On Statistics

• “Statistics are like bikinis. What they reveal is interesting. What they conceal is vital!”
  – Professor Aaron Levenstein

• “The purpose of analysis is insight, not bull****”
  – T.C. Weston, The Boeing Company, 1974
Basic Process

• Extract the appropriate Cherokee accidents from the NTSB databases from 2001 to 2010
  – Leave off foreign accidents
• Determine "fleet size"
  – Average number of aircraft from Dec 2000 to January 2011
• Assemble accidents into an analysis database using existing template
• Determine accident causes
  – Read the narrative (not Probable Cause) of each accident
  – Assign to one of 50+ cause categories
• Compare causes for Cherokees vs. a “control group”
• Compare...contrast...analyze
Why Not Just Use the NTSB’s “Probable Cause”? 

A Typical Accident

Flying Along

Engine Quits

Heading for forced landing

Landed Short

The Probable Cause was the failure of an oil line....

The Probable Cause was the pilot's failure to maintain his glide path...

NTSB Investigator #1

NTSB Investigator #2
**Data Sources**

- NTSB makes the full accident reports (less the exhibits) available for downloading
  - Only addressed US accidents of N-Numbered aircraft
- For aircraft fleet sizes, used FAA registration database
  - Personal tradition of downloading every January
- Compared PA-28 rates to those of the Cessna 172

<table>
<thead>
<tr>
<th>Average Fleet Size 2001-2010</th>
<th>Cherokee 140</th>
<th>6127</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warrior I</td>
<td>1238</td>
</tr>
<tr>
<td></td>
<td>Warrior II/III</td>
<td>2033</td>
</tr>
<tr>
<td></td>
<td>Cherokee 180/Archer I</td>
<td>4256</td>
</tr>
<tr>
<td></td>
<td>Archer II/III</td>
<td>2509</td>
</tr>
<tr>
<td></td>
<td>Pathfinder</td>
<td>1062</td>
</tr>
<tr>
<td></td>
<td>Arrow II</td>
<td>1572</td>
</tr>
<tr>
<td></td>
<td>All PA-28</td>
<td>21417</td>
</tr>
<tr>
<td></td>
<td>Cessna 172</td>
<td>25870</td>
</tr>
</tbody>
</table>
Analysis Challenges

- All "PA-28s" are not created equal!
  - "PA-28-XXX" Runs gamut from 140s to Arrow IIs
- Several different models used the same model number for significantly different airframes
  - E.g., Cherokee 180 and original Archer were both PA-28-180s
    - Lengthened fuselage, larger wing and tail span, higher gross weight
- Many models have too few accidents to produce a decent sample size
  - For detailed analysis, required >100 accidents in the ten year period
- Therefore: detailed analysis only of the "PA-28 Set"
  - PA-28-140, -161, -180, -181
  - Covered other models at times

Several different models used the same model number for significantly different airframes

- E.g., Cherokee 180 and original Archer were both PA-28-180s
- Lengthened fuselage, larger wing and tail span, higher gross weight

Many models have too few accidents to produce a decent sample size

- For detailed analysis, required >100 accidents in the ten year period

Therefore: detailed analysis only of the "PA-28 Set"

- PA-28-140, -161, -180, -181
- Covered other models at times
Overall Accident Rates
Terminology Note

• "Fleet Annual Accident Rate":
  – Average number of accidents in a year, divided by the average number of registered examples over the same 10-year period
  – Does NOT take number of hours into account

• "Fatality Rate"
  – Percentage of accidents that resulted in fatalities
Fleet Rate Summary

• Fleet accident rate is about 2/3rds that of the Cessna 172s!
• "Yes, but the Cessna 172 is used as a trainer!"
  – Surprisingly, the PA-28 group was involved in training accidents at a nearly identical rate (~30%)
  – Almost half the Warrior II/III accidents were during training
Fatality Rate

Cessna 172

PA-28 Set

Arrow II

Pathfinder

Archer II/III

Cherokee 180/Archer 1

Warrior II/III

Warrior I

Cherokee 140

Average Fatality Rate
Why is the Cessna 172 Rate Lower?

• Energy in a crash is related to the square of the speed at impact
  – But speed ranges for the most-common PA-28s are about the same as the 172
• Note that the Warrior II fatality rate is a bit less than the Cessna 172
  – Training accidents are generally low-speed affairs
• My work with homebuilts led to a theory that wing position has strong effect on survivability
  – High wing places solid structure above occupant’s heads
Wing Position and Fatality Rate

Cruise Speed (MPH)

Fatality Rate

Wing Position

PA-28-140
-180 -181
PA-28-161
C-172
Homebuilt
Production
Fleet/Fatality Rate Summary

- Training accidents affect both the fleet rate and the fatality rate
- The PA-28 sample used has an almost identical percentage of training accidents, but its fleet rate is about \( \frac{1}{3} \) lower than the Cessna 172
- However, the fatality rate is almost twice as high as the 172
  - May be due to less occupant protection in low-wing aircraft
  - Only way to prove it would be an injury survey
Cherokee Accident Causes
Analysis Process

• Convert NTSB reports to database, including:
  – Date and location
  – Pilot qualifications
  – Type of operation (Personal, Instruction, etc.)
  – Aircraft total time
  – NTSB ruling of the cause of accident

• Read full narrative of each accident
  – Probable Cause often leaves out significant clues

• Enter my own estimation of the cause into database
  – "Initiator"

• Repeat ~560 times for Cherokees, ~1100 times for Cessna 172s

• Compare & Contrast
**Guess Which One is Pilot Miscontrol?**

- **Pilot Miscontrol***
- Maintenance Error
- Undetermined Loss of Power
- Engine Mechanical
- Fuel System
- Landing Gear/Brakes
- Other Mechanical
- Fuel Exhaustion
- Fuel Starvation
- Carb Ice
- VFR to IFR
- Maneuvering at low alt
- Taxi Accident

* "Pilot Miscontrol": Accidents stemming from the pilot's physical handling of the aircraft...overshoot/undershoot, stalls, etc. Does not include Judgment issues such as Fuel Exhaustion, Fuel Starvation, VFR into IFR, etc.

**Percent of Total Accidents**

<table>
<thead>
<tr>
<th>Category</th>
<th>PA-28 Set</th>
<th>Cessna 172</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot Miscontrol*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance Error</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undetermined Loss of Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Mechanical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing Gear/Brakes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Mechanical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Exhaustion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Starvation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carb Ice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VFR to IFR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maneuvering at low alt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi Accident</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Key Points in Causes

• The PA-28 set has a "Pilot Miscontrol" rate ~1/3rd lower than that of the Cessna 172
  – Again, both types have the same percentage of training accidents

• The #2 cause of Cherokee accidents: Fuel Exhaustion!

• PA-28 Set has an accident rate due to Fuel Starvation five times higher than the 172!
  – The good news: Fatality rate for Fuel Exhaustion/Starvation is low (11%)

• Add up all pilot-related errors:
  – PA-28 set: 62%
  – Cessna 172: 76%
Comparing the PA-28 Set

- Maintenance Error
- Undetermined Loss of Power
- Engine Mechanical
- Fuel System
- Landing Gear/Brakes
- Other Mechanical
- Fuel Exhaustion
- Fuel Starvation
- Carb Ice
- VFR to IFR
- Maneuvering at low alt
- Taxi Accident
- Undetermined

Pilot Miscontrol:
- PA-28-140: 39.4%
- PA-28-161: 44.0%
- PA-28-180: 35.1%
- PA-28-181: 40.5%
The Problem With Percentages

- Comparing accident causes by percentages is a bit deceptive
  - If one parameter is higher, the others must be lower
    - Has to still add up to 100%!
- Better approach is to compare the raw numbers of accidents
  - But if the numbers of aircraft don't match, the comparison of meaningless
- Let's **normalize** the number of accidents between types
  - Compute the number of accidents they would have had if the fleet sizes had been the same
    - Multiply PA-28 Set accidents by 1.75
Normalized PA-28/Cessna 172 Comparison

- Maintenance Error
- Undetermined Loss of Power
- Engine Mechanical
- Fuel System
- Landing Gear/Brakes
- Other Mechanical
- Fuel Exhaustion
- Fuel Starvation
- Carb Ice
- VFR to IFR
- Maneuvering at low alt
- Inadequate Preflight
- Fuel Contamination
- Taxi Accident
- Undetermined

Pilot Miscontrol:
- PA-28 Set: 388
- Cessna 172: 740

Number of Accidents
What Does It Mean?

- Really looks like the PA-28 Set is easier to handle than the Cessna 172
  - Number of Cessna 172 miscontrol accidents almost double!
  - Remember, the same rate of training accidents
- Looks like the PA-28 Set is more prone to errors made during maintenance
  - Smaller fleet size, perhaps mechanics aren't as familiar
  - However, this could merely reflect the diligence of Piper Corporation reps involved in investigations
- Higher VFR to IFR accidents probably reflect greater use as traveling aircraft
  - "Gethomeitis" is more prevalent if it's a significant distance
Normalizing Within the PA-28 Set

• Can do the same mathematical trick to compare the four airplanes in the PA-28 Set

• Average Fleet Sizes, 2001-2010:
  – PA-28-140 (Cherokee 140):  6127
  – PA-28-161 (Warrior II/III):  2033
  – PA-28-180 (Cherokee 180/Archer I: 4256
  – PA-28-181 (Archer II/III):  2509
Mechanical Failures
# Mechanical Failures Involved in Cherokee Accidents

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Mechanical</th>
<th>Engine Internal</th>
<th>Fuel FWF</th>
<th>Controls</th>
<th>Gear/Brakes</th>
<th>Propeller</th>
<th>Other</th>
<th>Carburetor</th>
<th>Ignition</th>
<th>Fuel (Airframe)</th>
<th>Oil System</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>556</td>
<td>60</td>
<td>17</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cherokee I40</td>
<td>180</td>
<td>24</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Warrior II/III</td>
<td>125</td>
<td>11</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cherokee I80</td>
<td>130</td>
<td>18</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Archer II/III</td>
<td>121</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Summary Columns*

*Includes both Initiator and Secondary Causes*
# Individual Summaries

## Engine Internal (17)

<table>
<thead>
<tr>
<th>Valve</th>
<th>Valve Lifter</th>
<th>Connecting Rod</th>
<th>Crankshaft</th>
<th>Cylinder</th>
<th>Piston</th>
<th>Muffler</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

## Fuel Firewall Forward (10)
- 8/10 due to faulty maintenance (MX) - mostly disconnected/loose lines
- One due to failed mechanical fuel pump (coinciding with electrical failure)
- One vapor lock

## Controls (7)
- **MX**: Two cases of a cracked vertical stabilizer and the unapproved maintenance modification to the rudder
- Two case of binding/jamming throttle control
- **MX**: Disconnected throttle at carburetor
- Sheared mixture cable
- Disengagement of the left control wheel from the control column (manufacturer error)

## Gear/Brakes (6)
- Three fatigue cracking of the upper torque link attach lugs
- Stress cracking of gear
- Excessively worn brake pads and rotors
- Spongy brakes (pilot elected to fly)
Accidents Related to Maintenance Mistakes

<table>
<thead>
<tr>
<th>Mistakes Made</th>
<th>Procedures Not Followed</th>
<th>Inadequate Inspection</th>
<th>Unapproved Mod</th>
<th>AD/SB not complied with</th>
<th>Unqualified Mx</th>
<th>Misapplied Placard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- "Maintenance Mistakes" are not necessarily made by an A&P
  - Owner modifications
  - Owner not complying with ADs and Service Bulletins
- "Procedures Not Followed" may be an indication of lack of PA-28 experience/documentation

<table>
<thead>
<tr>
<th>System Affected</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel FWF</td>
<td>8</td>
</tr>
<tr>
<td>Engine Internal</td>
<td>3</td>
</tr>
<tr>
<td>Carburetor</td>
<td>3</td>
</tr>
<tr>
<td>Controls</td>
<td>3</td>
</tr>
<tr>
<td>Prop/Spinner</td>
<td>3</td>
</tr>
<tr>
<td>Fuel (Airframe)</td>
<td>2</td>
</tr>
<tr>
<td>Ignition</td>
<td>2</td>
</tr>
<tr>
<td>Gear/Brakes</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>
Wrap-Up
Summary

- While the "Pilot Miscontrol" rate for the PA-28 Set is lower than for Cessna 172s, it is still *four times higher* than the next-highest accident cause.
- That second-highest cause is *fuel exhaustion*.
- Mechanical failures seem to be happening somewhat more often, especially associated with maintenance failures.
  - Could be affected by parts availability.
  - Could just be age.
- Most-common maintenance errors are related to fuel line attachment/routing in the engine compartment.
  - Find a mechanic that knows your aircraft!
- One quarter of all PA-28 accidents start with an engine failure...are you ready?

•
The Fault Lies Not With the Stars...

• Pilots can't usually can’t blame anyone else for an accident
  – Even if it's the maintainer’s fault, it's still our heinies on the line....

• Statistics predict the aggregate, not the individual
  – Just because ~1 in 250 Cherokees will crash this year, DOESN’T mean
    you have a 1 in 250 chance of an accident!

• Minimize your exposure by controlling risks
  – Stay current!
  – Manage your fuel (9% of all PA-28 accidents are fuel exhaustion)
  – Pick your weather (25% of pilot error accidents involve strong winds)
  – Avoid VFR into IFR Conditions (6% of accidents)
  – Learn to manage the Cherokee's fuel system (4% of all accidents)

• Use the resources out there
  – WINGS program
  – Owner’s Group support