Transport Canada Safety and Security
Civil Aviation

Transports Canada Sécurité et sûreté
Aviation civile

TP 13748 E

An Evaluation of Stall/Spin Accidents in Canada

1999

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Canada is the last major aviation country to test spins on the private pilot flight test. The spin hasn't been required in primary training in the United States since 1949. It is not required in the JAA standard adopted in Europe, nor is it required in private pilot training in either Australia or New Zealand.

Other aviation authorities have moved to a model of stall/spin awareness in the hope of focusing the training on recognition of situations that could lead to an inadvertent stall and spin. In addition to the fact that Canada's major aviation partners do not include the spin in either training or testing for the private pilot licence (or, for that matter, the commercial pilot licence), it is becoming increasingly difficult to obtain new aircraft that are certified for spins.

To support flight training development and be sure that Canada was moving in the right direction, it was decided to examine the safety record related to stall and spin accidents in general aviation aircraft in Canada. This evaluation, which reviews Canadian stall/spin accidents over the last ten years, was launched in the hope that it would help everyone understand the reality of these accidents and determine whether changes to training may be effective in advancing safety.

One fact that emerges clearly in this study is this: *"One feature that stands out in all except one of the 39 stall/spin accidents examined is that knowing how to recover from the stall or spin was of no benefit to the pilots in these circumstances. They stalled at altitudes so low that once the stall developed, a serious accident was in progress. Safety will be advanced therefore by preventing stalls and spins."*

To some degree, the way spins are taught in the current syllabus may even create risk by fostering the illusion that real spins are typically entered from a classic, power-off clean stall and, for some aircraft, a lot of effort is needed to initiate and maintain the spin. However, such apparently docile aircraft spin quite differently when fully loaded, when they are operated outside the utility category, and in the real world the spins that kill tend to be entered at low altitude and in situations that don't resemble the classic clean stall and don't give enough room to recover. Some occur when speed is allowed to decay on approach and when a cross-control situation develops. Some occur when full power has been applied in an overshoot. Some occur in an attempt to turn back to the airport when the engine fails immediately after take-off. In these situations, the development of the spin is sudden and aggressive, unlike anything the pilot might have seen in training.

If the Canadian approach to spin training and testing has left us with a continuing concern about the numbers of fatal stall/spin accidents, would we do better with a stall/spin awareness model? In the United States, where stall/spin awareness has been used for years, spins still account for roughly 12 percent of general aviation accidents and 25 percent of the fatal accidents. In Canada, the stall/spin accident rate is not appreciably different from the American experience. Ten years ago, the spin related accident rates in Canada varied from a low of 0.8% to a high of 2.4% whereas in the United States the rate varied from a low of 1.3% to a high of 2.4%. (TSB, 1987)

Comparison of different statistical environments is always difficult - Canada and the United States count and define things differently - but there is not a significant difference in the stall/spin accident rate between the two countries. Canada is not gaining an obvious safety dividend from the current approach to spin training and testing.

METHOD

The first step was to identify the accidents relevant to the question at hand. A key word search was conducted on the TSB data base to identify stall and spin accidents over the past ten years in Canada. A total of 39 stall/spin accidents involving single engine or light twin certified aircraft were identified. TSB occurrence reports and occurrence briefs were obtained.

There is a tendency to consider accidents to be events. They are events, often tragic events, but, if your goal is accident prevention, accidents are better understood as processes, the results of a series of events, conditions, and human actions/decisions with decidedly negative outcomes. Understanding the processes that lead to accidents and incidents is a vital step in identifying changes that will prevent or mitigate the negative outcomes. To arrive at a common understanding of the factors that lead to accidents, it was important to apply a standardized approach to analyzing occurrences to identify the causal and contributing factors for each occurrence reliably and accurately.

The Civil Aviation Human Error Model and its companion analytic process were used to analyze the accidents. A detailed description of the model and process are available at Annex A. The aim is to identify and analyze the unsafe acts and unsafe conditions which contributed to the accident. When the factors that lead to unsafe acts or errors are understood, it is possible to identify interventions which have the potential to reduce the number or severity of accidents.

RESULTS

The Civil Aviation Human Performance/Human Error model was used to analyze each occurrence. In every case at least one unsafe act or error was identified. In some cases the background data were not sufficient to support a complete analysis and identify the antecedents or contributing factors. In most cases, however, the model helped understand the accident and identify factors that contributed to the mishap.

The occurrences broke down into three principal groups:

a. stall or spin accidents resulting from aircraft handling (27);
b. stalls or spins following engine failure (9); and
c. stalls or spins resulting from loss of control in IMC (3).

Handling Accidents

Twenty-seven accidents resulted from mishandling the aircraft into an aerodynamic stall. These accidents resulted in 26 fatalities and 16 serious injuries. In two cases it appears that the engine was not producing full power, but the aircraft was capable of controlled flight and the stall was avoidable. In all cases, the stall, which sometimes precipitated a spin or wing drop, occurred at low altitude and at low airspeed. The stalls and spins occurred at a height where recovery was very difficult and probably impossible. Sixteen stalls resulted from turning at low airspeed, 10 occurred in straight ahead flight, and one inverted spin developed when the pilot was practising aerobatics at about 1500 feet above ground level.

Most of the 27 handling accidents happened during the takeoff/initial climb out or approach phase. There were 13 stalls during the climb out after taking off and at least six of these occurred during a low speed, low altitude turn. Five stalls, all in turns, occurred during the approach/landing phase, most often on turning base to final. One practice overshoot ended in a stall when the instructor waited too long to take control and the airspeed fell too low.

Three of the en route accidents occurred in mountainous terrain. A navigational error led to a very difficult situation in one of them. Better mountain flying technique might have prevented all three accidents. At the moment of impact, damage and injury might have been reduced if the aircraft had been under control rather than stalled. Two pilots were flying while intoxicated. One spin occurred during aerobatic practice. The spin occurred at about 1500 feet and using the approved recovery technique might have prevented or reduced the severity of the accident. One accident happened when an unqualified instructor was teaching slow flight below the manufacturer's recommended altitude and did not apply the correct recovery procedure.

Several seaplane pilots made what are, in retrospect, obvious planning errors by taking off toward rising terrain with insufficient room to clear terrain or not accounting for downdraft conditions when taking off from steep banked lakes. Theses errors are obvious now, but probably were not apparent to the pilots involved until it was too late. Contributing factors include human visual limitations. People are not able to judge absolute distances. This makes judging how far away an obstacle is, very difficult, especially when the field of vision is flat and featureless, like a body of water. It is possible that some pilots, due to perceptual limitations misjudged the distance available and did not recognize the problem until it was too late. Downdraft occurring as the aircraft approached a shoreline and drift illusion appear to have taken three pilots by surprise. Lack of awareness and not being prepared to cope with the effect led to stalls and crashes.

Two float equipped aircraft stalled and crashed when the pilots undertook instructional or check flights with no rear seat control column installed. The instructor/check pilot was, therefore, unable to exert any control when the front seat pilot mishandled the aircraft.

In some cases, heavy, possibly even overweight aircraft may have contributed as well. Lack of experience flying aircraft near, or at, maximum gross weight, in one case with an external load, may have led to the pilots being surprised at the effect that fuel weight and loads had on aircraft performance. The importance of weight and balance calculations was emphasized by the fact that at least one aircraft was flown with the centre of gravity aft of the design limit.

Currency, supervisory factors and the importance of developing and ensuring compliance with standard operating procedures were all identified as contributory factors. The young glider tow plane pilot who took an unauthorized passenger, flew a low pass over the field, and stalled in a steep climbing turn was in violation of several rules. Standard operating procedures can contribute consistency but in commercial operations, those with supervisory responsibilities must be vigilant in promoting compliance.

Several of the pilots who mishandled their way into stalls were not current on their aircraft. One private pilot, demonstrating his aircraft to a potential purchaser, had flown only ten hours in the previous 12 months. He climbed out too steeply after takeoff, airspeed decayed and the aircraft stalled. Several other private pilots were either low time pilots, flew infrequently, or both. Skill decay is likely to affect such pilots if any unusual circumstances requiring quick assessment of the situation and rapid accurate decisions should arise.

Accidents Following Engine Failure

Nine accidents resulted from stalls/spins following engine failures. Two of the aircraft were twins and the rest were single-engine. Preventing engine failure is the best way to reduce this type of accident and several of the engine failures could have been prevented. Losing power, however, is not always preventable. It is a critical emergency and effective management of the situation is essential to achieve the best possible outcome.

Poor maintenance, fuel contamination, and taking off with insufficient fuel led to preventable engine failures. In one case, a pilot had a rough running engine. He landed, removed the engine winterizing kit, and tried to conduct a test flight. The engine failed shortly after takeoff. One engine failure resulted from using contaminated fuel. The pilot in that instance continued the flight after two partial power losses. Two pilots took off with so little fuel on board that the engine stopped on climb out. Another crash was traced to poor maintenance.

An accident may be inevitable after an engine failure but the task of the pilot is to minimize personal injury and damage to the aircraft. Losing control of the aircraft is the worst possible outcome after losing power.

Regardless of the fact that some of the engine failures were preventable, inadequately coping with the situation is an even more serious failure. All of the engine failures occurred at low altitude so that recovery from a stall or spin was impossible. It is vital, therefore, in such situations that control be maintained and the aircraft not stall. All nine stalls/spins resulted from mishandling the aircraft in an emergency and most of the problems can be traced to poor decisions. At least eight out these nine did not follow approved procedures. Deviations include basic items such as failing to raise the landing gear and not flying recommended airspeed. Five pilots stalled after turning back to the runway following an engine failure after takeoff.

Loss of Control in IMC

Three accidents resulted from loss of control in IMC. In one case the pilot, after being warned about the weather, still went flying and in fact lost control of the aircraft three times and recovered, but continued the flight. He apparently did not recover the fourth time and perished. This is the only stall accident examined which involved a high altitude stall. Another pilot had made several attempts over a period of days to deliver his passengers but was prevented by weather. Pressure to complete the job and a forecast of improving conditions at destination may have lured him into the attempt. The aircraft stalled and spun to the earth from tree top height resulting in three serious injuries. The final accident also involved passengers. The aircraft stalled at very low height. Weather information may have been lacking as the nearest observation site was 60 miles away.

DISCUSSION

One feature that stands out in all except one of the 39 stall/spin accidents examined is that knowing how to recover from the stall or spin was of no benefit to the pilots in these circumstances. They stalled at altitudes so low that once the stall developed, a serious accident was in progress. Safety will be advanced therefore by preventing stalls and spins. In this section of the paper we will continue the analysis of the unsafe acts which caused or exacerbated the accidents and begin the task of identifying potential countermeasures which could be implemented in training and flight testing.

Currency and Skill Decay

Different types of skills, once learned and not practised for periods of time, will degrade at different rates. Continuous movement skills, such as steering, guiding or tracking are relatively impervious to decay. Decision making, recalling bodies of knowledge and skill at tasks which require verbal communication between people, however, are subject to fairly rapid decay if not practised.[1] A measurable skill decrement at information processing and communication tasks can be apparent in a couple weeks if the skills are not practised.

The pilot who has not flown for a period of several weeks or months could be misled in certain situations. Such a pilot might expect that there has been some degradation in skill, but once in the aircraft, find that the stick and rudder skills are fairly intact. During a routine flight, there might not be much demand for problem solving and the pilot might conclude that no serious skill decay has occurred. In fact, the skill decay is hidden and may not become apparent until the pilot is faced with an emergency or complex situation.

To preclude this, infrequent fliers should engage in a periodic review or refresher activity to ensure that the relevant knowledge is available for recall and the information processing and decision making skills stay sharp.

Aircraft Handling

Aircraft handling is a psychomotor skill involving both mental and physical components. The mental skills involve information processing and decision making while the physical skills involve eye-hand-foot co-ordination, and aircraft control. With extensive practice, the control skills can become so well learned that the normal adjustments that are required to maintain or change attitude or direction can be accomplished without conscious thought. This does not imply a lack of attention, but is, in fact, a very efficient and effective way of handling well-learned,

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[1] Rullo, JoAnn C,, McDonald, L. Bruce. (1990). Factors Related to Skill Degradation and Their Implications for Refresher Training. Paper presented to the 34th Annual Meeting of the Human Factors Society.

often complex tasks. (See Human Performance/Human Error model at Annex A and Reason, 1997, P. 68).

Departures from the normal, well practised routines involve a greater degree of conscious cognitive activity. Most of the situations a qualified pilot encounters are resolved at the rule-based level of performance (see human error model). The most important factor in arriving at the correct action is accurate recognition of the situation. Exposure to situations teaches us to recognize similar conditions when we encounter them again. Training teaches us how to deal with those situations. Repeated practice allows us to incorporate the required action into a routine which can be accomplished, virtually on automatic, without consciously thinking through all the steps.

Examination of the stall/spin accidents leads us to conclude that a significant number of pilots failed to recognize the symptoms of a developing aerodynamic stall. This is based on an assumption that no one would willingly enter a stall at a height which precludes recovery. It is possible, in some cases, to identify potential distractors which, by occupying the pilots' attention, may have prevented recognition of the developing stall. In other cases, it is likely that one or more aspects of the situation was not familiar. Since the pilot had never seen such a situation, he/she did not recognize the condition or the solution.

Stall and spin training for the PPL begins with briefings and discussions on the ground so that the student pilot understands what is happening and how to deal with it. In the air the aircraft is stalled, typically straight ahead with power off. The stalls that led to the accidents were not entered that way. Most of the stalls leading to accidents occurred at low altitude, taking off or landing when airspeed is significantly less than cruise. If a pilot's experience does not go beyond the basic straight ahead, power off stall and spins, it is very possible that the pilot will not recognize the situation and therefore will not take action in time to prevent the full stall.

Every pilot needs to know how to recover from a stall, but the accident record indicates that there are instances where recovery is impossible. Therefore, in these circumstances, early recognition and stall avoidance is even more important than being able to recover. To maximize the likelihood that a pilot will recognize the symptoms of a stall in other than straight ahead, power-off conditions, student pilots should be exposed to the variety of stall initiation possibilities. They should learn to recognize the flight conditions that make stalls most likely and to take appropriate action to avoid the stall. To ensure that pilots can recognize the hazard and avoid the stall, the skills should be evaluated in the private pilot flight test. They must also learn that if a crash is inevitable, a controlled collision with terrain is far preferable to a stall or spin.

Coping with Emergencies

There are two types of skills which are both of critical importance when coping with emergencies: cognitive skills and motor skills. The cognitive skills are the mental activities relating to assessing the situation and selecting or developing the plan or course of action. The motor skills relate to controlling the aircraft to accomplish the plan. The brain is a single channel processor. This means that people can only consciously solve one problem at a time. If the motor or aircraft control skills are well learned, to the point that a pilot can perform them automatically, without conscious thought, then decision making capacity is not being used on aircraft control tasks. This capacity is, then, available for assessing the situation, monitoring progress towards the goal, problem solving, or communicating.

In an emergency situation, such as an engine failure, acute stress will have predictable physiological and behavioural effects. Heartbeat and respiration rate increase. Attention often narrows down to one or two apparently salient features of the situation. This narrowing of attention often leads to problems because so much attention is devoted to one aspect of a situation that other important features, such as decaying airspeed are not noticed. The normal scan of the instruments and the environment will become more rapid, but more superficial. People become susceptible to particular kinds of error at times of acute stress.

Historically, the forced landing is the most difficult exercise on PPL flight tests. This is understandable because it is a complex exercise and the situation, even in a practice environment, is inherently stressful. Although the requirement to perform a forced landing occurs rarely, the consequences of inadequate performance are dire and it is illogical to conclude that after the granting of a licence, skill at the task will improve, or even be maintained without practice.

Three measures are worth consideration to improve performance in forced landing situations. The first is to examine the task to identify all the component skills and practice each of these in isolation until proficiency is achieved. Then, the individual skills can be integrated. This approach is often used by flight instructors, but perhaps the practice could be improved by redefining the component skills and specifying the level of proficiency required before integrating the components. The second measure is to practice the skills often, both before and after earning a licence. Forced landing skills would be an ideal candidate for inclusion in a periodic review, should such an initiative be adopted. Thirdly, to ensure that the student is aware of the stall hazard and appropriate preventive measures during forced landing, stall/spin recognition training must include situations, such as descending turn stalls, than can be encountered during forced landings.

Takeoff Planning on Floats

A number of float equipped aircraft stalled during the climb out after taking off because the pilot had selected a takeoff route which was inadequate for the conditions. The human visual system is not capable of judging absolute distances. Seaplane training should include information on how susceptible we are to misjudging distances and techniques to ensure the adequacy of a takeoff area.

Effects of Weight and Balance

Typically in flight training the aircraft will carry no more than the student, an instructor, and fuel. The student pilot learns about weight and balance, but learning about it and the experience of flying a heavy aircraft may be very different. It may be advisable for pilots to actually experience flying and manoeuvring an aircraft at or near its maximum gross weight in controlled conditions. Having had the experience, a pilot may be more able to recognize the change in handling characteristics and avoid stall conditions.

Turn Back After Takeoff

Several stalls occurred when the pilot decided to turn back to the runway when the engine failed. Typically, guidance on this topic recommends that the pilot land straight ahead unless the aircraft has enough altitude to make the turn back to the runway. This constitutes a "fuzzy rule". That is, the rule requires interpretation, but the rule provides little or no guidance in making that interpretation. How much altitude is enough? Is it always the same? What variables may affect the requirement? The pilot is better off not having to consider these questions. Lives would be saved if the guidance required no thought or assessment. If an engine failure after takeoff results in an accident, the pilot is at least eight times more likely to be killed or seriously injured turning back than landing straight ahead. The easiest decisions to make are those which are prescriptive. As soon as the situation is known to exist, the procedure to follow is defined. Engine failure after take off should be such a decision.

Drift Illusion

All pilots learn about drift illusion, but without experience, it is difficult to understand how compelling an illusion can be. Exposing the students to drift illusion so that they can learn to recognize and cope with it is difficult and potentially dangerous. Simulation may be an effective and safe alternative for teaching about drift illusion. Consideration should be given to developing better ways to teach student pilots about illusions.

EXECUTIVE SUMMARY

Pilots must be taught to recognize and recover from the onset of a stall/spin situation. Prevention must be the aim and the key to prevention is recognition. Skill in recovery from stalls is needed, especially stalls in those situations that lead to a wing drop and autorotation requiring immediate, precise, and confident handling. Once the spin develops, as this study shows, the situation is too often an accident in progress.

Canada's insistence that we continue to include spins on the private pilot flight test, including assessing the ability to ENTER a spin, has not given us a safety benefit over other countries that have moved away from this requirement. Results of instructor flight tests, and flights with instructors conducted on refresher courses in the past, tell us that some instructors may not be skilled at teaching the advanced stalls that will prepare pilots to recognize the onset of a stall/spin situation. We have to bring the skill level of ALL instructors to the point where they can confidently show their students, at altitude, how mishandling during events such as a forced landing, a turn to final approach, an overshoot, or attempting to return to the runway after a power loss after take-off, can lead to an overwhelming emergency at low levels. They need to be able to teach their students how to recognize these situations. They need to be able to teach their students how to recover from these stalls as soon as the wing drops and before autorotation develops.

Removing the spin from private pilot training is not the solution that Canada should be embracing, but a move toward the stall/spin awareness emphasis seen elsewhere is recommended provided that the following steps are taken:

1. Replace the spin on the private pilot flight test with a second stall, an advanced stall.
2. Place more emphasis on the proficiency of private pilot students in recognizing and recovering from advanced stalls.
3. Give examiners better guidance on how to test the advanced stall.
4. Require that spins and the correct recovery technique continue to be demonstrated during private pilot training
5. Sample the advanced stall more heavily on instructor rating flight tests.
6. Emphasize the teaching of advanced stalls on instructor refresher courses.
7. Continue to require spin training and testing for commercial pilots but use the development of the integrated commercial program to give more specific recommendations for improvement.
8. Enhance training in the teaching of spins and advanced stalls during instructor rating training.
9. Continue to sample the teaching of spins and advanced stalls on instructor rating flight tests.

Annex A

Human Error Model

Introduction

Individual actions and decisions, viewed out of context can appear to be virtually random events, defying explanation. Human behaviour, however is not random. It usually conforms to some pattern and can be understood. The reason for using a model of human error is to guide the analyst in:

a. identifying the information needed to complete an analysis; and

b. analyzing the information to arrive at an understanding of the factors that lead to specific errors.

The model is predicated on research which indicates that people in operational settings do not usually use an analytical approach to decision making. Rather, they use much more efficient methods which capitalize on their training, experience and knowledge of the systems they are working within.

Levels of Performance

The model provides for three levels of performance,[2] distinguished from each other by the degree to which the performance requires conscious information processing.

Skill-Based Performance When people are performing familiar work under normal conditions, they know by heart what to do. They react almost automatically to the situation and do not really have to think about what to do next. For instance, when a skilled automobile driver is proceeding along a road, little conscious effort is required to stay in the lane and control the car. The driver is able perform other tasks such as adjusting the radio or engaging in conversation without sacrificing control. Errors committed at this level of performance are called slips or lapses.

Rule-Based Performance The rule-based level of performance is used when tackling problems which can be diagnosed and for which there are readily available solutions. People have all kinds of "Rules" stored in their memories. These are not necessarily regulations, but are more of the "If this condition exists, then do that" variety. Rule based performance requires more conscious thought than skill-based performance. The amount of mental effort will depend on the clarity of cues available to diagnose the situation and whether the response is prescribed, or a choice of options is required. Errors committed at the rule-based level of performance are called mistakes.

Knowledge-Based Performance The final level of performance is used when the situation cannot be readily diagnosed, or there is no procedure to follow. The person in this situation has to rely on his/her knowledge of the system and

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[2] Human Factors for Aviation: Basic Handbook. 1997. Transport Canada TP 12863.

creativity to devise a new way out of the problem. This level of performance involves the highest level of mental effort. One of the most famous examples of knowledge-based performance in aviation is the Sioux City DC-10 crash where the flight crew devised a way to control the aircraft after a complete hydraulic failure. There were no procedures so the crew developed a creative solution and in doing so saved lives. Errors at this level are also called mistakes.

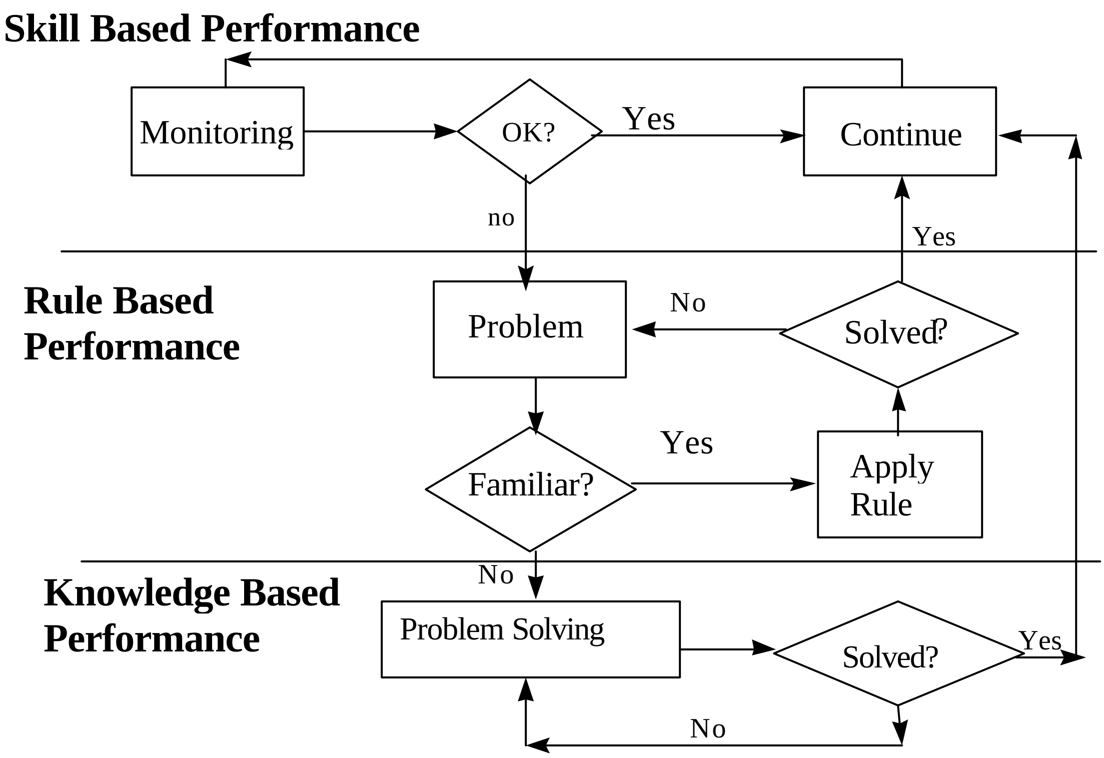

Figure 1 Human Performance Model

The three levels of performance form a sort of hierarchy of responses. People tend to be most comfortable at the skill-based level. Only when it is necessary do we progress to
the rule-based level. If an appropriate rule comes to mind, it will become the plan. Only after the possibility of identifying a rule is exhausted, will we progress to the knowledge-based level of performance.

Error Types

Errors can be classified a number of different ways. In the most basic terms, however, there are two kinds of errors, execution errors and planning errors.

Planning errors involve thinking. Execution errors do not[3]. Execution errors occur at the skill-based level of performance and planning errors occur at the rule and knowledge-based levels of performance. Violations are a particular type of planning error. Most planning errors are probably describable as "honest mistakes". Violations, however, exhibit a wilful disregard of standards or regulations. For the purposes of this study, unsafe acts were classified as execution errors, planning errors, or violations.

The Analytic Process

Arriving at this classification was accomplished by a systematic step-by-step process using accident investigation reports published by the Transportation Safety Board.

Step one is to read the report to understand the chronological sequence of events, actions, and conditions that produced the accident or incident.

Step two consists of identifying the unsafe act, acts, or conditions that are apparent from the sequence.

Step three is to determine the error type. This involves two substeps:

a. determine whether the unsafe act was intentional or unintentional. Did the person intend the action? Unintentional actions are actions that did not go as planned. They are errors of execution. Intentional actions are those that are carried out as planned, but the actions are inappropriate; these are errors in planning; and

b. the second substep is to identify the error type that best describes the error. The choices are: slip, lapse, mistake, or violation.

[3] See James Reason Human Error. 1990. Cambridge. Cambridge University Press.

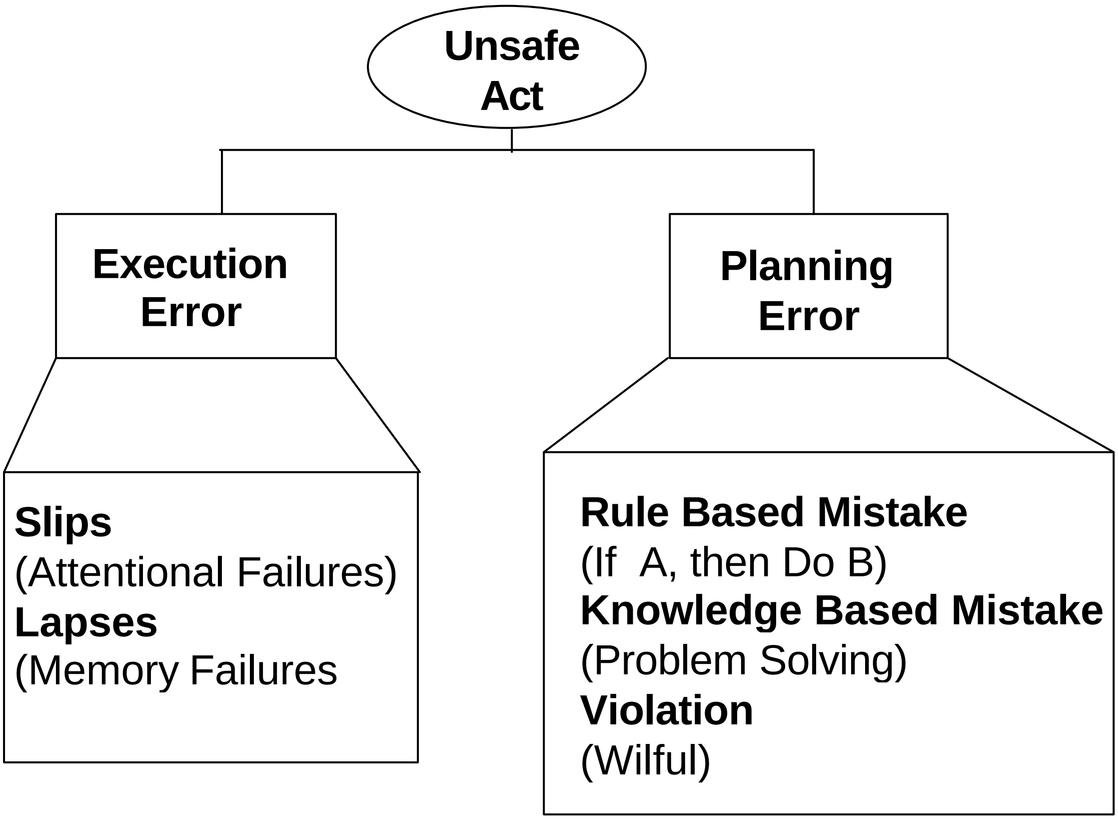

Figure 2. Analytic Process

A slip is an execution error that involves attention, such as selecting the wrong frequency on a radio.

A lapse is an execution error involving a memory failure, such as forgetting to lower the landing gear before touching down.

A mistake is an intentional action, but there is no deliberate decision to act against a rule or standard. Inadvertent VFR flight into IMC is an example.

A violation is a planning error which involved a deliberate decision to act against a rule or standard. Departing on a flight into meteorological conditions known to be below legal limits is a violation identified in this study.

Step four was, to extent possible from the investigation report, identify what events, conditions, knowledge or skill levels were contributory to the unsafe acts. Lack of experience, regulatory inadequacy, fatigue, design features of the aircraft, and operating pressures are examples of such antecedents identified by Reason[4] and others.

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[4] James Reason. Human Error. 1990. Cambridge. Cambridge University Press.