Aircraft Systems Interactions

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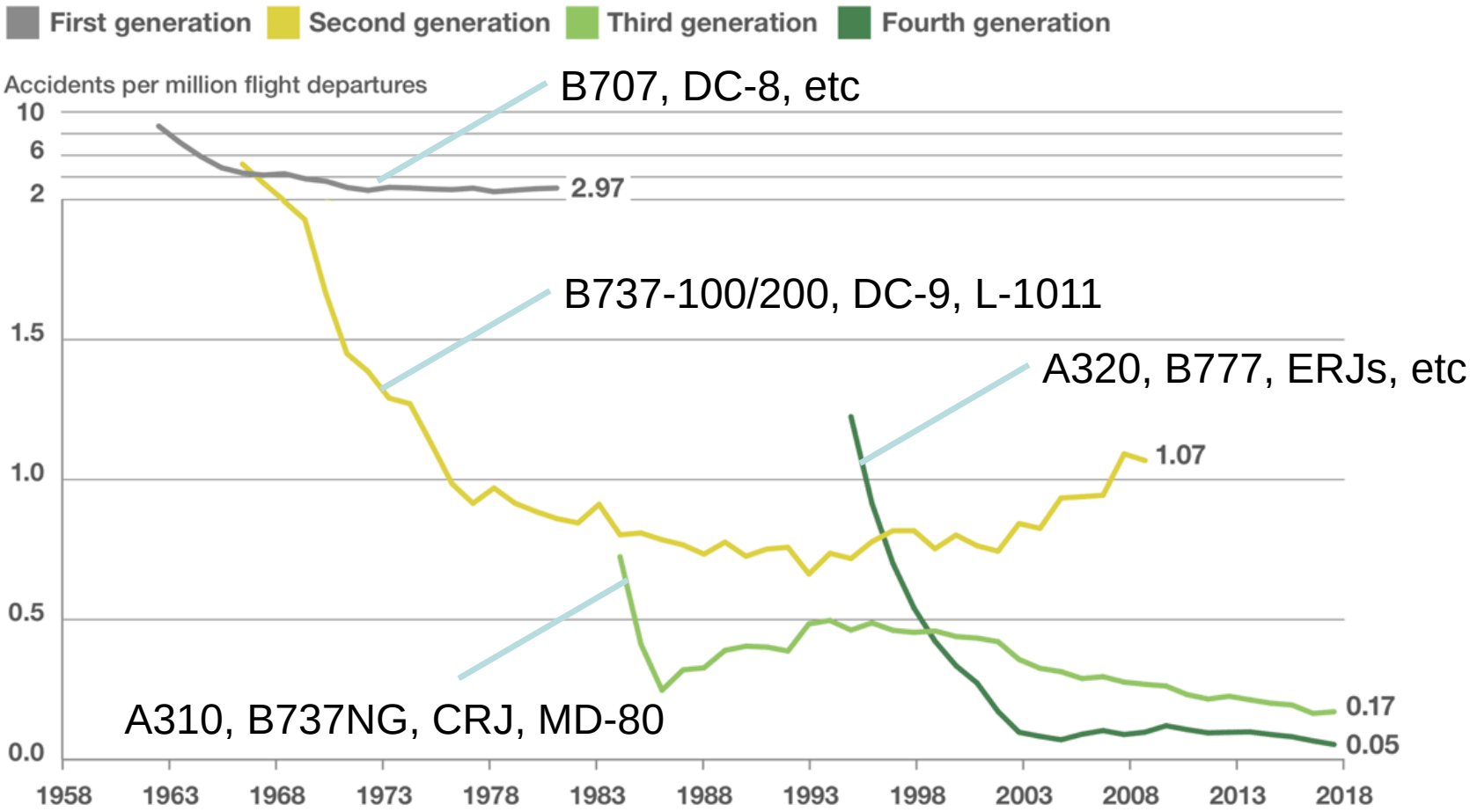
Main points

- Continue to be surprised by systems interactions
- Regulations exist…challenge is proving they are met
- Nothing replaces understanding

Outline

- Accidents
- Regulation
- More capability → more difficulty
- Architecture evolution and challenges
- Monitoring/alerting evolution
- What to do

Accidents


First generation
Second generation
Third generation
Fourth generation
Accidents per million flight departures
10
6
2
1.5
1.0
0.5
0.0
2.97
1.07
0.17
0.05
B707, DC-8, etc
B737-100/200, DC-9, L-1011
A320, B777, ERJs, etc
A310, B737NG, CRJ, MD-80
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018

Aircraft Systems Accidents

- Airbus Industrie Flight 129, June 1994, Toulouse
  - A330
  - Demonstrating takeoff capability with single engine
  - Autopilot in altitude acquisition climbed towards 2000 ft, pitching to 32 degs
  - Airspeed decreased to 100 kts due to insufficient thrust
  - Hull loss, all 7 aboard killed
- Contributing cause: Lack of attitude protection in altitude capture mode

Aircraft Systems Accidents

- China Airlines 140, April 1994, Nagoya
  - A300
  - First officer inadvertently selects TO/GA at 1000 ft
  - Crew attempts to correct by reducing thrust, but A/P remains in TO/GA mode
  - Stab continues trimming nose-up. First officer counters with nose-down column
  - Control transferred to Captain who calls for a go-around
  - Stabilizer position with full go-around thrust causes uncontrolled pitch-up and stall (~34 kts airspeed)
  - Hull loss, 264 fatalities
- Contributing cause: Autopilot should have disconnected with first officer's nose-down column inputs…also, simulator may have suggested enough elevator authority was available in go-arounds

Aircraft Systems Accidents

- Turkish 1951, Feb 2009, Amsterdam
  - B737-800
  - Left radar altimeter shows -8 ft, putting A/T into retard flare mode
  - ATC had crew intercept glideslope from above, masking A/T mode
  - Aircraft not stable at 1000 ft, yet approach continued
  - Aircraft pitches up to maintain glideslope and speed decreases to shaker activation
  - F/O pushed throttles forward
  - Capt takes control and A/T again reduces throttles to idle…aircraft stalls
  - Hull loss, 9 fatalities, 5 serious injuries
- Contributing cause: Faulty radar altimeter caused autothrottle to go to retard flare mode

Aircraft Systems Accidents

- Asiana 214, July 2013, San Francisco
  - B777
  - ILS inoperative, visual approach
  - Well above glidepath at 5 nmi
  - To capture path, pilot selects FLCH SPD, which causes climb
  - Pilot disconnects A/P, moves thrusts levers to idle, which puts A/T in HOLD mode
  - Aircraft slows, descends rapidly, shaker activates, go-around decision too late
  - Hits seawall
  - Hull loss, 3 fatalities, 48 seriously injured
- Contributing cause: Complexities of the autothottle and autopilot systems…mode error

Aircraft Systems Accidents

- Emirates 521, Aug 2016, Dubai
  - B777
  - Shifting winds on final from headwind to 16-kt tailwind
  - Main landing gear touch at 1100 m from threshold at 162 kts IAS
  - Runway Awareness Advisory System aural activates
  - 5 secs after touchdown, aircraft becomes airborne, flaps to 20, gear up
  - Reaches 85 ft at 134 kts, and sinks back to runway
  - Throttles moved from idle to full forward 12 secs after becoming airborne
  - Belief is that TOGA activated after mains contacted – requires manual throttle
  - Hull loss, 1 fire fighter killed, 1 serious injury
- Contributing cause: Final report not complete

Regulations

- Part 25.1302 - Installed systems and equipment for use by the flightcrew
  - "…The applicant must show that these systems and installed equipment, individually and in combination with other such systems and equipment, are designed so that qualified flightcrew members trained in their use can safely perform all of the tasks associated with the systems' and equipment's intended functions."
- Part 25.1309 – Equipment, systems, and installations
  - (b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that
    - (1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and
    - (2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable

More capability → more difficulty

- More complexity (in function, followed then by software) makes analysis and testing more difficult
- Assumptions in failure identification and mitigation by pilot may be accordingly optimistic
- Trend is more interaction between both systems and equipment, which adds to verification and validation process…more possible errors

Architecture evolution and challenges

- Federated architecture

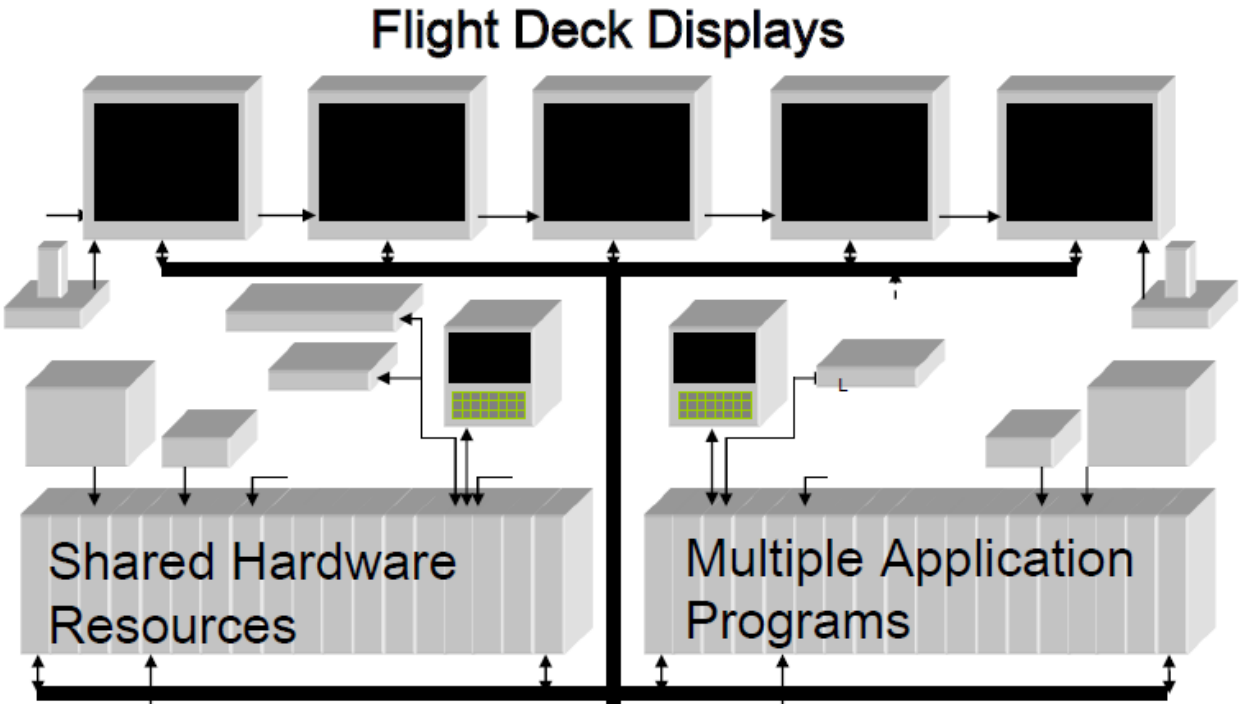
<u>Single string</u>
Apollo guidance
AV-8B Harrier

<u>Dual strings</u>
B737
A300

<u>Triplex</u>
A330

Architecture evolution and challenges

- Integrated Modular



B777, B787, A350, A380, A220

Monitoring and alerting evolution

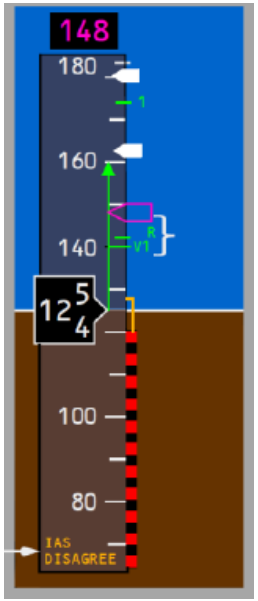
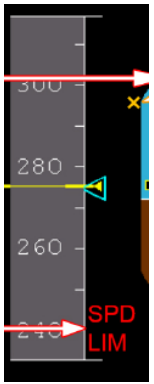
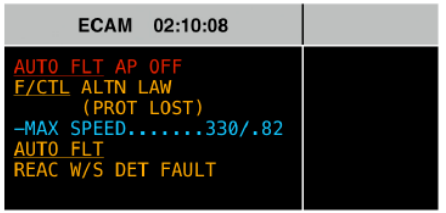


Figure 4. PRIMARY EICAS.





With time, going from alerts to prioritization to checklist steps

What to do

- Study, study, study
- Simulate, simulate, simulate
- But, probabilities are determined analytically…and they can be wrong
- So, even though you study, study, study and simulate, simulate, simulate:
  - the probabilities can be wrong…that is, what you thought never could happen ends up happening
  - as there are an infinite number of possible failure conditions, you might not study or simulate the one that happens to you
- Certainly, data sharing for remote events helps!

Conclusions

- Continue to be surprised by systems interactions
- Regulations exist…challenge is proving they are met
- Nothing replaces understanding