Robert (Bob) Bogash FAA Public Comments to 737 MAX Airworthiness Directive (AD) 2018-23-51

737 MAX FAA-2020-0686-0169

The following are some of my credentials:

My name is Robert Bogash. I am a retired Boeing engineer with more than 30 years with the company. I retired as the Director of Quality Assurance for Boeing Commercial Airplanes. I have been a licensed pilot since 1964, built and currently fly my own airplane, (Vans RV-12 N737G), and have flown all Boeing commercial jets, either live or in the simulator, from the 707 through the 767. I am an Associate Fellow of AIAA and a Full Member of ISASI (International Society of Air Safety Investigators.) I have given the Keynote address 5 times to the annual meeting of the SETP (Society of Experimental Test Pilots.) I have been a life-long contributor to matters involving aviation safety, particularly transport category and air carrier safety.

I participated in the design, development, construction, and flight testing of the first Boeing 737 in the 1965-1968 time period. I continued working hands-on with the 737 in various capacities for the remainder of my career. After my retirement in 1995, I restored the very same Number One 737 airplane (NASA 515 N515NA) for the Museum of Flight in Seattle and was Crew Chief on the last flight from Moses Lake to Boeing Field in Seattle (September 2003.) I have continued looking after that airplane since that date. I have literally worked on Boeing 737 airplanes for 55 years!

I have a large and very active web site:

http://www.rbogash.com/

with a substantial section devoted to Air Safety. Ten years ago, troubled by a series of air carrier accidents that seemed to have a common involvement of auto-trimming the horizontal stabilizer, I did a study and released a White Paper on my website that condemned in the strongest terms the authority of Autoflight systems over movement of the horizontal stabilizer in Part 25 airplanes:

http://www.rbogash.com/Safety/autopilots.html

"I THINK AUTOPILOTS SHOULD HAVE LIMITED STAB TRIM AUTHORITY."

They should be able to trim within a "normal" flight envelope band - beyond that, the pilot needs to be brought into the loop so as to recognize a developing situation, and not presented with a fait accompli. My definition of "normal" is very much truncated from what is "available." A stab that is at its trim limits should be there ONLY due to pilot command (VERY unlikely!) Although the trim position is annunciated with assorted dials and warning lights, etc. - often the pilot is unaware of the severe miss-trim, and in most cases, fails to rectify it when the autopilot suddenly says "***Your airplane!***"

I go on to say:

"Trimming those (stabs) to large positions creates a poorly configured airplane and sets up the flight crew for a bad "gotcha" when the autopilot is disconnected. Very few human pilots would think of trimming the stab to such large values."

This White Paper generated quite a bit of discussion in the aviation community, but little substantive action, including none from Boeing. It did, though, basically predict the 737 MAX accidents involving the Maneuvering Characteristic Augmentation System (MCAS), in which the Autoflight systems commanded the stab to its full airplane nose down mechanical stop position.

With regard to the 737 MAX accidents and the proposed resolutions, I must disagree with the FAA's statement that the proposed fixes have been developed with inputs from the aviation community and with complete transparency. In fact, myself, and my colleagues - many of whom have much more impressive credential sets that I do - are basically in the dark as to the substance of the proposed fixes. The Notice of Proposed Rule Making (NPRM) is extremely vague in delineating the specifics of the proposed changes, merely requiring installing and verifying "revised software." This provides little info with which to judge the adequacy of the proposed changes to the MCAS!

We did, in fact, on our own, submit proposals to Boeing early on during this grounding process - they were submitted by a highly qualified retired V.P., directly, in writing, to Boeing's then-CEO; the input was never even acknowledged. After Boeing top management changes, they were resubmitted again to Boeing senior executives, including the new CEO of Boeing, and the new President of Boeing Commercial, again without acknowledgement.

Early Boeing airplanes (B-17, B-29, B-47, C-97, B-377) did not have movable stabilizers. They were trimmed via pitch trim tabs on the elevator surfaces. The B-52 was the first Boeing airplane with a movable stabilizer (hardly a new concept, BTW, the configuration being exactly like a J-3 Cub), and all Boeing commercial jets have such a trimmable surface. Movement is via an aft hinge point and a forward jackscrew, driven by electric or hydraulic motors. There was a fear within the pilot community that a failure of the drive system, or their controls, could result in a "runaway" stab which could drive the stab to its mechanical stops without the pilot being able to stop the motion. Two schemes were developed to address those concerns. One was the creation of a cockpit control, very similar to the old elevator tab control - namely a trim wheel on the aisle stand that the pilot could literally grab and stop the unwanted motion. This trim wheel is directly connected via conventional steel control cables to the stab trim mechanism in the tail.

While this system does work, it also comes with some problems - one of which is that under some flight conditions, the aerodynamic loads on the stab create trim wheel forces that exceed

the pilot's capability to move the wheel. To address this problem, for much of the early jet age, Boeing taught a method that involved pitching the airplane in small increments in the direction of the miss-trim. This would unload the stab enough to manually move the wheels and thus slowly recover pitch control of the airplane. For reasons unknown, this training was removed from the pilot training curricula between those earlier days and the present.

Beyond grabbing the trim wheel to stop the stab movement, Boeing developed an ingenious, yet simple, interlock system. Beneath the cockpit floor, immediately below the control column, were a set of beefy "lockout cams". These sensed column motion and stab motion, and in the event of movement of the column in a direction opposite to stab movement, they would engage (with a very loud and startling bang), and stop further stab motion. There were no troubleshooting actions required, no referrals to the Non-Normal Checklist in the QRH, no Memory Items. If the stab moved uncommanded creating an unwanted airplane pitch, the pilot (any pilot) would intuitively and instinctively respond by pushing or pulling the column in the opposite direction. Presto, the stab movement in the undesired direction would be immediately stopped.

At some point in the 737's development history, those beefy lockout cams were replaced, likely to save weight, by a set of micro switches that had the same functional effect. Those switches are present on the MAX, but for reasons completely unfathomable by myself and my expert retiree group, were bypassed and locked out of the system when MCAS activates (the time when they were needed the most!) Thus the pilot could no longer respond to the unwanted pitch-down by instinctively pulling on the stick. Because of lack of detail provided to the public, I do not know if this bypassing of the column actuated stabilizer cutout switches is retained after the MAX modification. This one change from the original 707/727/737 design can be accurately described as being the direct cause of the 2 MAX accidents. Had this function been left active in the MAX, these accidents would not have happened, despite the failure of the Angle of Attack (AOA) vane.

COMMENT #1 Nowhere in the (limited) info provided regarding the MAX resolution fixes have we seen any mention of eliminating the stab/stick lockout neutering activated by MCAS. We view this as the simplest and most urgent of the fixes to the MCAS stab trim-down problem. Perhaps this is, in fact, addressed, but the lack of transparency prevents us from gleaning that information.

The situation my White Paper was trying most to address was the critical point where the stab trim authority crosses over and exceeds the elevator pitch authority. This is sometimes referred to colloquially as "jack-knifing the stab", (the pilot pulling while the stab is pushing), and results in an airplane in which the pilot has effectively lost pitch control. His only recourse to regaining pitch control is to re-trim the stab - a difficult proposition and one which requires the above-mentioned special (no longer taught and not easily accomplished) technique.

The AD fix apparently incorporates my 10 year old suggestions by limiting stab trim authority to a level where the elevators still retain enough power to control the airplane in pitch. For this, we applaud the proposed change.

From our perspective, the MCAS system seems to address a marginal stick force per G condition which is only present at certain gross weight and aft CG airplane configurations. One of our suggestions to Boeing was to actually remove the MCAS system completely, and modify the airplane CG envelope charts to eliminate operation in that airplane configuration/flight regime. Although this might reduce somewhat the airplane's design goal capability, the number of actual operations in that small segment of the chart would, in our view, be minimal. In fact, it is our understanding that the Airbus A320/A321 airplane series does, in fact, have that identical problem, and the "fix" has been to truncate the operational envelope in just that way, with some airlines actually removing one or two aft rows of seats to comply. Again, because of the limited information available to the public in the NPRM, we have no way to judge the feasibility of this simple change.

Nevertheless, since a truncated GW/CG configuration is one that would likely allow safe operation with the MCAS system deactivated, it would be important for operators to perform continued operation with MCAS Inoperative as a Minimum Equipment List (MEL) item and should be considered for MEL incorporation. The NPRM touches on this MEL issue but makes no details available beyond "incorporating certain provisions."

COMMENT #2 When an airplane has marginal compliance with the pitch stability requirements of FAR 25, many have installed a “stick pusher” or “stick nudger” which operates directly on the control column, and is overridable by the pilot. Indeed Boeing has, on some Boeing 707 and 727 airplanes - with the identical control column as the 737 - had such a device installed for certification to comply with unique British rules. Colloquially, I suggest “if you have an elevator stability problem meeting the rules, use an elevator solution for the problem”. Such a solution would leave the elevator operated stabilizer cutout function undisturbed for all cases, eliminate the need for MCAS entirely (with its demonstrated negative potential), and require minimal pilot training or familiarization. We recognize that this hardware solution, in lieu of a software solution, would increase the cost, certification burden, and time of compliance, but it would be the superior solution.

One of the failings in the development of the MCAS system was clearly an inadequate (grossly inadequate) Failure Mode Effects Analysis (FMEA). This failing simply mystifies us. Virtually ANY FMEA, rigorous or otherwise, would start with examining LRU failures of all units in the Logic Tree and the very first one would appear to be a failure of the AOA vane - the starting point for the Tree.

COMMENT #3 Make available to the public the Logic Trees and FMEA's of the MCAS system both before and after the proposed revisions. This is a particular area in which Boeing could have availed itself from consultation with expert retirees, but, to our knowledge, chose not to do so in the original design, and mysteriously, chose not to do so again during the “fix” of MCAS.

The 737 is a fairly unique airplane in today's Transport Category world. It is a MANUAL airplane in a world of either Fly-by-Wire (FBW) or hybrid-FBW airplanes. The pitch (elevator and stab) and roll controls all have Manual Reversion capabilities. So do other systems, like the spoilers and braking systems. When the pilot pushes/pulls the column forward or aft, he is directly connected

to the elevators via bell-cranks, cables and pulleys. In the event of total loss of electrics or hydraulics, the pilot can readily control the airplane "the old-fashioned way." I have done this personally numerous times both in flight and in the sim. Some people view this as a weakness, I view it as a strength. I have suggested to friends who are 737 line pilots, that they consider turning off all the electrics if the airplane starts to do something grossly abnormal, and return to manually hand-flying the airplane while they sort out the difficulties.

One of the problems (from my knothole) in the MAX configuration, was a subtle but significant movement away from a purely Manual airplane and into a hybrid FBW airplane. MCAS was one of those FBW schemes. It is especially deadly and insidious because its incorporation was silent (unpublished to the flight crews, and untrained for), and especially because its operation is uncontrollable. Specifically, although part of the Autoflight system, it is not controllable via the Autopilot controls. Every pilot experiences instances of strange Automation behavior ("What's It Doing Now?") and the solution is instinctively to "step down a level" in the automation - in this case - Disengage the Autopilot. Disengaging the Autopilot will not stop MCAS - in fact it only operated when the Autopilot was disengaged - leaving the pilot scratching his head in a rapidly changing flight condition. Boeing inserted this little bit of FBW surreptitiously into this Manual airplane, and as we all now know, it didn't go too well.

One of my concerns is that Boeing inserted another wee bit of FBW into the 737 MAX airplane - another system that operates independently of pilot input and control. This system involves the FBW spoilers. The spoilers on the 737 used to be entirely manual, operated via a speed brake handle on the left side of the aisle stand. This handle moved cables that ported hydraulic fluid via a control valve in the wheel well to the spoiler actuators. The actual spoiler positions were further modulated via a mechanical spoiler mixer box in the RH wheel well that adjusted their positions to account for simultaneous roll inputs to the ailerons from the pilot's wheel.

On the 737 MAX, these hydraulic/mechanical controls have been completely replaced by a computer controlled FBW system. I have seen several reasons for this change, one that particularly concerns me being to adjust the pitch attitude of the airplane on final approach to mimic closely that of the 737 NG series of airplanes.

Per writings in the media and trade-press, it has been alleged that the MCAS system software was designed by off-shore engineers in a low labor rate country. Assertions were made that the software architects had little practical knowledge of airplane systems and performance and hence an inadequate job was done designing the logic tree and performing the FMEA to lack of transparency, none of that is known for sure by us. However, the question immediately arises as to the robustness of the software controlling these new FBW spoilers and, especially, the FMEA that was performed.

Inadvertent spoiler extension on final approach in an environment of low speed and low altitude can be catastrophic (Example Air Canada Flight 621, DC-8-63, Toronto 1970.)

COMMENT #4 Has the FBW spoiler system received any scrutiny during the MCAS review or has all the attention been devoted to the MCAS and stab control system exclusively. It appears to me that a similar design situation, namely insertion of a hidden, uncommanded and uncontrolled FBW system, perhaps by the same individuals who were involved in creation of the MCAS system, is involved here, with the same consequent risks.

Personally, none of us want another 737 accident - we have devoted our careers to that remarkable airplane - and my suggestions and comments are aimed at ensuring that the outcome of this prolonged grounding are as effective as possible.