An Alternative Method of Identification of a Failed Engine in Twin-Engine Propeller Aircraft

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Introduction
TransAsia Flight 235

- ATR 72-600 aircraft
- Uncommanded feather of the right engine
- Captain reduced throttle of the left engine and shut it down
- No power at 1,500 feet AGL, engine restart attempts unsuccessful
- Uncontrolled stall and crash
- 43 fatalities
Engine misidentification

• Turboprops: From 1985 to 1997, almost 50% of in-flight engine shutdowns involved a shutdown of the working engine (Sallee & Gibbons, 1999)
• Turbofans: From 1958 to 1997, 29% of in-flight engine shutdowns involved a shutdown of the working engine (Sallee & Gibbons, 1999)
• Twin-engine helicopters: 40% of interviewed pilots admitted moving the throttle of a working engine in emergency in real life/simulator (Wildzunas et al., 1999; as cited in Aviation Safety Council, 2016)
Dangers of twin-engine propeller aircraft operations

• Failed engine creates drag due to the windmilling propeller
• Asymmetric thrust follows, resulting in a significant yaw
• Climb performance loss of up to 80% (Federal Aviation Administration, 2016)
Identify-Verify-Feather

• Identify: “Dead leg – dead engine”
  • Compensate for the yaw by applying rudder
  • Dead leg (not pushing the rudder pedal) is on the side of dead (failed) engine

• Verify: Confirm correct identification
  • Pull back the throttle of the identified engine
  • Expect no change in the direction of flight and engine sound

• Feather the propeller of the failed engine

Source: (Gardner, Schiff, & Bringloe, 2011)
Purpose of the study

• Current method is believed to be too resource-demanding
  • An alternative method was proposed and tested
• The alternative method was based on the visual sensory channel
• Participants flew three flights with simulated engine failures
• Response times and accuracy of identification were measured and compared between two groups (Traditional vs Alternative)
Hypotheses

• H01: There is no difference in accuracy of engine identification between participants using the traditional and the alternative method.
• H02: There is no difference in response time across the three flights between participants using the traditional and the alternative method.
• H03: There is no difference in average response time for all three flights between participants using the traditional and the alternative method.
Lit. Review
Human Capabilities and Limitations

• Stress
  • Stress can affect operator’s judgment and assessment of the situation
  • Evidence that conflicts with expectations may be explained away or ignored (Kontogiannis & Malakis, 2009)

• Workload
  • Increase in workload can impair performance (Casto & Casali, 2013) and lead to problems with task prioritization (Morris & Leung, 2007)
  • Pilot error can become the source of increased workload (Morris & Leung, 2007)
  • Planning for the increase in workload helps avoid detriments to performance (Andre & Heers, 1995)
Human Capabilities and Limitations

• Attention
  • Human brain can handle up to four tasks concurrently without decrease in performance (Fisher, 1984; Julesz, 1981; James, 1980; as cited in Strayer & Drews, 2007)
  • Attention can be influenced by anxiety, making pilot’s gaze behavior more chaotic (Allsop & Gray, 2014)
Haptic vs Visual Sensory Channels

- 80% of information we perceive is visual (Geruschat & Smith, 2010)
- People are more likely to notice visual cues (Hecht & Reiner, 2008) over haptic or auditory
- Information coming through the visual channel gets priority even if an operator knows that it is less reliable than the haptic channel (Xu, O’Keefe, Suzuki, & Franconeri, 2012)
Method
Materials and Apparatus

- X-Plane 11 flight simulation software
- Engine Status Panel
  - Indicates which engine has failed based on the fuel flow value
- Training video
  - Explained basic concepts and the method of identification of a failed engine
- Pre- and post-flight questionnaires
  - Demographics
  - Confidence in correct engine identification
- Three simulated takeoffs
  - Flight 1: Left engine failure 30 sec after rotation
  - Flight 2: Right engine failure 20 sec after rotation
  - Flight 3: Right engine failure 45 sec after rotation
Procedure

• 50 student pilots who did not have multi-engine rating (MEL) and had not started their training were sampled
  • Students received $20 for participation
• Participants were assigned to two groups
  • Traditional Group
  • Alternative Group
• Participants watched a training video
• Participants flew a practice flight
  • Engine failure was demonstrated
  • Participants were given an opportunity to practice the procedure
• Participants performed three takeoffs
  • Engine failure was simulated by failing fuel pumps on the corresponding engine
  • Participants were asked to announce verbally which engine had failed and comment aloud their actions after the failure
Results
Results: Demographics

- 42 Males & 8 Females
- Mean age $M = 20.22$ years ($SD = 2.67$ years)
- Mode age 18 years
- Average flight experience $M = 145.90$ hours ($SD = 75.45$ hours)
Result: Hypotheses testing

• H01: Difference in accuracy of identification between group
  - All participants feathered the correct engine
  - H01 retained

• H02: Difference in response time across flights and between groups
  - 2x3 mixed ANOVA within-subject variable test was not significant
  - H02 retained

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<th>Std. Error</th>
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</table>
Result: Hypotheses testing

• H03: Difference in response time between groups
  • 2x3 mixed ANOVA between-subjects variable was significant at $F(1,48) = 10.83, p = 0.002$
  • Alternative Group ($M = 3.09$ seconds, $SD = 1.84$ seconds) was faster at identification than Traditional Group ($M = 5.09$ seconds, $SD = 2.43$ seconds)
  • H03 rejected
Do you feel that you identified a failed engine correctly for each of the three flights?

<table>
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<th>Flight 1</th>
<th>Flight 2</th>
<th>Flight 3</th>
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<tr>
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</table>

Do you feel that you identified a failed engine in adequate amount of time during each of the three flights?

<table>
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<th>Flight 2</th>
<th>Flight 3</th>
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</tbody>
</table>
Results: Suggestions for improvement

- Audio: 40%
- Instruments: 27%
- Other: 20%
- Other (ESP): 13%
Discussion
Discussion

• Alternative Group was significantly faster at identifying a failed engine than Traditional Group

• Some Traditional Group participants reported using visual cues for identification

• Alternative Group participants were generally more confident in correct identification

• Alternative Group participants reported being generally less confused in regard to which engine was failing
  • Traditional Group: $M = 2.28$, $SD = 1.27$. Alternative Group: $M = 1.84$, $SD = 1.03$. 
Limitations

• The response time was reducing from Flight 1 to Flight 3 for Alternative Group
  • With more power, there could be a significant difference

• 8 participants (6 in Traditional Group and 2 in Alternative Group) moved the wrong throttle initially, but feathered the correct engine propeller
  • Increased response time
  • Might have hastily moved the throttle
  • Possible confusion due to no experience in multi-engine aircraft
  • Observing participant actions could help avoiding the issue in future research

• Participant behavior was not consistent
  • Did not retract landing gear
  • Did not power up
Further research

• Perform similar experiment with multi-engine-rated pilots
  • Determine how past experience affects the ability to use the new method for identification
  • Possibly make further changes to the method

• Identify engine parameters most indicative of the failure
  • Fuel flow was used, but is not enough
  • Several parameters might need to be used
  • Examples: Fuel Flow + Exhaust Gas Temperature
Suggestions

• Particular benefit to General Aviation
  • Reason: Lack of sophisticated systems in GA aircraft
  • Reduce risk of human error in emergency situations
  • Engine Status Panel can be installed aside from other instruments (to avoid clutter)
  • Newly-built aircraft are equipped with glass cockpits, hence the panel can be shown on a display
Conclusion
Conclusion

• Currently recommended method of identification might be too confusing and resource-demanding
  • This is dangerous in case if an engine fails on takeoff (high-workload)
• Using a method based on the visual sensory channel requires less time for identification of a failed engine
• A panel with a visual indicator is recommended to be installed in GA aircraft to reduce the risk of engine misidentification
References


THANK YOU