Proposed Airworthiness Standards for BA 609 Tiltrotor (TR) Acceptance Under the Special Class Rule

On September 27, 2007, the FAA published a notice (Federal Register Vol. 72, No. 187) requesting comments on proposed certification basis for acceptance of the BA609 Tiltrotor under 14 CFR 21.17(b), designation of applicable regulations for special classes of aircraft for which airworthiness standards have not been issued.

Since the comment period closed January 25, 2008, the FAA has reviewed and responded to comments received as summarized in this document. Comments are grouped together if more than one commenter made similar comments.

The FAA will soon publish the updated proposed certification basis for acceptance of the BA609 Tiltrotor and again request comments.

Subpart A

Comment TR.10 – Para (a) defines airplane mode as having the rotor speed set to cruise RPM. It is considered that any RPM with the nacelles at zero degrees would qualify as airplane mode.

FAA response – This certification basis is for the BA609 only. Airplane mode is a discrete RPM (current design is 84%) and locked on the down stop. V_{con} remains the speed limit until the RPM is reduced to cruise (airplane) RPM and therefore the configuration is considered VSTOL until the RPM is reduced to 84%.

Comment TR.10 – Para (j) defines the Power Lever as "A cockpit control that, in synergy with the rpm governor. . ." The word "synergy" sounds like something out of a pop psychology self-help book rather than an airworthiness standard. It is suggested that "A cockpit control that, in conjunction with the rpm governor. . ." would be preferable in a regulatory document.

FAA response – The FAA concurs with removing synergy.

Comment TR.10 – Para (k)(2) - It is suggested that the phrase "for immediate control of aileron, elevator, and yaw direction" be changed to "for immediate control of pitch, roll, and yaw". This would be consistent with Para (k)(1) and §§ 673 of Parts 23 and 29, which refer to attitudes rather than control surfaces.

FAA response – The FAA is in the process of revising TR.10 for consistency and will adopt the recommended wording.

Comment TR.11 – V_{MIN} is defined as the minimum authorized speed for each configuration but there are no criteria given in the body of the requirements for determining this speed.

FAA response – There is no need to define additional criteria for this speed. The applicant selects V_{MIN} as the minimum speed that it can meet all the airworthiness requirements for the configurations/modes requested for certification.

Subpart B

Comment TR.33 – The propeller speed and pitch limits of § 25.33 are not included in this paragraph. Are the pitch requirements associated with autorotation compatible with the requirements of § 25.33?

FAA response – The propeller requirements of § 25.33 are not appropriate requirements for the BA609.

Comment TR.38(a) – The proposed certification requirement does not take into account landing the BA609 onto an elevated helipad such as provided in off shore oil rigs, roof tops of high rise downtown buildings, or other types of elevated helipads, where the aircraft could encounter hazardous flight conditions without advance warning. The certification requirements should account for this since this is a unique aircraft.

FAA response – The appropriate airworthiness requirements are defined in Subparts B and G. Appropriate limitations will be defined for takeoff and landing from elevated structures or helipads as determined during flight test and established per TR 51, TR.53, RE 55, TR 60, TR 61, TR 62, TR 63, TR 67, TR 77, TR 79, TR 81, TR 85, and TR.1583. The operational considerations will be included during Function and Reliability testing in accordance with § 21.35(b)(2). The FAA continues to evaluate the need to define additional requirements to address vortex ring state for this design.

Comment TR.51(b)(3) – Para (b)(3) indicates that takeoff data must be corrected to assume a level takeoff surface. This is incorrect. The takeoff data must include operational correction factors for effective runway gradients. It is suggested that the wording of TR.51 (b) and (d) be rearranged and the wording of § 25.105(d) be used.

FAA response – The intent of TR.51(b) is to use the same requirements as for transport category rotorcraft since the BA609 will make all takeoffs and landings in the VTOL/Conversion mode. As more information is gathered for the BA609, take off and landing requirements will be assessed as appropriate for the tiltrotor capability to operate from runways. Requirements from § 25.105(d) will be reviewed for application as appropriate for the BA609.

Comment TR.51 – There are no definitions of take-off speeds analogous to § 25.107. It is assumed that this is because for this type of aircraft significant points in the take-off may be defined by a combination of speed and altitude. Also it is not expected that there will be any V_{MC} considerations. However, there may be a case for defining V_R and V_{EF}. As noted above, there are currently no criteria governing V_{MIN} and none for V_{TOSS}.

FAA response – This certification basis is specific to the BA609 tiltrotor. Take-off speeds analogous to § 25.107 are unnecessary because the requirements are defined to be the same as for transport category rotorcraft making all takeoffs/landings to a helipad in the VTOL/Conversion mode. The criteria governing the airspeeds for takeoff and landing are derived from the associated 14 CFR 29 requirements for Category A takeoff and landing.

Comment TR.59(a)(3) – Paragraph (a)(3) reads "After the critical engine is made inoperative, the aircraft must continue to the TDP, and then attain V_{TOSS}". This wording is the same as that in §29.59(3) and both are incorrect. If the critical engine becomes inoperative at some time between the start of the takeoff and the TDP then the takeoff is rejected.

FAA response – The wording in TR.59 and §29.59(a)(3) are correct. The takeoff path begins with the aircraft accelerating to the engine failure point (EFP), and then continues with a one-engine-inoperative (OEI) acceleration the Takeoff Decision Point (TDP) and to the takeoff safety speed (V_{TOSS}). In showing compliance to TR.59 or §29.59(a)(3), the EFP and TDP are separated by pilot recognition time. Since the TDP serves as the "Go/NoGo" point, the intent of this requirement is to show that continued safe flight is possible for the TDP. This requirement is necessary since TDP is defined as the first point in the takeoff path from which continued takeoff capability is assured.

Comment TR.59(a)(4) – Paragraph (a)(4) states "Only primary controls may be used while attaining V_{TOSS} and while establishing a positive rate of climb and no change in power that requires action by the pilot may be made until the aircraft is 400 feet above the takeoff surface". TR.10(k)(1) includes the power lever as a primary flight control in the V_{TOL}/conversion mode. Para (a)(4) and TR.10(k)(1) are contradictory.

FAA response – The FAA is still reviewing definitions for primary control for this aircraft as well as the prohibition in this paragraph for changing power below 400 feet. The FAA will revise as appropriate.

Comment TR.59 (f)(4) – Paragraph (f)(4) should read "demonstrated continuous takeoffs" rather than "continuous demonstrated takeoffs".

FAA response – The FAA concurs and will revise.

Comment TR.62 – There is no mention of stopways as described in FAR 25.

FAA response – The BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The FAA determined that the certain part 25 requirements were not appropriate due to these low speeds. The intent of TR.62 is to use the same requirements as transport category rotorcraft since the BA609 will make all takeoffs and landings in the VTOL/Conversion mode.

Comment TR.62 – There is no consideration of all engines rejected take-off as provided in FAR 25. This is considered a significant deficiency as the all engines case may be more limiting under some circumstances than the one engine inoperative case.

FAA response – The BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The FAA determined that the certain part 25 requirements were not appropriate due to these low speeds. The intent of TR.62 is to use the same requirements as transport helicopters since the BA609 will make all takeoffs in the VTOL/Conversion mode.

Comment TR.62 – There is no accountability for wet runways.

FAA response – The BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The FAA determined that the certain part 25 requirements were not appropriate due to these low speeds. The intent of TR.62 is to use the same requirements as transport helicopters since the BA609 will make all takeoffs in the VTOL/Conversion mode.

Comment TR.67 – Typo in Para (a). Should be "must be measurably positive …"

FAA response – The FAA concurs. We will correct the typo.

Comment TR.67 – For the enroute climb, 30 minute power is not appropriate. OEI service ceilings, driftdown and minimum enroute altitudes are all based on enroute climb performance and it is expected that the aircraft will be capable of sustaining the enroute climb performance for the duration of the mission. The appropriate power setting is MCP.

FAA response – The BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The intent of TR.67 is to use the same requirements for OEI climb as transport category rotorcraft since the BA609 will make all takeoffs in the VTOL/Conversion mode. MCP power is used for all engines operating (AEO) not OEI. As more performance information is gathered, the FAA will evaluate the applicant's proposal to determine if changes to the certification basis are required. The "or" in TR.67 (c) and TR.69 (b) (1) will be changed to "and."

Comment TR.67 – The OEI performance of this paragraph is all related to the takeoff configuration and there is no requirement governing the OEI performance for the approach case as provided in FAR 25.121 (d).

FAA response – BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The intent of TR.67 is to use the same requirements as transport category rotorcraft since the BA609 will make all takeoffs in the VTOL/Conversion mode. The BA609 approach speed will not be based on V_{SR} and therefore for §25.121(d) is not appropriate.

Comment TR.67 – There is no all engine landing climb (go around) performance requirement as provided in FAR 25.119.

FAA response – The BA609 will be certified and operated at typical transport category rotorcraft takeoff and landing speeds. The FAA determined that the certain part 25 requirements were not appropriate due to these low speeds. The intent of TR.67 is to use the same requirements as transport category rotorcraft since the BA609 will make all takeoffs in the VTOL/Conversion mode. When the certification basis was drafted, it was agreed that the landing configuration would be one of the approved takeoff configurations. The FAA will review the applicant's proposed takeoff and landing procedures to determine if changes to the certification basis are required.

Comment TR.75 – For this type of aircraft it is possible that accountability for temperature will be required if the distance depends on lift and hence power from proprotors.

FAA response – The FAA concurs with this comment, and the requirement will be changed to the wording used for Transport Rotorcraft.

Comment TR.75 – FAR 25 states that the aircraft shall be in the landing configuration. This statement is missing in these requirements.

FAA response – When the certification basis was drafted, it was agreed that the landing configuration would be one of the approved takeoff configurations. The FAA will review the applicant's proposed takeoff and landing procedures to determine if changes to the certification basis are required.

Comment TR.79 – Para (a) refers to the climb requirements of TR.67 which as stated above is referenced to the take-off configuration. Approach and Landing climb performance as provided in FAR 25 is required.

FAA response – When the certification basis was drafted, it was agreed that all approaches and landings would be flown in the VTOL/Conversion mode. Consequently, the climb performance requirements taken from 14 CFR 29 suffice in meeting the approach and landing climb performance requirements from 14 CFR 25. As more information is gathered, the FAA will review the applicant's proposed takeoff and landing procedures to determine if changes to the certification basis are required.

Comment TR.79(a) and TR.85 – Given the 609's engine placement and the critical nature of balanced power and center of gravity stability during vertical descent, it is *imperative that this a/c have a cross-wing interconnect drive shaft system similar to that in the V-22* so that one engine can supply power to the other in the event of single-engine failure. That said, it *should be mandated that the interconnect drive shaft NOT be made of composite material*. Titanium or stainless steel would be good. Composite burns should one engine be on fire. In V-22 crash #2, the interconnect drive shaft burned and failed under just such conditions. 7 people died. (b) Regarding complete power failure during normal cruise (i.e., level flight), see comment above re: TR.34 and Loss of All Powerplants. Finding a 'prepared surface' may or may not be an option. The essential question concerns glide ratio, prop-jettison capability, and composite fuselage capability of surviving belly landing at high speed. (609 wings are relatively shorter than those on similar capacity a/c resulting in higher horizontal landing speeds...when the a/c is not even designed for horizontal aircraft type landings...)

FAA responses – The FAA dictates minimum airworthiness requirements and not design. The requirements in TR.79 require safe flight and landing after loss of the critical engine. The cross shaft requirements are detailed in subpart D.

Comment TR.103 – Para (b)(1), the question of power setting for stall may require discussion for this type of aircraft, depending on the thrust produced by the prop rotors at idle, particularly if there are cases to be considered for which the nacelle angle is not zero.

FAA response – The FAA concurs that power setting for stall needs to be reviewed.

Comment TR.143 – TR.143 (p16) Controllability and Maneuverability: See especially previous comments re: landing approach under heavily laden conditions into area where local aerodynamic conditions may be variable--wind gusts, trailing vortices from buildings or oil rig structures, etc. Approach *direction* under such conditions may be crucial.

FAA response – The appropriate airworthiness requirements are defined in Subparts B and G. Appropriate limitations will be defined for takeoff and landing from elevated structures or helipads as determined during flight test and established per TR.1583.

Comment TR.143 – Para's (c) and (d) specify gear retracted whereas the FAR 25 equivalents specify gear extended.

FAA response – As more information is gathered, the FAA may determine other requirements are appropriate based on the data developed during this certification activity. Based on that, the FAA will review the BA609 certification basis to determine if a gear extended requirement should be added to these paragraphs.

Comment TR.143 – The "power on" requirement of (c) 4 should be defined. FAR 25 specifies MCP.

FAA response – As more information is gathered, the FAA may determine other requirements need to be added to the certification basis. Based on that, the FAA will review the BA609 certification basis and determine the appropriate requirement for "power on". The current requirement is for all power-on conditions instead of just MCP.

Comment TR.143 – TR.143 (and elsewhere) has several tests that require movement of the flaps that would be abnormal for a tiltrotor even under emergency situations. For example, TR143(d)(3) implies a go-around in airplane mode with flaps manually adjusted. This would be highly unusual since approaches are typically flown in conversion mode and flaps are left in auto. Recommend defining "autoflaps" as the normal configuration and then ensure stability/controllability for approved configurations within the flight envelope. Ensure that the approved flap configurations are charted in the operating limits.

FAA response – The normal configuration will be defined by the applicant and tested in normal configuration as well as degraded configurations. The appropriate flap limitations will be listed IAW with subpart G.

Comment TR.143 – In Para (h), it is suggested that the preamble, "If marginal conditions exist . . . of this section exceed the following" be deleted and maximum control forces be prescribed as in § 25.143 (d).

FAA response – The FAA will remove the first half of the sentence before the comma and add "to meet the requirements of this subpart" after the word necessary. The FAA determined the requirements of part 23 are more appropriate and conservative for the BA609 certification basis.

Comment TR.145 – FAR 25.145(c) concerning the retraction of high lift devices has not been included in these requirements.

FAA response – This is covered in paragraph (e) of the proposed requirement.

Comment TR.145(d) – The wording ". . . Gradient of the curve-of-stick force versus . . ." should be ". . . Gradient of the curve of stick force versus . . .”

FAA response – The FAA agrees with this editorial comment.

Comment TR.145(g) – Para (g) could be considered ambiguous as it requires consideration of "any approved configuration" but references the speeds determined for showing compliance with TR.69 Enroute flight paths in the flaps retracted configuration. Although the speeds are quoted as a factor of stall speed it is possible that a manufacturer could argue that the flaps retracted speeds could be used to show compliance in the flaps extended configurations which would not be conservative.

FAA response – Since TR.69 includes auto flaps the applicant will be required to show compliance to all approved configurations and therefore no change required to this rule.

Comment TR.147 –Sustained oscillations, controllability, etc. As much may have to do with flight control software as with pilot capabilities. The 609 has a digital engine control system (FADEC, presumably), computer-controlled. Many V-22 'incidents' were caused by software problems, including an uncommanded takeoff and contributions to the crash that killed 4 Marines. Suggest the FAA institute testing parameters specifically for flight control software and engine control software--x hours of testing with y cycles involving different commands, or whatever. Presumably, because of long V-22 related delays in its own program, the BA609 will have THOROUGHLY tested software since it has had more than enough time to do so...

FAA response – The civilian requirements for software are covered in TR.1309. Software is generally qualified using acceptable standards, such as RTCA/DO-178.

Comment TR.175 – The landing configuration is not addressed. Para (g) should become Para (f); Para (f) should become Para (g) and retitled "Approach and landing".

FAA response – FAA concurs.

Comment TR.195(a) – What is the definition of "approved airspeeds"? If this includes speeds down to V_S or V_{SW} in airplane mode, this would be an unnecessarily stringent requirement. In fact, it could be argued that it would lead to a lower level of safety as having to hold a control force at these low airspeeds is an additional cue to the pilot that the speed is low.

FAA response – FAA is revising this paragraph to separate the requirements between VTOL/Conversion mode and Airplane mode with the additional requirement in both modes that it be possible to trim all control forces to zero.

Comment TR.195 – Para (c) does not have the FAR 25 requirement of § 25.161(c) (1)(ii) for trim in the take-off configuration. It appears that all the trim requirements are for airplane mode only.

FAA response – FAA is revising this paragraph to separate the requirements between VTOL/Conversion mode and Airplane mode, with the additional requirement in both modes that it be possible to trim all control forces to zero.

Comment TR.195(d) – The second sentence reads, "The airplane must maintain. . . " It is assumed that it should read, "The aircraft in airplane mode must maintain. . .". The bank angle requirement is not relevant to this design as there is no thrust asymmetry due to engine failure.

FAA response –Based on the applicant's preliminary test and analysis, the aircraft demonstrates some amount of asymmetry. Consequently, it is appropriate to maintain a requirement allowing for a maximum bank angle to shoe compliance with this requirement.

Comment TR.195 – There is no requirement to be able to trim on the approach. This is considered important for instrument approaches in particular and the requirement of §25.161(c)(2) should be included. If it is considered that this is covered by Para (a) then it is not clear why paragraphs (c) and (d) have been included. These remarks also apply to the requirements of §25.161(c)(3) for trim in cruise flight gear up and gear down.

FAA response – As stated above, the FAA is revising TR.195 to include specific requirements for each aircraft mode. As currently written, the requirements assume that approaches will be flown in a VTOL/Conversion mode under a "stabilize approach" concept. As more information is gathered on which modes will be authorized for flying an approach, additional requirements may be added.

Comment TR.195 – There doesn't appear to be any requirements dealing with prop rotor ground and structural clearance such as § 25.925 Propeller clearance or §29.661 Rotor blade clearance.

FAA response – Reference §29.661 and TR.661 address the requirements for ground and structural clearance.

Subpart C

Comment TR.571 – TR.571 Damage Tolerance and Fatigue Evaluation of Metallic Structure: Fine. But I see no equivalent relating to composite structures, when the fuselage is composite, as are the prop blades, and various other panels and structures. Just as there are specific guidelines regarding metal corrosion and fatigue, where are those guidelines for the composite areas of the a/c? According to thickness and type (whether load-bearing or honeycomb panel), different non-destructive testing methods will be required and should be individually recommended. And visual inspection is not enough: if through a hairline crack from a bump by baggage cart moisture has intruded into paneling or skin and then gone through freeze thaw cycles because of flights at 25,000 feet (etc.) over many cycles, there is danger of hidden delamination, disbonding, etc. These are still new technologies in general and business aviation a/c and the 609 as a hybrid tilt-prop are even newer.

FAA response – The BA609 certification basis addresses composite structure is the requirements in 14 CFR 23.573(a).

Comment TR.571 – It is suggested that §25.571 be used in lieu of the proposed TR.571 for the following reasons: (a) FAR 25.571 explicitly requires the use of crack growth analysis (fracture-mechanic-based) and/or tests, assuming the structure contains initial cracks to determine inspection intervals. This requirement, of course, is based on slow crack growth that is essentially one of the main design criteria for the structures of fixed-wing aircraft. (b) AB609 structures, except the mechanism design for VTOL/conversion, are basically those of a traditional fixed-wing aircraft: pressurized cabin, wing, control surfaces, etc. In other words, the rotorcraft-inherent n/rev loading is non-existent for tiltrotor structures. In absence of such extremely high frequency n/rev loading, the crack growth analysis would become possible and, actually, would be the most reliable analytical tool available for the determination of inspection intervals for the structures of the BS 609. (c) The draft TR.571 apparently does not require, or even make reference to, crack growth analysis to be employed to determine inspection intervals. The term "damage tolerance" employed in this draft TR requirement is apparently a repeat use of the traditional-rotorcraft terminology that has the general meaning that the structures is "tolerant" to the external damages such as manufacturing and in-service damages. This is, in fact, the basis for traditional flaw tolerance safe-life and flaw tolerance fail-safe approaches to evaluate the fatigue strength of the structure. For metallic structure, crack initiation and crack growth are the main indications of the fatigue strength degradation due to in-service repeat operational loads and environment. The inspection techniques for cracks have been well developed and have become reliable and effective maintenance tools for the modern fixed-wing aircraft. Therefore, the damage tolerance analysis based on fracture-mechanics should be a preferred analytical tool for the fatigue evaluation of the tiltrotor AB 609 primary structures and §25.571 would provide sufficient design standards for fatigue certification of this model.

FAA response – Because the BA609 is not a typical fixed wing aircraft and the BA609 fatigue loads are not typical fixed wing fatigue loads, the requirements of §25.571 were determined to be inappropriate to adequately address the full fatigue spectrum of the BA609. While parts of §25.571 were used, the requirements were written to address the unique characteristics of the BA609.

Subpart D

Comment §25.697– 25.697(a) reference to 25.101(d) is not applicable for the BA609. For the BA609, the reference should be TR45(d).

FAA response – The FAA concurs.

Comment TR.777 (a) – How is the conversion mode addressed within the power inceptor requirements for the BA609? As the nacelles rotate into the forward (0°) position, the power inceptor remains fixed (does not rotate to accommodate for the current nacelle angle) in the "collective" style mode. Mixed pilot populations (i.e. fixed wing vs. rotary wing pilots) have significantly different control style strategies due to the vehicles they have their primary/majority of their training/experience in. The specifications for these vehicles (fixed & rotary wing) are outlined in FAR parts §25.779 & §29.779 respectively. In each instance of the respective vehicle, the direction of travel of the vehicles power inceptor is ALWAYS congruent with the acceleration vector (up is up, down is down, forward is faster, and backwards is slower) of the aircraft. In the BA609, the only instance of congruent (thrust vector to inceptor movement) control is when the nacelles are in the vertical position. In the nacelle forward positions, the BA609 inceptor is in some cases completely reversed from the desired action (i.e. pull backward/up on the inceptor to accelerate the aircraft forward and push down [i.e. away from the pilot] to decelerate the aircraft). The current configuration requires the pilot to pull up and back (similar to a collective control style strategy) to accelerate (counterintuitive) and down and forward from the pilot to decrease thrust (also counterintuitive). In the forward nacelle airplane mode this is completely counterintuitive and reversed from that that is engrained in fixed wing pilot training. There is ongoing research investigating if an adaptive interface, one that allows for congruent (up is up, forward is faster and vice versa) inceptor travel to thrust vector movement is more beneficial (i.e. reduces pilot workload, mitigates errors, allows for shorter/no transition times) than a fixed collective or throttle style inceptor.

FAA response – The applicant and the FAA recognize the difference between the application of the TR.777(a) rule for airplanes and rotorcraft. The FAA will evaluate the design to ensure that it does not have objectionable characteristics. The FAA's responsibility is to evaluate the applicant's design to determine if it meets the minimum safety standard for that type of aircraft.

Comment TR.777 (a) – The current BA609 collective style power control configurations raises serious Human Factors concerns such as Negative transfer of skills, Peripheral constraint concerns, and stress/workload concerns that could have significant impact on the pilot. Negative transfer of skills: "When two situations have similar (or identical) stimulus elements but different response mapping or strategic components, transfer will be negative (transfer refers to the skill set being moved from one task, in this case flying either rotary or fixed wing, to another, in this case tiltrotor. In the case of the BA609, the power inceptor is a classic collective, pilots transitioning from a fixed wing environment are going to be highly susceptible to negative transfer due to the stimulus (operational environment) being the same yet the control strategy being significantly different, more so depending on which phase of flight the aircraft is in (i.e. nacelle forward; airplane mode, or nacelle aft; helicopter mode). This type of condition can lead to control reversal as seen in the USAF V-22 accident. On July 9th, 1991, a former CH-47 pilot who was PIC in a V-22 (Vehicle #5) commanded a control reversal leading to an increase in thrust (the desired action was a decrease in thrust). The pilot had difficulties controlling the aircraft which had two of its three roll gyros incorrectly wired. The pilot was able to successfully place the aircraft back on the ground but once planted, the pilot, intending to maintain the vehicle "grounded" pushed to power inceptor to its full forward (away from him) position. This action launched the aircraft into the air and onto its side completely destroying the aircraft. The pilot had reverted back to his prior training (Negative Transfer) in the CH-47 in which the same action would have executed a cut in power. The pilot in interviews and the Flight Data Recorder (FDR) both confirmed this. It is also important to note that the pilot was an experimental test pilot (XP) and to make the distinction that XPs possess a skill far superior then the average ATP or commercial pilot for that matter. It would be assumed that non-XPs would have greater difficulty in modifying their control actions when the power inceptor is incongruent with the axis of thrust and that Negative Transfer would be of <u>higher</u> concern during incongruent inceptor travel to thrust vector situations. Instances of negative transfer are not isolated in aviation. Circa 1966 there was a documented crash of a USAF F-111. The subsequent investigation revealed that the aircraft impacted on approach in a flat landing due to an incorrect wind setting. The contributing and main factor for this accident was that the engineers created the wing sweep selector inceptor to move forward to sweep the wings back. The reasoning behind this was that forward meant faster; pushing the wing seep inceptor forward swept the wings backward. This was completely reversed from the pilot's mental model of how the selector should operate.

FAA response – The BA609 is to be type certificated per the requirements of §21.17(b) and will be first in operations for its category, powered lift, and first in class, tiltrotor. Because of the uniqueness of powered lift, it will require a pilot type rating with the requirements defined in Part 61.

Comment TR.777 (a) – In all FAA certified aircraft (except for tiltrotors), inceptor movement intuitively controls the device it is intended for in a congruent fashion: (1) Throttle - forward (relative to the Aircraft) accelerates while backward decelerates. (2) Collective - Up (relative to the aircraft) increases lift while down decreases lift. (3) Flaps - Up raises the flaps while down lowers them (4) Landing Gear - Up (relative to the aircraft) raises the gear while down lowers them. Spoilers/speed brakes - Down or back relative to the aircraft) decelerates the aircraft while up or forward retracts allowing acceleration.

FAA response – The FAA concurs. The applicant and the FAA recognize the difference between the application of the §25.777, §25.779 and §29.779 rules for airplanes and helicopters. The FAA will evaluate the BA609 design to ensure that it does not have objectionable characteristics throughout the entire operating envelope.

Comment TR.777 (a) – There is significant concern for tiltrotor operation when the aircraft's thrust vector does not match the direction of travel of the power inceptor. To further compound this, as the BA609 is entered into service, it would be an obvious assumption that the majority of eligible pilots will come from the V-22 tiltrotor pilot pool. The V-22 uses a forward to accelerate and back to decelerate style power inceptor. Currently it is estimated that it takes <u>new</u> V-22 pilots about 100 hours to transition to the appropriate control strategy. Pilots transitioning to the BA609 in its current configuration from the V-22would have to "relearn" the power control strategy. Questions have been posed as to what happens in situations of high workload or stress; will pilots revert back to their initial training.

FAA response – The BA609 will require a pilot type rating in accordance with Part 61. The BA609 power lever design will be evaluated during the certification for compliance to the requirements of TR.777 and TR.779. The FAA's responsibility is to evaluate the applicant's design to determine if it meets the minimum safety standard for that type of aircraft.

Comment TR.777 (a) – Peripheral constraints**:** In the BA609, the only way for the pilot to reference the nacelle angle is to either utilize an eye movement to view the nacelle angle on the Primary Flight Display or to utilize a head movement to lookout at the Nacelle. Without an "adaptive" power inceptor each of the previous methods can lead to peripheral constraint concerns. Peripheral constraint is a physical constraint or inability of the user to accomplish a task. In this example, the peripheral constraint concern arises from the user only being able to look at one place at any given time. During nominal conditions, a brief eye glance or head movement might not be problematic, but during a malfunction either one of those movements could be costly if not impossible. From a Human Factors perspective, Nacelle Angle is considered Low Bandwidth. High Value from an information stance. This is to say that the information on at what angle the

Nacelle is set at is relatively static (low bandwidth) but highly important (high value) for the operation of the vehicle. In the event the operator needs to enter the loop (loop refers to the task at hand) rapidly and does not have an understanding of Nacelle Angle, it could affect the outcome of the task, especially in an emergency situation.

FAA response – The FAA's responsibility is to evaluate the applicant's design to determine if it meets the minimum safety standard for that type of aircraft. The FAA does not dictate design.

Comment TR.777 (a) – With a mixed pilot group (Rotary & Fixed wing) being eligible, there is concern that pilots with their primary or the majority of training or operational experience in rotary wing aircraft will fare better in the Nacelle "up" position. Unfortunately it is not predicted within the author's research that fixed wing pilots will fare better in precision vehicle control in the Nacelle forward position. The reason for this, outline in the Negative transfer of skill section, is because the control strategy is opposite from their primary and/or bulk training/experience. Though mental rotation and/or control strategy manipulation can be accomplished in nominal (non-emergency) situations, there is concern that high workload or stress environments (i.e. an emergency) could cause control reversal inputs (as in the case of USAF V-22 Vehicle #5) leading to serious or fatal consequences.

FAA response – The FAA's responsibility is to evaluate the applicant's design to determine if it meets the minimum safety standard for that type of aircraft. The FAA will base its assessment with regards to an “average” pilot having no exceptional skill, alertness, or strength. The BA609 flight control design will be evaluated during certification for compliance to the requirements of TR.777 and TR.779, including system failure modes. Additionally, the FAA Aircraft Evaluation Group will conduct a Flight Standardization Board to assess the need for an Aircraft Type Rating, to assess the training requirements for initial and recurrent pilot training, and to develop the Master Minimum Equipment List (MMEL).

Comment TR.777 (a) – There is supporting research that indicates that a fixed, non-rotational/congruent power inceptor for tiltrotor aircraft would increase susceptibility for pilot error especially during moments of high workload. Currently two systems, the Magnum and the Rotational Throttle Interface (RTI) have been proposed but each one has been met with little interest from the manufacturer. Each interface would give the pilot haptic (tactile) feedback of nacelle position during ALL phases of flight. The primary difference between the two devices were that the Magnum required the pilot to remove their hand during the nacelle transition phase while the RTI does not, allowing the pilot to maintain contact of the power inceptor through all ranges of nacelle angle travel. Persons at both the FA and NASA have expressed interest in a congruent, intuitive interface for tiltrotor.

FAA response – The FAA's responsibility is to evaluate the applicant's design to determine if it meets the minimum safety standard for that type of aircraft. The FAA does not dictate design – but requires compliance to the minimum safety requirements for the aircraft type submitted for certification.

Subpart F

Comment TR.1309 – The header paragraph and paragraph (a) to (d) appear to be new wording not based on any existing version of 1309. It does not appear to be deficient but it is different and may benefit from a review by systems specialists.

FAA response – This proposed BA609 requirement was developed by the FAA system specialists based on the draft revision to 25.1309 and the current 29.1309. This requirement is currently under review.

Subpart G

Comment TR.1581 – The requirement of §25.1581 pertaining to noise limitations has not been included

FAA response – The proposed noise requirements will be incorporated into the next revision of the certification basis.

Comment TR.1583 – It is noted that this is the FAR 23 version of 1583 which incorporates performance weights as operating limitations.

FAA response – Portions of 14 CFR 23 were determined to be the most appropriate for the BA609 design.

Appendix H

Comment HTR.63(c) – Emergency landing following an engine failure at any point along the flight path'... the flight path during vertical takeoff is up for grabs, as is where you land after engine failure. See previous comments relating to single-engine failure in the 609. What if there is DUAL engine failure shortly after takeoff? That needs to be addressed.

FAA response – This requirement applies only to the Normal category, not the Transport category. For civil certification the flight path will be defined. For Normal category performance there is a limited exposure time where single engine performance is not guaranteed. Dual engine failure will be addressed, such as the requirements of TAR.143.

Comment HTR.1585(a) – Strongly recommend easy availability of SHORT emergency check list for pilot/co-pilot. The V-22's until recently (and perhaps even now) is/was 144pp. long. In an emergency, that is USELESS.

FAA response – There is no requirement for an emergency checklist. Each required emergency/abnormal procedure will be reviewed to determine if it is a memory item. The FAA will evaluate the Aircraft Flight Manual submitted by the applicant.

General Comments

Comment – Please refer to and think about this aircraft as a tilt-PROP design, not a tilt-rotor. There is a huge aerodynamic difference between the approximately 47-degree twist on this prop vs. the minimal 8-degree twist typical of helicopter blades. This difference has safety ramifications in several different flight modes.

FAA response – This aircraft is in the powered lift category and tiltrotor class because it has independent proprotor blade control through cyclic control (like a helicopter) when it is in VTOL/conversion mode; therefore, it is a tiltrotor.

Comment – Two things are missing in the 609 certification basis published in Federal Register that are necessary for proper navigating through conflicting references: a) A guideline on how to interpret the references & b) A note to section 25.697 that reads: "References in (a) to 25.101(d) is not applicable. For BA 609 the reference should be to TR 45(d)"

FAA response – The FAA concurs. The certification basis will be revised to include in TR.1 information to address conflicting references.

Comment – Throughout the document the words “nacelle” and “pylon” are used interchangeably. Recommend standardize the terminology to "nacelle".

FAA response – These terms are not intended to be used interchangeable. Pylon is the structure that attaches the engine and gearboxes to the wing. The nacelle enclosure houses the pylon, engine and gearboxes and is attached to the wing via the pylon. The tiltrotor class is unique in that the pylon is not fixed but rotates to change the nacelle angle. The certification basis will be reviewed to ensure nacelle and pylon are used appropriately.

Comment - Only two “aircraft modes” are defined however the tilt-rotor has four distinctive modes of operation that directly affect the performance and flying qualities, which are: VTOL (100% of Lift from Prop/Rotor, AIRPLANE - (100% of Lift from wing/lifting surfaces), TRANSITION (changing from 100% Prop/Rotor lift to lift shared by both the prop/rotor and wing/lifting surfaces), CONVERSION Mode (changing from lift provided only by wing/lifting surfaces to lift shared by both the prop/rotor and wing/lifting surfaces. There is a definition in the "draft" for AIRPLANE Mode as "nacelles on the down stop and rotor speed set to cruise speed:. Recommend provide Clear definition of all four modes of operation to include nacelle angles and RPM and include all four modes in all applicable performance and flying qualities FAR sub-paragraphs.

FAA response - The BA609 aircraft modes are defined by proprotor RPM. TR.10 and TR.11 are being rewritten to clarify the definitions and abbreviations to ensure all terms are clearly defined and used consistently throughout the certification basis.

Comment - The tilt-rotor has various unique “aircraft modes” as the nacelles are tilted throughout the different phases of flight (take-off, climb, transition, cruise, conversion, approach, landing); however they were not included in the specific FAR guidance which appears to be confined to either VTOL or Airplane. Recommend include the various nacelle angles for short take-off, climb, approach and short landing capability for all applicable nacelle angles in all applicable FAR subparagraphs.

FAA response - The applicant is responsible to define the specific configurations/modes for each of the maneuvers to be certified. Each of these will be evaluated, and if necessary, limitations established.

Comment - The cockpit control that controls the nacelle angle is defined as a “conversion controller” however the nomenclature does not reflect its intended function. Recommend define the cockpit control that changes the nacelle angle as a “nacelle control”.

FAA response – The BA609 design includes the conversion controller which has a dual function, it controls both proprotor RPM and nacelle angle. The aircraft mode change, or conversion, is based on the change in prop rotor RPM, therefore, it is not just a nacelle controller.

Comment - The cockpit control that affects pitch and roll changes is defined as a “center stick” however that definition assumes a particular design. Recommend define the cockpit control that affects pitch and roll as a “control stick”

FAA response - The definition of cockpit controls are specific to the BA609. This certification basis is for the BA609 only and is not a generic regulation for other powered lift designs.

Comment - No regulatory guidance is provided for establishing limitations for the following safety related aircraft configurations: Min/max nacelle angle for take-off and landing which is of concern for ground impact of prop/rotors. Max nacelle angle in a hover which is of concern to ensure adequate flight control margins in a hover where large flight control displacements may be required to counteract excessive nacelle angles in a hover. Recommend provide a requirement to establish limitations for min/max nacelle angle for take-off and landing and max nacelle angle in a hover.

FAA response - The applicant is responsible to define the specific configurations/modes for each of the maneuvers to be certified. This includes the acceptable nacelle angles for hover. The BA609 has discrete nacelle angle detents unlike the V-22. The certification basis already includes the requirements for flight control margins for the flight envelope. TR.11 defines the min (V_{MIN}) and max (V_{CON}) airspeed for each nacelle position, which will be displayed to the pilot.

Comment - No regulatory guidance is provided for establishing prop/rotor speed limitations for each aircraft “mode”(VTOL, AIRPLANE, TRANSITION, CONVERSION). Recommend provide a requirement to establish prop/rotor speed limitations for each aircraft “mode”, as applicable.

FAA response - Aircraft modes are defined in TR.10 and are based on the two defined in-flight proprotor RPMs.

Comment - Stall speeds/stall characteristics are just stated for a nacelle angle of zero however they should be determined and demonstrated for all nacelle angles where a “significant” amount of lift is being generated by the wing. Recommend provide a requirement for Stall speeds to be determined and demonstrated for all nacelle angles, and associated rpm, where a “significant” amount of lift is being generated by the wing. If the selectable nacelle angles are “gated” then the stall speed/characteristics should be determined for all gated positions, other than VTOL (90 degrees).

FAA Response - The applicant is responsible to define the specific configurations/modes for each of the maneuvers to be certified. The BA609 has discrete nacelle angle detents. The certification basis will require the applicant to show control margin and acceptable flight characteristics at each approved nacelle angle. V_{MIN} will include stall margin in the VTOL/conversion mode.

Comment - The tilt rotor may include a cockpit control for changing the prop/rotor RPM however no regulatory guidance is provided as to the sensing of the switch. Note: Consider that as the aircraft transitions from VTOL to AIRPLANE, and airspeed increases, the RPM is decreased”. The opposite applies for conversions from AIRPLANE to VTOL. Recommend establish a requirement for the sensing of the RPM control switch.

FAA response - The BA609 does not have a RPM control switch, it has a conversion controller. It controls both proprotor RPM and nacelle angle. As the aircraft converts from VTOL/Conversion mode to Airplane mode, all movement of the conversion control are in the forward direction and vice versa. With nacelles at 0 degrees, the last forward movement of the conversion control reduces the RPM, and V_{MO} replaces V_{CON} as the airspeed limit.

Comment - "Conversion" is defined as "Rotation or tilting of the proprotor/nacelle assembly between VTOL mode and airplane mode? "Transition" is defined as "the flight segment in which nacelle angle is converted from one gated position to another gated position". "reconversion" is referenced in the text but is not defined. As defined, these three terms are confusion. Conversion and transition seem to say the same thing. Recommend using the already established language. The USMC and USAF have agreed to standardized definitions where "transition" is the movement of the nacelles downward (toward airplane mode) and "conversion is the movement of the nacelles upward (toward VTOL mode). Using this already established language would add clarity to current and future tiltrotor documents.

FAA response - The BA609 aircraft modes are defined by proprotor RPM. TR.10 and TR.11 are in the process of being rewritten to clarify the definitions and abbreviations, and "reconversion" will not appear in the certification basis.

Comment - Proprotor is sometimes spelled "Prop Rotor". Should be consistent

FAA response – FAA concurs. The certification basis will use proprotor consistently

Comment - "nacelle", "proprotor/nacelle assembly" and "pylon" are used interchangeably to describe the conversion angle. Recommend using "nacelle".

FAA response - These terms are not intended to be used interchangeable. Pylon is the structure that attaches the engine and gearboxes to the wing. The nacelle enclosure houses the pylon, engine and gearboxes and is attached to the wing via the pylon. The tiltrotor class is unique in that the pylon is not fixed, but rotates to change the nacelle angle. The certification basis will be reviewed to ensure nacelle and pylon are used appropriately.

Comment - Primary flight controls are defined differently for VTOL/Conversion mode and Airplane mode. Most notably, the power lever is a primary flight control for VTOL/conversion but not airplane mode. Recommend using the same primary flight control definition for all phases of flight. If you do not want to include the conversion controller in airplane mode, I can understand that logic (although I disagree), but the power lever should be included.

FAA response - The certification basis is being revised to move the definition of primary controls to TR.673. The conversion control and power lever will be considered primary control in VTOL/conversion mode only.

Comment - Critical Engine is undefined for an aircraft with counter-rotating proprotors and an interconnecting driveshaft that keeps both rotors turning while OEI.

FAA response - The FAA disagrees. 14 CFR Part 1 defines Critical engine as the engine whose failure would most adversely affect the performance or handling qualities of an aircraft. This definition is adequate to define the critical engine for all the BA609 engine failure modes in showing compliance with the certification basis to ensure a safe design. The certification flight test will determine if the BA609 has a critical engine.

Comment - All engines inoperative requirements seem like overkill for a multiengine aircraft.

FAA response – All Civil Transport Category aircraft require demonstration of safe dual engine out flight, due as a result of cockpit mismanagement, fuel exhaustion, fuel contamination, improper maintenance, or unforeseen mechanical failures.

Comment - There are a number of different terms used to describe the aircraft including aircraft, airplane (e.g. TR.45(f) and TR.59(f)(2)), rotorcraft (TR.79(a)), and tiltrotor (TR.103). It is believed that the correct term should be aircraft and that this term should be applied consistently.

FAA response - The use of the terms “aircraft”, “airplane”, “rotorcraft”, and “tiltrotor” will be incorporated into TR.1 and, if necessary, corrected in the corresponding TR paragraphs. When a 14 CFR 25 or 14 CFR 29 rule is used, the original wording will be retained.

- - - END- - -