Bird strikes to aircraft sensors: an overlooked concern for aviation safety?



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Findings and recommendations expressed in this presentation do not necessarily represent the position of the U.S. Federal Aviation Administration

United flight from Tampa spends hours burning fuel after bird strike

Mar 16 2018

TAMPA (FOX 13) - Shortly after 8 a.m., United Airlines flight 2051 took off for San Francisco. Moments later, it hit a flock of birds.

As a result, the pilot flew in circles around the Gulf of Mexico for 3 hours to burn fuel so the A320 aircraft could lose enough weight to land properly. It finally landed at about 11:30 a.m.

Pilot reported damage to Pitot tube.

Right Pitot tube was inspected and had visible bird snarge inside (Rock pigeons).

Sent: **March 16, 2018**

To: Dove, Carla; Dolbeer, Richard

Subject: Simulation of Snarge-Clogging Aircraft Sensors

We recently had a question arise regarding how we might be able to predict, via simulation, **the clogging of air sensors** by snarge resulting from a bird strike.

I have conducted a preliminary literature survey without much success… Any guidance would be greatly appreciated.

Peter Kohlert
Advanced Structural Analysis
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	Part of aircraft	Struck	Damaged
1	Radome	✓	✓
2	Windshield	✓	
3	Nose		
4	Eng #1		
5	Eng #2		
6	Eng #3		
7	Eng #4		
8	Propeller		
9	Wing/rotor		
10	Fuselage		
11	Landing gear		
12	Tail		
13	Lights		
	Struck_other	✓	✓
	Other_specify	Pitot tube	

NWSD

Structure of data entry:

-Parts struck

-Parts damaged

Free text

7 months after Northrop Grumman inquiry about Pitot tubes

29 Oct 2018: Lion Air Flight 610, a Boeing 737 Max, crashed in the Java Sea 12 minutes after takeoff from Jakarta, **killing all 189 people** on board.

9 days later

7 Nov 2018: FAA issues Emergency Airworthiness Directive (2018 23-51) to owners of B-737 Max aircraft

7 Nov 2018: Emergency Airworthiness Directive (2018 23-51) to owners of B-737 Max aircraft

"This AD was prompted by analysis performed by the manufacturer showing that **if an erroneously high single angle of attack (AOA) sensor input** is received by the flight control system*, there is a potential for repeated nose-down trim commands of the horizontal stabilizer…..which could cause the flight crew to have difficulty controlling the airplane, and lead to excessive nose-down attitude, significant altitude loss, and **possible impact with terrain**."

***The stall prevention system, known as MCAS, relied on a single sensor for Angle of Attack (AOA) measurement.**

MCAS = Maneuvering Characteristics Augmentation System

132 days after Lion Air crash
123 days after Emergency AD 2018 23-51

10 Mar 2019, Ethiopian Airlines flight 302 from Addis Ababa, to Nairobi, faltered and crashed soon after taking off, **killing all 157 people** on board.

Note: This was not the first B-737 to crash in Ethiopia. On 15 Sep 1988, a B-737 ingested speckled pigeons in both engines on take-off run from Bahir Dar airport: 35 fatalities, 21 injuries, hull loss.

72 days later: Wall Street Journal, 21 May 2019

“U.S. aviation authorities regard a collision with one or more birds as the most likely reason for trouble with the sensor, according to industry and government officials familiar with the details of the crash investigation.”

“U.S. government and industry safety experts…have said information downloaded from “black box” flight-data recorders *points strongly to a sensor that was sheared off or otherwise rendered inoperable shortly after takeoff.*”

https://www.wsj.com/articles/boeing-official-played-down-scenario-that-may-have-doomed-ethiopian-jet-11558439651

So, relevant questions are:

- **Are data available documenting bird damage to AOA vanes and other sensors critical to flight safety?**
- **Should aircraft have redundant sensors/back-up plans in case such damage occurs?**
- **Can sensors be made more resistant to bird damage?**

New York Times 1 June 2019

Bird strikes on angle-of-attack sensors are relatively common.

A Times review of two FAA databases found hundreds of reports of bent, cracked, sheared-off, poorly installed or otherwise malfunctioning angle-of-attack sensors….

Since 1990, one database has recorded 1,172 instances when birds damaged sensors of various kinds, with 122 strikes on angle-of-attack vanes.

….. a single angle-of-attack sensor was the lone guard against a misfire. Although modern 737 jets have two angle-of-attack sensors, **the final version of MCAS took data from just one.”**

https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html


Parts struck by birds
(N = 180,000)*
1%
60%
14%
4%
12%
*FAA National Wildlife
Strike Database, 1990-2018

Reported bird strikes with sensors in NWSD, civil aircraft, USA, 1990-May 2019

Part	Reported strikes	% with damage or NEOF
Pitot tube	711	53.6
Antenna	247	71.3
AOA vane	148	56.8
Temp sensors (TAT)	143	35.7
Ice sensors	62	58.1
Total	1,311	55.5

NWSD examples: strikes to AOA sensors on B-737s (1 of 2)

REMARKS
Broke Angle of Attack probe.
Bird knocked off AOA probe on Captain's side.
Bird hit rt side AOA vane, split in half
Struck AOA vane and then hit right wing.
Birdstrike broke left AOA vane, immediate stick shaker.
Large bird strike appeared to shear off alpha vane.
Declared emergency; Alpha vane sheared off.
Birdstrike @ liftoff; overwt landing. AOA vane broken off.
Stall warning vane damaged

NWSD examples: strikes to AOA sensors on B-737s (2 of 2)

REMARKS
AOA vane damaged. Bird ingested.
Pilot rptd the loss of some systems; AOA vane sheared off.
Emergency landing. Angle of Attack indicator sheared off.
AOA broken off the a/c when the a/c hit bird
Pilot notified SEA that AOA indicator was broken
Birdstrike broke off left side AOA sensor
Bird hit AOA sensor on right side; Also damaged fan blade.
Birds struck the AOA vane right side and ripped it off

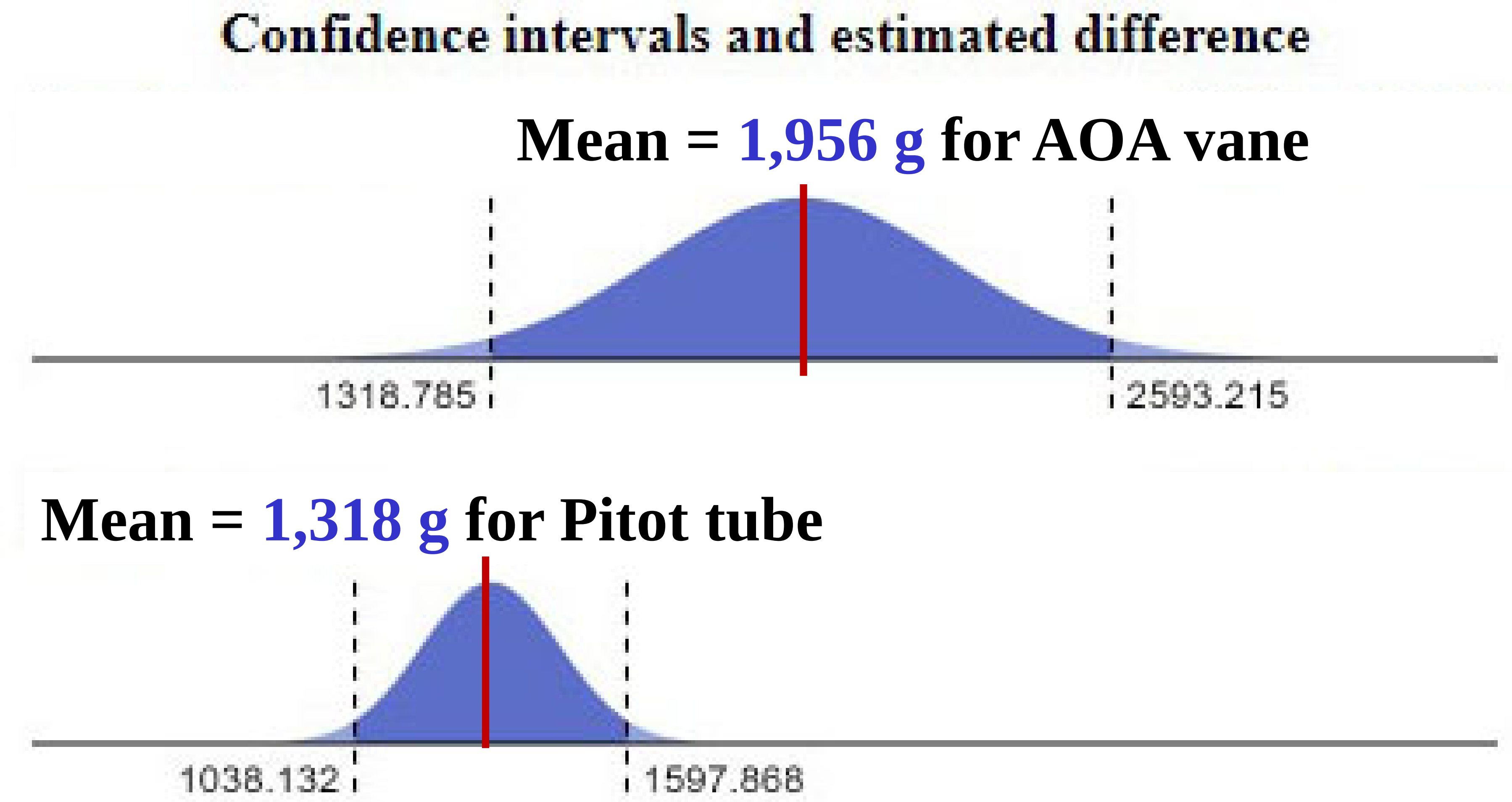
Phase of flight for strikes with AOA sensors, civil aircraft, USA, 1990-2018

Phase of flight	Reported strikes	% of total known
Take-off run	16	11
Climb	28	20
Enroute	1	1
Approach	80	57
Landing roll	15	11
Total known	140	100
Unknown	8	
Total	148	

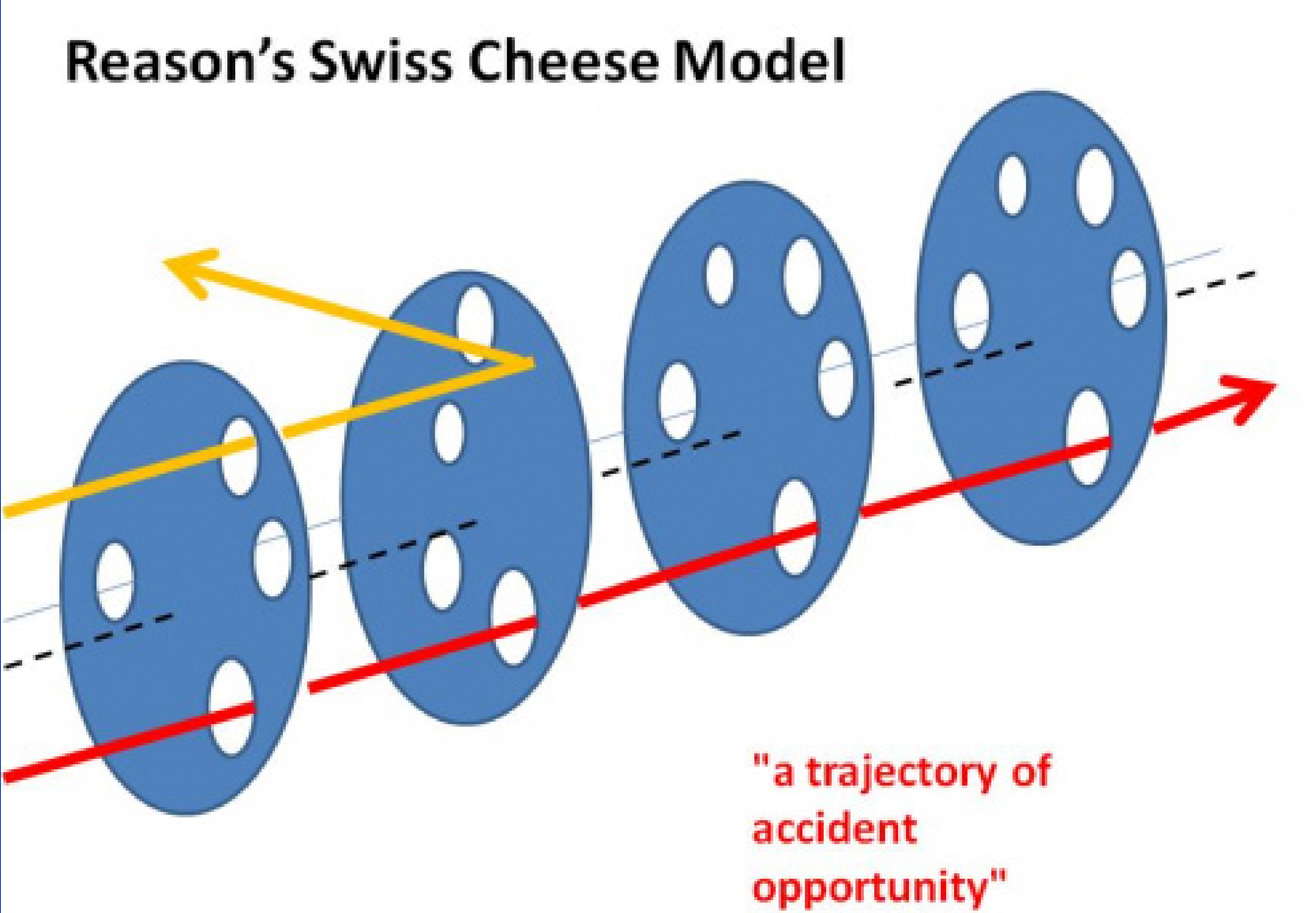
Bird species causing adverse-effect events involving AOA sensors, civil aircraft, USA, 1990-2018

Species group	Number
Gulls	13
Geese and swans	8
Herons and egrets	6
Raptors	6
Doves and pigeons	5
Ducks	5
Owls	4
Small passerines	4
Vultures	3
Pelicans	1
Crows	1
Shorebirds	1
Unknown bird	27
Total	84

Mean mass of bird causing adverse effect on flight for AOA vanes vs Pitot tubes, civil aircraft, USA, 1990-2018

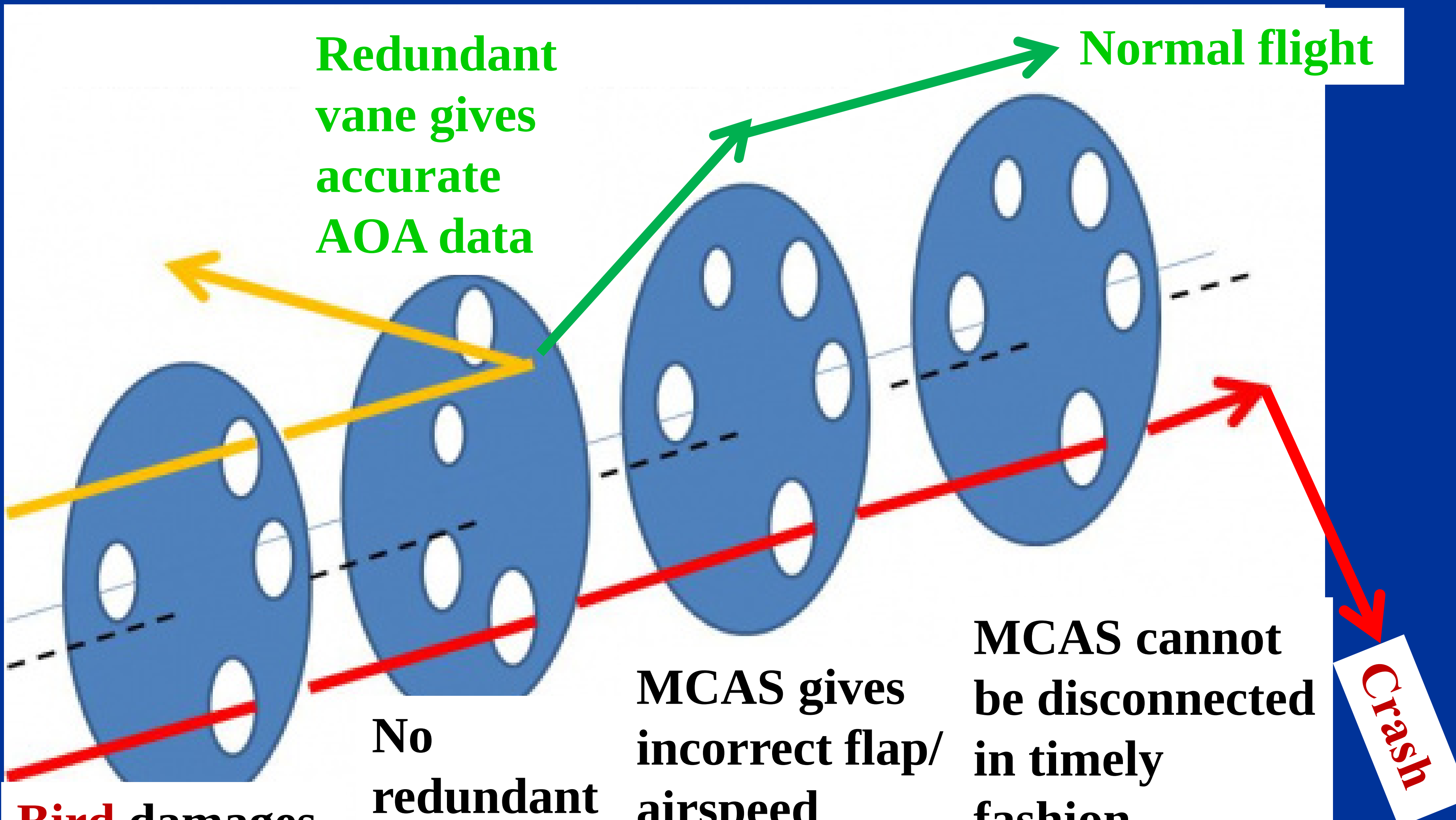


Difference of means = 638 g (1.4 lbs), *p* = 0.07



Reason, James. 1990. **The contribution of latent human failures to the breakdown of complex systems**. Philosophical Transactions Royal Society of London. Series B, Biological Sciences. 327 (1241): 475–484.

Possible scenario for Ethiopian Flight 302, 10 Mar 2019*



Bird damages AOA vane in initial climb

No redundant AOA vane for MCAS

MCAS gives incorrect flap/ airspeed commands

MCAS cannot be disconnected in timely fashion

*Based on accounts in WSJ, NYT, other media sources

Conclusions

- Sensors are critical components of modern aircraft.
- The NWSD has unequivocal data demonstrating sensors are vulnerable to damage by birds.
- These data provide characteristics of damage for sensors (e.g., bird species/mass, phase of flight, location of sensors on A/C) useful in risk mitigation regarding:

  a) design, placement & redundancy of sensors;
  b) procedures to handle erroneous data from damaged sensors.

- Strikes to sensors should be carefully documented when reporting strikes.

Our Goal:

Safer Skies for all who fly ….

Birds *and* People!

Questions?