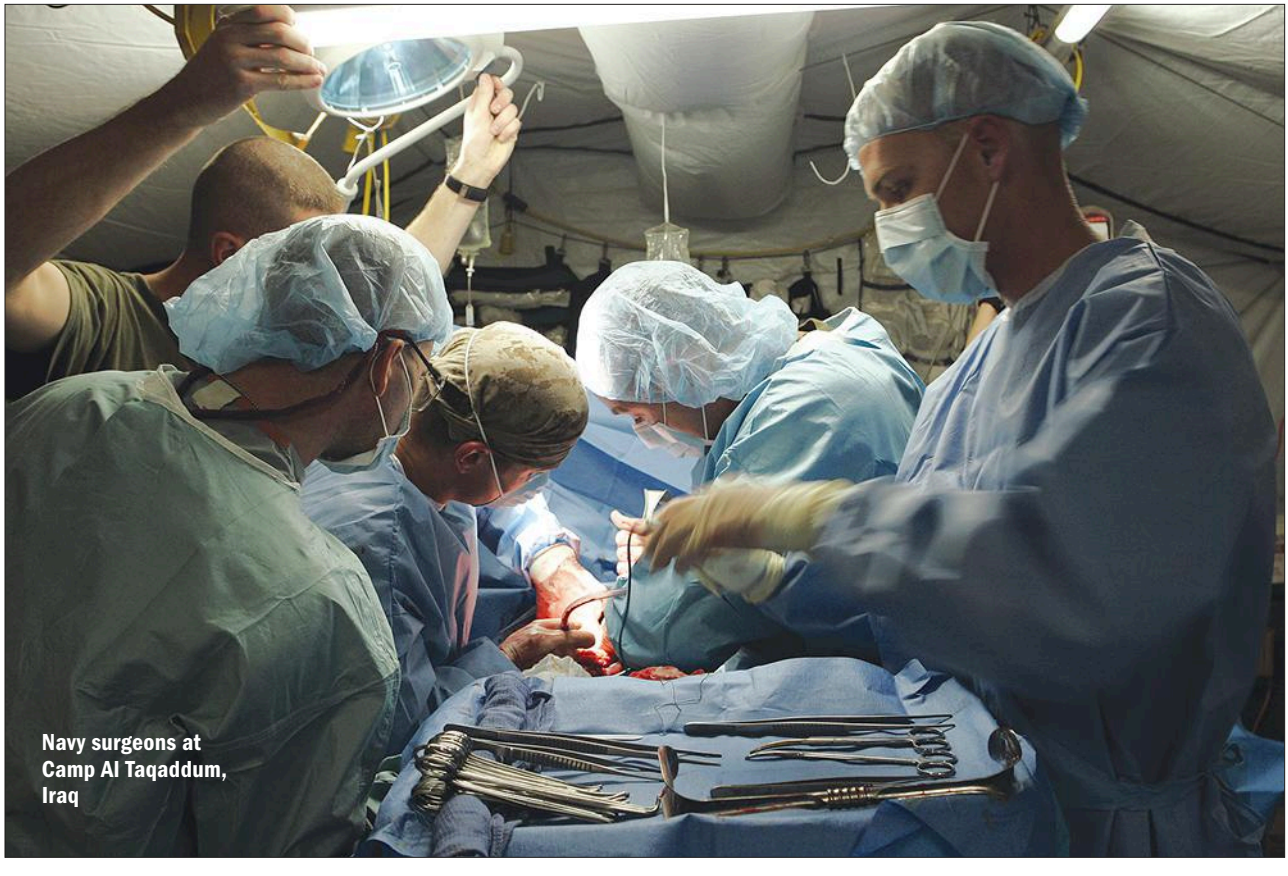
I believe about half of us are in what many call the "challenge/response" mode, or what the FAA considers the "Challenge-Do-Verify" process. Here, the checklist item is read, the action is accomplished, the accomplishment is confirmed, and that process is repeated until the checklist is completed. The other half of us believes in what we call "the flow," what the feds call "Do-Verify." Everything gets done first, followed by a checklist to make sure each step was completed.

But there is also a secret society of pilots who do "silent-memory checklists," whereby the checklist is done from memory, even in a crewed aircraft, with no words exchanged between pilots at all. I think these silent-memory checklists are equivalent to running no checklists at all. Let's address this secret society first.

After you've logged a few thousand hours and years in an airplane, chances are you will have subconsciously memorized much of what it takes to take off and land again. It may become as simple to you as driving a car, if nothing goes wrong. So, you can be forgiven for thinking the checklist is only for the lesser others in aviation. But unlike driving a four-wheeled contraption down the highway, flying an airplane is far less forgiving of even the slightest memory lapse. I once counted the number of checklist steps to bring my aircraft from a cold start to takeoff and totaled 326.

While I don't have all those steps memorized, if you ask me to recall the procedures for many of the subtasks in that list, I can do that pretty well. Here's one I have down pat — starting the auxiliary power unit (APU) in a Gulfstream G450:

(1) Emergency power — armed.
(2) Left/right batteries — on.
(3) Battery volts — check.
(4) Display unit 1 — on.
(5) APU fire test — perform.
(6) Display unit 1 — off.
(7) Navigation light — on.
(8) Left main boost pump — on.
(9) APU master switch — on.



Navy surgeons at Camp Al Taqaddum, Iraq

U.S. NAVY

(10) APU ready light — illuminated.
(11) APU start button — press.

In eight years flying this aircraft, I've never gotten this wrong. Except when I did. Maybe looking at the checklist problem from another perspective will provide a little insight.

The Checklist Argument: It Isn't Brain Surgery

There are more than a few parallels between the medical profession and aviation. We have many complex tasks that, taken as a whole, seem too varied and difficult to break down into checklists. But there are individual subtasks that do lend themselves to the idea that we can and should check for proper completion. Still, if you suggest a checklist for these subtasks, you are likely to hear they are so simple that a checkoff would be a waste of time.

Dr. Atul Gawande, author of The Checklist Manifesto: How to Get Things Right, studied a simple five-step surgical procedure that has been in use for many years. Nobody gets them wrong. Except when they do. Gawande writes about a critical care specialist at Johns Hopkins Hospital who decided to give a surgery checklist a try. He didn't attempt to make the checklist encompass everything an intensive care unit team might need to do in a day. Rather, he designed it to tackle just one of their hundreds of potential tasks. On a sheet of plain paper, he plotted out the steps to take in order to avoid infections when putting in a central line into a vein. Doctors are supposed to:

(1) Wash their hands with soap.

(2) Clean the patient's skin with chlorhexidine antiseptic.

(3) Put sterile drapes over the entire patient.

(4) Wear a mask, hat, sterile gown and gloves.

(5) Put a sterile dressing over the insertion site once the line is in.

These steps seemed so simple that it would be silly to make a checklist. But nurses were asked to observe doctors for a month to record how well doctors complied with these procedures, which had been known and taught for many years. They were surprised to find that in more than one-third of events, doctors skipped at least one step.

The next month, nurses were authorized to stop doctors if they saw them skipping a step on the checklist. This was revolutionary. Many nurses weren't sure it was their role to correct the doctor or whether a given measure was worth a confrontation. (Does it really matter whether a patient's legs are draped for a line going into the chest?) The new rule made it clear: If doctors didn't follow every step, the nurses would have backup from the administration to intervene.

Hospital administrators monitored what happened for the next year and the results were so dramatic they weren't sure whether to believe them. The 10-day line-infection rate went from 11% to zero. So, they followed patients for 15 more months. Only two line infections occurred during the entire period. They calculated that, in this one hospital, the checklist had prevented 43 infections and eight deaths.

Some pilots will tell you they have actually completed a checklist, even if the checklist is nowhere to be seen. Much like the surgeons, they have the checklist memorized. The most infamous demonstration of how such a philosophy can go wrong occurred on May 31, 2014, at Hanscom Field, Bedford, Massachusetts (KBED). That's the day a Gulfstream GIV failed to take off after its pilots forgot to disengage a gust lock. This step was required by the engine start checklist. They also forgot to do a flight control check, as required by their after-engine-start checklist. Both pilots, the flight attendant and four passengers were killed as a result. In the course of its investigation the NTSB looked into this procedural noncompliance and reported, "A pilot who had previously flown the GIV airplane with the PIC stated that the PIC had memorized the GIV checklists and that he did not normally ask for the checklists to be formally completed."

At the time of the accident, the engine start checklist had 15 items and the after-engine-start checklist had 22 items. If a surgeon can forget one item in a list of five, is it any wonder these pilots could miss one each in lists of 15 and 22? We often forget that the concept of a checklist didn't happen overnight in aviation.

View of the Boeing XB-17 (Model 299) after the fire.

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The Checklist's Origin

In the earliest days of aviation, all the way back to 1903 with the Wright brothers, pilots were simply required to know what to do. Perhaps one of the first attempts at a checklist of any sort was created for the Curtiss JN-4 "Jenny" and a handbook called Hints on Flying. One section provided a list of 18 items, each with considerable detail. Five items were devoted to actions to take before takeoff, nine covered inflight procedures and safety precautions, two advised on landings, and two discussed ways to avoid stalls and spins. Another version is found in the 1918 Hints on the Bristol Fighter, written by the officer commanding No. 39 Squadron. The section headings are similar to modern checklists, including

sections designed to ensure pilots see that the pressure is holding, the ignition is fully advanced, the oil pressure is OK, the blinds are open and the tail lever is forward. But for the most part, aircraft were not flown by use of a strict checklist as we now perceive it.

In 1934, the U.S. Army Air Corps asked industry to come up with a replacement for the twin-engine Martin B-10 bomber. While Douglas and Martin proffered aircraft that offered marginal improvement, Boeing's Model 299 represented a revolutionary leap forward in bombers. The Model 299 made its first flight on July 28, 1935, flown by Boeing's chief test pilot Leslie R. Tower. The sight of the airplane inspired Seattle reporter Richard L. Williams to dub the aircraft the "Flying Fortress," and the name stuck.

But on Oct. 30, 1935, the Model 299 crashed on takeoff from Wright Field. At the controls was Maj. Ployer P. Hill, Wright Field's Flying Branch chief, a highly experienced test pilot and the officer for which Hill Air Force Base, Utah, is now named. Witnesses say the Model 299's takeoff appeared normal, although it broke ground in a "tail low" attitude. As its speed increased, the bomber's nose went up much higher than normal. It reached an altitude of about 300 ft., stalled, turned 180 deg., and fell back onto a field. It crashed on its left wing, cushioning the impact, which probably saved the lives of several crew. Lying flat on the field, the bomber burst into flames. Amazingly, four crewmembers were able to crawl from the blazing wreckage.

About the only part of the aircraft to survive the fire was the tail, where the accident board discovered the cause of the accident: an internal control lock that immobilized the elevator and rudder. The board ruled that the size of the airplane and the inherent design of the control system made it improbable that any pilot, taking off under the same conditions, would discover the locked controls until it was too late to prevent a crash.

Since the crashed aircraft could not finish the evaluation, the Model 299 was disqualified from the competition. While the Army still wanted the aircraft, Army Chief of Staff Gen. Malin Craig cancelled the order for 65 YB-17s,and ordered 133 of the twin-engine Douglas B-18 Bolos instead. However, the Army Air Corps found a legal loophole to permit the purchase of 13 YB-17s, which became the XB-17.

It was said at the time that the airplane was just too big and complicated for any pilot to safely control. To avoid another accident, Air Corps personnel developed checklists the crew would follow for takeoff, flight, before landing and after landing. As it turned out, the XB-17 wasn't too complicated to fly and went on to become the B-17, of which 12,730 were delivered and helped America and its allies win World War II.

Although the term "checklist" first appeared in the Merriam-Webster dictionary in 1853, it didn't find widespread use in airplanes until the Model 299. Today, a checklist is a required document in every pilot's cockpit.

The FAA's Point of View

While 14 CFR 91.503 mandates that you have a checklist, what that checklist must contain, and that it "shall be used by the flight crewmembers when operating the airplane," it doesn't tell you how it shall be used. You need to get into commercial operations and FAA Order 8900.1, Volume 3, Chapter 32 for those particulars. But even when operating strictly under Part 91, the commercial regulations provide what many consider the best practices for checklist usage, and identify two primary methods of checklist accomplishment.

The "Challenge-Do-Verify" (CDV) method consists of a crewmember making a challenge before an action is initiated, taking the action, and then verifying that the action item has been accomplished. The CDV method is most effective when one crewmember issues the challenge and the second crewmember takes the action and responds to the first crewmember, verifying that the action was taken. This method requires that the checklist be accomplished methodically, one item at a time, in an unvarying sequence. The primary advantage of the CDV method is the deliberate and systematic manner in which each action item must be accomplished. The CDV method keeps all crewmembers involved (in the loop), provides for concurrence from a second crewmember before an action is taken, and provides positive confirmation that the action was accomplished. The disadvantages of the CDV method are that it is rigid and inflexible, that crewmembers

Gulfstream G150 on approach to Geneva, Switzerland (LSGG).

MARKUS EIGENHEER

cannot accomplish different tasks at the same time, and if a step is missed it will not be looked at again.

The "Do-Verify" (DV) method consists of the checklist being accomplished in a variable sequence without a preliminary challenge. After all of the action items on the checklist have been completed, the checklist is then read while each item is verified. The DV method allows the flight crew to use flow patterns from memory to accomplish a series of actions quickly and efficiently. Each individual crewmember can work independently, which helps balance the workload between them. Some cockpits are poorly suited for a DV flow, however. Having spent much of my examiner experience in jump seats, I believe the DV method has a higher inherent risk of an item on the checklist being missed than does the CDV method.

The FAA order, which follows, says operators may use either method but recommends they adopt and apply a consistent checklist design policy. The order provides contradictory advice, however, and fails to say one method must be used over the other.

(1) "Both the CDV and the DV methods of checklist design are currently being successfully used for normal checklists. Traditionally, operators have preferred the DV method for normal checklists and the CDV method for non-normal and emergency checklists. Operators have, however, successfully used the CDV method for all checklists."

(2) "All checklists, except the after-takeoff and after-landing checklists, should be accomplished by one crewmember reading the checklist items and a second crewmember confirming and responding to each item. POIs shall ensure that critical items on the before-takeoff and before-landing checklists are confirmed and responded to by at least two crewmembers."

In my view, it certainly makes sense that the after-takeoff and after-landing checklists are exceptions to the CDV method, since both pilots are very busy and both sets of eyes need to be outside. But I believe every other checklist needs to be accomplished using a Challenge-Do-Verify method. Of course, my view may be a minority opinion.

Objections to Challenge-Do-Verify

Having argued for CDV for many years, I've fielded a number of objections that can be summarized into several arguments. First, DV proponents will hold that the CDV method takes too much time. Secondly, they say a DV "flow" is actually safer because you accomplish the checklist twice. And when presented with evidence that the DV flow does miss an item now and then, they will say that is possible with the CDV method, too. Let's look at all three arguments.

For some reason, the after-engine-start checklist seems to be a tempting time to flow the checklist in a mad dash to get moving in a turbine aircraft. It is as if we had a Hobbs meter ticking away the dollars. The left seater races through each item as quickly as possible and then calmly calls for the checklist. The right seater reads the checklist as quickly as possible to a cacophony of "check," "set" and whatever else is called for. But is this method really faster than a more methodical approach? To find out, I asked two highly experienced Gulfstream G150 pilots to time both methods.

This operator uses a customized checklist to provide standardization with its other aircraft; the customized list is optimized for a DV flow:

(1) R/L STBY PUMP . . . AUTO

(2) R/L DEEC . . . CHECKED/AUTO

(3) APU/GEN . . . (ON/OFF)

STEVEN FOLTZ

The after-starting-engines flow for an example, Gulfstream G150.

(4) PROBES HEAT . . . TEST/AUTO
(5) BAGGAGE HEAT . . . TESTED/(ON/OFF)
(6) CABIN SIGNS . . . ON
(7) BATT . . . ON
(8) GEN LOAD . . . CHECKED
(9) APR . . . ARMED
(10) T/Rs . . . ARMED
(11) ECS . . . (APU/BOTH)
(12) GND A/B . . . (CHECKED/TAKE-OFF)
(13) AUX PUMP/PRESSURE . . . AUTO/3000
(14) FLT A/B . . . CHECKED/RE-TRACTED
(15) FLIGHT CONTROLS . . . CHECKED
(16) NWS . . . CONNECTED

Tracing the steps on a photo of the cockpit reveals an economy of motion for the left seater accomplishing the checklist steps, as well as for the right seater reading the checklist and verifying each item. Over a series of trials, the time to accomplish either method was fairly consistent:

- Challenge-Do-Verify: 1 min., 33 sec.
- Do-Verify: 2 min., 17 sec.

I've tried this in various cockpits and come up with similar results. It actually takes more time to flow the procedure and follow up with the checklist, than it does to methodically read the checklist, item by item, and accomplish each step, in turn. "OK," DV proponents will say, "it may take longer, but it is safer because we do the checklist twice." I ran a one-month trial in a Gulfstream GIV using the after-engine-start checklist using the DV flow with a highly experienced crew. While the crew usually got all 22 steps exactly right, they did occasionally miss an item or two. The following month they used the CDV method where their performance was flawless. Of course, these are anecdotal results and you could argue this crew's performance may or may not be indicative of your results. Besides, don't most aircraft have adequate warning systems and other safeguards to prevent critical mistakes?

Technological Safeguards

My first jet was the Cessna T-37 U.S. Air Force trainer equipped with a "foolproof" way to ensure fledgling pilots didn't forget to extend the gear before landing. The system involved a beeping sound transmitted to the pilot's earpieces and a light in the gear handle that activated anytime the throttles were reduced below 70% with the gear handle in the up position. And yet, one of my classmates, who certainly was not a "fool," landed gear up during a solo flight. The sound of the beeping warning could be heard through the radio as he transmitted his mandatory "gear down" call to the tower.

These days the warning systems are far more sophisticated, some incorporating radio altimeter and Global Positioning System inputs to ensure the gear is down and the aircraft is headed for a recognized runway. And, yet, gear-up landings still occur. NASA's Aviation Safety Reporting System has recorded as many as 100 such landings a year.

On June 12, 1991, the pilots of Korean Air Flight 852 didn't use their before-landing checklist and pulled a circuit breaker to silence an annoying warning horn before landing gear up and destroying a perfectly good Boeing 727. Five years later, on Feb. 19, 1996, the pilots of Continental Airlines Flight 1943 landed gear up and substantially damaged a Douglas DC-9. The captain, acting as the pilot monitoring, was interrupted several times and skipped several items in the in-range checklist that left them with inadequate hydraulic pressure. The crew failed to perform the landing checklist and missed the fact that their gear and flaps were not extended, the three green gear-down lights were not illuminated, the landing gear warning horn was sounding, and the ground proximity system alert was activated.

We've also seen more than a few attempts to take off without the flaps set, often with disastrous results. On Dec. 26, 1968, all three crewmembers on Pan American World Airways Flight 799, a cargo Boeing 707, were killed when the pilots skipped the checklist item requiring the flaps be extended before takeoff. The crew was distracted with departure timing and the cold weather allowed them to set the proper thrust without activating a mechanical warning switch. On Aug. 16, 1987, a McDonnell Douglas MD-82, operating as Northwest Airlines Flight 255, was destroyed, killing 154 of 155 on the aircraft and two more on the ground. The crew failed to use the taxi checklist to ensure the flaps were set. A takeoff warning system failed to activate for reasons that could not be determined. A similar story, including the failure of a warning system for undetermined reasons, can be told of Delta Air Lines Flight 1141. This Boeing 727 crashed on Aug. 31, 1988. Since then, there have been 16 additional cases of civilian transport category aircraft attempting (and failing) to take off with improperly set flaps, slats or trim settings. While the mechanical failure of warning systems was sometimes cited, in each case the proper, disciplined use of a checklist could have prevented each crash.

The Many Benefits of a CDV Disciplined Approach

We've seen through government and private studies that a CDV approach to checklist accomplishment can result in greater accuracy, fewer omissions, faster accomplishment and improved crew coordination. But there is one more benefit that you will rarely see in any formal study: The CDV method forces pilots to slow down and ritualize checklist accomplishment. It is easy for pilots to state "checklist complete" when crew participation becomes understood or unnecessary. Unspoken checklists can lead to complacency and procedural noncompliance.

Perhaps the greatest lesson from the Hanscom crash and the many other examples of skipped takeoff and landing checklist items is that we pilots need to slow down. We should become more methodical and disciplined about our approach to checklists. As the FAA Order notes, there are two exceptions to the need for a CDV approach. The seconds immediately after takeoff require us to accomplish several things immediately without reference to a checklist: gear up, flaps up, scan for traffic.

The same can be said for the moments immediately after landing: speed brakes, thrust reversers, brakes. But for all other checklists, a Challenge-Do-Verify method forces the pace of the checklist to slow to as fast as the cited items can be accomplished. Pilots are far less likely to skip items that are read at this measured pace than they are when one pilot responds rapid fire, "checked" or "set" as quickly as possible.

I believe the Challenge-Do-Verify method of checklist accomplishment is a proven solution to problems that have been vexing us pilots since the days of the Model 299. Accident case studies are filled with crashes in which a checklist was either skipped or accomplished too quickly to catch critical errors. A profound irony of this "need for speed" when flowing a checklist is that the slower, more methodical approach to checklist accomplishment can also be a time saver. **BCA**