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Checklists — Guideposts Often Ignored

Why do accidents and incidents continue to occur that are traced to improper checklist use, when the purpose of these simple memory joggers is to improve aviation safety through cockpit coordination and proper accomplishment of multiple tasks?

by
John A. Pope
Aviation Consultant

Checklists have been a part of cockpit paraphernalia for a long, long time. As far back as the 1920s, U.S. Air Service airplanes had a checklist item that read "Do not trust any altitude instrument."

Pilots who trained in twin-engine aircraft during World War II had the G-U-M-P check indelibly printed on the backs of their hands and sorry, indeed, was the aviation cadet who failed to call out:

G — Gas

U — Undercarriage

M — Mixture

P — Props

The simple, fundamental purpose of a checklist has not changed through the years, no matter how many air crew members are involved or how sophisticated the aircraft may be. There are operational tasks in the aircraft that are vital to the safety of flight that must be accomplished in an orderly manner and verified as completed.

"Challenge and response," or the "do-list" (call-do-response), methods are the most common procedures in use. A checklist item is read or heard, the item is accomplished and verified; the correct setting or doing the task stated, and the loop is closed when there is a response indicating the outcome of the action.

In a two-man crew, the sequence might be: pilot-flying calls, "Flaps 20." The pilot-not-flying repeats, "Flaps 20," moves the flap lever to the appropriate selection, monitors the movement of the flaps and calls, "Flaps 20, selected and set." The pilot-flying acknowledges, "Flaps 20." In aircraft crewed by one pilot, the pilot reads, calls out, accomplishes and responds, a process that demands considerable self-discipline.

If their purpose is to improve aviation safety through cockpit coordination and if checklist methods are relatively simple, why are there continuing accidents and incidents that can be traced to improper checklist use?

As aircraft have become more sophisticated and complex, checklists have grown in proportion to that sophistication and complexity. For instance, a DC-9-50 has a checklist with 81 items for engine start, taxi and takeoff.

The length of the checklist, particularly in a flying environment that is influenced by such external considerations as meeting a specific schedule time, can tempt the air crew to introduce shortcuts in the interest of time.

Because pilots sometimes fail to understand the significance of checklist use as a means of preventing accidents, carelessness in accomplishment and verification of checklist items creeps in as a human factor. If constant repetition seldom reveals any discrepancy, repeating the same process again and again in a familiar airplane can breed complacency.

Verbal communications for certain functions may give way to hand signals — thumb down for "Gear down" or a finger drawn across the adam's apple to indicate "Cancel IFR," followed by a finger thrust forward that implies, "Going VFR direct."

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Airline crew scheduling is such that captain and first officers may fly together infrequently, and the experience level of each air crew member may be unknown to other crew members. Rigid adherence to checklist accomplishment should be the order of the day for those aircrews, but U.S. National Transportation Safety Board (NTSB) accident investigations have revealed a number of instances where checklist discipline was poor and was a causal factor in aircraft accidents.

In corporate aircraft operations, where aircrews fly together with great regularity, there is a tendency to abridge a checklist based on familiarity with the aircraft and with each other's experience, talents and traits. Instead of running the full checklist for every flight during the day, a corporate operator may feel disposed to a procedure that calls for a complete checklist on the first flight of the day but, on subsequent legs of the trip, allow the pilot-in-command to call for the "shortened checklist," an abbreviated version of the complete checklist that reduces the number of items to those deemed essential for a routine operation.

Shortened versions of the complete checklist arouse controversy as to which items are critical and important enough to be on the checklist. What must be considered is whether a checklist item is imporant from a systems engineering approach or a human performance and psychological aproach. The systems engineering approach suggests that if the checklist procedure is supposed to verify that the aircraft is configured correctly, then *all* items should be checked. The human performance approach suggests that the checklist should accommodate human nature — its capabilities as well as its limitations.

Study Reports on Accidents Caused by Improper Checklist Use

The U.S. National Aeronautics and Space Administration (NASA) has released a report entitled, "Human Factors of Flight-deck Checklists: The Normal Checklist" compiled for the Ames Research Center by Asi Degani, San Jose State University Foundation, and Earl L. Weiner, University of Miami.

The report traces the history of checklists, checklist concepts, the effect of airline mergers on cockpit discipline, line observations of checklist performance, factors influencing checklist incidents, analysis and design issues, and the checklist as a system. The authors performed field studies of 42 different air crews at one U.S. carrier. Although the study concentrates on airline checklist use, study data is pertinent to all aircrews and pilots.

The report refers to four airline accidents within a two-year period where the misuse of a checklist was cited as a probable cause of the accident. Those accidents were a BAe Jetstream 31 commuter aircraft that crashed immediately after takeoff because the crew failed to apply maximum takeoff power; a McDonnell Douglas MD-80 that crashed on takeoff from Detroit Metro Airport following a no-flap/no-slat takeoff attempt; a Boeing 727 that crashed shortly after liftoff at Dallas-Fort Worth Airport after a no-flap/no-slat takeoff; and a Boeing 737 that overran Runway 31 on an aborted takeoff at LaGuardia Airport because of misplaced rudder trim (February 1991 FSF *Flight Safety Digest*, page 1).

The authors of the study encountered several occasions when the following statement was made, "Checklists.

They are simple and straightforward, so what is there to study about them?"

The answer to that question, according to the NASA report, is that a closer look into the usage of checklists and the controversy that surrounds them reveals a device and an associated procedure that, in addition to its basic function as a memory guide, is a generator and coordinator of many cockpit tasks. Nevertheless, says the report, its (checklist) importance and vulnerability have long been neglected.

Objectives and Methods Outlined for Study

The objectives of the study were to understand the role of the checklist, to identify factors that contribute to the misuse or nonuse of the checklist and to present guidelines for checklist design.

Methods used were field studies, interviews with line pilots from seven major U.S. carriers, incident/accident reports from NASA's Aviation Safety Reporting System (ASRS), NTSB and the International Civil Aviation Organization (ICAO), interviews with FAA and NTSB personnel, information from manufacturers and general literature information in the fields of aviation , psychology, typography and human performance.

Checklists are particularly important during takeoff, approach and landing segments … .

What Is a Checklist?

The NASA-Ames study states that the major function of the checklist is to ensure that the crew will properly configure the aircraft for flight and maintain this level of quality throughout the flight and during every flight. Checklists are particularly important during takeoff, approach and landing segments which comprise only 27 percent of average flight duration. However, 76.3 percent of hull-loss accidents occur during these phases (Lautman and Gallimore, 1988).

Checklist Objectives Are Aimed at Safety

The study lists the following objectives of a checklist:

- Aid the pilot in recalling the process of configuring the plane.
- Provide a standard function for verifying aircraft configuration that will defeat any factor that results in a reduction in the flight crew's psychological and physical condition.
- Provide convenient sequences for motor movement and eye fixations along the cockpit panels.
- Provide a sequential framework to meet internal and external cockpit operational requirements.
- Allow mutual supervision (cross-checking) among crew members.
- Enhance a team (crew) concept for configuring the plane by keeping all crew members "in the loop."
- Dictate the duties of each crew member in order to facilitate optimum crew coordination as well as logical distribution of cockpit workload.
- Serve as a quality control tool by flight management and government regulators over the pilots in the process of configuring the plane for the flight.

Often overlooked, says the study, is the promotion of a positive "attitude" toward checklist use. In order to accomplish that goal, the checklist must be well grounded within the present day operational environment, and the operator must have a sound realization of its importance instead of regarding it as a nuisance task.

Abnormal Checklists Make a Difference

Abnormal checklists, which include non-normal and emergency checklist, are intended to help the pilot during emergencies or malfunctions of aircraft systems. In such situations, the abnormal checklist serves to act as a memory guide; to ensure that all critical actions are taken; to reduce variability between pilots; and to enhance coordination during high workload and stressful conditions.

Abnormal checklists are very rarely performed, but pilots are aware of the critical nature of them and are very much aware that misuse or non-use of the abnormal checklist can transform a routine abnormality into an accident.

Checklist Concepts Reflect Company 'Culture'

The study points out that the philosophy of checklist use is the outgrowth of the airline company's corporate "culture." That includes such factors as management style, supervision concepts, delegation of responsibilities in the chain of command, punitive actions, traditional methods of operation, pre-defined work policies and management priorities. The airline's culture, stated the study, is an important factor because it is mirrored by the manner in which flight management and training departments establish, direct and oversee flight operations.

The study's statements about airline culture apply equally well to corporate aviation operations. Management style, supervision concepts, traditional methods of operation, pre-defined work policies and management priorities create a culture for corporate aviation which can be mirrored by the way the aviation department establishes, directs and oversees flight operations, in addition to the manner in which corporate pilots function in the cockpit.

The study pointed out the inherent hazards of relying on memory techniques.

Line Observations On Checklist Use

The study divided the checklist process into three steps: initiation, routine calls and responses and completion of the task checklist.

The initiation of the checklist requires the pilot flying to judge when to call for the task checklist and to recall if previous checklists have been done and properly completed. This process, when coupled with high workload, stress and schedule pressures, can lead to checklist initiation errors.

The study states that many pilots use internal as well as external cockpit cues to aid them in initiating a checklist. For instance, the Before Start Checklist can be cued with the closing of passenger doors, the Before Takeoff Checklist by reaching the hold line before the runway, and the Descent Checklist at a transitioning altitude of 18,000 feet. The cues are not usually a part of the standard operating procedures but are more of a personal pilot technique.

The study points out that if pilots are occupied with other tasks, cues can pass unnoticed; it cites the MD-80 accident at Detroit Metro Airport as an example. Airline pilots indicated to the NTSB that they usually complete the Taxi Checklist within one or two minutes after the aircraft starts to move from the ramp. In the case of the accident aircraft, the Taxi Checklist for this flight was not completed within the first minutes of the taxi because of interruptions for new weather information and aircraft and runway data. The NTSB accident report stated, "By this time the airplane's location on the airport was such that the external cues and references available to the flight crew were not those normally associated with the initiation of the Taxi Checklist." In other words, by the time the distracting tasks were finally completed, the regular external cues had vanished.

Memory-guided Checklist Not Very Reliable

During line observations by the study authors, they noted several instances during night operations when the checklist card was drawn out of the slot (above the glare shield) but no light was turned on to allow reading, so the checklist was performed from memory. The authors observed a similar habit in both day and night operations — the pilot would stretch his hand out and touch the checklist card situated on the glare shield but would not draw the checklist out of its slot.

The authors noted that pilots had a habit pattern of associating a motor response with the checklist procedure. Nevertheless, the card was not drawn out and the checklist was read from memory. On another flight, they observed a flight engineer in a Boeing 727 run the entire trip checklist from memory with his paper checklist in a crack in the edge of his panel.

Verification Overlooked

In some cockpits, the task of verification was left only to the pilot responding to the checklist. The pilot challenging the checklist — pilot-not-flying — read checklist items but did not move his eyes away from the list to cross-check the other pilot. Therefore, the mutual supervision concept was lost.

Often, said the authors, the pilot-flying would answer with the proper response immediately when he heard the challenge from the pilot-not-flying, but without verifying that the item called was set accordingly. This was clearly evident in high workload phases of flight. Therefore, the configuration redundancy embedded in the procedure was lost.

Several pilots stated that they had their own checklist procedure to use as a personalized safeguard which they performed from memory just prior to takeoff. The study pointed out the inherent hazards of relying on memory techniques:

• It is dependent on the availability of time after the quick completion of the checklist.

- It is vulnerable to distractions such as ATC communications, outside scan, starting an engine during the taxi segment and more.

- It is based on memory and not on a step-by-step challenge and response.

Short-cutting the Checklist Can Lead to Trouble

In deviating from the challenge-and-response method to a faster technique, several challenge items were called in one batch while the other pilot replied with a series of also batched responses. This technique, said the study, undermines the concept behind the challenge-and-response procedure and is dependent on the pilot's short- and long-term memory for the order and completion of the checklist — which is exactly what the checklist is supposed to prevent.

With lengthy checklists, the study found a tendency to actually perform the items while reading the checklist in an effort to overcome a laborious and time-consuming procedure. For example, lights, pitot heat and transponder are usually toggle-type switches on the panel. The pilot would call the challenge and then position the item accordingly. By doing so, the crew lost the configuration redundancy embedded in the checklist. While this short-cutting may not always be related to the critical configuration items, it can easily migrate to items that are critical to the safety of the flight.

The checklist process itself can be a distractor for other cockpit tasks and duties.

Completion Indicator Needed

Paper checklists lack an indication that the task-checklist is fully completed and the only safeguard is a completion call such as "The Taxi Checklist is complete" which is made by the challenging pilot as he completes the checklist.

According to the study, some airlines write the completion call as the last item in each checklist, making the call itself the final checklist item. Others choose not to list this call but still require the pilots to make the completion call. A few airlines disregard this call completely.

The field study showed many cases where pilots (using a checklist without a written completion item) chose not to make this callout, or made a very faint (mumble) callout that probably was not heard by the other pilot. In these cases, it appears that the gesture of returning the checklist card to its place on top of the glare shield was the only notification of completion, and this movement is sometimes not observed by the other pilot.

Although the completion call is a redundant action and, in most cases, the crew members know that the checklist has been completed, it is the only reliable feedback available to indicate completion. The statement that a specific checklist is complete provides a "cap" to the checklist process and enables all crew members to mentally move from the checklist to the other operational areas with the assurance of completion.

Distractions Interrupt the Flow

Distractions and interruptions can break the checklist process and may result in a checklist error and, conversely, the checklist process itself can be a distractor for other cockpit tasks and duties. In a 1979 NASA study relating to cockpit distractions, 169 air carrier distraction reports were analyzed and 22 were labeled as distractions caused by checklist procedures.

That report showed that there were two checklist-related characteristics common to all 22 reports:

- Every report indicated that checklist accomplishment received cockpit priority over air traffic control requirements.

- The normal checklist activities were almost always going on at the same time other cockpit tasks were being performed — radar monitoring, minor malfunctions, system monitoring, traffic watch, etc.

Checklist accomplishment became a cause for distraction not by itself but as part of cockpit workload. In the incidents reported, the workload became "excessive" and "time ran out" before all tasks could be completed.

Indexing the Checklist Has Mixed Results

Pilots used several personalized techniques to guard against omitting a checklist item. Most commonly seen by the authors was the habit of moving the left thumb along the left-justified checklist items. The thumb is used as an index for the current item as well as an indicator once the checklist is interrupted. The study found some problems with this technique:

- In most checklists, the vertical spacing between lines is too small to precisely identify the location of the thumb to a particular line.

- If the checklist is interrupted for a length of time, it requires the pilot to hold the card with his thumb on the "hold" item throughout this period.

- If the checklist is organized in two columns on the card, this technique will only be effective for the left-most column.

Using a grease pen to mark the location of a hold in the checklist and to "tick off" accomplished items becomes cumbersome in the cockpit operational environment, particularly at night. Some pilots write the item where the checklist was interrupted on a pad and use this note when going back to complete the checklist.

According to the study, checklist distractions and interruptions lead to the following consequences:

- Elimination of the vital cross-checking of the other crew member.

- Disruption of the sequential flow of the checklist.

- Committing to memory the location of the interruption in the checklist sequence.

Paper checklists do not allow for visual indication of the point where a checklist was interrupted, nor do they differentiate between accomplished or non-accomplished items. Therefore, the study notes, the step-by-step sequence of conducting a checklist is the only available technique to control this procedure.

Many Factors Influence Checklist Incidents

Psychological Effects, Perception and Mental Models. Several checklist-related incidents were the result of a situation in which a pilot though he had set and checked a control properly but actually had not.

The study states that to perceive something is to be conscious of it and to pay attention to it. Perception is a dynamic process that changes constantly depending on the physical stimuli and on the way in which the brain blends incoming information with information already stored in memory. Therefore, the mere existence of a physical stimulus obtained by a receptor (eyes, for example) is not an absolute predictor of what the pilot will perceive and act upon while performing a task or doing checklist items.

When a certain task is performed repetitively in the same manner, pilots become experienced with the task and, in a sense, create a mental model of the task. With experience, the shape of the model becomes more rigid, resulting in faster information processing, the ability to divide attention and consequently leading to a reduction in workload. In return, this model may adjust, or sometimes even override the perception of physical stimuli coming from the receptors and bias the brain ("seeing what one is used to seeing").

There is a relationship between the speed of performing the checklist and the quality … .

Many pilots told the study authors that at one time or another they had seen a checklist item in the improper status, yet they perceived it as being in the correct status and replied accordingly. For example, the flap handle is at the zero degree slot (physical stimulus) but the pilot perceives its location on the five degree position and calls, "Flaps five" because he *expects* it to be there. This incorrect reply is based on numerous similar checks in which the flap handle was always in the proper setting during this stage in the checklist. Often, this phenomenon is coupled with unfavorable psychological and physical conditions such as time pressure, high workload, fatigue, noise, etc. Nevertheless, the result is human failure. *[Note: This phenomenon has also been described as "mind set" by some psychologists. For instance, the pilot hears what he wants to hear and not what is being said to him. If a pilot expects a clearance to level off at 7,000 feet, mind set may take place and the pilot will level off at 7,000 feet although air traffic control may have specified another altitude. — Ed.]*

Speed-Accuracy Trade-off. There is a relationship between the speed of performing the checklist and the quality, or accuracy, of the check. Laboratory research has shown a very definable relationship between response time and error rate. If the pilot scans the appropriate panel(s) rapidly because of time pressure, the accuracy of his perception will suffer and the probability of error will increase.

Realization of Checklist Importance. The relationship between the task and its expected outcome is another factor that affects checklist outcome. Without the crew witnessing the apparent effectiveness, the redundant function of the checklist can sometimes lead to a decline the perception of the task's importance. The combined effect of expectations, experience and the pattern-analyzing mechanism is a double-edged sword. On one side, this ability makes the user flexible and faster in responding to multiple conditions. On the other side, it can lead the operator to make a disastrous mistake just because part of the information which was collected quickly or without sufficient attention appeared to match the expected condition.

Non-standard Phraseology. Although most companies require standard phraseology for checklist procedures, the authors' field studies indicated that some pilots violated these standards for the following reasons:

- The pilot considers that the standard phraseology is too cumbersome or not adequate. This is primarily the result of improper discipline or may portray management reluctance to obtain feedback from pilots regarding checklist design problems.

- The pilot wishes to be unique. This is quite common among many professional operators (i.e., pilots, controllers, mariners). In using standardized communication, operators presume they lose their individuality and the only way to restore this significance is to perform communications in a unique way by demonstrating a personal style, perhaps to add humor.

- The pilot wishes to show a high level of competency. Departure from standard phraseology was observed in field studies. Among non-standard actions were initiation calls such as "let's do it"; challenge and response calls such as "fuel, we are OK"; and hand signals (thumb up) to indicate completion of task-checklists.

By not using standard phraseology, the following may occur:

- The other crewmember might not detect a checklist error.

- The other crewmember might not be able to follow the sequence of the checklist procedure.

- The other crewmember might confuse the checklist callout with other intra-cockpit communications.

- The seriousness of the checklist and standardized checklist procedures are disparaged in the eyes of other crew members, particularly if committed by the captain.

The captain must … constantly evaluate the quality of the checks performed by himself or other pilot(s).

Checklist Ambiguity. Many checklists used the ambiguous responses "set," "check," "completed," etc. to indicate that an item is accomplished. The study suggests that, whenever possible, the response should always portray the actual status or the value of the item (switches, levers, lights, fuel quantities, etc.).

The same logic applies to calling out V speeds while checking the airspeed bugs prior to takeoff and landing. In most checklists examined by the authors, the response to the V speeds challenge is "check" or "set." However, by calling out the actual numbers (V1, Vr , V2, Vref, etc.) as a response, the pilots have a verbal confirmation to the setting they have placed on their respective airspeed indicators. In addition, this overt recall can aid in the mental preparation for takeoff/landing.

Cockpit Resource Management (CRM). Checklist procedures are accomplished by coordinated actions and communication between the captain and the other pilot(s). In addition, the checklist procedure is designed in such a way as to assign very distinct role definitions. It also requires assertiveness from subordinates when the checklist is not initiated properly by the captain, as well as firm leadership by the captain when subordinate officers are the culprits. These interactions between cockpit resource management precepts and the process of checklist usage makes CRM a valued area of interest in understanding checklist problems.

Checklist Management. Initiating any task checklist call must be evaluated by the captain and consideration given to:

- Are other pilot(s) overloaded with other tasks?

- What are the consequences of having the other pilot(s) running the checklist and, therefore, not participating in the current task?

- What is the likely outcome of delaying the checklist because of the above considerations?

Following the initiation of the checklist, the captain must also constantly evaluate the quality of the checks performed by himself or other pilot(s). If due to any factor (i.e., interruptions, distraction, time limitation, workload), the quality of checklist performance appears to be below the acceptable level, it is the captain's responsibility to stop the checklist, allocate additional time for proper execution and, possibly, run the checklist again.

Included in its conclusions, the report outlined design weaknesses of the traditional (paper) checklist and the limitations of the humans who interact with it. Other influences can closely interact with checklist use, including those inside the aircraft such as conflicts that occur when following the checklist is placed into a second priority during critical phases of operation, as well as outside factors that include distractions such as takeoff and en route clearance changes while the crew is in the middle of following a checklist. These interactions, if not properly accounted for in the checklist design process, may combine to reduce the effectiveness of this procedure.

The authors also stated they strongly believed that merely improving the engineering design and the procedural sequence will not eliminate the problem. The pilot is still the center of this tasks and the socio-technical environment in which he operates has a substantial effect on checklist performance, regardless of the type or method in use.

Since the pilot is in control, and will continue to be so in the foreseeable future, accommodating the human strengths and limitations in conducting this procedure should be at the heart of any checklist design.

In short, checklists must be "human-centered." It must be clearly understood by all parties involved in checklist design that if the individual captain chooses not to use the checklist for any reason, *no one can force him to use it.* ♦

About the Author

John A. Pope established John A. Pope & Associates, an aviation consulting firm located in Arlington, Va., U.S., after retiring in 1984 as vice president of the U.S. National Business Aircraft Association. He specializes in developing comprehensive operations manuals for corporate flight departments.

Pope, former Washington editor for "Aviation International News," is a frequent contributor to Flight Safety Foundation's publications.

He served as a command pilot in the U.S. Air Force and the Air National Guard. He retired as a colonel from the U.S. Air Force Reserve after 33 years of service.

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