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Major problems that must be addressed before an air worthiness certificate is issued for the 737 MAX.

This aircraft can be fixed and redesigned eliminating the need for the Maneuvering Characteristics Augmentation System (MCAS).

A. Inadequate 737 Max rudder cable protection

The rudder control cables could be severed in the event of an un-contained engine failure. This dangerous design flaw has been overshadowed by concerns regarding the MCAS software problems. Correcting this flaw will require redesigning the routing and redundancy of the rudder control cables to prevent them from severing, which can happen easily if an engine compressor section fails. Recall the Southwest 737 NG that had an engine failure causing shrapnel to hit the windows, resulting in the death of a passenger who was partially sucked out of a window. Engine failure producing shrapnel could also easily sever the rudder control cables.

The FAA's Transport Airplane Directorate in 2014 sent a memo to the FAA's Aircraft Certification Service saying the Max's rudder cable had inadequate protection and noting Boeing had agreed to comply with 1997 guidance issued by the FAA in response to the deadly 1989 crash of a United Airlines aircraft near Sioux City, Iowa.

As noted in a November 7, 2019 letter from Representative Peter DeFazio, Chair of the House of Representatives Transportation and Infrastructure Committee, and Representative Rick Larsen, Chair of the aviation subcommittee to FAA Administrator Steve Dickson, Boeing "objected to making changes to the design of the 737 Max rudder cable, arguing that changes would be impractical and noting the company's concern about the potential impact on resources and program schedules".

The letter from Representatives DeFazio and Larsen also pointed out that the FAA in 2016 offered Boeing the ability to comply with regulations without design changes, even though six FAA "specialists" refused to support that decision.

B. Boeing's flawed and dangerous fix for MCAS entails three changes to the system design.

The three changes are listed below. These changes are totally inadequate since they dull and limit the response of the MCAS and they do not fix the physical aerodynamic design flaw caused by the flawed placement of the GE LEAP engines.

1. The MCAS system will take input from the jet's two angle of attack (AOA) sensors instead of just one. If AOA sensors disagree by more than a nominal amount, the system assumes a false signal and will not activate.

2. If both AOA sensors somehow get stuck at the same wrong high value — perhaps if they got frozen in the wrong position — MCAS won't activate because the MCAS upgrade is designed to activate only when the angle moves suddenly from below the threshold to a new high value.

3. If both AOA sensors register a sudden movement to a high angle of attack, the system will activate only once — not repeatedly, as occurred in the 737 Max crashes.

The capability of the MCAS to move the horizontal stabilizer so as to pitch the jet nose-down will be limited. The pilot will always be able to counter it by pulling back on the control column. There is, however, still an unresolved problem. Newer Boeing aircraft like the Boeing 787, have triple redundancy. The 737 MAX still uses two AOA sensors. There is a fairly low risk that both AOA sensors would fail for the same reason. However, if one AOA sensor has failed it can be difficult to determine which AOA sensor is correct. In flight critical applications where the airplane cannot fly without the sensor (not the case here as the airplane can continue to fly) it is standard practice to have triple redundancy. This is not always a third identical sensor but preferably an equivalent, but different sensor that can be the tiebreaker.

The 737 MAX did not incorporate this tiebreaker design. The MCAS just shuts off and requires the pilots to deal with the problem. Shifting the burden to the pilots to control a stall caused by the inherent instability of the present 737 MAX design is dangerous. Moreover, this approach does not fix the faulty design caused by locating the engines forward and higher than is prudent to allow for clearance of larger nacelles needed for the GE LEAP engines. These nacelles with a long moment arm act like control surfaces that can increase the angle of attack uncontrollably. Boeing engineers found that under certain conditions the 737 MAXs engines -- which are larger and located higher and closer to the front of the plane -- boost the chances that the aircraft would tilt upward too steeply -- causing the aircraft to stall.

To offset the stall risk, Boeing engineers installed MCAS in the 737 MAX "to compensate for the extra pitch up produced by its larger engines at elevated angle-of-attack (AOA)," but Boeing did not identify all the failure modes nor did Boeing explain the new systems to the pilots and offer the needed flight simulator training.

The painful reality is that the MCAS system in its updated form remains a band-aid that would be totally unnecessary if the 737 MAX did not exhibit an aerodynamic flaw called a divergent condition. It should be noted that many high-performance aircraft have this tendency but it is not acceptable in transport category aircraft where there is a requirement that the aircraft is stable and returns to a steady condition if no forces are applied to the controls.

C. Permanent fix of this divergent condition on the 737 MAX, eliminating the need of MCAS is much more involved and expensive since it will require modification and rework of the present design versus the unsafe software patch to “fix” a design flaw.

The steps below identify ways to correct the design flaws with the 737 MAX:

1. Go back to the drawing board and study the needed increase in under wing clearance necessary to mount the larger GE LEAP engines correctly, thus eliminating the nose up instability.

2. Develop a program that will implement the engineering changes needed to make the landing gear taller, thus raising the fuselage higher off the tarmac, similar to the clearance that the Airbus

320 NEO, which sits much higher than the 737 MAX, to accommodate safely the same GE LEAP engines.

3. Develop a rework program for the present 737 MAX planes that have been produced and delivered. Boeing could take back the planes that have been delivered and rework them with the planes that remain in inventory on a custom rework manufacturing line.

4. Rewrite the Flight Control Computer (FCC) software and associated programs removing the MCAS and following the re-certification process as set forth by the FAA and other agencies. There is a standard testing and software validation and verification process that all flight control software must go through. The problems with the 737 Max are not dissimilar to the initial problems with the A320 when it initially entered service, which Airbus addressed correctly without applying software patches to meet financial targets.

5. Typically a list price for a Boeing 737 MAX is 90 Million USD +/- but the discounts on large volume orders can be as high as 50% plus free maintenance. A reference point is the deal that IAG (parent company of British Airways and Iberia) made with Boeing on a massive order for the Boeing 737 MAX valued at 24 Billion USD with a 50% discount. Taking such hefty discounts into consideration, Boeing can smartly invest in the aerodynamic and structural repairs and design modification to cure the flawed positioning of the engine on the wing which causes the instability and the need for the MCAS system, which was never used before on a commercial airliner. The estimated costs including the re-engineering, supply chain components ordering, modifications of the existing fleet after certification and cycle time needed to perform will not exceed 3% to 5% of the list price.