# What the Processing Industry Must Learn From the Boeing 737 MAX Crashes


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- Complex physical and electronic systems
- Operated by trained and experienced personnel
- Potentially catastrophic incidents caused by multiple failures
- Automatic and manual safeguards

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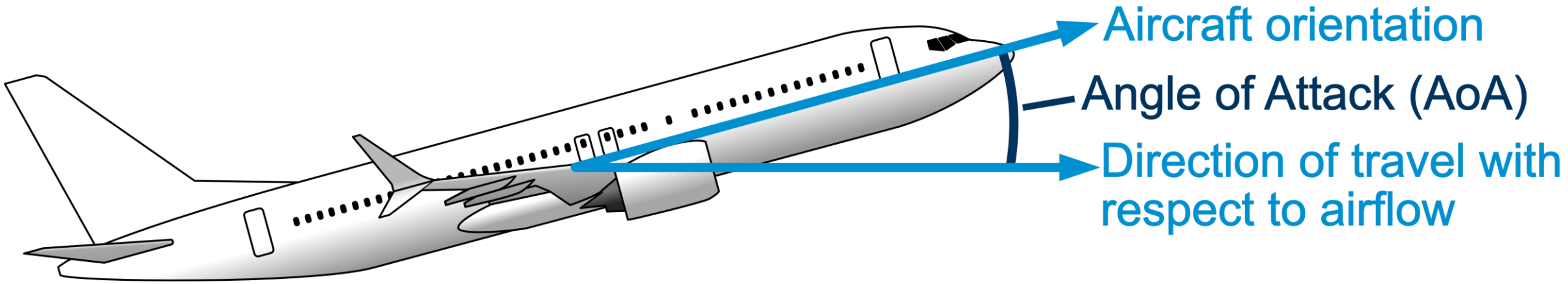
# Maneuvering Characteristics Augmentation System (MCAS)



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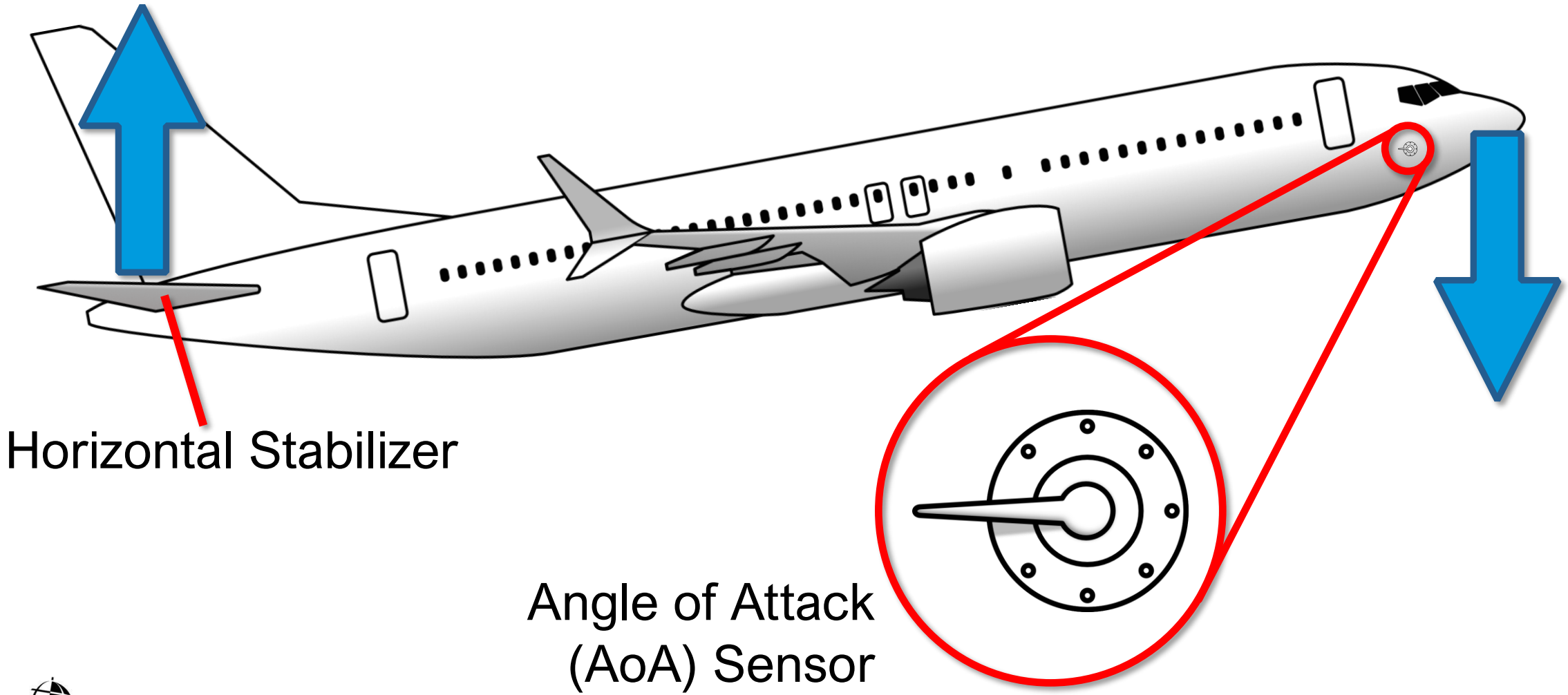


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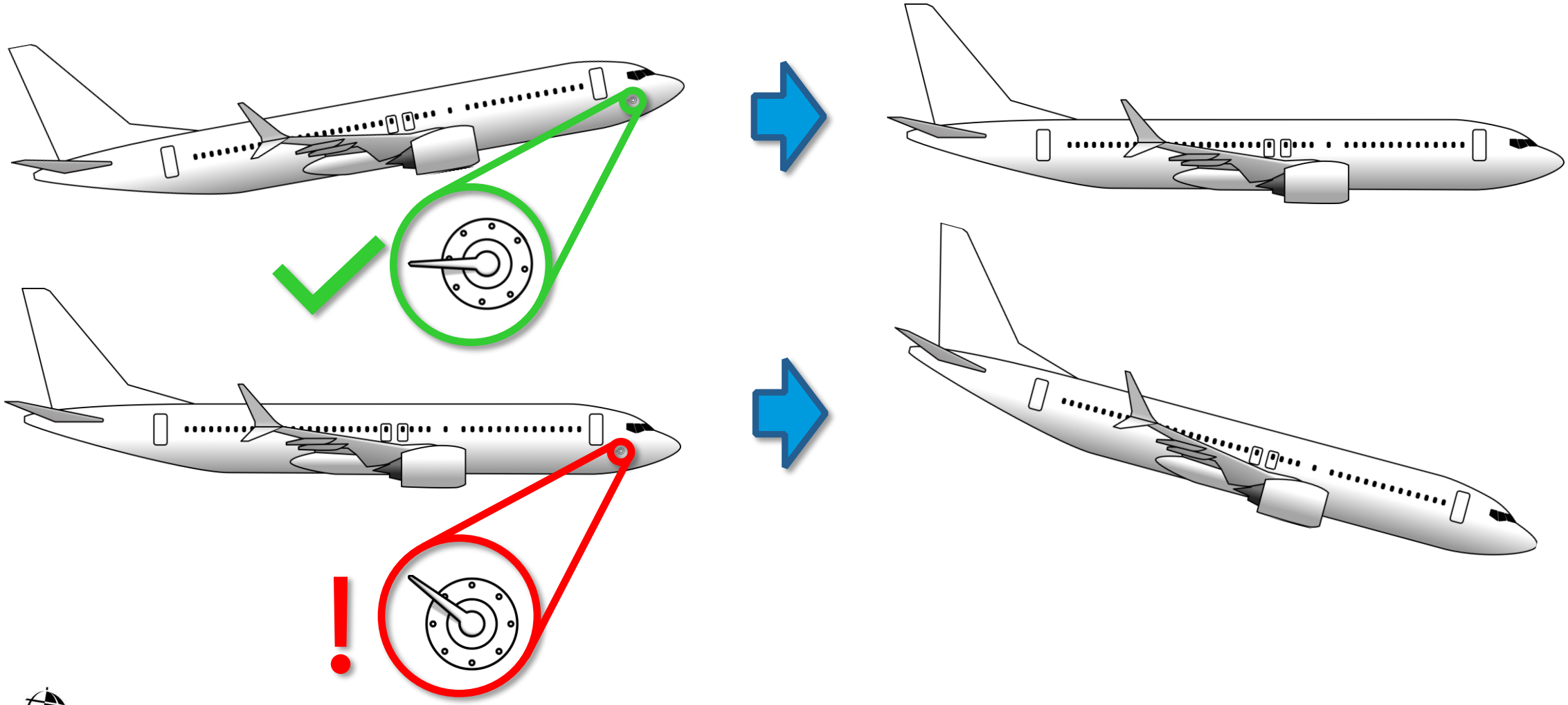


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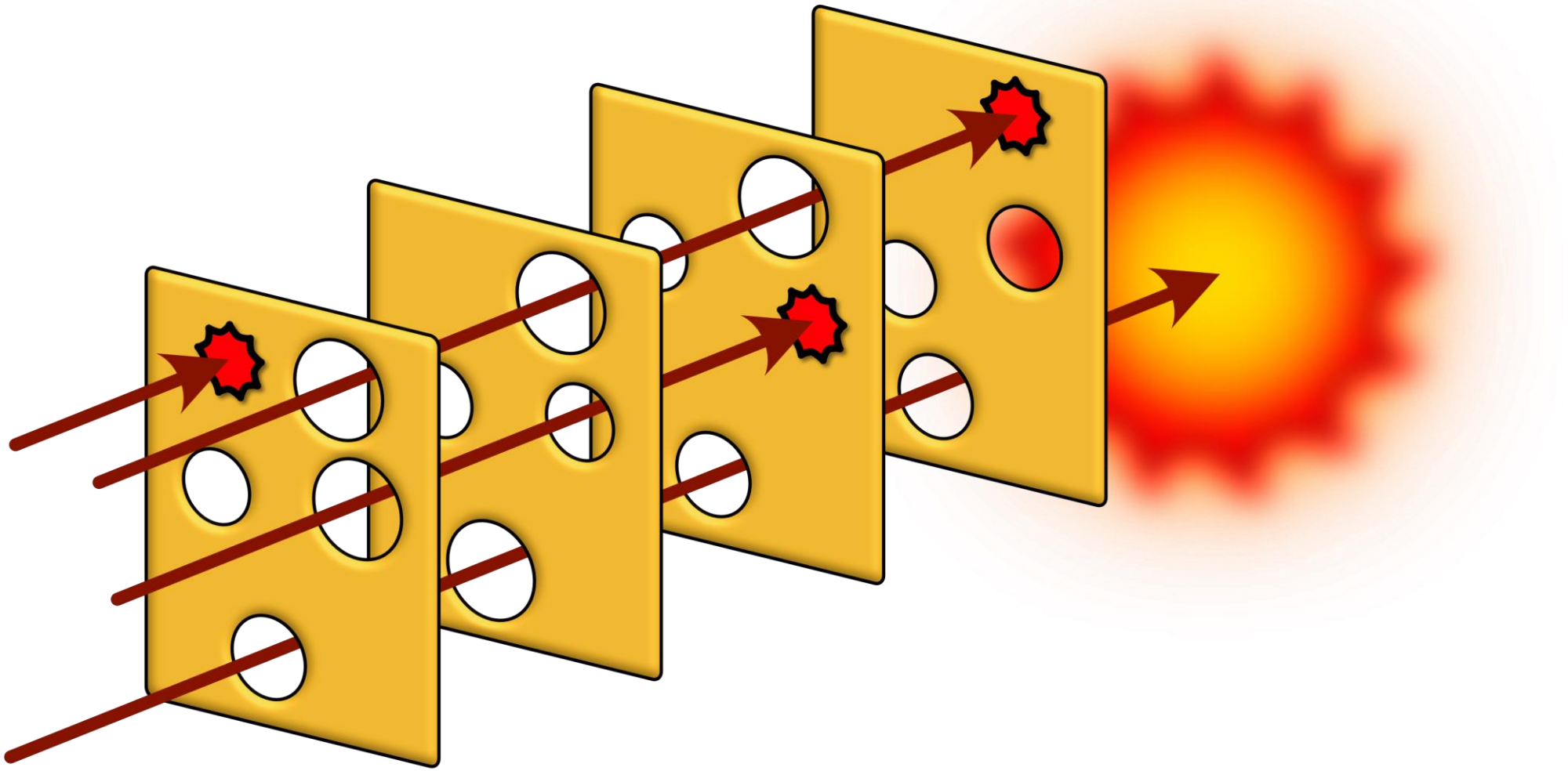
# Key Learnings:
# Every Layer is an Opportunity for Prevention



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# Financially-Driven Deadlines Create Risk

- Racing against rival Airbus A320neo
- “Countdown clock” in conference room
- Authorized Representatives (ARs) could validate on behalf of the FAA
- 39% of Boeing ARs said they experienced “undue pressure”

*RBPSM Element:*

**Process Safety Culture**

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# Do Not Hide or Ignore Warning Signs

- $200-400 million impact in one contract if simulator training was required
- Simulated test flight scenario deemed “catastrophic” by test pilot
- References to MCAS removed from pilot training manual

*RBPSM Elements:*

**Stakeholder Outreach**

**Training and Performance Assurance**

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# Provide Appropriate Redundancy

- 737 MAX fitted with 2 AoA sensors
- MCAS only took input from one of them
- AoA sensors are known to be susceptible to damage

*RBPSM Element:*

**Asset Integrity and Reliability**

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# Validate Explicit and Implicit Assumptions

- Risk assessment assumed that flight crew would override MCAS
- But it was not clear what was going wrong, and flight crew was unaware of MCAS
- In a real scenario it can be hard to tell what the cause is

*RBPSM Elements:*

**Hazard Identification**

**Emergency Management**

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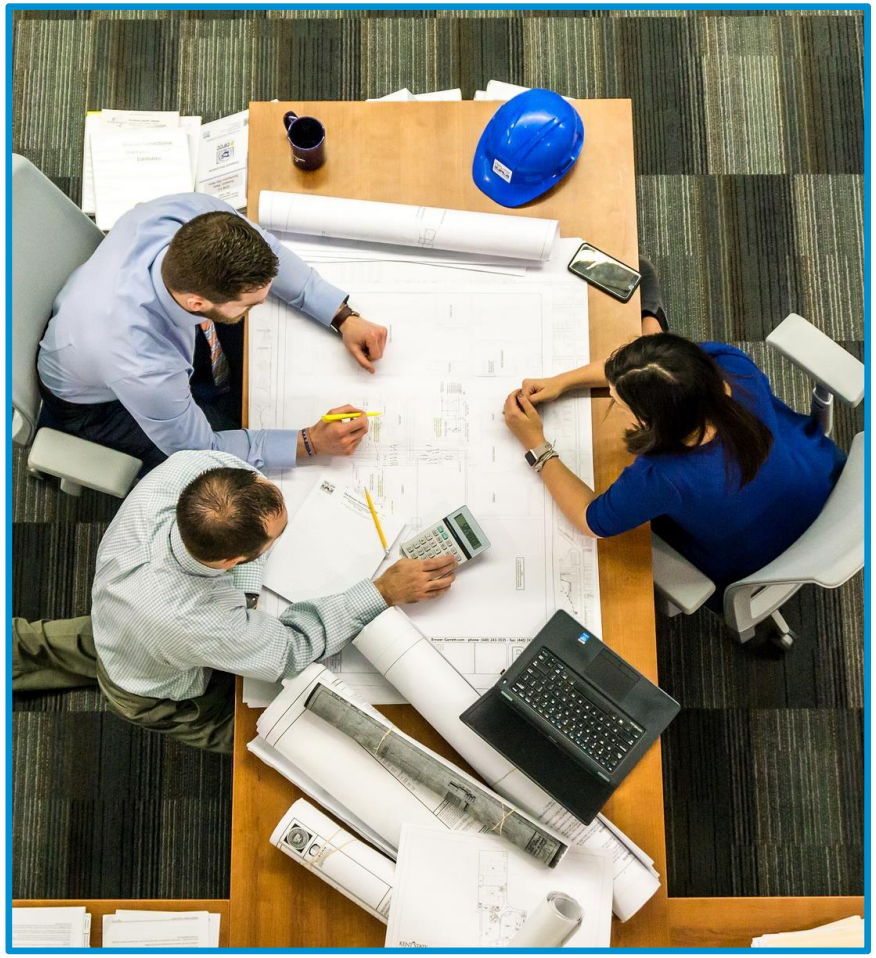
# Review and Revalidate After Changes

- At time of risk assessment, MCAS could move horizontal stabilizer by 0.6°
- Later increased to 2.5° (~50% of full range) - more than 4 times as powerful
- Certification plans were not updated

*RBPSM Element:*

**Management of Change**



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# Ensure Everyone Understands the System

- MCAS was not originally intended to activate multiple times
- Repeated activation of MCAS caused greater impact than intended
- Pilots were not aware of the system
- Risk assessment did not include repeated activation

*RBPSM Elements:*

**Training and Performance Assurance**

**Hazard Identification and Risk Analysis**

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# Missing or Inoperable Safeguards Require Revalidation

- An AoA disagree alarm was intended
- Software was tied to an optional AoA indicator instrument
- This instrument was not installed on over 80% of 737 MAX aircraft

*RBPSM Element:*

**Management of Change**

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# "Near-Hits" are an Opportunity to Prevent Harm

- The MCAS scenario occurred on the same aircraft the day before the first crash
- The cautions and warnings were logged but not the action the flight crew took
- Further investigation may have prevented the crashes

*RBPSM Element:*

**Incident Investigation**

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# CONCLUSIONS

- Balance schedule and budget with safety
- Share, and ask for, warning signs
- Test and validate risk assessment assumptions
- Revalidate when things change
- Investigate and follow up on “near-hits”

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# THANK YOU

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