Topics

• Trajectory of accident flight
• Bird-strike airframe certification standards
• Variables affecting structural damage sustained during a bird-strike
• Precautionary strategy for minimizing damage in advance of a bird-strike
Trajectory of Accident Flight

- No FDR or CVR data available
- Trajectory estimated using:
  - Radar data
  - Surveillance camera footage
  - Evidence at crash site
  - Simulation
Trajectory of Accident Flight

Approximate bird-strike location

Aircraft image not to scale
Bird-Strike Certification: Part 25

- Several FARs specify bird-strike standards
- FARs 25.571 & 25.631 most relevant to this accident
- Both require continued safe flight and landing following bird-strike
- 25.571 (general structure): 4-lb bird at airplane cruise speed
- 25.631 (empennage): 8-lb bird at airplane cruise speed
- FAA: “a specific rule applying to the entire airplane would only add to the substantiation effort without providing any significant design changes”
Bird-Strike Energy

• Speed and mass define the kinetic energy of the bird relative to the airplane ("bird-strike energy"):

\[ E = \frac{1}{2} m V^2 \]

Where:
- \( E \) = bird-strike energy
- \( m \) = mass of bird
- \( V \) = speed of bird relative to airplane

• Bird-strike damage increases with bird-strike energy
Bird-Strike Energy

\[ E = \frac{1}{2} m V^2 \]
Bird-Strike Energy

- 4 lb bird @ 287 kts has an energy of 14,586 ft-lb.
Bird-Strike Energy

- 4 lb bird @ 287 kts: 14586 ft-lb
- 8 lb bird @ 287 kts: 29172 ft-lb

FAR 25.571 vs. FAR 25.631
Bird-Strike Energy

- 4 lb bird @ 287 kts: 14586 ft-lb
- 8 lb bird @ 287 kts: 29172 ft-lb
- 20 lb bird @ 200 kts: 35416 ft-lb

FAR 25.571
FAR 25.631
Accident

NTSB
Comparison of 4, 8, & 20 lb Birds

- Cormorant (4 lb)
- Canada Goose (8 lb)
- American White Pelican (20 lb)
Example of Bird-Strike Damage

Cessna Citation 500 wing leading-edge damage: 4 lb bird at 287 kts
Minimizing Bird-Strike Damage

• Damage should be survivable if energy is below demonstrated certification values

• To remain below demonstrated bird-strike energy, airplane speed must decrease as bird mass increases

• However, airplane must always remain at or above a safe maneuvering speed

• Other operational considerations may preclude flying at lower speeds
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

Empennage requirement: 8 lb bird at 287 knots
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

Empennage requirement: 8 lb bird at 287 knots
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

Empennage requirement: 8 lb bird at 287 knots

General structure requirement: 4 lb bird at 287 knots
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

Empennage requirement: 8 lb bird at 287 knots

General structure requirement: 4 lb bird at 287 knots

1.3 $V_{STALL}$ (flaps up)
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

General structure requirement: 4 lb bird at 287 knots

Airplane weight = 11,200 lb
Minimum safe speed = 128 kts

1.3 \( V_{STALL} \) (flaps up)
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

General structure requirement: 4 lb bird at 287 knots

Airplane weight = 11,200 lb
Minimum safe speed = 128 kts
Maximum bird weight = 20 lb

1.3 \(V_{STALL}\) (flaps up)
Minimizing Bird-Strike Damage

Airplane speed and bird weight relationships for equivalent bird-strike energy

General structure requirement:
4 lb bird at 287 knots

Airplane speed = 200 kts
Maximum bird weight = 8 lb

1.3 \( V_{STALL} \) (flaps up)
Summary

• Analysis of radar, video, crash site, and simulation data indicates loss of control and rolling dive following bird-strike

• Energy of bird-strike exceeded certification requirements of the Cessna 500

• FARs governing bird-strikes do not require uniform bird weights across all aircraft structures

• The risk of catastrophic damage from a bird-strike can be reduced by remaining within the demonstrated bird-strike energy envelope
### Part 25 Bird-Strike Standards

<table>
<thead>
<tr>
<th>FAR</th>
<th>Component(s)</th>
<th>Bird-strike parameters</th>
<th>Performance requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.571(e)(1)</td>
<td>General structure</td>
<td>4 lb.</td>
<td>$V_C$ @ sea level / .85 $V_C$ @ 8000 ft</td>
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<tr>
<td>25.631</td>
<td>Empennage</td>
<td>8 lb.</td>
<td>$V_C$ @ sea level</td>
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<tr>
<td>25.775(b)</td>
<td>Windshield</td>
<td>4 lb.</td>
<td>$V_C$ @ sea level</td>
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<tr>
<td>25.775(c)</td>
<td>Windshield</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>25.1323(j)</td>
<td>Duplicate pitot tubes</td>
<td>Not specified</td>
<td>Not specified</td>
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## Part 23 Bird-Strike Standards

<table>
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<th>FAR</th>
<th>Component(s)</th>
<th>Bird-strike parameters</th>
<th>Performance requirement</th>
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</thead>
<tbody>
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<td>23.775(h)(1)</td>
<td>Windshield</td>
<td>2 lb.</td>
<td>Maximum flap approach speed</td>
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<td>Bird does not penetrate windshield</td>
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<tr>
<td>23.1323(f)</td>
<td>Duplicate pitot tubes</td>
<td>Not specified</td>
<td>Not specified</td>
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<td></td>
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<td>Bird does not damage both tubes</td>
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</tbody>
</table>
# Part 29 Bird-Strike Standards

<table>
<thead>
<tr>
<th>FAR</th>
<th>Component(s)</th>
<th>Bird-strike parameters</th>
<th>Performance requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.631</td>
<td>General structure</td>
<td>Bird mass: 2.2 lb. Aircraft speed: Lesser of $V_H$ or $V_{NE}$ to 8000 ft.</td>
<td>Continued safe flight and landing (Category A); Safe landing (Category B)</td>
</tr>
</tbody>
</table>
Part 33 Bird-Strike Standards

- Bird ingestion standards for turbine engines are specified in FAR 33.76
- Standards consider multiple scenarios involving different sizes and numbers of birds, depending on engine inlet area
- Performance criteria include both safe-shutdown and run-on requirements
- This subject discussed at Public Hearing on US Airways Flight 1549
Minimizing Bird-Strike Damage

- 4 lb bird @ 287 kts: 14586 ft-lb
- 8 lb bird @ 287 kts: 29172 ft-lb
- 20 lb bird @ 200 kts: 35416 ft-lb

Bird-strike energy, ft-lb

FAR 25.571  FAR 25.631  Accident