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The Honorable Walter B. Jones, Jr.
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Jones,

In early July 2015, you requested that I review the record of the fatal MV-22 accident that occurred at the Marana airport on April 8, 2000. After such review, you asked that I pay particular attention to the Marine Corps press release dated July 27, 2000, which announced the findings of the Marine Corps Judge Advocate General Manual (JAGMAN) investigation into the accident. You believed that the press release unfairly placed primary blame on the two pilots of the aircraft, Marine Corps Lieutenant Colonel John Brow and Major Brooks Gruber.

This letter summarizes the key observations derived from my review, and communicates to you my conclusions and the reasons I arrived at them.

On the night of April 8, 2000, during an Operational Evaluation (OPEVAL) flight into Marana airport, Arizona, Lieutenant Colonel Brow and Major Gruber piloted the second of two MV-22 Osprey tiltrotor aircraft on the approach. While attempting to maintain their position behind the lead MV-22, the pilots lost control of their aircraft and crashed into the ground. Tragically, both were killed, along with 17 other Marines aboard the aircraft. Immediately after the crash, the pilots in the lead MV-22 attempted to wave off their own landing but were unable to do so; their aircraft experienced a "hard landing" approximately 420 feet away from the crash site and skidded another 330 feet before coming to rest. No one was seriously injured during the hard landing.

The aircraft safety of flight regulations for all fixed wing, rotary wing and tiltrotor Naval aircraft are found in the Naval Air Training and Operating Procedures Standardization (NATOPS) flight manual, a specific version of which is published for every type and model. At the time of the accident, the Preliminary MV-22 NATOPS manual stated, "The landing approach for the MV-22 shall be a precise maneuver and should not be so low that the pilot loses sight of the landing point or so high that a very low power setting with a high rate of descent is required." It specifically warned pilots to avoid descent rates of 800 feet per minute (fpm) or greater at airspeeds less than 40 knots calibrated airspeed (KCAS).

Data from the Vibration, Structural Life and Engine Diagnostics (VSLED), or Crash Survivable Memory Unit (CSMU), indicates that the MV-22 was functioning according to its design at the time of the accident. In other words, neither mechanical nor material failure contributed to the accident in any way. However, the CSMU also indicated Brow and Gruber exceeded the NATOPS landing approach limitations. CSMU data indicates that the aircraft departed controlled flight while descending at a rate of 2190 fpm and operating at well below 40 knots KCAS.

Based on this data, the subsequent Marine Corps JAGMAN investigation concluded that the primary cause of the crash was the mishap aircraft's high descent rate/low airspeed approach for landing, which most likely caused the aircraft to enter into an asymmetric vortex ring state (VRS, also known as power settling) and/or blade stall condition. Once entering VRS, the aircraft began to roll to the right. The pilots attempted to counteract the roll, but it continued until the aircraft was inverted and in a nose down attitude, too low to the ground for the pilots to recover. A contributing factor to the mishap was the Flight Lead's decision to attempt a high descent rate/low airspeed landing into Marana airport after arriving at the final approach point 2,000 feet higher than planned. The JAGMAN assigned fault to the Flight Lead for his decision to continue the approach as well as for poor crew coordination and lack of situational awareness.

On July 27, 2000, the Marine Corps issued a press release announcing the findings of the JAGMAN investigation. The release highlighted a combination of "human factors" that led to the crash:

Deviations from the scheduled flight plan, an unexpected tailwind and the pilot's extremely rapid rate of descent into the landing zone created conditions that led to the accident...Although the report stops short of specifying pilot error as a cause, it notes that the pilot of the ill-fated aircraft significantly exceeded the rate of descent established by regulations for safe flight.

The press release went on to say: "the tragedy is that these were all good Marines joined in a challenging mission. Unfortunately, the pilots' drive to accomplish that mission appears to have been *the fatal factor*" (emphasis added). These words were incorrectly interpreted by many to mean that the actions of Lieutenant Colonel Brow and Major Gruber were solely responsible for the fatal crash.

I personally read and reviewed all relevant accident materials—to include the JAGMAN investigation conducted by the U.S. Marine Corps, the Safety Investigation conducted by the Naval Safety Center, the independent Report of the Panel to Review the V-22 Program (henceforth, the independent V-22 Program Review), and a wealth of additional material provided by you. The JAGMAN and Safety investigations properly focused primarily on the specific events on the night of 8 April that contributed to the crash. In contrast, the independent V-22 Program Review focused primarily on the events leading up to the accident. Without contradicting any findings from the JAGMAN and Safety Investigations, which I found to be thorough and fair, the totality of evidence confirms the adage that every accident is the result of an interrelated chain of events; if any link in the chain is broken, the accident never occurs. And after considering all of the links in the chain of events that led to this particular accident, I disagree with the characterization that the pilots' drive to accomplish the mission was "*the fatal factor*" in the crash. While the available evidence indicates Lieutenant Colonel Brow and Major Gruber did indeed violate warning limits in the preliminary MV-22 NATOPS manual, there were several other events and circumstances leading up to the Marana crash that contributed substantially to its fatal outcome. For example:

- Prior to the accident, the Integrated MV-22 Test Team flew only a limited number of test points to verify the validity of the NATOPS warning not to exceed 800 fpm at 40 knots or less. In essence, the test program started from the exact same NATOPS flight limits established for helicopters and verified it would also be safe for tiltrotors. It did not attempt to define fully the VRS boundary, discover its impact on V-22 flight characteristics, or derive emergency procedures to recover from its effects. This decision seems incongruent with the novel, “revolutionary” aspect of the MV-22 tiltrotor concept
- There are two factors that cause a rotary-wing or tiltrotor aircraft to enter VRS. The JAGMAN and Safety investigations focused on the rate of descent, keying on the fact that pilots Brow and Gruber exceeded the 800 fpm limit by over 2.5 times. However, the second factor associated with VRS is low airspeed. Indeed, post-accident testing revealed low airspeed to be the more critical of the two factors. Test pilots found that above 40 knots KCAS, VRS could not occur *regardless of the magnitude of the sink-rate*. Because the CMSU data storage recorder did not record calibrated airspeeds below 40 knots, we do not know conclusively what the aircraft’s speed was when it departed controlled flight; the airspeed was interpolated from engineering data after the accident. For this reason, the independent V-22 Program Review warned that the V-22 airspeed indication system was likely not adequate as it was unreliable below 40 knots.
- Because of the decision not to fully define VRS effects during the flight test program, OPEVAL pilots did not fully understand MV-22 VRS characteristics. Three of the four pilots involved in the Marana mission were CH-53 heavy helicopter pilots who were quite familiar with the danger of VRS/power settling in rotorcraft, and the fourth had recently completed formal training in VRS in a helicopter transition program. Therefore, they were all aware that VRS/power settling in single or tandem rotor helicopters caused uncommanded rates of descent and, depending on altitude, could result in a hard landing or controlled crash. However, they also knew such an event would normally result in the aircraft hitting the ground in an upright attitude. This proved not to be the case for the MV-22. Post-crash flight testing showed that because of the lateral separation between the tiltrotors on the MV-22 wing edges, one rotor could be impacted by VRS and the other not, resulting in an asymmetrical roll-off event like the one observed at Marana. Moreover, power settling in helicopters is most commonly preceded by a very noticeable aerodynamic vibration, providing a sensory warning to the pilot about the impending condition. Post-accident testing revealed there were no such clear warning cues in the MV-22, and the direction of roll-off was unpredictable. Worse, applying control movements in the opposite direction to counteract the roll not only did nothing to stop the uncommanded roll-off, it accelerated it. As a result, even though the V-22 engineering and safety personnel correctly forecast VRS/power settling would occur if pilots exceeded the NATOPS warning, they failed to forecast the violence of the roll response or the lack of any sensory warning cues, and published no associated emergency

procedures to recover the aircraft (although in the case of Marana, the aircraft's low altitude meant that recovery was likely impossible).

- This failure was compounded by the fact that the warning to avoid sink rates in excess of 800 fpm at airspeeds below 40 knots was inappropriately placed in the NATOPS manual in the Emergency Procedures paragraph titled "Settling with Power." There were two problems associated with this mistake. First, settling with power is a different phenomenon than power settling. Second, in other helicopter manuals, power settling is discussed in the Flight Characteristics section. Moreover, the Interim Flight Clearance in effect at the time of the accident did not have any warnings or operating limits related to power settling. As a result, the independent V-22 Program Review believed there may have been less than appropriate concern for the grave danger of power settling in tiltrotors among OPEVAL pilots, and the "poor coverage of the topic in NATOPS may have been a contributor."
- As a result of these interrelated pre-accident circumstances, beyond being told to avoid a specific flight region, the OPEVAL pilots had, at best, an incomplete understanding of the dangers and manifestation of VRS in the MV-22. All four were handpicked aviators; they all possessed well-above-average piloting skills. Nevertheless, the independent V-22 Program Review noted that, "Although they undoubtedly violated a warning in the NATOPS, it is not obvious from their actions that the pilots clearly understood the safety threat." They went on to recommend that the results of the post-accident high-rate-of-descent tests be used to "update operating limitations, procedures, the NATOPS manual, pilot training...and a cockpit warning system."
- After the accident, the MV-22 Integrated Test Team conducted a 14-month long flight-test exploration of the Osprey's high-rate-of-descent/low-air-speed boundary. The objectives were to derive the boundary of VRS, derive a fleet operational envelope, define the recovery technique from VRS, determine applicability for warning systems, and document the condition in pilot training ground school simulations and the [NATOPS manual]. As a result of these tests, the MV-22's air speed indicator was improved, the rate-of-descent scale on its cockpit displays was expanded from 1,000 to 2,000 fpm, a visual and aural "sink" warning system installed that was triggered when the airspeed and rate of descent exceeded NATOPS limits, and "easy, immediate, and effective" pilot recovery procedures were identified.

After considering these circumstances, I find myself in total agreement with the Marine Corps officer who conducted the JAGMAN investigation, who wrote:

After reviewing the evidence collected, it was concerning to see how "easy" it was for the recipe of uncontrolled flight to be concocted. During the investigation, we found nothing that we would describe as criminal negligence, deliberate pilot error, or maintenance/material failure. The facts show that a section of MV-22s

approached an LZ with a high rate of descent, steep approach angle and slow airspeed and one aircraft departed controlled flight. *This scenario was troubling in that it is a scenario that can quite possibly be repeated as the MV-22 sees increased exposure to the fleet...*

Aircraft performance envelopes are developed, and procedures and guidance are published (NATOPS) to prevent pilots from putting the aircraft in a situation that would exceed safe parameters. *The MV-22 performance envelopes may be one that fleet pilots can operate within, but given the rigors of combat, real world operations, and realistic training for both, the consequences for exceeding this particular envelop appears to be excessively grave (departure from controlled flight with no warning) [emphasis added].*

After the accident, the Commandant of the Marine Corps referred to Lieutenant Colonel Brow and Major Gruber as “superb aviators, among the finest in our Corps.” However, he went on to say that “Notwithstanding their talent and skill, the MV-22, like all new aircraft, contained certain *unexplored* capabilities and limitations at the time of the mishap [emphasis added].” And it is exactly for this reason that I disagree with the characterization that the pilots’ drive to accomplish the mission was *the* fatal factor that contributed to the Marana accident. While I cannot in good faith overlook the fact that their actions were the last in a long chain of events that ultimately caused the tragic events on April 8, 2000, I believe the links in the chain leading up to the crash made the accident—or one like it—probable, perhaps inevitable.

My sentiments are appropriately characterized in the conclusion of the independent V-22 Program Review:

In summary, the V-22 community appears to have been poorly prepared for the situation that caused the Marana accident. The NATOPS manual did not properly address VRS; the test program had not fully defined it; and although the engineering and safety program forecast power settling for the V-22 in the right circumstances, they failed to forecast the violence of the roll response, or to clearly communicate the issue to one another. The accident itself has made the entire community aware of the real potential and disastrous consequences of VRS. This fact alone is the biggest single risk mitigator for this hazard in the future, but it must be followed by appropriate testing, procedures, flight limits, cockpit cues, and especially training, or this same mishap will happen again as memory of the mishap dims and rotary-wing experience level and quality of the pilots reduces to normal levels. The unwritten root cause of the accident may have been poor communications among engineers (power settling vs. settling with power) and between the operators and engineers...

In sum, human factors undoubtedly contributed to the Marana accident. These factors include the Flight Leader’s decision to execute the approach after arriving 2,000 feet higher than planned, Brow and Gruber’s decision to follow, and their exceeding of NATOPS limits when trying to maintain position behind the lead aircraft. Considering all of the circumstances outlined above, however, it is clear that there were deficiencies in the V-22’s development and

engineering and safety programs that were corrected only after the crash—and these deficiencies likely contributed to the accident and its fatal outcome. ***I therefore conclude it is impossible to point to a single “fatal factor” that caused this crash.*** Rather, it was a unique series of decisions, events, and circumstances that together led to this mishap.

Congressman Jones, thank you for bringing this matter to my attention. I hope this letter will provide the widows of Lieutenant Colonel Brow and Major Gruber some solace after years in which the blame for the Marana accident was incorrectly interpreted or understood to be primarily attributed to their husbands. I believe Lieutenant Colonel Brow and Major Gruber were two fine young aviators who gave their lives in service of the country and their Corps. I also hope and expect this letter will end further debate over the cause of this tragic accident.

Sincerely,

A handwritten signature in black ink, appearing to be "R. W. ...", written in a cursive style with a long horizontal stroke extending to the right.