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CHIEF AEROSPACE
SAFETY OFFICE

Perceived Risk: Hard Landings

Ensuring a Balanced & Proportionate Approach

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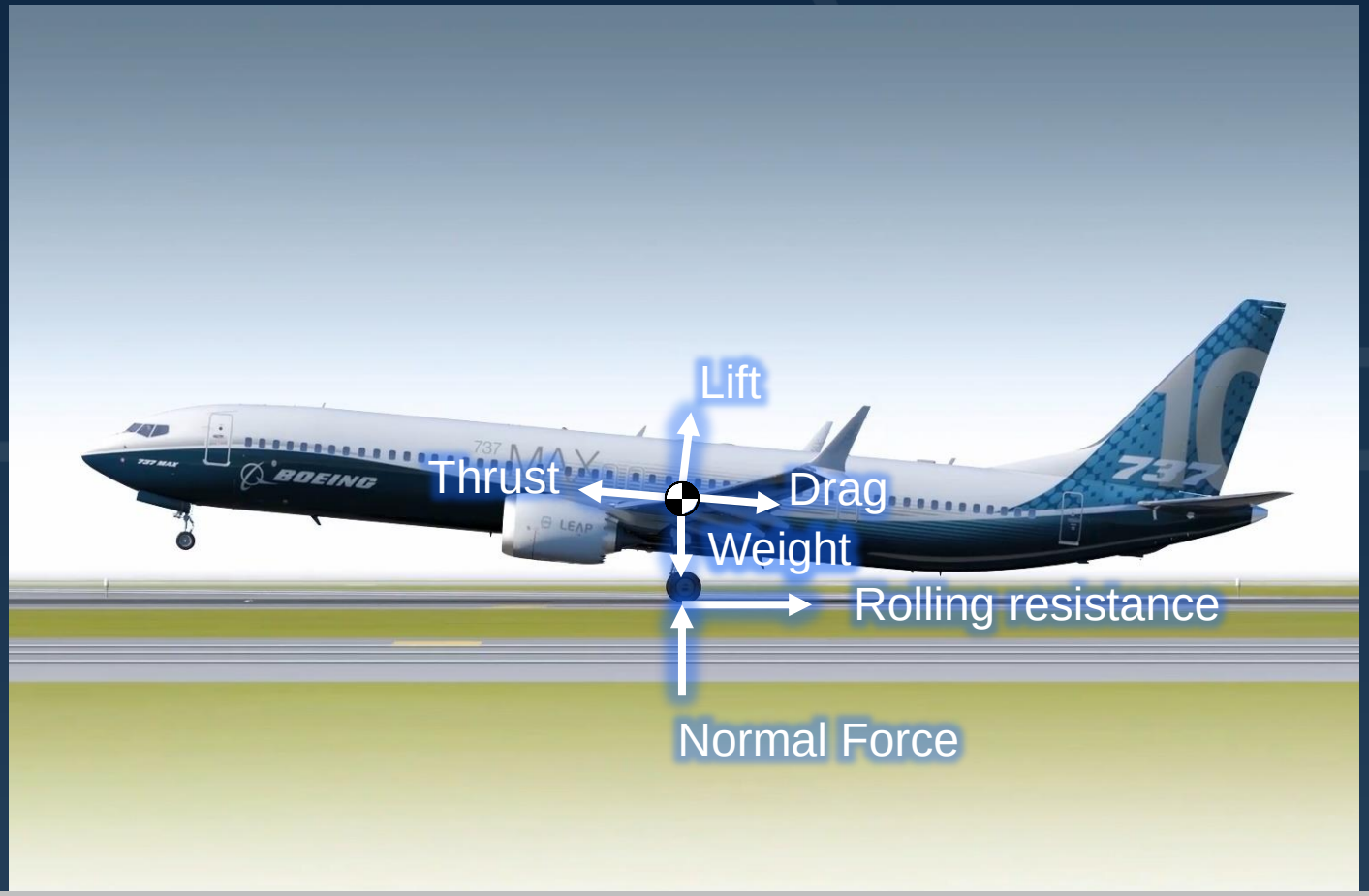
Landing Sequence of Events

- As the aircraft touches down:
  1. The inertial resistance of the wheel spinning up pulls the landing gear back like a stiff spring and then it rebounds
  2. The wing rapidly loses lift as the airplane decelerates
  3. The landing gear shock is compressed as the weight of the airplane transitions from being carried by the wing to being carried by the landing gear
  4. Thrust reverser and spoilers deploy
  5. Brakes are applied, further decelerating



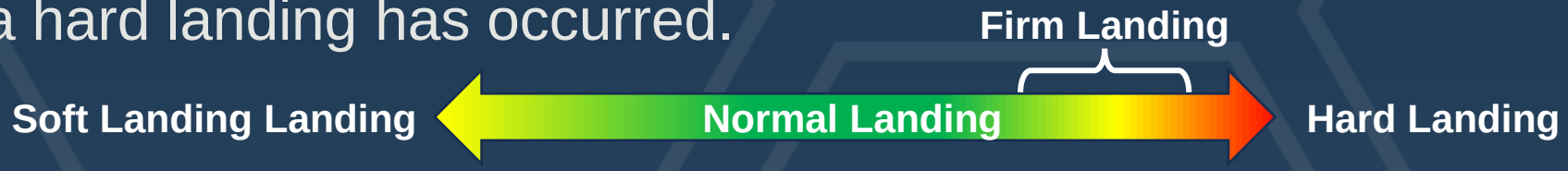
The combination of these events in short sequence causes complex/dynamic structural resonances

What is a Hard Landing?

ANSWER: A Hard Landing occurs when the structural loads exceed the design limits of the aircraft.

QUESTION: What causes the structural loads to exceed the design limits?

ANSWER: If the rate of descent (or sink rate) of the aircraft exceeds 10 feet per second* (~3.1 meters per second*), then the structural loads have exceeded the design limits, a hard landing has occurred.



*For Boeing aircraft

How are Hard Landings Determined?

- The flight crew's judgment is the most reliable qualitative criterion for determining if a hard landing has occurred. Flight crew are generally conservative.
- Quantitatively, modern aircraft are able to directly measure Sink Rate
  - Measuring Sink Rate at the moment of touchdown is the most accurate/direct way to numerically measure if a hard landing has occurred because Sink Rate is the parameter to which the aircraft is designed
- Earlier aircraft rely on accelerometers to measure the deceleration – sometimes referred to as "CG Load Factor" which is the Gravitational Constant multiplier
  - This method is indirect and not as accurate because:
    1. The aircraft is not a rigid body – meaning that an aircraft is highly flexible and responsive to the dynamic loads that occur at the moment of touchdown – not all points on the aircraft experience the same "G" and yet an accelerometer measures one point in space
    2. Accelerometers pick up other "noise" – meaning structural resonances such as auto deployment of the spoilers, etc

Why do we Need to Know?

- If a hard landing has occurred, structural damage may have occurred and must be fixed
- If a hard landing is suspected to have occurred, a structural inspection is required
- Structural inspections are expensive, time consuming and introduce risks of their own
- Accelerometers were originally introduced on aircraft as a way to safely determine if a structural inspection could be waived

Accelerometers were never intended as “black-and-white” hard landing indicators

Industry Concerns

- Safety risks associated with hard landings are often perceived to be irrationally high
  - The bodily sensations at landing are perceptible to everyone who flies; even firm landings startle people
- Just Culture is needed: pilots are often penalized for “Firm” or “Slightly Harder than Normal” landings
  - Pilot performance is sometimes associated with how “gentle” the landing is felt to be

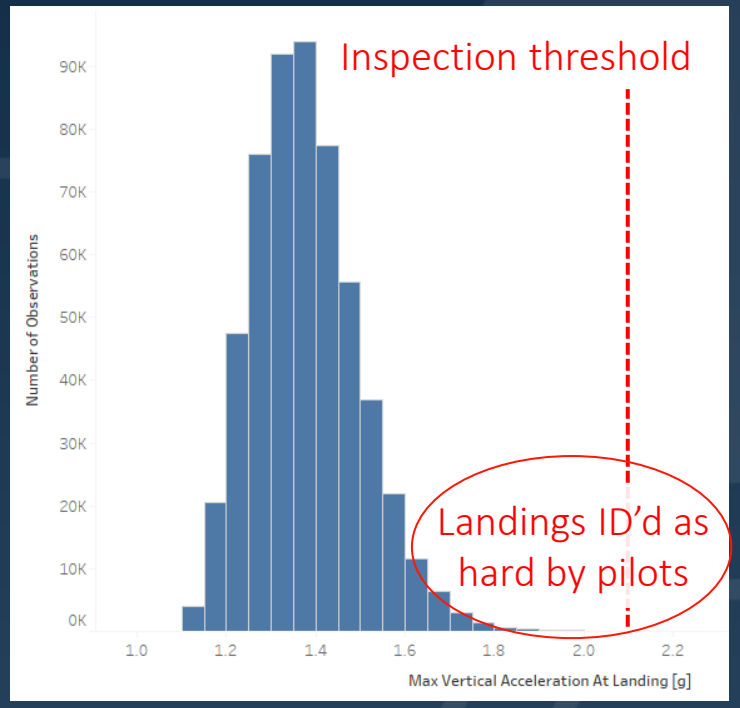
- Punitive actions for “Firm” or “Sightly Harder than Normal” landings tend to cause pilots to focus on achieving a landing that feels soft to the exclusion of other important parameter

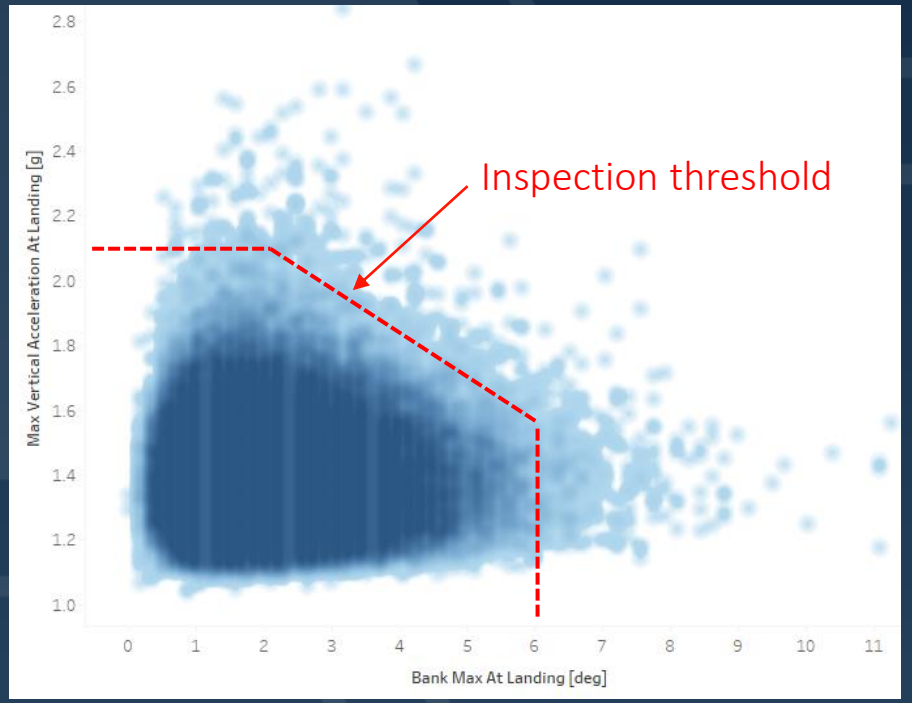
Unstable approaches, long flares, missed touchdown zones, etc increase runway excursion risk

Viewing Hard Landings in Proportion to Risk

- Boeing conducted a study based on 570,000 flights by 737 NG/MAX operators
- With regard to structural load limit, **99.97%** of landings were found to be below the Load Factor inspection threshold, which is itself conservatively below the threshold of a hard landing

Many pilots admit to being conservative in what they self-report as a hard landing **for fear of being seen as trying to cover up a hard landing** should subsequent analysis of FOQA data reveal a hard landing.



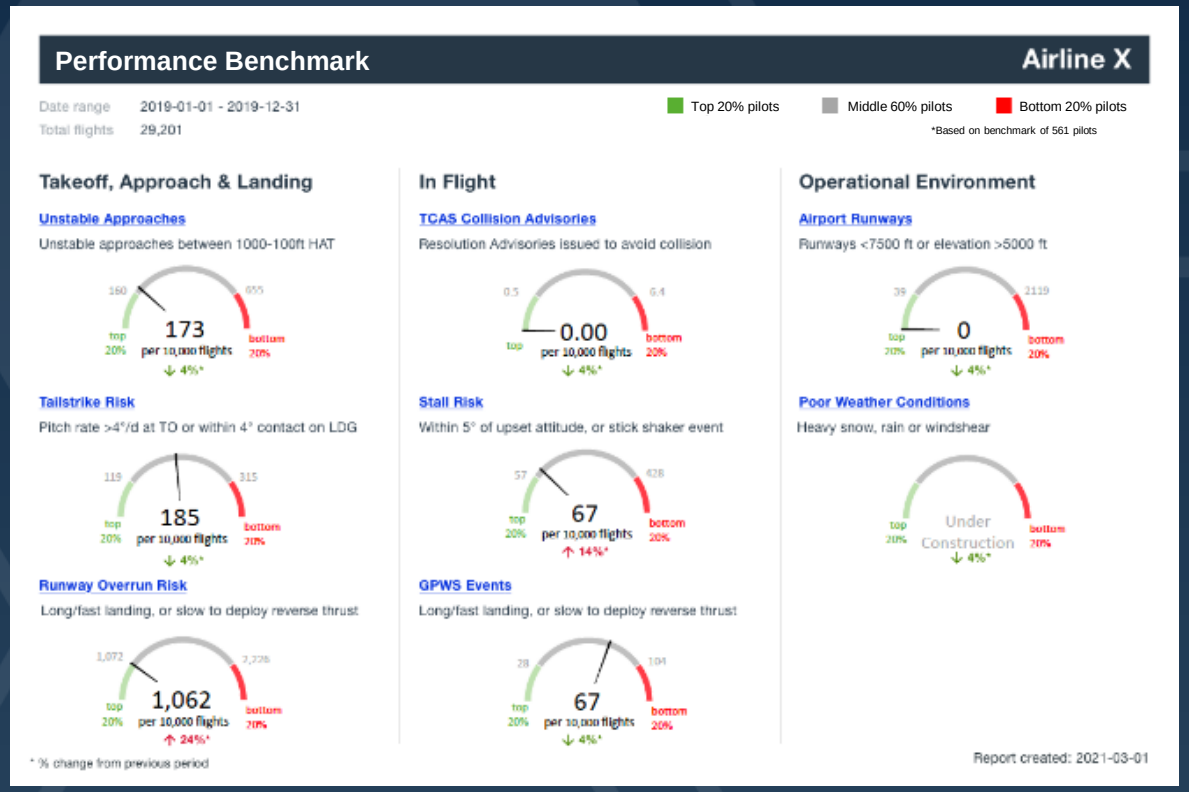


Avoiding Unintended Consequences

- The industry must actively discourage disproportionate attention given to hard landings at the expense of other important Safety Performance Indicators (SPIs)

Examples (not exhaustive)

- Pitch rate on take-off
- Excessive bank
- Excessive heading change (approach)
- Rough taxiing (excessive speed / braking)
- Deviation above glideslope
- High rate of descent (<100ft)
- Excessive bank on landing (below flare height)
- Spoilers used at low altitude
- Late landing flap
- Approach speed high (<50ft)
- Abnormal pitch landing (low)
- Approach speed high (<1000ft)
- Deviation below glideslope
- Long flare (duration from flare height)
- Climb out speed high
- Pitch attitude high during take-off



Key Takeaways

- Reduce the risk of tail strikes, long landings and runway overruns by discouraging the inappropriate use of the CG Load Factor as an SPI
- CG Load Factor is not an accurate measure of a hard landing and should be used only as a structural inspection threshold
- Pilot performance should be measured holistically without overly weighting lower risk parameters

Airlines and regulators should work together to ensure hard landings are not disproportionally prioritized as an SPI compared to the actual risk they pose

Questions / Feedback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