BY HEMANT BHANA

# By the Book

## Good written guidance and procedures reduce pilots' automation complacency.

As flight deck automation technology has advanced, most commercial transport pilots have transitioned from active participants in many processes to supervisors of the automation. Unfortunately, this shift can lead to complacency. Aviation-related automation complacency occurs when a pilot over-relies on and excessively trusts the automation, and subsequently fails to exercise his or her vigilance and/or supervisory duties.[1]

Stated differently, "Pilots may become complacent because they are overconfident in and uncritical of the automation, and fail to exercise appropriate vigilance, sometimes to the extent of abdicating responsibility to it [which can] lead to unsafe conditions."[2] The U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) publication *Callback* defines complacency throughout multiple issues as "the state of self-satisfaction that is often coupled with unawareness of impending trouble."[3]

These definitions imply that complacency occurs when the automation supervisor is unaware of the current or impending actions of the machine. Sometimes, this can have tragic results, as evidenced in December 1995, when an American Airlines crew flying a Boeing 757 did not notice the aircraft's automation activity, resulting in a fatal crash near Cali, Colombia.[4]

Against this backdrop, the author developed a scale to measure automation complacency–related behaviors as part of a broader study on complacency and boredom.[5] That broader study was based on ASRS reports from the 10-year period between January 1999 and January 2009. The search criteria were restricted to anomaly reports from U.S. Federal Aviation Regulations Part 121 operations, in which the causal factor category was flight crew human performance.

The search looked for any narrative or synopsis containing variations of the terms "FMC/FMS" (flight management computer/flight management system), "automation" and "complacency." The search criteria revealed over 560 records, which the author cataloged and categorized. Those, in turn, were used to develop questions probing the identified behaviors for the survey whose results are shown here. The questions emphasized routine practices and the deliberateness of a particular action (e.g., "How often do you deliberately … "). Survey instructions accentuated the need for honest answers and guaranteed anonymity.

Participants in the survey completed their responses online without time constraints. Each pilot was experienced in advanced automated aircraft because of the nature of the airline's fleet. Of the 273 respondents, 87.8 percent were male. The majority (54.4 percent) were between the ages of 41 and 50, with the next highest group between the ages of 51 and 60 (28.2 percent). Examining their types of flight operations found that 64.3 percent flew narrowbody aircraft in domestic U.S. operations plus Canada and Mexico, while 35.7 percent flew widebody aircraft in the international realm. Finally, 54.5 percent had flown their airplane type for more than four years. The next highest group (22.3 percent) had flown their airplane type between two and four years. The "aircraft longevity" pilot groups of one to two years experience and less than one year experience comprised 9.9 percent and 13.4 percent of the sample, respectively. The sample group represented 4.5 percent of the total pilot population of the airline.[6]

The term *automation complacency* is interchangeable with *automation overconfidence*, and broadly defined as an operator no longer applying the appropriate automation supervision and monitoring. Examining the results from the ASRS data allowed a factorial approach to the issue and revealed four subcategories. Following each subcategory below are the related survey questions and results. The results indicate the frequency of the queried behavior as a function of time. For example, a pilot could report being engaged in a particular behavior between 31 and 45 percent of the time.

## Failure to Notice

Pilots fail to notice the automation mode or autopilot state after an FMS reprogram or other distracting event (distraction complacency; Table 1). Common behaviors include:

Air traffic control (ATC) issues a late runway change, causing pilots to reprogram the FMS. The pilots do not notice that the descent mode has changed or do not notice that the altitude crossing restrictions have dropped out. In both cases, an altitude-crossing deviation occurs;

The pilots reprogram the FMS with new information during a mode change (for example, the aircraft leveling after a descent or climb). The pilots do not notice the ensuing mode reversion, resulting in an altitude deviation;

Pilots reprogram the FMS with a new lateral route and fail to notice that the disruption in navigation information has caused the automation to revert to HDG (heading) mode. This causes the automation to follow heading information instead of programmed track guidance, possibly resulting in a track deviation; and,

The pilots experience an event that causes their workload to spike, such as a system failure or a procedure interruption caused by nonessential issues. The pilots then fail to recognize any resulting improper automation modes.

## No Cross-Checking

Pilots do not cross-check the automation for the correct restrictions, route or information (cross-check failure complacency; Table 2). Common behaviors include:

A pilot failing to ensure the FMS has the correct departure, en route or arrival route programmed, resulting in a track deviation;

Pilots receive a new routing from ATC, and subsequently fail to ensure the FMS has activated the correct waypoint;

Pilots fail to program the correct altitude-and-speed crossing restrictions in the FMS;

Pilots enter a direct-to routing, and fail to ensure that the aircraft is proceeding to the correct waypoint;

Pilots fail to confirm that the selected arrival or departure procedure waypoints and/or restrictions match the charted procedure;

Pilots set the automation guidance (FMS, instrument landing system [ILS], etc.) to the incorrect parallel runway, resulting in inbound tracking of the incorrect runway; and,

## Failure to Monitor

Pilots fail to notice incorrect performance information, resulting in improper altitudes, speeds and weight-and-balance information.

Pilots fail to monitor the automation to ensure it is behaving as expected or required (monitoring complacency; Table 3, p. 50). Common behaviors include:

Pilots fail to monitor vertical automation with raw data information to ensure the aircraft will adhere to the altitude crossing restriction;

Pilots fail to ensure the aircraft automation is performing as expected by failing to notice the aircraft has

**Distraction Complacency, U.S. Airline Pilot Sample**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. On the majority of your flights, if ATC issues a runway change or other event that causes an FMS reprogram, how often do you deliberately check the automation mode (managed/VNAV PATH/open descent/level change, etc.)? | | | | | | |
| M = 5.03<br>SD = 1.46<br>N = 276 | **0–15%**<br>5.8% (16) | **16–30%**<br>5.1% (14) | **31–45%**<br>3.3% (9) | **46–60%**<br>6.5% (18) | **61–85%**<br>25.4% (70) | **86–100%**<br>54.0% (149) |
| 2. On the majority of your flights, if ATC issues a runway change or other event that causes an FMS reprogram, how often do you deliberately check to ensure any altitude crossing restrictions are still programmed? | | | | | | |
| M = 5.11<br>SD = 1.31<br>N = 276 | **0–15%**<br>3.3% (9) | **16–30%**<br>4.7% (13) | **31–45%**<br>3.6% (10) | **46–60%**<br>9.4% (26) | **61–85%**<br>24.6% (68) | **86–100%**<br>54.3% (150) |
| 3. If you are interrupted by an event (such as a cabin issue, restroom break, etc.) how often do you deliberately check the aircraft's automation mode after the event? | | | | | | |
| M = 3.89<br>SD = 1.69<br>N = 276 | **0–15%**<br>12.7% (35) | **16–30%**<br>13.0% (36) | **31–45%**<br>12.7% (35) | **46–60%**<br>15.6% (43) | **61–85%**<br>25.7% (71) | **86–100%**<br>20.3% (56) |
| 4. When ATC issues a direct-to or a new flight plan routing or another lateral event that requires an FMS reprogram, how often do you deliberately check to ensure the NAV mode is engaged? | | | | | | |
| M = 5.37<br>SD = 1.07<br>N = 276 | **0–15%**<br>1.4% (4) | **16–30%**<br>2.5% (7) | **31–45%**<br>3.6% (10) | **46–60%**<br>4.3% (12) | **61–85%**<br>26.4% (73) | **86–100%**<br>61.6% (170) |

ATC = air traffic control FMS = flight management system; M = mean; N = number of respondents; SD = standard deviation

**Note**: Pilots sampled were from a U.S. airline operating under U.S. Federal Aviation Regulations Part 121.

Source: Hemant Bhana

**Table 1**

not acquired the top of descent point; failing to notice the aircraft is not in the appropriate automation mode; and failing to ensure proper navigation or speed capture and hold;

Pilots fail to monitor lateral automation with raw data information to ensure the aircraft is on the correct navigation track; and,

Pilots fail to notice the automation has either overshot or undershot the assigned altitude.

## Inappropriate Automation

Pilots use the automation inappropriately, or rely only on automation flight guidance, instead of exercising manual pilot skills or abilities (over-reliance complacency; Table 4, p. 51). Common behaviors include:

Pilots attempt to use the automation to salvage a poor approach or a violation of the FARs (such as exceeding the 250 kt indicated airspeed limit below 10,000 ft);

Pilots use the autopilot to capture the localizer and glideslope on the ILS, and do not manually take over when the aircraft does not capture the landing guidance or behaves unexpectedly;

Pilots fixate on programming the FMS during high-workload situations to the exclusion of monitoring the aircraft's state;

Pilots exhibit poor flying skills when the automation disengages without pilot action; and,

On an ILS, the pilots continue to follow erroneous flight director guidance despite localizer and/or glideslope anomalies.

The results indicated good automation practices by the sample group and, by extension, the entire pilot population. The automation practices, when viewed against the airline's operations manual, indicated a strong adherence to standard operating procedures and good automation techniques.

This finding increases the importance of having written and enforceable guidance for pilots to follow. For example, the results from question 3 show a wide distribution of answers relating to the frequency of automation mode awareness after a distraction (mean [M] = 3.89, standard deviation [SD] =1.69). A pilot examining the airline's operating manual will find very limited guidance about deliberately checking the aircraft's automation mode after an interruption. The closest analog in the flight manual

### Cross-Check Complacency, U.S. Airline Pilot Sample

5. On your flights, how often do you deliberately check that the FMS is programmed with the correct SID, en route path, and STAR against the flight plan and/or ATC clearance?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.85<br>SD = 0.49<br>N = 276 | 0.0% (0) | 0.4% (1) | 0.4% (1) | 2.2% (6) | 8.0% (22) | 89.1% (246) |

6. When receiving a direct-to instruction or programming the FMS and more than one waypoint with the same name is displayed, how often do you check the position (frequency, distance, LAT/LONG) of the selected waypoint to ensure it is the desired one?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.09<br>SD = 1.48<br>N = 276 | 5.4% (15) | 5.1% (14) | 5.4% (15) | 4.3% (12) | 18.8% (52) | 60.9% (168) |

7. When issued a departure or an arrival route, how often do you check to ensure the correct routing and/or altitude-crossing restrictions are programmed in the FMS against the Jeppesen or other kind of chart?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.60<br>SD = 0.91<br>N = 276 | 0.7% (2) | 2.2% (6) | 1.4% (4) | 4.3% (12) | 14.5% (40) | 76.8% (212) |

8. If ATC issues a "direct-to" instruction, how often do you switch to the plan view to ensure the aircraft is actually proceeding to the correct waypoint?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 3.49<br>SD = 2.21<br>N = 276 | 38.0% (105) | 6.9% (19) | 1.8% (5) | 6.9% (19) | 14.1% (39) | 32.2% (89) |

9. When operating at an airport with parallel runways (for example, Runways 35L and 35R), how often do you deliberately check (during the approach briefing or any other time) to ensure the correct runway and/or localizer frequency is programmed in the FMS and/or NAV radios?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.79<br>SD = 0.64<br>N = 276 | 0.4% (1) | 0.7% (2) | 0.7% (2) | 1.8% (5) | 10.1% (28) | 86.2% (238) |

10. When inputting performance data (such as V-speeds, center of gravity, and weight information), how often do you deliberately check the data for accuracy and/or reasonableness?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.57<br>SD = 0.94<br>N = 276 | 1.4% (4) | 1.1% (3) | 1.8% (5) | 5.4% (15) | 15.2% (42) | 75.0% (207) |

ATC = air traffic control; FMS = flight management system; LAT/LONG = latitude and longitude;
M = mean; N = number of respondents; NAV = navigation; SD = standard deviation;
SID = standard instrument departure procedure; STAR = standard terminal arrival procedure

**Note**: Pilots sampled were from a U.S. airline operating under U.S. Federal Aviation Regulations Part 121.

Source: Hemant Bhana

**Table 2**

**Monitoring Complacency, U.S. Airline Pilot Sample**

11. When issued an altitude crossing restriction, how often do you monitor the aircraft's computed vertical path using mental math and/or raw-data information?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.42<br>SD = 1.03<br>N = 276 | 1.8% (5) | 1.4% (4) | 2.5% (7) | 6.5% (18) | 22.8% (63) | 64.9% (179) |

12. On the majority of your flights, when ATC issues an altitude crossing restriction, how often do you deliberately monitor your proximity to the top of descent point, and, if applicable, ensure the automation has captured the descent path?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.68<br>SD = 0.73<br>N = 276 | 0.4% (1) | 0.4% (1) | 2.2% (6) | 3.3% (9) | 15.9% (44) | 77.9% (215) |

13. For the majority of your flights, when conducting flight maneuvers (starting a descent, starting a climb, leveling off from a climb/descent, engaging NAV, etc.), how often do you deliberately monitor the aircraft's mode to ensure it is doing what is desired?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.69<br>SD = 0.61<br>N = 276 | 0.0% (0) | 0.0% (0) | 1.4% (4) | 3.6% (10) | 19.2% (53) | 75.7% (209) |

14. When issued a SID that is "navable" by the FMS (not an RNAV SID), how often do you deliberately back up your lateral guidance with raw-data information and/or mental computations?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 3.65<br>SD = 1.87<br>N = 276 | 20.7% (57) | 14.5% (40) | 9.1% (25) | 11.6% (32) | 23.2% (64) | 21.0% (58) |

15. For the majority of your flights, how often do you track the actual waypoint time and fuel burn against the predicted values during cruise?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 4.45<br>SD = 1.56<br>N = 273 | 8.1% (22) | 5.5% (15) | 12.1% (33) | 14.3% (39) | 27.5% (75) | 32.6% (89) |

16. On your flights, how often do you deliberately watch the altimeter to ensure the automation has captured the correct (assigned) altitude after a climb and/or descent?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 5.46<br>SD = 0.94<br>N = 273 | 0.7% (2) | 1.5% (4) | 2.6% (7) | 8.1% (22) | 20.5% (56) | 66.7% (182) |

ATC = air traffic control; flight management system; M = mean; N = number of respondents; RNAV SID = area navigation standard instrument departure; SD = standard deviation

**Note**: Pilots sampled were from a U.S. airline operating under U.S. Federal Aviation Regulations Part 121.

Source: Hemant Bhana

**Table 3**

describes procedures for handling a checklist after a distraction.

However, question 5 results indicated a very narrow answer distribution regarding cross-checking the FMS for route accuracy (M = 5.85, SD = 0.49). The operational guidance in this case deliberately tasks each pilot with independently verifying the accuracy of the FMS entries.[7] Further written guidance at several other locations in the flight manual emphatically requires pilots to compare their routing with the pre-departure clearance (PDC) and flight plan. Training syllabi, evaluations and line checks further emphasize these practices.

As another example, the results on question 14 also indicated a wide distribution of answers, indicating variance among the responses about how pilots cross-check lateral navigation (LNAV) data not based on area navigation (RNAV) (M = 3.65, SD = 1.87).

The ASRS narrative data contained multiple instances when pilots did not cross-check their LNAV data, resulting in a lateral track deviation. Many of these deviations occurred when the pilots did not have an adequate situational awareness of their current position during LNAV operations — a problem mitigated by referencing raw data information such as a radio magnetic indicator needle for additional reference. The airline flight manual guidance issued to pilots on this topic is conditional, and only references certain conditions when flight crews are required to back up LNAV information with radio-based raw data information, despite anecdotal evidence of the benefits of radio-based raw data for additional situational awareness.

Moreover, the language used to advise pilots on this matter is complex, requiring high cognitive processing to understand. This example highlights the benefits of clear and concise language in the flight manual. When technical writers create complex guidance stipulating multiple conditions, they inadvertently cause inconsistency in pilot behavior.

In contrast, procedure description that is declarative, clear, concise and well emphasized causes little variance in the associated pilot behavior, as shown by the data for question 13. The airline's flight manual instructs pilots in boldface that "during all phases of flight, both pilots must be aware of the [automation modes] and verify that they reflect the intended autoflight modes." In other sections of the manual, the guidance emphasizes this concept by further instructing pilots to say aloud the automation mode during specific phases of flight.

The responses to question 13 indicated a strict adherence to this

**Over-Reliance Complacency, U.S. Airline Pilot Sample**

17. Think about the occasions where you have been "behind the airplane" with the autopilot on. For those times, how often did you turn the automation off when correcting (no autopilot or auto-thrust) versus keeping the automation on?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 3.79<br>SD = 1.61<br>N = 273 | 12.8% (35) | 12.1% (33) | 12.8% (35) | 22.3% (61) | 24.9% (68) | 15.0% (41) |

18. During high workload situations when FMS reprogramming is required, how often have you found yourself fixating on the FMS?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 2.92<br>SD = 1.31<br>N = 273 | 16.1% (44) | 26.4% (72) | 21.6% (59) | 23.1% (63) | 11.4% (31) | 1.5% (4) |

19. For the majority of your flights, how often have you found yourself focusing on the flight director to the exclusion of other guidance cues (LOG/GS indications, map view, RMI, etc.)?

| | 0–15% | 16–30% | 31–45% | 46–60% | 61–85% | 86–100% |
|---|---|---|---|---|---|---|
| M = 2.14<br>SD = 1.28<br>N = 273 | 41.0% (112) | 28.6% (78) | 14.3% (39) | 8.8% (24) | 6.2% (17) | 1.1% (3) |

20. How confident are you in being able to turn off all the automation (autopilot and auto-thrust) and hand fly the aircraft in any weather condition, day or night, should the automation start behaving unexpectedly?

| | Very confident | Confident | Somewhat confident | A little confident | Not confident at all |
|---|---|---|---|---|---|
| M = 1.39<br>SD = 0.67<br>N = 273 | 69.2% (189) | 23.8% (65) | 5.9% (16) | 0.7% (2) | 0.4% (1) |

ATC = air traffic control; FMS = flight management system; LOC/GS = localizer or glideslope; M = mean; N = number of respondents; RMI = radio magnetic indicator; SD = standard deviation

**Note:** Pilots sampled were from a U.S. airline operating under U.S. Federal Aviation Regulations Part 121.

Source: Hemant Bhana

**Table 4**

guidance, with low variation in the answers, indicating that pilots are closely adhering (M = 5.69, SD = 0.61). Proper emphasis in the form of formatting, language and repetition can positively affect automation behavior.

Finally, this airline encourages hand-flying proficiency. Its manual says, "Stick and rudder proficiency is critical to the full set of skills necessary to successfully operate autopilot/autoflight airplanes. Hand flying is encouraged when traffic and workload permit." This operating philosophy could explain the confidence pilots have in their flying skills.

According to the survey responses to question 20, 69.2 percent of pilots in the sample are "very confident" of their piloting skills, probably because the associated standard operating procedures (SOPs) both permit and encourage hand flying practice. Another question in this survey (not published in this article) indicated that 85.3 percent of the sample group hand flew as much as possible, thus possibly avoiding an over-reliance on the automation. Moreover, hand flying proficiency reduces the pilots' dependence on the automation by allowing manual practice under pilot-controlled terms rather than only when the automation is misbehaving or disengages without pilot action. The ability to slowly develop hand flying proficiency under controlled, non-ideal conditions will reduce the chance a pilot will exhibit an automation complacency–related behavior.

Despite advanced automation in modern airliners, the results of this survey indicate that sound standard operating procedures that focus on the fundamentals of aviation can mitigate many automation complacency–related behaviors. Creating an awareness of the potential pitfalls of modern automation through written SOPs and automation-focused training might prevent a future tragedy.

## References

1. Parasuraman, R.; Riley, V. (1997). "Humans and Automation: Use, Misuse, Disuse, Abuse." *Human Factors* 39: 230–253.
2. Research Integrations (2007). *ASRS Incident Report Analysis*. Retrieved September 2009, from Flight Deck Automation Issues: <www.flightdeck-automation.com/incidentstudy/incident-analysis.aspx>.
3. NASA ASRS (October 2009). *Callback*. Retrieved from Aviation Safety Reporting System, <asrs.arc.nasa.gov/publications/callback.html>.
4. Aeronáutica Civil of the Republic of Colombia (1996). *Controlled Flight Into Terrain, American Airlines Flight 965, N651AA, Near Cali, Colombia, December 20, 1995.* Santa Fe de Bogotá: Aeronáutica Civil of the Republic of Colombia.
5. Bhana, H.S. (2009). *Correlating Boredom Proneness with Automation Complacency in Modern Airline Pilots.* Unpublished master's thesis. University of North Dakota, Grand Forks, U.S.
6. The sample size of 273 (out of roughly 6,000) of the airline's pilots yields a confidence level of 95 percent with an error rate of 5.8 percent. That is, one can be 95 percent confident that the sample's answers reflect the total pilots in the airline with up to a 5.8 percent error rate.
7. I have not cited the airline's flight manual. To do so would identify the airline and violate my research agreement with the company.