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Situational Awareness and Decision Making as it relates to Single Pilot Resource Management in Technically Advanced Aircraft

Mark R Adams

Embry-Riddle Aeronautical University

Daytona Beach, Florida

Worldwide Online

Instructor: Vincent Zaccardi

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Abstract

This paper will briefly look at the areas of situational awareness and decision making with respect to single pilot resource management. General aviation operations in technically advanced aircraft will be the focal point. Research data on the cognitive issues of these two elements will be presented in the context of how the information and automation capabilities of these aircraft affect the pilot's ability to gather, process, and use the information to effectively make sound decisions during pre-flight and in-flight planning. The information presented is based upon research data and findings from numerous experts in the field of human factors cognition as well as the author's thirty six (36) years of aviation experience, the last fifteen (15) years having been spent operating and instructing in "glass cockpit" aircraft. Finally, the adequacy of current training methods will be reviewed.

Introduction

"The single pilot operating in General Aviation has arguably one of the most demanding civil aviation tasks, which is reflected in the disproportionate rate of accidents experienced compared with other sectors of the aviation industry. Studies have shown that some form of human failure is present in over seventy percent (70%) of all GA accidents, with poor judgment and decision making, and inadequate pre-flight and in-flight planning being cited as major causal factors" (Freedman & Nendick, 1998).

Pilots operating in today's National Airspace System are subjected to an increasingly complex system of procedures, equipment, and facilities designed to increase overall system capacity while simultaneously improving safety. The single pilot operating light (less than 12,500 lbs.) general aviation aircraft is subject to the same system complexities that were normally once reserved for highly sophisticated aircraft operated in a multi-crew environment. The ability of the single pilot to gather, process, and effectively act upon a vast array of information in a timely manner is paramount to a successful flight in today's environment.

The arrival of new technology to general aviation aircraft has generated noticeable changes in three areas: information, automation, and options. Pilots now have an unprecedented amount of information available at their fingertips. A suite of cockpit information systems provide pilots with data about aircraft position, planned route, engine health, and performance, as well as surrounding weather, traffic, and terrain (FAA, AAH, 2009). To process large amounts of information and not allow flight safety to suffer, pilots must add the title of "systems manager" to basic stick and rudder skills (AOPA Air Safety Foundation, 2007). The constantly evolving complexity of the national airspace system, as well as technology present in new and retrofit general aviation aircraft brings with it a requirement for an enhanced level of situational awareness and decision making. These human factors skills until recently were emphasized only in multi-crew environments under the concept of Crew Resource Management.

Technically Advanced Aircraft

While there are many variants that meet the definition of a technically advanced aircraft[1] (TAA) the model used here is one that utilizes a primary flight display (PFD), multifunction display (MFD) and an automated flight control system.

The PFD replaces the traditional analog flight instruments. The presentation may differ from conventional instrumentation in both format and location. In addition to flight instrumentation the PFD (see Appendix A) will display navigation and autoflight status information. The latest technology, such as Garmin's Synthetic Vision Technology[2] (SVT™) (see Appendix A) can provide a three-dimensional view of upcoming terrain, obstructions, and flight path guidance.

The MFD (see Appendix A), as the name implies, has the capability to show a vast array of information to include; a global positioning system (GPS) moving map with navigation information, terrain, data link weather, on board weather radar, traffic information, engine instrumentation, electronic checklist, instrument approach data, and more. The aircraft will also include one or more (GPS) receivers, generally with wide area augmentation system[3] (WAAS) capability.

Many automated flight control systems rely on two different but integrated systems; one is the autopilot that actually controls the aircraft through a series of servo actuators, and the second is the flight director which is considered the brain of the autopilot. Most flight director computers obtain their input from multiple sources in the aircraft. Typical inputs include; an air data computer (ADC), the attitude and heading reference system (AHRS), multiple navigation sources such as VOR, ILS, (see Appendix B) and GPS, the pilot's control panel, and servo feedback information from the autopilot (FAA, AAH). Modern autoflight systems allow the aircraft to be flown by automation in both the lateral and vertical dimensions. They provide multiple modes of lateral and vertical navigation and may be engaged shortly after takeoff and remain engaged, if desired, to approach minimums.

The AOPA Air Safety Foundation estimates that ninety percent (90%) of all production aircraft are being delivered with "glass cockpits" as described above….there is no current reliable estimate of how many aircraft have been retrofitted to become TAA, but it will be into the tens of thousands. The Air Safety Foundation goes on to observe that the TAA takeover goes beyond just equipment. "The larger definition includes a new mindset for pilots, encompassing a revised view of what constitutes GA flying, with airline-style procedures, regular use of autopilot, and greater dependence on avionics for multiple tasks beyond pure navigation" (AOPA Air Safety Foundation). This new mindset requires the single pilot to develop and use an enhanced mental skillset over and above what was previously required to operate legacy aircraft. Workload and information management in order to avoid task saturation and the subsequent loss of situational awareness become the basis for this mental skillset. The Air Safety Foundation refers to this as "the mental airplane".

Situational Awareness and Decision Making

Maintaining a high level of situational awareness is one of the most critical and challenging elements of a pilot's responsibilities. Simply stated, situational awareness is knowing where you are and what's going on. It's the "big picture", and one of the very foundations of pilot competency….situation awareness is gained by searching for and collecting information (Edwards, Douglas, & Edkins, 1998). Situational awareness must begin well before the aircraft leaves the ground, in the form of pre-flight preparation, and continue throughout the flight to the point where the aircraft is parked at the destination. If situational awareness were a crystal ball, it would tell you everything that is happening and is going to happen with respect to the plane, the path, and the people (pilot, passengers, air traffic control (ATC), etc.). Situational awareness includes the need to anticipate what is going to happen in the future and consider contingencies. "The current and future state of the plane, the path, and the people are components of the plan" (Chappell). The developed mental model of what has happened, what is happening, and what will happen is the result of successfully gathering, processing, and applying this information.

Situational awareness is a skill set that must be learned, applied, and practiced to maintain proficiency. Two themes of this skill set include; monitoring and evaluation and anticipate and consider contingencies (Chappell). Monitoring is a combination of maintaining the big picture as well as examining the details with respect to what is happening. This requires the single pilot to gather information from multiple sources both inside and outside the aircraft. The pilot must monitor the plane (PFD), the path (MFD), and the people (ATC). Evaluation of the status of these items leads to an understanding of what is happening. Anticipating what will happen is a key element of maintaining situational awareness. This is particularly important in high workload environments such as departure and arrival phases of flight. The majority of all accidents occur in these two phases of flight (AOPA Air Safety Foundation, Nall).

Considering contingencies or the "what if" scenarios can give the pilot a tremendous advantage in the management of situational awareness (Chappell). Examples of "what if" scenarios might include; anticipating a go-around or missed approach procedure, the need to divert to an alternate due weather, the need to deviate around enroute weather. TAA provide the potential for increased situational awareness. "The tremendous flexibility and amount of data made available to the pilot of modern aircraft has the ability to inform or distract. Which result takes place is largely dependent on how the pilot flies the mental airplane and manages the use of that information" (AOPA Air Safety Foundation).

Decision making in its simplest form is the process of coming to a conclusion or determination about something and choosing a subsequent course of action. Situational awareness is one of the key ingredients in making sound decisions. There are numerous other factors that influence a pilot's decision making model such as; judgment, experience, risk assessment, personality, training background, etc. These elements are beyond the scope of this paper and any one of them would lend itself to in-depth research on its own merits. The focus here is on a pilot's ability to make an informed decision, based upon information that has been gathered from the sources available in the TAA. Pilots involved in accidents tended to interpret cues inappropriately, often under-estimate the risk associated with a problem and over-estimated their ability to handle dangerous situations…general aviation pilots who performed poorly in deciding to continue into inclement weather were poorly gauged in terms of matching their skill level to the situation (Endsley & Robertson, 2000).

Overreliance and failure to understand the limitations associated with new technology increase the potential for poor decision making. Examples of this would include; the pilot not realizing or choosing to ignore the fact that data link information (such as NEXRAD radar) does not represent a real time picture of thunderstorms, or using a terrain awareness system (TAWS) to continue VFR flight into IMC conditions, or to "scud run" to attempt to avoid IMC conditions. Perhaps the pinnacle of this overreliance is exemplified in the Ballistic Recovery System (BRS) or parachute system used to aid in recovering the aircraft from certain loss of control situations. "Pilots may come to rely on them when better decision making would have prevented them from getting into a bad situation in the first place" (AOPA Air Safety Foundation).

The Concept of Single Pilot Resource Management

Single Pilot Resource Management (SRM) is the art and science of managing all the resources (both on-board the aircraft and from outside sources) available to a single-pilot (prior and during flight) to ensure the successful outcome of a flight. This concept includes the key elements of situational awareness, workload management, communication, and decision making (FAA, RMH, 2009). The ability to automate tasks such as maintaining altitude, intercepting and tracking navigation courses, maintaining an assigned heading, etc. is a fundamental element in reducing the single pilot's workload.

The pilot is free to concentrate on; systems management, weather, terrain, and traffic avoidance, and compiling with ATC instructions. Automation can add to the overall quality of the flight or, if improperly managed, can lead to degradation in situational awareness and poor decision making. Since advanced avionics systems offer multiple levels of automation from basic manual to fully automated flight, it is up to the pilot to determine what level of automation is appropriate for the given flight situation. Automation does not replace basic flying skills and the pilot must be able to monitor the system(s) for proper operation and be prepared to take appropriate action if the system(s) is not performing as expected. "Before any pilot can master aircraft automation, he or she must first know how to fly the aircraft" (FAA, RMH).

The key to effectively managing automation lies with the pilot's understanding of what is required for the particular task and phase of flight, being able to extract that information, and then programming the automation at an appropriate level to accomplish the mission. As human beings we have limits on how much information we can process at any given moment. The pilot must prioritize the information needed to accomplish a specific operation. Examples include; programming the autoflight system to intercept and track an approach course, utilizing the terrain awareness page while flying in mountainous terrain, displaying NEXRAD weather to circumnavigate areas of convective activity.

Training in Technically Advanced Aircraft

With the introduction of advanced technology aircraft came the need for a new concept in how general aviation pilot's utilizing this new technology are trained. A more "airline style" approach to training is being undertaken by aircraft and avionics manufacturers. This style of training begins on the ground with systems training. Training providers have teamed with aircraft manufacturers to develop state of the art training products. These products include home computer and internet based simulators for aircraft and avionics systems, with the ability to practice the full range of functions that are available in the actual aircraft. Aircraft and avionics specific flight training devices (FTD) and flight simulators are becoming the norm for manufacturer specific training.

Advanced avionics systems present three important learning challenges as the pilot develops proficiency:

1. How to operate advanced avionics systems. Many systems allow multiple methods of accomplishing a task. It is important that the pilot obtain and use the manufacturer's operating manual for each system. In addition to basic system operations, these manuals will explain how to use each system to its fullest capability.

2. Which advanced avionics systems to use and when. There are multiple methods of accomplishing the same function. The pilot should be familiar with all the methods available and choose the one most appropriate for the task at hand.

3. How advanced avionics systems affect the pilot and the way the pilot flies. Choosing automation such that it is working for the pilot, and not the pilot working for the automation, is essential to reducing workload and effectively managing the aircraft. (FAA, AAH).

Mastering these three elements will help the pilot optimize safety and efficiency. Failure to be familiar with these elements can lead to a loss of situational awareness and result in poor decision making.

One area that needs special emphasis is the use of the autoflight system. General aviation pilots have traditionally been taught that the autopilot was ancillary rather than essential. For the single pilot operating TAA in the IFR environment the autoflight system is an essential component to safety. Training should include all modes of operation as well as their limitations. Improper use of the autoflight system can quickly lead to an increase in workload and potential loss of situational awareness. The FAA now requires demonstration of autopilot skills for the Instrument Airplane practical test (if the aircraft is so equipped).

Once the basics of the system are understood, training can progress to the aircraft. Any safety advantage that these systems provide can be negated by attempting to learn these advanced systems in flight. The ASF observes that "Too much training is currently done in the actual airplane, resulting in great inefficiencies and higher risk situations because of pilot and instructor distractions. These include midair collision risk, airspace blunders, blown ATC clearances, possible loss of control, and extended training time required in the aircraft" (AOPA Air Safety Foundation).

The FAA teamed up with industry leaders in aircraft and avionics manufacturing as well universities conducting large scale training activities. The FAA/Industry Training Standards Program (FITS) is the product of that initiative. One of the core elements of FITS is scenario based training (SBT). SBT has its roots in the airline industry in the form of line oriented flight training (LOFT). LOFT scenarios are training in which crews fly real time, highly scripted, simulator based training scenarios requiring demonstration of crew resource management skills that rely heavily on situational awareness and decision making. SBT uses the same type of scripted scenarios and is designed for TAA. SBT lessons can be tailored to fit the needs of a particular aircraft and level of student. This a major step forward from the traditional "one size fits all" approach to training. A report done by the University of North Dakota examined whether or not the concept of SBT resulted in improvements in the quality of training experienced by their students when compared against the more traditional maneuvers based training (MBT). The results of the report indicate that the students who received SBT overall outperformed their counterparts who received MBT. In the key area of decision making the SBT students performed better than their MBT counterparts (Schumacher & Lease, 2007).

Conclusions

The complexities of TAA present both technical and human factors challenges over and above their legacy predecessors. The advanced avionics systems installed on TAA are capable of providing the pilot with tremendous amounts of information about the aircraft systems, its location, the location of other traffic, and the environment in which it is operating with respect to weather and terrain. This wealth of information has the ability to inform as well as distract. In order to avoid being overloaded with information the single pilot must develop and use an enhanced set of situational awareness skills to effectively monitor and evaluate what is happening in order to anticipate and consider what will happen in the future as the flight progresses. Proper decision making on when and where to effectively use the automation capabilities of the aircraft can reduce the pilot's workload, increase situational awareness by handling routine tasks, and increase the overall safety of the flight.

"The traditional method of spending a few hours in ground school on aircraft systems and a cursory review of the avionics before hopping in the aircraft for a few hours of familiarization is now long outdated" (AOPA Air Safety Foundation). Proper training beginning with the ground phase of system instruction, followed by actual flight training. The use of SBT consisting of scripted, real world scenarios can effectively enhance the pilot's situational awareness and decision making skills. By providing multiple opportunities to practice these skill sets in a structured and supervised environment, individuals operating single pilot are better equipped to handle the complexities of operating TAA in the national airspace system. Detailed pre-flight planning is essential in order to minimize the time taken for in-flight decision making. The payoff for these actions has been a reduction in accidents. According to the Air Safety Foundation, TAA have had fewer than half as many takeoff/climb related accidents when compared to the overall general aviation fleet. Additionally, glass cockpit TAA have had no fatal accidents related to fuel management, which has been a long time cause of general aviation accidents (AOPA Air Safety Foundation).

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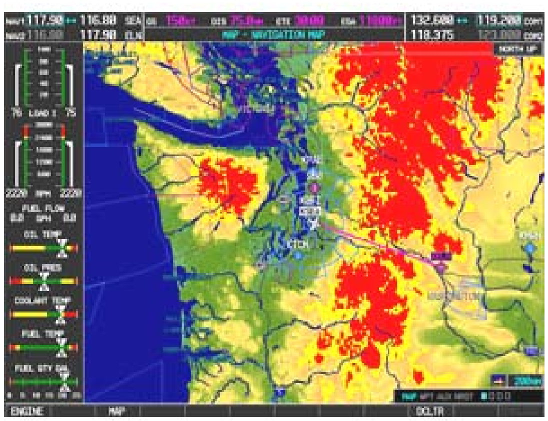
Appendix A

Garmin G1000 PFD w SVT™

Avidyne Entegra PFD



Garmin MFD w TAWS

Avidyne Entegra MFD w NEXRAD

Appendix B

LIST OF ACRONYMS

AOPA Aircraft Owners and Pilots Association

ATC Air Traffic Control

CRM Crew Resource Management

FAA Federal Aviation Administration

FITS FAA/Industry Training Standard

GPS Global Positioning Systems

IFR Instrument Flight Rules

ILS Instrument Landing System

IMC Instrument Meteorological Conditions

LOFT Line Oriented Flight Training

MBT Maneuvers Based Training

MFD Multi Function Displays

NAS National Airspace System

PFD Primary Function Displays

SBT Scenario Based Training

SRM Single-Pilot Resource Management

SVT™ Synthetic Vision Technology

TAA Technically Advanced Aircraft

TAWS Terrain Awareness System

VFR Visual Flight Rules

VOR VHF Omni Directional Range Station

WAAS Wide Area Augmentation System

Footnotes

1 The FAA defines a TAA as one equipped with at least the following; a moving map display, an IFR approved GPS navigator, and an autopilot.

2 SVT^{TM} uses projected images to provide a virtual view of terrain and other data in reduced visibility.

3 WAAS augments the basic GPS satellite constellation with additional ground stations and enhanced position integrity information transmitted from geostationary satellites FAA, 2007).