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Identification of a Failed Engine in Twin-Engine Propeller Aircraft: Pilot Surveys

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Twin-engine propeller aircraft accidents occur for many reasons including misidentifying a failed engine. Pilots learn to use a procedure called dead leg-dead engine to identify the failed engine; however, misidentification of the failed engine still occurs, questioning the effectiveness of this procedure. Two surveys were created. Survey 1 was completed by 49 airline pilots operating twin-engine turboprop aircraft; Survey 2 was completed by 22 instructor pilots operating twin-engine piston aircraft. Survey 1: Average flight time was 6,230 hours. Approximately 19% of respondents reported using the Engine-Out procedure at least once. Twenty-nine percent agreed that there could be a better method for failed engine identification. Survey 2: Average flight time was 420 hours. Half of respondents reported using the Engine-Out procedure at least once. Fourteen percent agreed that there could be a better method for failed engine identification. Forty percent of all respondents who suggested improvements recommended adding a visual indicator.

Engine failure is not a rare occurrence in aviation. A review of the National Transportation Safety Board (NTSB) database showed that in visual conditions, engine failure and incorrect handling caused one-third of all accidents in twin-engine piston aircraft (Boyd, 2015). Although a second engine provides additional power and reliability, twin-engine propeller aircraft require special handling in case of an engine failure to ensure the safe outcome of the situation. Not only does a failed engine stop providing power, it also can add significant drag in flight as its propeller starts windmilling, which is followed by a notable yaw toward the failed engine due to thrust asymmetry. An engine failure on takeoff, combined with the propeller drag, may result in a power loss as high as 80% (Federal Aviation Administration [FAA], 2016). Such power loss would be most detrimental at climbout immediately after takeoff when the aircraft is at full power and at a high angle of attack. Hence, a significant portion of multi-engine pilot training is devoted to single-engine operation of twin-engine aircraft and a successful recovery, especially if the failure occurs on takeoff.

Since at least the 1970s (Bramson & Birch, 1973), multi-engine pilots operating propeller aircraft have been trained to utilize the Identify-Verify-Feather (I-V-F) procedure as a response to an engine failure in flight, particularly on takeoff. Per the procedure, as a pilot depresses one rudder pedal to compensate for the yaw from the thrust asymmetry in an effort to stabilize the aircraft, he or she identifies the failed engine by determining which leg is not pushing the rudder pedal (dead leg). The dead leg is on the side of the dead engine, hence this method is called "dead leg – dead engine." Identification is verified by pulling back the throttle of the presumably dead engine and expecting no change in engine sound or power. Finally, the propeller is feathered, i.e., propeller blades are turned parallel to the airflow to minimize drag.

Data collected for a period of 12 years (Sallee & Gibbons, 1999) showed that almost half of all inflight shutdowns in turboprop multi-engine aircraft involved the good (i.e., working) engine. Investigations from several past fatal accidents involving an engine failure on takeoff in a twin-engine propeller aircraft suggested that a working engine was shut down in error (Aviation Safety Council, 2016; National Transportation Safety Board, n.d.). The method currently used for identifying a failed engine may not be effective in all circumstances and may, on the contrary, create confusion in a situation where a startled and preoccupied pilot has little room for error. On takeoff, when pilot workload is at elevated levels, the mental capacity and time available to make a decision are limited, and thus the identification of the failed engine and the action to feather it shall be quick and accurate to avoid a catastrophic outcome. The “dead leg – dead engine” method, however, is reliant on one’s sensation of leg movement and requires mental resources to process that information. Hence, pilots operating twin-engine aircraft may benefit from a simpler and more straight-forward identification method using other sensory channels. Babin et al. (2020) introduced and tested a visual indicator of a failed engine and compared it to the “dead leg – dead engine” method. The visual indicator was designed to provide accurate information at a glance and consisted of a panel with two circles imitating aircraft annunciator lights (one for each engine), colored either in green (engine working) or red (engine not working). The color changed based on the corresponding engine parameters. The results revealed that, in a simulated scenario involving an engine failure on takeoff, pilots who used the visual indicator were able to identify a failed engine significantly faster than those who used the traditional method.

Although the data in the simulated environment highlights the benefits of using a visual indicator, it is important to learn the perspective from operators who have had to deal with real-life engine failures. Even with past accident data and research findings as supporting evidence, reluctance to change exists among the general population, especially when it comes to an FAA endorsed procedure (dead leg-dead engine) commonly taught, practiced, and used. Eliciting pilots’ experiences and opinions would be beneficial to understand the general attitude and receptiveness to potential changes to the current procedures of how pilots identify a failed engine. Two surveys were conducted on twin-engine propeller aircraft pilot opinions of procedure, identification, and verification of a failed engine.

Method

Two surveys were created and distributed to two different pilot groups. Survey 1 was distributed to pilots of a US regional airline operating twin-engine turboprop aircraft. Survey 2 was distributed to instructor pilots at a US aeronautical university.

Participants

Survey 1. Forty-nine airline pilots participated in Survey 1. All participants were employed as pilots (either captain or first officer) at the time of participation and had prior or current experience in operating twin-engine piston and turboprop aircraft.

Survey 2. Twenty-three instructor pilots participated in Survey 2. All pilots had at least a Certified Flight Instructor (CFI) rating and were actively engaged in flight instruction at the time of participating in the survey.

Materials and Apparatus

Survey 1 contained 10 questions, with four open-ended questions, four categorized questions (Yes/No), and one scaled item. Survey 2 contained 11 questions, with six open-ended questions, three categorized questions, and one scaled item. The questions in both surveys asked pilots about their experience flying twin-engine aircraft (and twin-engine turboprop aircraft for airline pilots), difficulties handling an engine failure during simulator training, engine problems encountered in real-life operations, and their opinions on the current method of identification of a failed engine, including how comfortable they were with the I-V-F procedure (scaled from 1 to 5), any positive and negative aspects of the method, and if they had any suggestions for improvement to the current method of identifying a failed engine. Some categorized questions had additional comment fields for participants to provide additional information. Some questions had to be modified between surveys to account for the difference in experience between the two participant groups. Both surveys were created through the https://www.surveymonkey.com website (SurveyMonkey). The surveys had unique links that could be used by participants to access the survey and answer questions. Microsoft Excel and IBM Statistical Package for Social Sciences (SPSS) software were used for data analysis.

Procedure

Each Survey was distributed to pilot groups via an internal email (sent from the Safety Department for Survey 1 and Training Department for Survey 2) asking for their participation and providing a direct link to the survey. Upon following the link, each participant was provided a consent form. Individuals who volunteered to participate were redirected to the next page containing the survey. Individuals who did not agree to participate were redirected to the last page of the survey and prompted to close the browser window. All data were automatically collected and scored by SurveyMonkey and later exported into a spreadsheet for analysis.

Results

Survey 1

The average experience in flying twin-engine turboprop aircraft was 8.97 years (*SD* = 11.21) and 6,230 flight hours (*SD* = 8,695.11). The average experience flying all types of multi-engine aircraft was 13.91 years (*SD* = 12.53) and 7,229 flight hours (*SD* = 8,924.87). The most experienced participants in the sample had 40 years as a pilot and over 30,000 flight hours.

Almost a fifth (18.75%) of all respondents reported utilizing the Engine-Out procedure when operating the twin-engine turboprop aircraft in their capacity as a pilot with the airline. For past simulator training, 23% of respondents admitted having problems with identifying a failed engine at least once, 5.71% of respondents had problems with feathering an engine, and the rest did not report having any problems. Fifty-three percent of respondents reported encountering engine problems at least once in their real-life experience flying all types of aircraft. Although most pilots (71.43%) indicated that they were very comfortable with the I-V-F procedure, 24.49% were somewhat comfortable, 2% felt neutral, and 2% felt somewhat uncomfortable. The most commonly reported benefits of the I-V-F procedure were categorized as “redundant,” “accurate,” and “simple,” and the most mentioned negative aspects of the I-V-F procedure included opportunity for error, high workload that the procedure may introduce, and long time required to complete it. Of the one-third of participants who provided their suggestions for improvement of the current method, 34% suggested adding visual indication (e.g., a light), 22% proposed audio indication, 22% suggested other improvements to the indications, and the other 22% proposed improving aircraft automation to better handle a failure (see Figure 1).

Survey 2

The average flying experience in operating twin-engine aircraft was 4.0 years (*SD* = 7.2) and 419.64 flight hours (*SD* = 631.31). The most experienced participant had 25 years as a pilot and 2,500 flight hours.

Half of the participants reported previously using the Engine-Out procedure in their experience operating twin-engine aircraft. Regarding simulator training experience, 9% reported difficulties identifying a failed engine, 9% reported difficulties verifying a failed engine, and 18% reported problems feathering the failed engine. Forty-one percent of participants reported having had engine problems in their real-life experience. Regarding the current I-V-F procedure, 59% reported that they were very comfortable with the current method, 32% were somewhat comfortable, and 9% were neutral. Most common reported benefits of the I-V-F procedure were described as simplicity, reliability, and ease of remembering, while the most mentioned negative aspects included opportunity for an error if the method is rushed or pilot stress levels are high in an emergency which could potentially cause loss of aircraft control due to a pilot fixating on the procedure. Three pilots (14%) provided suggestions for improvement to the current method. The suggestions included a visual indicator of a failed engine, both an aural or a visual indicator, and an aural indicator that plays a signal on the side of the failed engine (see Figure 1).

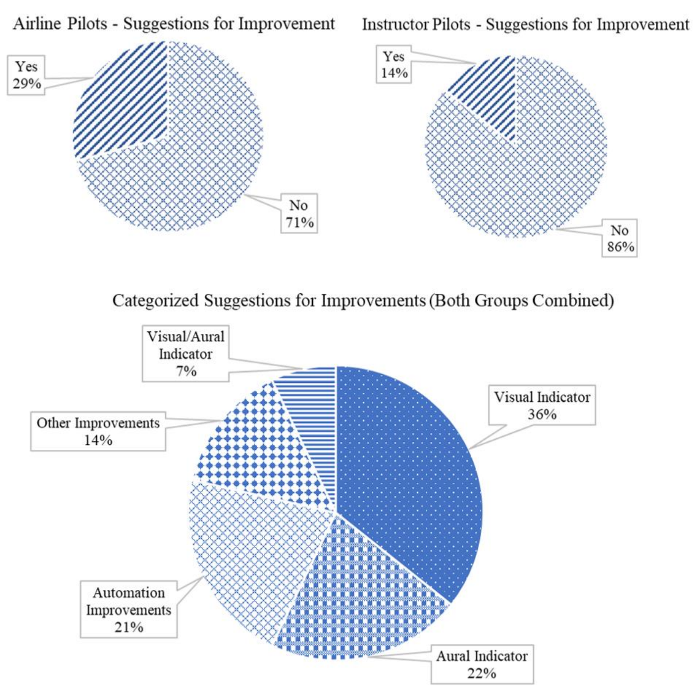

Figure 1. Percentage of participants providing suggestions for improvements to the current method (top) and all suggestions categorized and combined for both groups (bottom).

Discussion and Conclusion

The two pilot groups had different experience, with participants in Survey 1 having more years and hours of flying and aircraft type ratings than participants in Survey 2. This difference provides insight into perspectives and opinions from various representatives of the pilot population, from aspiring pilots at the beginning of their airline careers to seasoned captains. It is notable that both groups had a similar number of pilots who reported experiencing engine troubles before, showing some consistency despite certain difference in aircraft types operated.

A greater number of instructor pilots from Survey 2 reported using the Engine-Out procedure in past experiences compared to the airline pilots from Survey 1. This finding is surprising, considering that overall, participants from Survey 2 had accumulated less flight hours than the participants from Survey 1. Although this greater experience with more Engine-Out experience (despite fewer flight hours) is possible, it could also be caused by the misinterpretation of the questions. In-flight simulation of an engine failure (completed by reducing its power to idle but not shutting it down) is part of the twin-engine pilot training, thus an Engine-Out procedure must be utilized before one becomes a CFI. Additionally, for someone who teaches other pilots to fly twin-engine aircraft, it would be a common practice to utilize the Engine-Out procedure as part of the training curriculum.

Another interesting similarity between the two groups was how comfortable pilots felt with the I-V-F procedure that includes the "dead leg – dead engine" method. Of all respondents (both surveys combined), only one pilot admitted being somewhat uncomfortable with the current method while the majority felt either neutral or comfortable, with most saying they were very comfortable. We believe that several factors may have contributed to this opinion. The "dead leg – dead engine" method is widely common, applicable to most twin-engine propeller aircraft types, hence it is then not unusual that pilots would feel comfortable using it. It is a practice which is recommended by the FAA and is extensively used in pilot training (personal experience revealed that many pilots rated for single-engine aircraft are also familiar with the I-V-F method). Additionally, as pilots undergo periodic proficiency checks to maintain their license, social desirability may have been an additional factor that contributed to their response. Despite the high comfort levels of using the dead leg-dead engine procedure, both groups listed multiple negative issues to the method, including opportunities for error and increased workload, further supporting the potential for a better method of identification of a failed engine.

Possibly the most important findings were in the suggestions provided by the pilot groups. Among all suggested improvements, the overall majority of participants proposed a visual indicator to help in the identification of a failed engine, a trend seen across both more and less experienced pilots. This recommendation can be explained by the fact that 80% of information we receive comes visually (Geruschat & Smith, 2010) and humans tend to prioritize and trust visual information over audio and haptic when it is received at the same time (Xu et al., 2012). Hence it may feel more natural to receive timely and critical information through the visual channel, especially if it is placed in a fashion that it is not intrusive yet remains within the operator's field of view. These suggestions further corroborate findings by Babin et al. (2020) and show that not only a method that relies on the visual channel is more effective in a simulated environment, but its implementation would most likely be accepted and acknowledged by trained and experienced pilots who operate twin-engine propeller aircraft and who would benefit from it.

The results of this study provide a good overview of the opinions of pilots who have been in the profession for years as well as those who may be just starting their careers. It is intriguing that despite the differences in age, flight hours accumulated, and aircraft types operated, one can see similarities in experiences with engine failures and pilot opinions on how to handle them. These results highlight the potential for a better method of identifying a failed engine as shown by the recommendations from those who are most likely to encounter these failures.

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References

Aviation Safety Council (2016). *Aviation occurrence report: 4 February, 2015, TransAsia Airways Flight GE235 ATR72-212A, loss of control and crashed into Keelung river three nautical miles east of Songshan airport* (Report No.: ASC-AOR-16-06-001). Author.

Babin, A. K., Dattel, A. R., & Klemm, M. F. (2020). An alternative method for identifying a failed engine in twin-engine propeller aircraft. *Aviation Psychology and Applied Human Factors*, 10(2), 103–111. doi: 10.1027/2192-0923/a000195

Boyd, D. D. (2015). Causes and risk factors for fatal accidents in non-commercial twin engine piston general aviation aircraft. *Accident Analysis & Prevention*, 77, 113-119.

Bramson, A. E., & Birch, N. H. (1973). *Pilot's guide to flight emergency procedures*. Garden City, NY: Doubleday & Company, Inc.

Federal Aviation Administration (2016). *Airplane Flying Handbook.* Oklahoma City, OK: Author.

Geruschat, D. R., & Smith, A. J. (2010). Low vision for orientation and mobility. In Wiener, W. R., Welsch, R. L., Blasch, B. B. (Eds), *Foundations of orientation and mobility (3rd ed., Vol. 1)*, pp. 63-83. New York, NY: AFB Press.

National Transportation Safety Board (n.d.). *National Transportation Safety Board aviation accident final report* (Accident No. LAX92MA1183). Retrieved from https: //aviation-safety.net/database/record.php?id=19920422-1

Sallee, G. P., & Gibbons, D. M. (1999). Propulsion system malfunction plus inappropriate crew response (PSM+ICR*). Flight Safety Digest*, 18, 1-193.

Xu, Y., O'Keefe, S., Suzuki, S., & Franconeri, S. L. (2012). Visual influence on haptic torque perception. *Perception*, *41*(7), 862-870. doi: 10.1068/p7090