

Winter 2004

Human Factors Issues of the Aircraft Checklist

Patrick Ross

Follow this and additional works at: <https://commons.erau.edu/jaaer>

Scholarly Commons Citation

Ross, P. (2004). Human Factors Issues of the Aircraft Checklist. *Journal of Aviation/Aerospace Education & Research*, 13(2). Retrieved from <https://commons.erau.edu/jaaer/vol13/iss2/4>

This Forum is brought to you for free and open access by the Journals at Scholarly Commons. It has been accepted for inclusion in *Journal of Aviation/Aerospace Education & Research* by an authorized administrator of Scholarly Commons. For more information, please contact commons@erau.edu.

FORUM

HUMAN FACTORS ISSUES OF THE AIRCRAFT CHECKLIST

Patrick Ross

INTRODUCTION

Formal checklists have been used in aircraft since before World War II. As aircraft developed and became more and more complicated, the checklist became more important. Modern cockpits have become so complex that it would be impossible to operate such aircraft without checklists.

Even though flight crews are trained in the use and importance of checklists, accidents still occur in which misuse of the checklist or poor checklist design are contributing factors. Proper checklist use and optimum checklist design are human factors issues. Degani and Wiener (1994) point out that until very recently, checklists have not undergone enough scrutiny and analysis by the human factors profession. The premise of this paper is that flight safety can be enhanced by proper checklist usage and good checklist design.

BACKGROUND OF THE PROBLEM**General**

Use and design of the aircraft checklist seems like a simple matter, however, there are many aspects to the checklist. Only recently have researchers begun to study the human factors issues associated with aircraft checklists. As of 1991 there were 228 aircraft accidents in the National Transportation Safety Board (NTSB) records in which checklist misuse was a contributing factor (Sumwalt, 1991). Additionally, there are numerous checklist related reports in NASA's Aviation Safety Reporting System (ASRS) database.

When one studies these accident/incident reports, it becomes clear that when the checklist is not used in the proper manner, or there are design flaws in the checklist, there can be serious consequences.

Sumwalt (1991) reminds us that there are good checklist techniques and bad checklist techniques. Sumwalt also categorizes checklist misuse into four categories. One, sometimes a crewmember, for various reasons, simply does not do the checklist. Two, the crewmember performs the checklist, but misses an item. Three, a crewmember responds that an item is checked or set, but the item really is not checked or set. Four, the checklist is started but is interrupted and not completed.

Check List Objectives

An aircraft checklist is a list used by the crew to make

sure the aircraft is in the proper configuration for a given phase of flight. These phases of flight include takeoff, climb, cruise, descent, approach, and landing.

The takeoff, approach, and landing phases are of particular importance. They make up 27 percent of an average flight, but account for 76.3 percent of accidents (Degani and Wiener, 1990).

The Challenge and Response checklist method is the routine most commonly used by the airlines. In this routine the designated pilot calls out a checklist item (switch or lever). This is the challenge. The pilot responsible for that item then responds by finding, grasping, and moving the item into the position called for.

Degani and Wiener (1990) remind us that from the human factors perspective, the checklist provides an interface between man and machine. The authors go on to list several objectives of the aircraft checklist as follows:

1. Help the pilot accurately configure the aircraft for flight phase.
2. Provide a systematic method to verify configuration, even if the crew is fatigued.
3. Provide a systematic and convenient eye scan of cockpit panels.
4. Provide a sequential framework to meet cockpit operational requirements.
5. Provide a method of crewmember cross checking.
6. Provide a systematic method of configuring the

Aircraft Checklist

- aircraft, keeping all crewmembers in the loop.
7. Provide a method of optimum crew coordination and distribution of cockpit workload.
 8. Provide a quality control tool that can be used to evaluate pilots.
 9. Promote a positive attitude about checklist use and safety.

Reasons for Deviations from Checklists

Distractions. Distraction is the most obvious reason for deviations from the checklist. When emergency or abnormal situations arise, the checklist can be forgotten or interrupted. Since checklist initiation is usually tied to external cues, the checklist is sometimes forgotten when these cues are missing, or are different.

In addition to distractions, Degani and Wiener (1994) discuss four factors why trained and standardized professional pilots deviate from standard operating procedures (SOP) and checklists. These factors are as follows:

Individualism. No matter how well-trained pilots are, they are individuals and will impose that individuality on a procedure or checklist. In some cases this individualism does not effect safety or may even enhance safety. However, in other cases, safety is compromised. The bottom line here is that there exists the possibility of conflict between individualism and standardization. An example where individuality and the flexibility of the human mind were useful was in the Sioux City DC-10 accident. In this case, the crew had to improvise an emergency procedure because it did not exist in the emergency checklist.

Complacency. Many studies have shown that pilots can become complacent. This complacency is caused by the inherent error tolerance of the aviation system and the fact that most pilots in the day-to-day routine of flying face few emergencies or abnormal circumstances. This complacency or easing up can be made worse by fatigue. Lately, human factors researchers have noticed what they call automation complacency. This is a type of complacency in which the pilot becomes too trusting of the cockpit automation (Parasuraman, Molly, and Singh, 1991).

Humor. Some pilots like to add variety and humor into the cockpit atmosphere. They do this because the cockpit atmosphere is inherently boring and humorless. To some extent, a little humor in the cockpit may be a good thing, however, it can cause problems. Degani and Wiener (1994) point out the case in which a pilot on the ground,

requesting his clearance, asked for "federal aid" to St. Louis. "Federal aid" was substituted for FAA clearance as a joke. The controller thought the aircraft was being hijacked. The FBI and the police were called to the aircraft. In the associated ASRS report, the pilot emphasized that he would use absolute standard phraseology in the future. Other cases sighted by Degani and Wiener are pilots saying "gasoline" instead of "fuel" and "uno mas" instead of "one thousand feet" (more to level off). These non-standard callouts force pilots to make unnecessary interpretations during high risk operations. This, in turn, makes it difficult to standardize cockpit procedure.

Frustration. When a task or procedure is frustrating, pilots tend to find ways to work around it. Degani and Wiener (1994) note the example of the oxygen mask. Oxygen masks are uncomfortable and hard to replace in their holders. Regulations require that when one pilot leaves the cockpit above 25,000 feet, the remaining pilot must put on the oxygen mask. Since this task is frustrating to the pilots, some will abandon the standard climb procedure and ask for a level off at 25,000 feet until the other pilot returns to the cockpit. This non-standard procedure costs extra fuel and ties up the Air traffic Control (ATC) system.

Design

Even though there have been some accidents in which checklist readability may have been a contributing factor, research into checklist design has begun only recently. Checklist design is interesting in that few people can agree on a standard. Even after aircraft manufacturers spend much time and money developing checklists, the airlines that buy the aircraft frequently produce their own checklist changing everything from type style and paper color to actual procedure sequences.

The researcher has personally witnessed checklist development meetings in which engineers, test pilots, training personnel, and Federal Aviation Administration (FAA) officials could not agree on issues such as paper size, decision tree format, and level of detail. Sometimes these meetings can even become emotionally charged due to strongly held opinions and beliefs.

It is refreshing that Degani of the NASA Ames Research Center has studied the problem of checklist design and has come up with some hard data. Using the data, Degani has developed guidelines for optimum checklist design. These guidelines will be discussed later

in this paper.

EXAMPLES OF THE PROBLEM

Detroit Accident

In August of 1987 a Northwest Airlines MD-82 crashed just after breaking ground from Detroit Metro airport. The NTSB report showed that the flaps were not set for takeoff. When the aircraft broke ground, there was not enough lift to sustain flight and the aircraft crashed killing all but one. Normally, a mistake like this is caught when the crew performs the taxi checklist. In this case the crew did not perform the taxi checklist.

From cockpit voice recorder transcripts, the NTSB concluded that the first officer was initiating the checklists even though Northwest SOPs specify that the captain should initiate them. Because the first officer became busy during a long taxi with a last minute runway change, he was distracted and did not initiate the taxi checklist. The NTSB concluded "the captain's passive involvement with checklist initiation did not provide a backup to the first officer's memory" (Sumwalt, 1991). The NTSB went on to say that because the pilots were distracted with the runway change, the aircraft ended up at a location on the airport where external cues and references were not the same ones normally associated with initiation of a taxi checklist.

New Orleans Accident

In May of 1987, an Air New Orleans BAe-3101 took off from New Orleans International Airport on a scheduled commuter flight. Just after takeoff, the aircraft experienced severe yaw and engine power surges. An emergency landing was made straight head. The aircraft overran the runway, crossed a highway, and ended up crashing into several cars. The NTSB determined that the engine RPM levers were not in the proper position for takeoff and questioned the crew's checklist discipline (Degani, 1992). Although the NTSB could not prove that checklist type face size was a factor, they did note that the Air New Orleans checklist typeface was 57 percent smaller than that recommended by human engineering criteria.

LaGuardia Accident

In March of 1994, a Continental Airlines MD-82 was damaged when it ran off the end of the runway at LaGuardia Airport in New York. The airplane ended up beyond the runway on top of a tidal mud flat in Flushing Bay. Twenty-nine passengers ended up with minor injuries and \$5.63 million worth of damage was done to the aircraft (Internet, 1996).

The captain had rejected the takeoff because he noticed

the airspeed indication stop at 60 knots, jump to 80, then return to 60. The runway was somewhat icy.

The crew had delayed starting the second engine during taxi out (against SOPs). Because of this, the crew hurried the takeoff preparations and missed several items on the checklist. The investigation that followed revealed that the crew missed one very important item, the pitot/static system heat. This heating system is used to keep ice off of the airspeed sensors. Because the system was partially iced over, the airspeed readings were wrong. This caused the pilot to abort the takeoff. A contributing cause was the captain's failure to recognize the erroneous airspeed reading soon enough.

Bryce, Utah Accident

In 1983, a Republic Airlines MD-82 was cruising at 35,000 feet, 20 miles north of Bryce, Utah when both engines stopped. The crew did an emergency descent, performed the proper checklist and turned on all fuel boost pumps. At about 12,000 feet, the crew got both engines restarted and accomplished a successful diversion to Las Vegas. It turned out that the engines had stopped because both main fuel tanks on each wing were empty. The rest of the fuel was in the center tank, but could not get to the engines because the center tank fuel boost pumps had not been turned on per the climb checklist. The NTSB concluded that during the takeoff, one of the autopilot knobs came off, distracting both pilots enough so that the captain called for the CLIMB checklist out of normal order. When the captain did call for the climb checklist, the first officer received a radio call. The combination of the checklist being out of order, coupled with some minor distractions, caused the first officer to miss the center-tank-boost-pumps-on checklist item.

SOLUTIONS TO THE PROBLEM

Checklist Usage

There are several techniques that can be used to insure that the checklists are used in the optimum manner. A checklist should be initiated only by the designated crewmember. This lessens the impact of distractions and reliance on another crewmember's memory to self-initiate a checklist. If the designated initiator forgets, then the other crewmember can say something like "are you ready for the checklist?"

Checklists should be initiated during times of low workload, if possible. For example, Degani and Wiener (1991) state that the taxi checklist should be accomplished as close to the gate as possible and as far from the active

Aircraft Checklist

runway as possible. This is because the probability of completing the checklist becomes less and less as the aircraft gets closer and closer to the runway.

Calling for the checklist should be done immediately following specific cues or events. For example, the After Takeoff checklist might be called for just after retracting the flaps or the Landing checklist might be called for just after lowering the landing gear. Caution must be used however, since in times of abnormal situations, the usual cues may not be available.

Standard checklist nomenclature should always be used by both the challenger and the responder. Hand signals should never be used. Humorous phrases should be avoided, especially by the captain. Humorous phrases used by the captain could give the crew the impression that the checklist is not important.

When a checklist is interrupted for any reason, the checklist should be stopped by the responding pilot. A good way to stop a checklist would be to say "stop it at flaps (or gear, etc)". This is referred to as an "explicit hold" on the checklist (Sumwalt, 1991). One simulator study of checklist interruption shows that explicit holds after an interruption can help a crew return to the checklist and complete it (Sumwalt, 1991).

After a checklist has been completed, the challenging crewmember should announce that the checklist is complete. This emphasizes the end of the checklist so that the crew can move on to other cockpit duties

Checklist Design

In addition to the human factors issues associated with checklist usage, there are also human factors issues associated with checklist design. For example, if the print is too small, or the nomenclature is not standardized, a checklist loses its effectiveness.

The checklist should not contain words that are ambiguous. Degani and Wiener (1990) inspected several checklists and noted usage of ambiguous terms such as set, check, and complete. Checklist nomenclature should always state the actual status or value of the item. For example, when calling out airspeed bugs, it is better to say "V1 121" instead of "V1 set."

Checklists should use consistent, standardized nomenclature. When an airline has different types of aircraft (especially from different manufacturers) the nomenclature can be confusing. One checklist may use the term throttles, and another may say power levers. Nomenclature can even vary between types of checklists.

For example the normal checklist may say fire handles and the emergency checklist may say ENG FIRE handles.

Degani (1992) points out that the two important factors that a checklist designer should consider are legibility of print and readability. A legible print is one that allows the reader to quickly and positively identify each individual character. Degani says that legibility depends on "character stroke width, form of characters, illumination on the page, and contrast between the characters and the background."

Readability is a characteristic that allows the pilot to rapidly recognize single words, word-groups, abbreviations, and symbols. Degani says that readability depends on "the spacing of individual characters, spacing of words, spacing of lines, and the ratio of character area to background area."

Legibility and readability are very important for checklists because cockpits have a variety of lighting conditions due to the changing sunlight situations, pilots must frequently shift their eye focus between near and far when reading charts and looking for traffic, distractions and abnormal situations frequently interrupt normal cockpit procedures, and pilots are of many different ages with varying seeing ability.

Degani (1992) lists several criteria for the optimum design for checklists. The researcher will paraphrase some of the highlights of these criteria as follows:

1. Fonts should be of the sans (without)-serif style.
2. Fonts that have similar looking characters should not be used.
3. Dot matrix type print should not be used.
4. Long strings of text should be in lower case.
5. When using upper case, the first letter of the word should be larger.
6. Font height-to-width ratio should be about 5:3.
7. The vertical spacing between lines should be at least 25-33 percent of the overall font size.
8. The horizontal spacing between characters should be 25 percent of the overall size and at least one stroke width.
9. Do not use long strings of words in italics.
10. Do not use more than one or two typefaces for emphasis.
11. Use black characters on a white or yellow background.
12. Avoid black on dark red, green, or blue.
13. Use anti-glare plastic to laminate documents.

14. Make sure that the print quality is excellent.
15. When developing a checklist, the designer should determine what pilot age group will be using the checklist and then take a conservative approach in using information obtained from graphs and research data.

CONCLUSIONS

Aircraft accidents have occurred in the past in which misuse of the checklist was a factor. These accidents may have been avoided if more emphasis had been placed on checklist use during initial and recurrent training.

Checklists are an important aspect of aviation's system of safety backups. They must be treated seriously. As aircraft become more and more technologically sophisticated, checklists become even more important.

Deviations from checklists can be caused by distractions, individualism, complacency, humor, and frustration. One way to minimize the effects of the above factors is to regularly and methodologically use a standard checklist routine.

The checklist should be initiated by the designated crewmember at specific times during the flight. The crew should keep in mind that abnormal situations can result in

an absence of the usual checklist cues.

Checklist design is a factor that should be considered by anyone developing a checklist. Type style, type size, paper color, and other characteristics can have an impact on usability.

RECOMMENDATIONS

Flight safety can be enhanced by proper checklist usage and good checklist design, if the following recommendations are followed. One, the importance of checklists should always be emphasized during crew training, especially during Cockpit Resource Management (CRM) training and Line Oriented Flight Training (LOFT). Two, during training, crews should be reminded of situations in which the checklist can be misused due to interruptions of abnormal situations. Three, funding should be provided so that researchers can continue evaluating checklist design. Four, airlines should attempt to standardize checklists as much as possible across various fleet aircraft types. Five, the Air Transport Association should sponsor a program in which the airlines get together and standardize checklist design. →

Patrick Ross earned an MBA from Embry-Riddle Aeronautical University and is currently a doctoral candidate at Pepperdine University in California. He is an aircraft operating manual editor with the Boeing Company and an adjunct instructor at Embry-Riddle Aeronautical University.

REFERENCES

- Degani, A. (1992). On the Typography of Flight-Deck Documentation. (NASA Contractor Report 177605). Moffett Field, CA: NASA-Ames Research Center.
- Degani, A. and Wiener, E. L. (1990). Human Factors of Flight Deck Checklists: The Normal Checklist. (NASA Contractor Report 177549). Moffett Field, CA: NASA-Ames Research Center.
- Degani, A. and Wiener, E. L. (1994). On the Design of Flight-Deck Procedures. (NASA Contractor Report 177642). Moffett Field, CA: NASA-Ames Research Center.
- Internet (1996, September 18). Runway Overrun Following Rejected Takeoff.
<http://www.safb.af.mil/hqamc/pa/tmf/marapr96/mwamma96.htm>
- Parasuraman, R., Molloy, R., and Singh, I. L. (1991). Performance Consequences of Automation-Induced Complacency. (Technical Report No. CSL-A-91-2). Cognitive Science Laboratory, Catholic University, Washington.
- Sumwalt, R. L. (1991, March). Checking the Checklist. Professional Pilot, 62-64.