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

Andrey K. Babin
Embry-Riddle Aeronautical University

Andrew R. Dattel
Embry-Riddle Aeronautical University

Twin-engine propeller aircraft accidents occur for many reasons including human factors, such as misidentifying a failed engine. Engine misidentification has led to several fatal accidents. Babin, Dattel, & Klemm (2020) found that, in a simulated engine failure scenario, using a visual indicator for engine identification resulted in significantly lower response time than the "dead leg-dead engine" procedure. To better understand the pilot perspective regarding the issue of engine failure and the method used for the identification of a failed engine, opinions and feedback were collected via surveys. Method: Two surveys were created and distributed among pilots to gather their opinions regarding the issue. Survey One was completed by airline pilots operating twin-engine turboprop aircraft; Survey Two was completed by instructor pilots operating light single- and twin-engine piston aircraft. Results: Forty-nine airline pilots and twenty-three instructor pilots responded to the survey. The average flight experience was 6,000+ flight hours/nine years for airline pilots and 420 flight hours/four years for instructor pilots. Approximately nineteen percent of airline pilots and half of the instructor pilots had had to utilize the engine-out procedure in their prior experience. Most respondents felt comfortable with the current method of identification of a failed engine. Twenty-nine percent of airline pilots and fourteen percent of instructor pilots agreed with the statement that there could be a better method of identification of a failed engine. Forty percent of all pilots who provided suggestions for improvement to the current method (both surveys combined) recommended adding a visual indicator to help with the identification. The results of the surveys provide greater insight into the problem of engine misidentification and suggest that many pilots favor visual cues, supporting findings described in Babin et al. (2020).

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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, but 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 80% to 90% loss in climb performance (Federal Aviation Administration [FAA], 2021). On initial climbout, when the aircraft is at full engine power and a high angle of attack, such reduction in performance is detrimental and can lead to an accident if not resolved properly. 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 in response to an engine failure in flight, particularly on takeoff. Per the procedure, while depressing one rudder pedal to compensate for the yaw from the thrust asymmetry in an effort to stabilize the aircraft, the pilot should determine which leg is not pushing the rudder pedal (dead leg). The dead leg will be on the side of the dead engine; hence this method is called "dead leg – dead engine." Correct identification is verified by pulling back the throttle of the presumably dead engine and expecting no change in engine sound or power. Finally, the pilot feathers the propeller, turning its blades parallel to the airflow to minimize drag.

Some findings point to issues with the identification of a failed engine in propeller aircraft. Data collected for a period of 12 years showed that almost half of all inflight shutdowns in turboprop multi-engine aircraft involved the good (i.e., working) engine (Sallee & Gibbons, 1999). 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.; South African Civil Aviation Authority, n.d.). Wildzunas, Levine, Garner, and Braman (1999; as cited in Aviation Safety Council, 2016) found that 40% of surveyed twin-engine helicopter pilots admitted having confused an engine lever in an emergency at least once either in real life or in a simulator.

It is possible that the method currently used for identifying a failed engine is not effective in all circumstances and can lead to confusion. On takeoff, the mental capacity of a pilot and the time available to make a decision are limited, while the workload is at elevated levels. The high workload is recognized to be correlated with higher error rates and reduced productivity (Harris, 2011). Hence, identification of the failed engine and the action to feather it need to be quick and accurate to avoid a catastrophic outcome. The "dead leg – dead engine" method adds complexity to the process of identification as it relies on one's sensation of leg movement (mechanoreception) and requires additional mental resources to process that information. Furthermore, startle and stress, both of which may accompany an unexpected event such as an engine failure, have been found to delay decision-making, negatively affect operator information processing, and reduce working memory capacity (Martin et al., 2016).

Therefore, pilots operating twin-engine aircraft may benefit from a simpler and more straightforward method for the identification of a failed engine, possibly involving other sensory channels. Many pilots seem to favor warning systems that can help reduce workload through clear indications of the failure and the status of aircraft condition (Ulfvengren, 2001). Typically, aircraft are equipped with visual and audio alerts, and there are advantages and disadvantages to using each. Audio alerts can assist in achieving a shorter response time, immediately bringing a failure to the pilot's attention. Response to a visual alert, on the other hand, has shown better performance of the task at hand (Niu et al., 2019). Niu et al. (2019) suggested that a combination of audio and visual alerts provide the best outcome for short response time and good performance; ultimately however, the selection of the alert type depends largely on its purpose.

The purpose of the "dead leg – dead engine" method, as well as any alert that can potentially replace it, is to relay the critical information to the pilot to ensure that a correct decision is made. Upon reaching the identification phase of handling an engine failure, the pilot would be aware of the failure through other salient stimuli (such as the yaw toward the failed engine or difference in engine sounds). Babin, Dattel, and Klemm (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. Babin et al. (2020) showed 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.

Findings by Niu et al. (2019) suggest that the visual channel may be suitable for handling an engine failure, and Babin et al. (2020) showed the benefits of using a specific visual indicator. However, it is also important to determine the perspective of operators who have had to deal with real-life engine failures and who are the primary users of any methodology for handling 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. For that purpose, surveys were conducted on pilot opinions regarding the procedure for identification and verification of a failed engine in twin-engine propeller aircraft. These surveys were also an attempt to build on the information found by Wildzunas et al. (1999).

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 flight school instructor pilots participated in Survey 2. All pilots had at least a Certified Flight Instructor (CFI) rating and were actively engaged in flight instruction in piston-powered propeller aircraft 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 in general as well as twin-engine turboprop aircraft for airline pilots, difficulties handling an engine failure during simulator training, and past experience with engine problems encountered when operating all types of twin-engine propeller aircraft in real life. The questions asked pilots to also provide 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 comment fields for participants to provide additional information. Several 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 participant in the sample had 40 years as a pilot and over 30,000 flight hours.

Almost one-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. Examples of engine problems are low oil pressure, high oil temperature, low power output, and failures of engine accessories. Although not every pilot mentioned the type of aircraft in which they experienced troubles, the aircraft types that were mentioned ranged from light twin-engine general aviation aircraft to military transport aircraft and civil airlines powered by propeller engines. Although most pilots (71%) indicated that they were very comfortable with the I-V-F procedure, 24% were somewhat comfortable, one (2%) felt neutral, and another one (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 an opportunity for an error, potential high workload, and long time required to complete it. Of the nearly one quarter of participants who provided their suggestions for improvement of the current method, four (34%) suggested adding visual indication (e.g., a light), three (25%) proposed improving aircraft automation to better handle a failure, two (22%) proposed audio indication, and the other two (22%) proposed other improvements to the indications. (see Figures 1, 2, and 3)

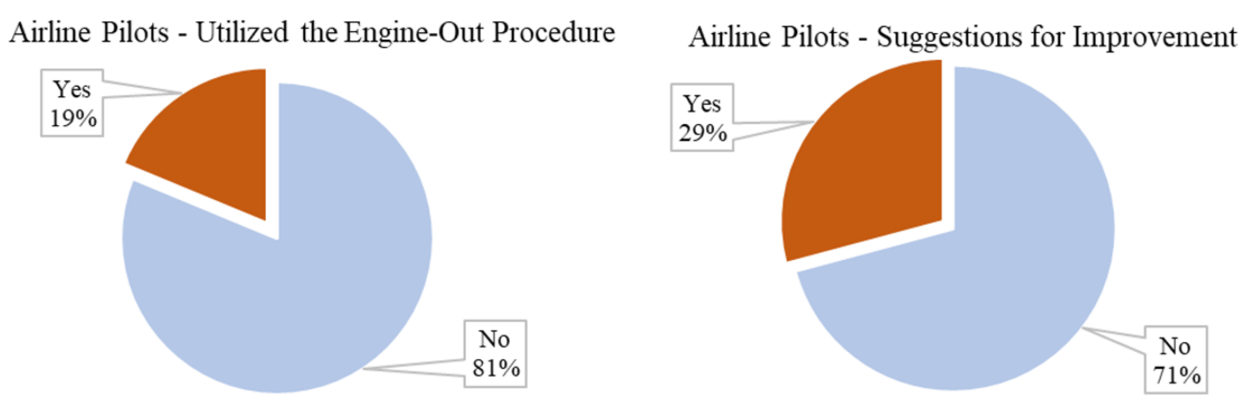

Figure 1. Airline Pilots – Engine-Out Experience and Suggestions for Improvement
Note. The figure shows *the* percentage of airline pilots who have utilized the Engine-Out procedure (left) and airline pilots who have provided suggestions for improvement of the current method (right).

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, two respondents (9%) reported difficulties identifying a failed engine, the other two reported difficulties verifying a failed engine, and four pilots (18%) reported problems feathering the failed engine. Forty-one percent of participants reported having had engine problems in their real-life experience. Most of the reported problems included malfunction of the Engine Control Unit (ECU) or the inability of the engine to maintain stable power output. Considering that surveyed pilots were instructor pilots at a flight school with fewer hours than participants in Survey 1, it seems likely that the engine problems they reported were experienced in GA twin-engine aircraft.

Regarding the current I-V-F procedure, 10 respondents (57%) reported that they were very comfortable with the current method, seven (33%) were somewhat comfortable, and two (10%) were neutral. The most commonly reported benefits of the I-V-F procedure were described as simplicity, reliability, and ease of remembering. The most-reported negative aspect was the 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 Figures 2, 3, and 4).

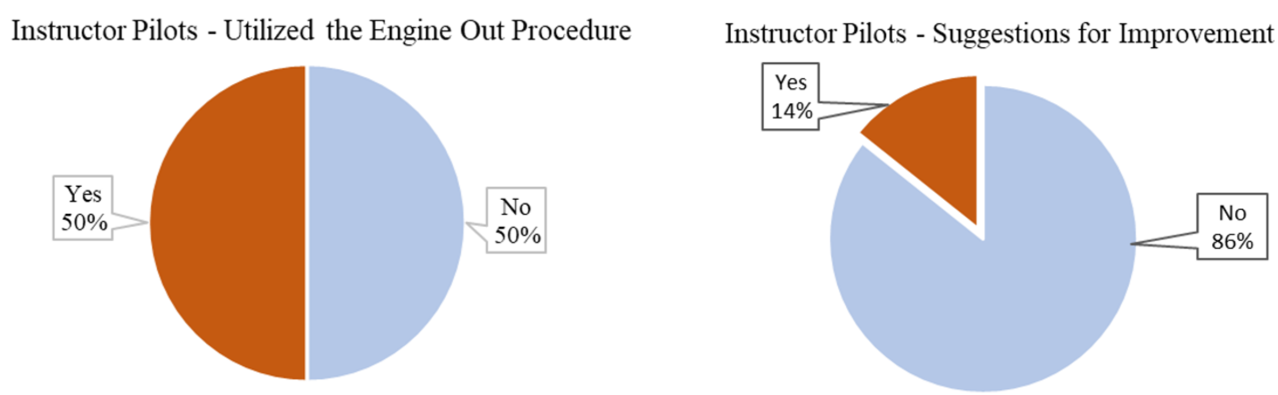

Figure 2. Flight School Instructor Pilots – Engine-Out Experience and Suggestions for Improvement

Note. The figure shows *the* percentage of instructor pilots who have utilized the Engine-Out procedure (left) and instructor pilots who have provided suggestions for improvement of the current method (right).

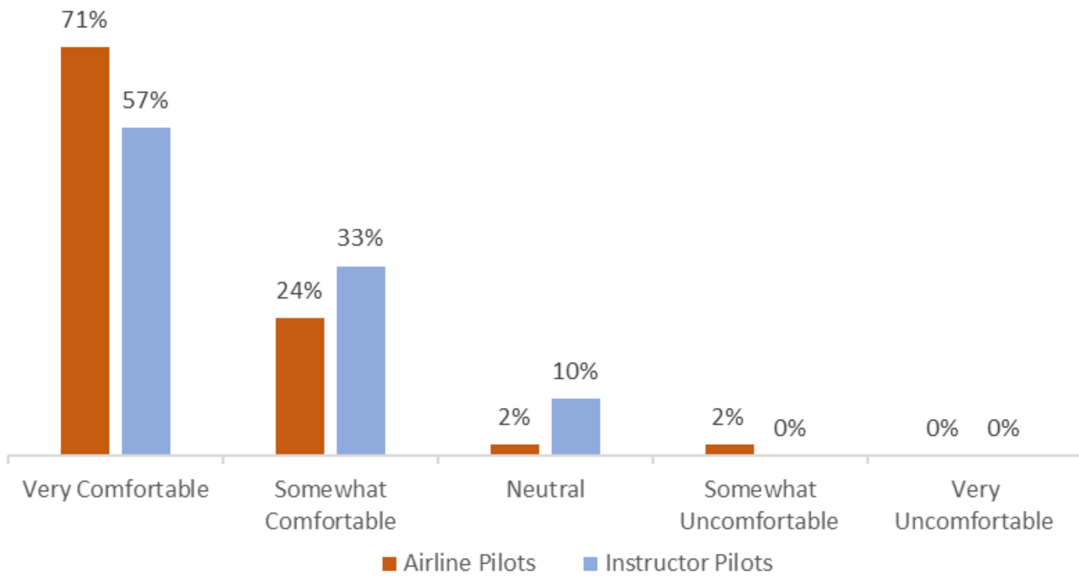

Figure 3. Comfort Levels with the Current Method, Both Groups Combined.

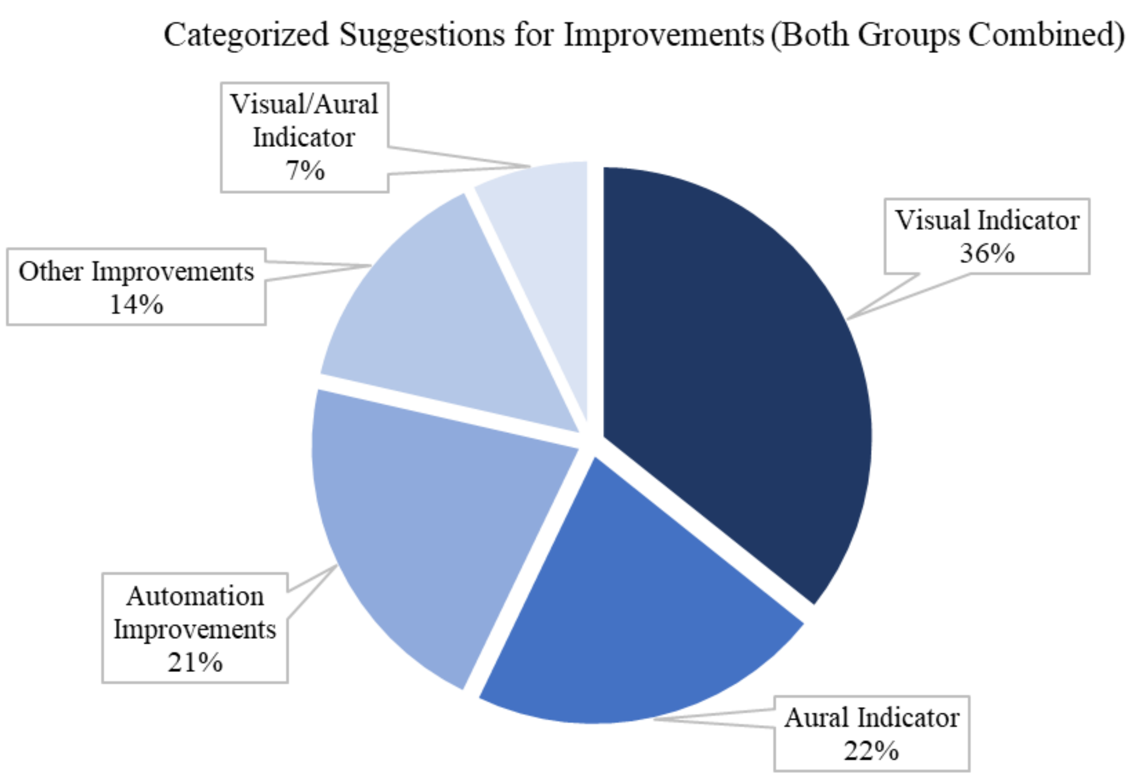

Figure 4. Suggestions for Improvement of the Current Method, Both Groups Combined.

Discussion and Conclusion

The surveys sought feedback from two pilot groups of different experience levels; airline pilots had notably more years and hours of flying and aircraft type ratings than flight school instructor pilots. 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.

A greater number of flight school instructor pilots from Survey 2 reported using the Engine-Out procedure in past flying compared to the airline pilots from Survey 1. Several factors may explain these results. First, targeting different demographics, the two surveys varied slightly – Survey 1 was designed for airline pilots operating a specific aircraft type; thus the Engine-Out question queried particular experience in the type of aircraft operated. Participants in Survey 2, on the other hand, were not trained or rated on a specific aircraft model. Hence the survey inquired about the engine-out experience in multi-engine aircraft in general. Second, because of how the question was structured, it could also be related to how it was interpreted by the respondents. In-flight simulation of an engine failure (completed by reducing its power to idle but not shutting it down) is part of 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. We recognize that a side-by-side comparison of the responses to this question from both groups may not be a one-to-one match and acknowledge that this is a limitation of the survey study. A more determinable finding may be the fact that in both pilot groups, a similar number of respondents reported having had engine troubles at least once while operating multi-engine aircraft. This similarity shows consistency in experience despite a notable difference in aircraft types operated.

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 reported being somewhat uncomfortable with the current method while the majority felt either neutral or comfortable, with most saying they were very comfortable; no pilot stated that they were very uncomfortable with the method. The “dead leg – dead engine” method is widely common and can be used in the operation of many twin-engine propeller aircraft. Considering pilots’ familiarity with the method, it is not unusual that the respondents would feel comfortable using it. The “dead leg – dead engine” is also recommended by the FAA and is part of multi-engine aircraft pilot training - anecdotal evidence from personal conversations suggests that even some pilots only rated for single-engine aircraft are familiar with the I-V-F method. Moreover, considering that commercial pilots undergo periodic proficiency checks to maintain their license, admitting that the pilot is not comfortable with a method that is an essential part of aircraft operation could have a negative effect on confidence. It is not unlikely that social desirability has contributed to survey responses. Therefore, such a finding is not unexpected. However, pilots in both groups listed multiple negative issues to the method, including opportunities for error and increased workload. Many of these respondents also provided suggestions for improvement. Despite the self-reported comfort levels of using the “dead leg-dead engine” procedure, these findings further highlight the potential for an alternative method of identification of a failed engine.

Perhaps 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 the more experienced pilots and the less experienced pilots. This recommendation can be explained by the fact that 80% of information received by humans comes visually (Geruschat & Smith, 2010). People are also more likely to notice visual cues (Hecht & Reiner, 2008) and tend to prioritize and trust visual information over audio and haptic when it is received at the same time (Xu, O'Keefe, Suzuki, & Franconeri 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 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 directly benefit from it. Furthermore, the benefits of the visual channel are recognized in the industry – some displays produced by Garmin offer an indication of a failed engine when a power differential is sensed by the system (Garmin, 2020).

The surveys of this study were intended to provide more insight on pilots' experience in handling a critical system failure while operating a specific class of aircraft as well as solicit their input regarding potential opportunities for improvement. Despite the subjective nature of survey responses, the results found in this study show certain similarities in pilot encounters with the issue of engine failure and engine troubles in general. Although most pilots feel comfortable with the current method, many also agree that it can be improved. We would like to emphasize that the majority of the suggestions for improvement included a visual indicator as means of delivering critical information to the pilot. These findings are important because they indicate the preferences of the end-user and align with evidence from past research.

Considering the benefits of using the visual channel and the preference voiced by the respondents, we recommend continuing to investigate the potential for implementing an alternative method of identification of a failed engine. This study primarily sought to understand whether there is a general interest in such an alternative method. To further explore this alternative method, Babin et al. (2020) recommended performing research studies with pilots who are certified and experienced in operating twin-engine aircraft. A more effective method for identification of a failed engine may not only make improvements to the safe operation of twin-engine propeller aircraft but consequently lead to changes in pilot opinions and preferences.

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