AIAA 80-1869R

Single Pilot IFR Autopilot Complexity/Benefit Tradeoff Study

Hugh P. Bergeron*
NASA Langley Research Center, Hampton, Va.

Abstract

A REVIEW of incident and accident data during general aviation (GA) instrument flight rules (IFR) flights[1,2] shows that there are several areas where incidents and/or accidents are most likely to occur. IFR flight in the terminal area, for example, during approach and landing, is associated with one of the highest incident and accident rates in single pilot IFR operations. In many of these cases it appears that some level of automation might help reduce pilot workload and thereby increase the safety of the flight. It is suggested that a simple low-cost partial capability autopilot may provide sufficient benefits in an IFR environment to justify its use, whereas a complete highly automated autopilot may be undesirable or unaffordable.

Contents

A study comparing the relative benefits vs complexity/cost of various levels of state-of-the-art autopilots in the IFR terminal area was performed on the NASA Langley general aviation simulator. The simulator, flown in the fixed-base mode, was configured and programmed as a typical high wing single engine aircraft. Five levels of autopilot automation were tested. The five, in order of increasing levels of automation, consisted of 1) no autopilot (NA), the basic aircraft; 2) wing leveler (WL); 3) heading select (HS), a heading select directional gyro was used in this mode; 4) heading select with lateral navigation coupling (HC), this mode included lateral guidance for both very high-frequency omni range (VOR) and instrument landing system (ILS) navigation; and 5) heading select with lateral navigation coupling and altitude hold with vertical navigation coupling (HAC), in addition to the previously discussed capabilities this mode also included a choice of pitch attitude hold, altitude hold, or vertical navigation guidance (i.e., glideslope coupler). The approaches were flown at five different airports. The airport/approach combinations were 1) ILS approach at Atlanta, Ga.; 2) ILS approach at Norfolk, Va.; 3) localizer back course (LOC/BC) approach at Newport News, Va.; 4) VOR approach at Franklin, Va.; and 5) nondirectional radio beacon (NDB) approach at Wakefield, Va. The ceiling and visibility were randomly chosen for each data run.

Seven subjects were used in the tests: two NASA test pilots and five IFR-rated pilots with various levels of IFR and autopilot experience. Each subject flew a total of 27 data runs (approaches). The piloting task consisted of flying the specified approach making the required pilot reports and performing a side task. The pilot reports were specified for the particular approach being flown. The side task was a self-pacing velocity/distance/time problem solved by using a hand-held E6B type flight computer. The data taken during each approach consisted of flight technical error, ground track and altitude profile plots, pilot workload rating, pilot comments, and side task results.

In analyzing the data, it was necessary to consider the interrelationship of several of the aforementioned data to fully interpret the results. The side task results, Fig. 1, in general are somewhat representative of all the data. Figure 1 shows the average number of problems completed per run during all the approaches for all the subjects at each level of autopilot complexity. The upper and lower limit bars represent the maximum and minimum of the averages of the individual subjects at each level of autopilot complexity. Implicit in using a secondary task is the assumption that the more difficult the task, the fewer problems completed, hence the higher the workload associated with the primary task. As can be seen in Fig. 1, the workload tends to decrease (increased secondary task performance) as the level of automation is increased. Significant, however, is the leveling off of the workload for automation levels higher than the HS mode. One interpretation of this phenomenon is that beyond the HS mode the subject trades off the workload associated with flying the control task for the workload required to monitor the autopilot's control of the flight task. This results in little net difference in primary task workload beyond the HS mode. The results of the pilot workload ratings tend to agree with the results from the side task, i.e., increased automation decreases workload. There is also a similar leveling off of the workload beyond the HS mode, but it is not as dramatic as in the side task data.

In general, of the five levels of autopilot complexity tested, the subjects rated each level of added automation to be somewhat easier to fly than the previous level, except for one mode. This mode, heading select, was considered to be much easier than its adjacent lower level of automation. The data also show that the heading select mode made the largest difference in decreasing workload and simplifying the approach task.

In addition to the varying levels of difficulty in flying the approach task due to a given level of autopilot automation, the different types of approaches were also found to be a factor in difficulty of flying the task. This was taken into consideration in analyzing and comparing the effects of autopilot complexity.

The ground track and altitude profile plot data exhibited two predominant frequency characteristics; a high frequency with low damping and a low frequency. As the level of automation increases, the high-frequency component decreases in both amplitude and frequency. This results in an apparent smoothing of the ground track trace. This smoothing trend with automation was noted for all the different approaches flown in this study.

Trends

Several disturbing trends were noted as the level of autopilot automation was increased. In general, an increased level of automation tends to take the pilot out of the aircraft control loop. He becomes a manager of the autopilot functions. The effects of this change in duty appear to be emphasized in the higher levels of automation. The subjects were more likely to lose track of where they were in the approach. It seemed that in monitoring the autopilot they would associate instrument readings with the autopilot functions rather than to situational awareness. Therefore, if the autopilot functions were either set incorrectly or interpreted incorrectly, the subject would frequently perform the wrong

Presented as Paper 80-1869 at the AIAA Aircraft Systems and Technology Meeting, Anaheim, Calif., Aug. 4-6, 1980; submitted Sept. 9, 1980; synoptic received March 12, 1981. This paper is declared a work of the U.S. Government and therefore is in the public domain. Full paper available from AIAA Library, 555 W. 57th St., New York, N.Y. 10019. Price: microfiche, $3.00; hard copy, $7.00. **Remittance must accompany order.**

*Aero-Space Technologist, Flight Dynamics and Control Division. Member AIAA.

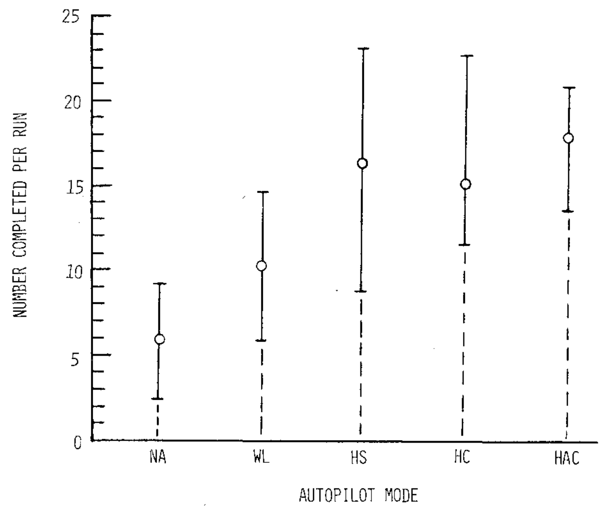

Fig. 1 Average number of side tasks.

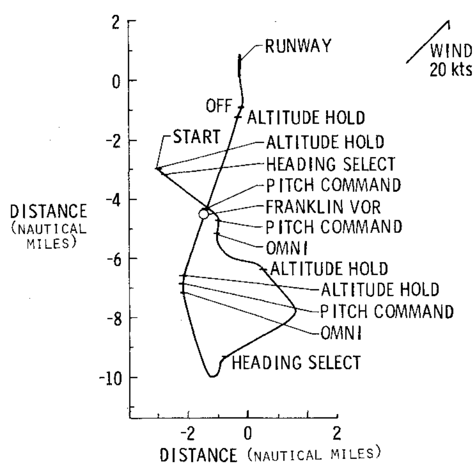

Fig. 2 Groundtrack Franklin VOR approach. HAC autopilot mode.

task, thinking that everything was normal. This would frequently lead to an incident or blunder. An example is shown in Fig. 2 (Franklin VOR approach, HAC mode). The run began with the autopilot in the heading select mode. After crossing the VOR, the pilot switched to omnicoupling but neglected to reset the correct bearing on the course deviation indicator (CDI). As can be seen in Fig. 2, a large excursion from the desired path was flown before the pilot realized his mistake and made the appropriate corrections. It is likely that incidents of this type frequently go unreported in the real world.

Another subject (Fig. 3, Wakefield NDB approach, HAC mode) became positionally disoriented and made his final letdown on an outbound heading. He leveled off and made his missed approach without ever realizing his mistake. Another interesting facet related to this run is the fact that the NDB at Wakefield is located on the airport. This missed approach

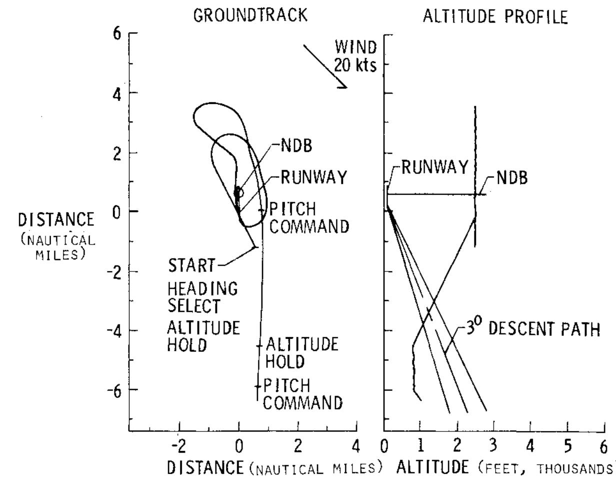

Fig. 3 Wakefield NDB approach. HAC autopilot mode.

should have been executed when, if in this case, the NDB was crossed.

Several other comments about the HAC mode are considered relevant at this point. A couple of subjects commented that, while flying the HAC mode, they had a tendency, at times, to forget to perform the side task. Another subject felt that the altitude hold and glideslope coupler could create a safety issue. The pilot can be lulled into a false sense of security or complacency with too many automatic features. The problem appears to be almost as if the pilot thinks of the autopilot as a copilot and expects it to think for itself. He allows himself to become completely engrossed in other tasks once the autopilot is set. Hence, he is frequently late in resetting new functions or he may become confused as to exactly where he is in the approach and not reset all the necessary functions or controls. One subject commented that the more automated his autopilot the less he trusted it. He stated he had trained himself to expect and look for problems of an insidious nature when using complex autopilots.

The preceding comments agreed with the relationship of blunders vs autopilot automation. The HAC mode encompassed the largest number of detectable blunders.

The results of this study indicate that automation is desirable when making IFR approaches in a high-workload environment, but also that some disturbing trends are associated with the higher levels of automation as presently implemented in state-of-the-art autopilots. It is believed, however, that a better man/machine interface could alleviate these problems. The data further suggest that the heading select mode currently may be the best choice for the IFR approach task when considering both benefits and costs.

References

[1] Forsyth, D.L. and Shaughnessy, J.D., "Single Pilot IFR Operating Problems Determined from Accident Data Analysis," NASA TM-78773, Sept. 1978.

[2] Bergeron, H.P., "Analysis of General Aviation Single Pilot IFR Incident Data Obtained from the NASA Aviation Safety Reporting System," NASA TM-80206, Oct. 1980.