National Transportation Safety Board
Washington, DC 20594

Response to Petition for Reconsideration

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Stuart Fraenkel, Counsel for the Petitioners
Nicole Andersen, Counsel for the Petitioners
Nelson & Fraenkel LLP
[redacted]

Anthony Tarricone, Counsel for the Petitioners
Kreindler & Kreindler LLP
[redacted]

In accordance with Title 49 *Code of Federal Regulations (CFR)* Part 845.32, the National Transportation Safety Board (NTSB) has reviewed the petition for reconsideration and modification of probable cause of the accident involving a Pilatus PC-12/45, N128CM, that occurred on March 22, 2009, at Bert Mooney Airport (BTM) in Butte, Montana (NTSB 2011a). The petitioners have met the requirements for the NTSB's review of their petition; specifically, as 10 immediate family members of the accident victims (including the president of Eagle Cap Leasing Inc., one of three owners of the airplane), the petitioners have a direct interest in the investigation. The petition, which was prepared for the petitioners by legal counsel, offers new evidence and information, and it claims that our report was erroneous.

In accordance with 49 *CFR* 845.32(a)(3), the petition requests that the NTSB's report, probable cause statement, and six of the findings be reevaluated, reconsidered, and modified; the petition also proposes 11 new findings. Based on the NTSB's review of the petition filed on June 21, 2017, as well as the supplemental information submitted on July 20, 2018, the NTSB grants the petition, in part.

1. Summary of Accident

The accident occurred about 1432 mountain daylight time, and the wreckage was located less than a mile from BTM. The pilot and the 13 passengers (7 of which were children aged 9 and under) were fatally injured, and the airplane was substantially damaged. The personal flight was operated under the provisions of 14 *CFR* Part 91. It departed Oroville Municipal Airport (OVE), Oroville, California, at

1110 Pacific daylight time (1210 mountain daylight time) on an instrument flight rules (IFR) flight plan en route to Gallatin Field (BZN), Bozeman, Montana. Visual meteorological conditions prevailed at the time of the accident. The accident occurred during the pilot's third flight leg that day and while the pilot was diverting the flight to BTM.

On the morning of the accident, the pilot fueled the airplane with Jet A fuel at Nut Tree Airport (VCB), Vacaville, California, before proceeding to OVE; however, there was no evidence that the pilot ensured that a fuel system icing inhibitor (FSII) was added to the airplane's fuel as specified in the "Limitations" section of the airplane flight manual (AFM) for all flight operations in ambient temperatures below 0°C. Engine instrument system (EIS) data for the accident flight recorded an average total air temperature of -32°C (which, when corrected for airspeed, corresponds with an average outside air temperature of -40°C) between 1237 and 1405 while the flight was operating at flight level 250.

The airplane's AFM contained information stating that ice crystals in the fuel could block the fuel filter and cause a low fuel pressure condition, which would result in the automatic operation of the fuel boost pumps to correct the condition. The AFM described that, in such a case, both fuel pumps would run continuously, cycling OFF/ON every 10 to 15 seconds, which would be indicated by green "L FUEL PUMP" and "R FUEL PUMP" central advisory and warning system (CAWS) advisories. For this cycling fuel pumps condition, the AFM advised descending the airplane to warmer air. The investigation found that the fuel boost pumps began cycling (and the corresponding CAWS advisories activated) in response to a sensed low fuel pressure condition about 1 hour 13 minutes into the accident flight, but the pilot did not descend the airplane.

Further, the investigation found that, as fuel boost pumps cycled, a left-wing-heavy fuel imbalance developed. Fuel quantity for the left and right tanks is indicated in the cockpit by a liquid crystal display (LCD) that shows each tank's capacity in 28 segments (or bars), each of which represents about 7.17 gallons or 48.3 lbs of fuel, representing a total of about 201 gallons or 1,352 lbs of usable fuel per tank (NTSB 2011a, 12-13) (see figure 1).

Figure 1. Fuel quantity indicator (NTSB 2011a, 13).

The AFM contained a limitation specifying that the maximum fuel imbalance for the airplane was 26.4 gallons (178 lbs), which would be indicated by three LCD segments. The AFM provided an emergency procedure stating that, in the event fuel balance within the limitation cannot be maintained, the pilot should land the airplane as soon as practical. The investigation determined that the accident pilot likely recognized the fuel imbalance sometime between about 1 hour 21 minutes and 1 hour 32 minutes into the flight but did not divert to land the airplane as soon as practical after his attempt to correct it was unsuccessful. The pilot instead continued the flight (as the fuel imbalance continued to worsen) past numerous suitable airports. By the time of the accident, about 50 to 61 minutes had elapsed since the pilot's unsuccessful attempt to balance the fuel.

The NTSB's report, adopted July 12, 2011, contained the following probable cause statement:

> The [NTSB] determines that the probable cause of this accident was (1) the pilot's failure to ensure that a fuel system icing inhibitor [FSII] was added to the fuel before the flights on the day of the accident; (2) his failure to take appropriate remedial actions after a low fuel pressure state (resulting from icing within the fuel system) and a lateral fuel imbalance developed, including diverting to a suitable airport before the fuel imbalance became extreme; and (3) a loss of control while the pilot was maneuvering the left-wing-heavy airplane near the approach end of the runway.

The NTSB's report also contained 19 findings, including the following six that the petition specifically references and disputes (NTSB findings 2, 3, 4, 9, 11, and 13):

2. The investigation found that the airplane was properly certificated, equipped, and maintained in accordance with Federal regulations and that the recovered components showed no evidence of any preimpact structural, engine, or system failures.

3. The low fuel pressure state and the restricted fuel supply from the left tank during the accident flight were the result of an accumulation of ice in the fuel system with an initial concentrated amount of ice at the airframe fuel filter.

4. If the pilot had added a [FSII] to the fuel for the flights on the day of the accident, as required, the ice accumulation in the fuel system would have been avoided, and a left-wing-heavy fuel imbalance would not have developed.

9. Although the pilot should have diverted to a nearby airport once the maximum allowable fuel imbalance had been exceeded, the pilot eventually diverted to [BTM] likely because he recognized the magnitude of the situation and his attempts to resolve the increasing left-wing-heavy fuel imbalance had been unsuccessful.

11. The large left rolling moment induced by the left-wing-heavy fuel imbalance could have been minimized or even avoided if the pilot had followed Pilatus Aircraft's required procedures for flight operations with a fuel imbalance.

13. The pilot underestimated the seriousness of the initial fuel imbalance warnings because he had not experienced any adverse outcomes from ignoring similar previous warnings.

2. Petition's New Evidence and Proposed New Findings

A summary of the petition's new evidence and proposed new findings is provided below. The NTSB's review of this evidence and our response to the petition's claims are provided in section 3.

2.1 New Examinations of Left Fuel Boost Pump Armature Assembly

Petitioners' representatives located the armature assembly (pump motor) of the left fuel boost pump among the released wreckage, which had not been located for examination during the NTSB's wreckage investigation. They examined this component both in the field (during a wreckage examination in December 2012 in Pearblossom, California, where the wreckage was stored) and at a laboratory.

The petition provides documentation of these examinations and its analysis of its findings (Fraenkel et al. 2017a, 2, 18).

2.2 New Documents on Pilatus PC-12 Development and Operation

The petition also provides new documents, including correspondence and testimony obtained during the discovery phase of litigation, related to the "the development, history, and operation" of the Pilatus PC-12 and its systems. The documents contain information about fuel system icing; fuel boost pump design, function, and testing; the airplane's CAWS design and function; and the contents of the AFM and quick reference handbook (QRH). These documents are subject to a protective order that allowed the petitioners to submit the documents with their petition but that precludes any further disclosure of the documents due to confidentiality and proprietary information concerns from Pilatus. As such, although we have received these documents for review, our response quotes only the excerpted information that is provided in the petition and the party comments and generally summarizes the contents of select referenced documents.

2.3 Proposed New Findings

In addition to disputing the NTSB's statement of probable cause and six of the NTSB's findings, the petition proposes the following 11 new findings:

1. Investigation and forensic testing found that the left fuel boost pump contained mechanical defects that prevented it from operating as designed and intended.

2. If the left fuel boost pump had operated as designed and intended, it would have maintained sufficient fuel pressure while balancing the fuel between the tanks, and a left-wing-heavy fuel imbalance would not have developed.

3. The recurring low fuel pressure condition, the lack of fuel supply from the left fuel tank, the uncorrectable increasing imbalance, and the inability for the system to correct the imbalance were the result of a mechanical defect in the left fuel boost pump.

4. Despite the fact that the left fuel boost pump was not operating properly on the accident flight, the cockpit was displaying green PUMP advisories to the pilot throughout the flight, which, according to the AFM, indicated that the left fuel boost pump was operational.

5. If the fuel boost pump advisories had been properly described in the AFM, the pilot would have an immediate indication that the left fuel boost pump had failed, at which point he would have troubleshot and diverted the plane and had a better chance of safely executing an emergency landing.

6. The CAWS system was defectively programmed with a timed delay that suppressed visual and audible indications for low fuel pressure, including hundreds of occurrences of low fuel pressure during the flights on the day of the accident.

7. The CAWS system incorporated a design that violates [Title 14 *CFR*] 23.1305 and 23.1332 [sic] because it does not use a red warning means to indicate low fuel pressure.

8. If the warning for low fuel pressure had operated in compliance with [federal aviation regulations], the pilot would have received visual and audible low fuel pressure warnings on the first flight of the day, indicating an emergency requiring immediate pilot action, and the pilot would have safely grounded the plane before any of the decedent passengers even boarded the plane.

9. The <u>only</u> caution or warning the pilot received during the flight was a "Fuel Level Low" warning for the right tank 6 minutes before the crash.

10. An updated version of the PC-12 AFM was published a year before the crash with revised fuel system emergency procedures, which may have prevented the crash, but the AFM was only

distributed to owners and operators of the new PC-12 47E or "NG" aircraft.

11. If the pilot had the revised fuel system emergency procedures contained in the PC-12 NG AFM, he would have been advised to land "as soon as possible" shortly after the green PUMP lights began cycling.

3. NTSB's Review of New Evidence and Response to Petition's Claims

The NTSB's review of the petition's new evidence and analysis, as well as its proposed 11 new findings, is discussed below. We have organized our response by safety issue area, addressing each claim and proposed new finding in the following order:

- **AFM information and procedures for responding to fuel imbalance.** This discussion addresses the petition's claims against NTSB findings 9 and 11 (section 3.1).
- **AFM information and procedures for fuel system indications.** This discussion addresses the petition's proposed new findings 4 (in part), 5, 10, and 11 (section 3.2).
- **CAWS fuel system annunciations during the accident flight.** This discussion addresses the petition's claims against NTSB finding 13 and the petition's proposed new finding 9 (section 3.3).
- **CAWS design and certification.** This discussion addresses the petition's claims against NTSB finding 2 (in part) and the petition's proposed new findings 6 through 8 (section 3.4).
- **Fuel system icing during accident flight.** This discussion addresses the petition's claims against NTSB findings 3 and 4 (section 3.5).
- **Left fuel boost pump mechanical condition.** This discussion addresses the petition's proposed new findings 3, 1, 2, and 4 (in part) (section 3.6).
- **Fuel system design and certification.** This discussion addresses the remainder of the petition's claims against NTSB finding 2 (section 3.7).
- **NTSB's statement of probable cause.** This discussion addresses the petition's dispute of the NTSB's statement of probable cause (section 3.8).

3.1 AFM Information and Procedures for Responding to Fuel Imbalance

The petition does not dispute that the pilot failed to ensure that a FSII was added to the airplane's fuel, that the airplane was operated in temperatures far below the 0°C limitation that required the addition of a FSII, or that a left-wing-heavy fuel imbalance developed during the accident flight.

The petition makes claims regarding the adequacy of the AFM information and procedures available to the pilot for recognizing and responding to a fuel imbalance. Although the petition disputes the NTSB report's finding that the imbalance resulted from of an accumulation of ice in the fuel system that restricted the fuel supply from the left tank (discussed in sections 3.5 and 3.6 of this response), we note that the AFM information and procedures for addressing a fuel imbalance would apply regardless of the reason the imbalance developed.

The petition claims that "PC-12 pilots are not equipped with any knowledge of the 'maximum allowable fuel imbalance' or any specific emergency procedure to be performed when the fictional limitation is exceeded." It also claims that the NTSB's report "suggests that the pilot should have immediately followed the emergency procedure for an ['Auto(matic) Fuel Balancing Failure'] even though the indication for this procedure was not present." The petition claims that the NTSB report's conclusion "that the pilot should have diverted and landed immediately when the maximum imbalance was reached" is inconsistent with the AFM procedure that instructs the pilot to "first troubleshoot," which they claim is "what the pilot did" (Fraenkel et al. 2017a, 8).

Based on these claims, the petition asserts that NTSB findings 9 and 11 are erroneous, specifically the text that the petition has underlined, as follows:

9. Although the <u>pilot should have diverted to a nearby airport once the maximum allowable fuel imbalance had been exceeded</u>, the pilot eventually diverted to [BTM] likely because he recognized the magnitude of the situation and his attempts to resolve the increasing left-wing-heavy fuel imbalance had been unsuccessful.

11. The large left rolling moment induced by the left-wing-heavy fuel imbalance could have been minimized or even avoided <u>if the pilot had followed Pilatus Aircraft's required procedures for flight operations with a fuel imbalance</u>.

As stated in the NTSB's report, pilots are required by regulation (specifically, 14 *CFR* 91.9[a]) to comply with aircraft limitations specified in the AFM. This pilot responsibility is emphasized throughout pilot training and in Federal Aviation Administration (FAA) basic guidance materials because compliance with limitations and knowledge of the performance information and operating procedures contained in the AFM are essential for the safe operation of the aircraft, powerplant, systems, and equipment (FAA 2003, 7-2; FAA 2008, 8-2). A limitation is the strongest directive an aircraft manufacturer can impose on an operator to compel the safe operation of the aircraft (Pilatus 2017a, 1).

As discussed in the NTSB's report, for the accident airplane:

- **The AFM specified a limitation for the use of a FSII and a limitation for the maximum fuel imbalance.** Specifically, AFM section 2, "Limitations," required the use of a FSII for all flight operations in ambient temperatures below 0°C, and it listed the "Maximum Fuel Imbalance" for the airplane as 26.4 gallons (178 lbs), indicated by "Maximum 3 LCD segments" on the indicator (NTSB 2011a, 1 and14; NTSB 2011b, 5).

- **The AFM described the indications for normal system operation.** AFM section 7, "Airplane and Systems Description," described that the airplane was equipped with a fuel balancing system designed to automatically maintain fuel symmetry and that "normal system operation is indicated by the left and right fuel quantity gauges remaining within 2 LCD segments of each other." It also stated that, "in the event of a system failure, the fuel load symmetry can be maintained by manually selecting the Fuel Pump switch to ON for the fuel tank with the higher quantity until a balanced fuel condition is restored and then turning OFF the fuel boost pump. During normal operation, the pilot should monitor the fuel quantity gauges to verify that the Fuel Balancing Device is operating properly" (NTSB 2011a, 15; NTSB 2011b, 9).

- **The AFM provided an emergency procedure for responding to a fuel imbalance.** AFM section 3, "Emergency Procedures," stated under "Auto Fuel Balancing Failure" that, for an indication of "3 segments or more difference between left and right without automatic activation," the pilot should turn ON the fuel boost pump for the fuller tank, monitor the fuel state, and, "if the difference cannot be balanced, land as soon as practical" (NTSB 2011a, 17; NTSB 2011c, 3).

Thus, contrary to the petition's claims, the AFM for the accident airplane provided sufficient information for the accident pilot to do the following:

- know the airplane's fuel required the addition of a FSII for the flights planned on the day of the accident,

- know the maximum fuel imbalance limitation ("a maximum of 3 LCD segments," or three bars),

- understand the responsibility to monitor the fuel quantity indicators to verify that the fuel balance remained within this limitation,

    - know what action to perform to manually restore fuel balance (by turning ON the fuel boost pump switch for the fuller tank) in the event it was not automatically maintained, and

    - understand that an inability to manually restore fuel balance was considered an emergency that required landing the airplane as soon as practical.

As described in the NTSB's report, the accident pilot did not land the airplane as soon as practical after his attempt to restore fuel balance was unsuccessful. Per guidance in the FAA's *Pilot's Handbook of Aeronautical Knowledge*, "land as soon as practical" means that the "landing site and duration of flight are at the discretion of the pilot" and that "[e]xtended flight beyond the nearest approved landing area is not recommended" (FAA 2008, G-17). The investigation determined (based on fuel balance estimates and CAWS fuel pump status data) that the fuel imbalance began to develop shortly after 1331 and that the pilot likely recognized the imbalance sometime between 1331 and 1342 and responded by turning ON the left fuel boost pump. During this time and despite the pilot's attempt to correct the imbalance, the difference between the fuel quantity indicators increased to about six bars by about 1342 (1 hour 32 minutes into the accident flight).

Rather than divert the flight to any one of several suitable nearby airports, the pilot continued the flight (as the fuel imbalance exceedance of the limitation continued to worsen), and he did not take action to divert until about 1402. By this time, the fuel quantity indicators were showing a difference between the right and left tanks of about 15 bars (NTSB 2011a, 57), indicating an imbalance of about 890 lbs. Further, the pilot not only delayed taking action to divert but also chose BTM as his destination, which was about 119 miles (29 minutes) away, and he continued to proceed there even though several suitable airports were much closer (NTSB 2011a, 53-55 and 62-63; and NTSB 2011e, 11-12).

We note that, based on the context of the NTSB report's analysis, it appears that the intent of finding 9 was to provide an explanation for the pilot's decision to divert from the original destination—that is, the pilot's recognition of an increasing left-wing-heavy fuel imbalance. In reevaluating this finding, the NTSB notes that, although the report accurately describes the AFM information referenced above and states that the pilot recognized the fuel imbalance and attempted to correct it before diverting, the summarized wording in finding 9 inaccurately omits the troubleshooting from the sequence of expected procedural responses.

Thus, we concur with the petition's claim that the wording in finding 9 is erroneous because of this omission. Also, as the petition points out, two paragraphs of related analysis in the report do not clearly specify the procedural expectation that the pilot, upon recognizing a fuel imbalance, should first try to manually balance the fuel before diverting the flight to land as soon as practical.

Therefore, we have revised finding 9 on pages 56 and 76 of the NTSB's report, as follows:

> Although the pilot should have diverted to land the airplane as soon as practical ~~a nearby airport~~ ~~once the maximum allowable fuel imbalance had been exceeded~~after his attempt to restore fuel balance within the maximum imbalance limitation was unsuccessful, ~~the pilot eventually~~his eventual decision to divert~~ed~~ to Bert Mooney Airport likely resulted from his ~~because he recognized~~recognition of the magnitude of the ~~situation and his attempts to resolve the~~ increasing left-wing-heavy fuel imbalance ~~had been unsuccessful~~situation.

In addition, we have revised the related analysis in the fourth paragraph on page 49 of the NTSB's report to consider that the pilot recognized and attempted to manually correct the fuel imbalance sometime between 1331 and 1342 before diverting about 1402, as follows:

> In addition, Pilatus' procedures required the pilot to (1) monitor the fuel quantity indicator in the cockpit to ensure fuel symmetry between the left and right fuel tanks during flight, and, in the event that fuel balance was not automatically maintained, (2) manually balance the fuel by turning ON the fuel pump for the fuel tank with the higher quantity, and, if unable to restore fuel balance, (~~2~~3) land the airplane as soon as practical ~~if the maximum allowable fuel imbalance was exceeded~~. During the accident flight, the pilot did not beg~~a~~in to divert ~~to BTM about~~ until about ~~3~~20 to 31 minutes after ~~the maximum allowable fuel imbalance was reached~~ his attempt to manually restore fuel balance was unsuccessful, and he chose BTM even though several closer airports along the airplane's route of flight were available.

Similarly, in the first paragraph on page 66, we have revised the last two bullet items of summary analysis, as follows:

- The maximum allowable fuel imbalance between the left and the right fuel tanks was estimated to have been exceeded sometime between 1331 and 1335, and the pilot attempted to manually correct the imbalance sometime between 1331 and 1342. The PC-12 AFM stated that, ~~when this imbalance occurred~~if the fuel cannot be balanced, the pilot should land the airplane as soon as practical.

- The pilot began to divert to BTM about ~~3~~20 to 31 minutes after ~~the maximum allowable fuel imbalance was estimated to have been exceeded~~his attempt to manually restore fuel balance was unsuccessful.

Further, we have revised the fifth paragraph of related analysis on page 49 to not only address the petition's claim but also use wording that is more consistent with the explanation of the adverse effects on the airplane's flight handling characteristics provided in section 1.6.5.4 of the NTSB's report, as follows:

> Because the pilot did not ~~divert when the maximum fuel imbalance had been exceeded~~ take action to land the airplane as soon as practical after his attempt to manually restore fuel balance was unsuccessful, the fuel imbalance continued to worsen beyond the maximum imbalance limitation, ~~and result in the airplane being operated outside of its design limits~~ increasing the airplane's left rolling moment as the flight progressed.

We note that this revised wording also more clearly supports NTSB finding 11; the pilot could have minimized or avoided the large left rolling moment induced by the left-wing-heavy fuel imbalance by following Pilatus' procedures and landing the airplane as soon as practical after his attempt to balance the fuel was unsuccessful.

Thus, we deny the petition's claim against NTSB finding 11.

3.2 AFM Information and Procedures for Fuel System Indications

The petition claims in its proposed new finding 4 that, "[d]espite the fact that the left fuel boost pump was not operating properly…the cockpit was displaying green PUMP advisories…, which, according to the AFM, indicated that the left fuel boost pump was operational." The petition claims in its proposed new finding 5 that the accident airplane's AFM did not properly describe the CAWS fuel boost pump advisories, and this hindered the pilot's ability to recognize the problem, troubleshoot, and divert. Further, the petition claims in its proposed new findings 10 and 11 that the revised procedures contained in the AFM for PC-12/47E airplanes, if available to the accident pilot, could have changed the outcome of the flight.

The petition does not dispute that the CAWS fuel boost pump advisories (green "L FUEL PUMP" or "R FUEL PUMP") illuminated as described in the NTSB's report. However, contrary to the petition's claims, the NTSB's report does not state that a CAWS low fuel pressure caution (amber "FUEL PRESS") ever illuminated during the accident flight. (The petition's claims concerning the CAWS logic for illuminating the low fuel pressure caution are discussed further in section 3.4 of this response.)

As described in our report, before the fuel imbalance developed, the accident airplane's fuel boost pumps repeatedly activated automatically, as designed, to restore adequate fuel system pressure (at least 3.5 psi) each time a low fuel pressure state (below 2 psi) was sensed (NTSB 2011a, 50). Each activation was accompanied by a CAWS fuel boost pump advisory (green "L FUEL PUMP" or "R FUEL PUMP").

Although the NTSB's report correctly describes that certain CAWS advisories would display only if the criteria for their activation were still met after a predefined time delay, the petition points out that the NTSB's report erroneously states that the AFM describes the delay for the activation of the CAWS low fuel pressure caution (NTSB 2011a, 32 and 50).

Therefore, we have revised the first paragraph on page 50 to remove the erroneous attribution, as follows:

> According to the Pilatus PC-12 AFM, the fuel boost pumps operate automatically if a low fuel pressure state exists—which occurs when the fuel system pressure drops below 2 psi—and the pump's switch is set to the AUTO position.[94] ~~Similarly, the PC-12 AFM also states that~~By design, the CAWS annunciates a low fuel pressure caution when fuel system pressure drops below 2 psi for more than 0.3 second. However, because the CAWS did not log any fuel pressure cautions during the flight, it is likely that at least one of the fuel boost pumps was able to provide adequate pressure to the fuel system (at least 3.5 psi) within 0.3 second of the low fuel pressure condition being sensed.

The petition claims in its proposed new finding 4 that, "[d]espite the fact that the left fuel boost pump was not operating properly…the cockpit was displaying green PUMP advisories…, which, according to the AFM, indicated that the left fuel boost pump was operational." The petition cites a 2001 Pilatus engineering report (which the petition provides as new evidence) that classifies "[g]reen advisory even though fuel pump is not operating correctly" as a "major" failure condition (Fraenkel et al. 2017a, 35). We note that, in system safety assessments for aircraft, "major" is the second lowest of the four severity classifications for failure conditions (minor, major, hazardous, and catastrophic) (FAA 2011, 5).

As described in the NTSB's report, by design, the CAWS advisories for fuel boost pump operation (green "L FUEL PUMP" and/or "R FUEL PUMP") illuminate when "power [is] being relayed to the respective pump." This applies to both automatic activations (when the fuel boost pump switches are set to AUTO) and manual activations (when the pilot selects either or both switches to ON). The NTSB's report also stated that a CAWS fuel boost pump advisory is "an indirect indication of boost pump operation" and that the CAWS is "not configured with a direct indication of boost pump operation or output" (NTSB 2011a, 15).

Thus, the fuel pump advisory information contained in the petition's proposed new finding 4 is already addressed in the NTSB's report. (The remainder of finding 4, which involves the petition's claims about the mechanical condition of the left fuel boost pump, is discussed in section 3.6 of this response).

The petition claims in its proposed new finding 5 that, if the fuel boost pump advisories had been properly described in the AFM, the pilot would have an immediate indication that the left fuel boost pump had failed, at which point he would have troubleshot and diverted the plane and had a better chance of safely executing an emergency landing."

Although we disagree with the petition's claims that the left fuel boost pump failed (discussed in section 3.6), we note that, had it ceased to function as the petition claims, the emergency procedure for responding to a fuel imbalance would still apply. The compelling and persistent indication that was available to the pilot was the increasing difference (beyond the three-bar maximum limitation) between the left and right fuel quantity gauges.

As described in the NTSB's report (and section 3.1 of this response), the AFM for the accident airplane provided sufficient information for the accident pilot to know that, in the event that fuel balance was not automatically maintained, the pilot should attempt to manually restore fuel balance and, if unsuccessful, land the airplane as soon as practical. Based on the recorded CAWS fuel boost pump advisory data, the pilot likely recognized the imbalance sometime between 1331 and 1342 and responded by turning ON the left fuel boost pump. During this time and despite the pilot's attempt to manually restore fuel balance, the difference between the fuel quantity indicators increased to about five or six bars (NTSB 2011a, 53 and 55).

Thus, the evidence supports that, through the indications available, which included both the cycling green CAWS fuel boost pump advisories and the fuel imbalance indicated on the fuel quantity gauges, the pilot did recognize the fuel imbalance in a timely manner and made a timely attempt to troubleshoot/manually correct it. Once the pilot's attempts to manually restore fuel balance were unsuccessful, the AFM-specified procedure for such a situation involved landing the airplane as soon as practical; as stated previously, the need to do so applied regardless of the reason the imbalance developed or why it could not be manually corrected.

Therefore, we deny the petition's proposed new finding 5.

The petition's proposed new findings 10 and 11 cite information from AFM procedures that were published a year before the accident and distributed to owners and operators of PC-12/47E airplanes. The petition claims that the accident could have been prevented if the low fuel pressure emergency procedures contained in the PC-12/47E AFM had been made available to the accident pilot; specifically, the petition points out that the PC-12/47E procedures include "[b]oth fuel pumps cycling on and off every 10s" after the "Indication" subheader. We note that this aspect of the PC-12/47E procedures (the inclusion of cycling fuel boost pumps under the "Indication" subheader) is similar to the revised PC-12/45 procedures, dated June 30, 2010, that were described on pages 17-19 and 61 of the NTSB's report.

As described in the NTSB's report, throughout the accident flight, the airplane's fuel system performed as designed; each time a low fuel pressure state (below 2 psi) was sensed, the automatic activation of the fuel boost pumps restored fuel pressure within 0.3 seconds to continuously supply fuel to the engine (NTSB 2011a, 31, 50, 52, and 55). As a result of the repeated automatic activation of the fuel boost pumps, no uncorrected low fuel pressure condition ever occurred. However, with each activation of the fuel boost pumps, the pilot was presented with green "L FUEL PUMP" and/or "R FUEL PUMP" CAWS advisories.

We note that the petition's screen capture from the accident airplane's AFM low fuel pressure emergency procedures includes only the top of the page, showing only the CAWS fuel pressure caution "Indication" subheader information (listing the amber "FUEL PRESS" caution) and omitting the remaining contents (Fraenkel et al. 2017a, 30). Specifically, the petition crops off the part of the low fuel pressure emergency procedures that stated that the automatic operation of the fuel boost pumps normally results from a low fuel pressure condition and that, in such a case, the indication is "both FUEL PUMPS running continuously, cycling OFF/ON every 10-15 secs" (indicated by green "L FUEL PUMP" and "R FUEL PUMP" CAWS advisories). For this cycling fuel pumps condition, the AFM advised descending the airplane to warmer air, noting "[a] possible cause is the fuel filter blocked with **ice crystals**" [emphasis in original] (see figure 2).

The cycling fuel boost pumps condition is the scenario that occurred during the accident flight. CAWS data showed that the fuel boost pumps activated 176 times during the first flight of the day and 337 times during the accident flight as they repeatedly corrected the sensed low fuel pressure condition, preventing engine flameout. (Data recorded for 477 other flights of the accident airplane showed that the fuel boost pumps activated only a total of 29 times.)

The petition's claims against the adequacy of these procedures are based, in part, on its assertions that the AFM's description of the cycling fuel boost pump "Indication" and the directive to descend to warmer air are "buried in a note" and that the pilot should not be expected to "have continued reading the emergency steps of a procedure for which he had no Indication…" (Fraenkel et al. 2017a, 38). The petition also claims that "whether the pilot added FSII to the fuel is entirely unrelated to how he would have reacted had he believed he was presented with a LFP [low fuel pressure] condition (Fraenkel et al. 2017a, 38).

PILATUS PC12

SECTION 3
EMERGENCY PROCEDURES

3.17 FUEL SYSTEM

3.17.1 LOW FUEL PRESSURE

Indication: FUEL PRESS CAWS CAUTION

1. Power — Reduce to minimum to sustain flight
2. Fuel pumps — ON

NOTE

Monitor the fuel state if the LH and RH FUEL PUMPS are set continuously on. If necessary, set the FUEL PUMPS on the emptier side to AUTO.

If **FUEL PRESS** caption remains ON:

3. Aircraft — Land as soon as possible

Retain glide capability to landing area if possible.

NOTE

Fuel low pressure will normally cause the fuel pumps to come on automatically.

In this case the Indication are both FUEL PUMPS running continuously, cycling OFF/ON every 10-15 secs.

L FUEL PUMP	R FUEL PUMP

4. Fuel Pumps — ON
5. Aircraft — Descent to warmer air: (A possible cause is the fuel filter blocked with **ice crystals**).

Figure 2. Low fuel pressure emergency procedure from the AFM for the accident airplane in effect at the time of the accident (NTSB 2011c, 2).

We note that such assertions demonstrate a lack of understanding of an AFM and how a pilot is expected to use it. The procedures contained in AFMs address various types of emergencies but cannot specifically itemize every possible scenario, variable, or mode of failure—particularly for operations conducted in noncompliance with any limitations. (The performance information contained in an AFM—which enables a pilot to predict certain aircraft performance parameters—is established based on data gathered during certification test flights; these test flights are conducted in an aircraft under normal operating conditions, which includes compliance with limitations [FAA 2016a, 11-16]). As such, AFMs describe aircraft systems in a manner appropriate to the expected level of knowledge and experience of the pilot most likely to operate the aircraft (FAA 2008, 8-4). According to the FAA, historically, few fuel system icing incidents involving turbine-powered aircraft have occurred, "likely due to the improved training, flight time, and expectations of pilots flying [such] complex aircraft" (FAA 2016b).

Basic FAA guidance sets the expectations that, to fly a particular aircraft, pilots must become familiar with its AFM and must comply with the information and instructions it contains (FAA 2008, 8-1 and 8-2). This guidance describes knowledge of AFM information as the basis for safe flying and good decision-making and recommends that pilots memorize the immediate action items for emergency procedures and, after completion, refer to the related checklist (FAA 2008, 8-4 and 8-15). As stated in the NTSB's report, the accident pilot's recurrent training instructor described him as having demonstrated a very high level of competency in the airplane, and his recurrent training about 10 weeks before the accident included a review of emergency procedures.

Based on the contents of the Pilatus PC-12 AFM, the pilot's level of competency, and the areas covered during his recurrent training, the scenario suggested by the petition—that the pilot was ignorant of fuel system basics, was unfamiliar with the information contained in the emergency procedures, and would fail to reference a specific procedure (or would cease referencing it at a specific line) because a specific indication was listed lower in the procedure than another—is improbable.

Also, contrary to the petitioner's claim, the pilot's knowledge that he did not add a FSII to the fuel (he personally fueled the airplane before the accident flight) is directly related to his expected reaction to the abnormally high number of CAWS fuel boost pump advisories he received while operating the airplane in temperatures far below the 0°C limitation that required the addition of a FSII. The pilot's awareness of the fuel's lack of FSII while operating in such conditions is particularly relevant considering that the AFM stated that such cycling fuel boost pump advisories may be indicative of fuel system icing.

The NTSB's report also addressed whether revised low fuel pressure emergency procedures (published for the PC-12/45 after the accident) could have changed the outcome of the accident flight. The report's discussion of the revised procedures (which, like the PC-12/47E procedures cited in the petition, listed the cycling fuel boost pumps earlier in the procedures by including them with the first "Indications" subheader) stated the following:

> The NTSB believes that, even if the revised procedure for low fuel pressure had been in place at the time of the accident, the outcome of the accident would still have been the same because the pilot did not

> (1) add a FSII to the fuel, (2) descend to warmer air when the fuel boost pumps were cycling, and (3) divert to a suitable airport when the maximum allowable fuel imbalance had been exceeded…. [The report then refers the reader to sections 2.2.5, which discusses the airports available along the airplane's ground track, and 2.2.6, which discusses the pilot's decision-making (NTSB 2011a, 61).]

We note that, contrary to the petition's claim that "the…three delineated reasons are based on faulty logic" and "implies that, since the NTSB determined the pilot did not follow other specific instructions and procedures, he would not have followed this new one" (Fraenkel et al. 2017a, 37), the intent of the NTSB's analysis was not to assess the pilot's likelihood of taking action (based on his inaction in response to other limitations and procedures). Rather, the intent of this analysis was to highlight three critical areas that the NTSB believed could have changed the outcome of the flight.

As described previously, the AFM available to the accident pilot contained procedures for the pilot to address these critical areas, including a limitation for preventing the accumulation of ice in the fuel system and a procedure to descend the airplane to warmer air in response to cycling fuel boost pumps (indicated by the green "L FUEL PUMP" and/or "R FUEL PUMP" CAWS advisories). As discussed previously, the petition is not compelling in its assertion that, because the cycling fuel boost pump indication was not listed on the top line of the low fuel pressure emergency procedures, the accident pilot would be unaware of the corresponding part of that procedure or ignorant of the possibility of fuel system icing.

Regardless, although the petition rejects the fuel system icing scenario described in the NTSB's report, the pilot's need to follow the AFM's emergency procedure for responding to a fuel imbalance (indicated by the increasing differential between the left and right fuel quantity gauges) applied, regardless of the reason the imbalance developed or why it could not be manually corrected. This involved landing the airplane as soon as practical if unable to manually balance the fuel. As described in our report, by the time of the accident, about 50 to 61 minutes had elapsed since the pilot's unsuccessful attempt to balance the fuel, during which time he continued the flight past numerous suitable airports closer than BTM.

Thus, the evidence supports that the pilot had sufficient indications to recognize the fuel imbalance in a timely manner, that he made a timely attempt to troubleshoot/manually correct the fuel imbalance, and that the AFM procedures available to the pilot were adequate to have prevented the accident.

Therefore, we deny the petition's proposed new finding 10, which is not a finding but rather a descriptive statement that provides the context for its proposed new finding 11. We also deny the petition's proposed new finding 11, which is not supported by the petition and for which the general context was addressed in the NTSB report's analysis of the revised PC-12/45 procedures.

3.3 CAWS Fuel System Annunciations During the Accident Flight

The petition makes claims related to the adequacy of the CAWS design regarding the fuel system annunciations it provided to the pilot. The petition claims that there are no "warnings" or "cautions" related to exceeding the maximum fuel imbalance limitation (Fraenkel et al. 2017a, 8). Based on this claim, the petition asserts that NTSB finding 13 is erroneous, specifically the text that the petition has underlined, as follows:

> 13. The pilot <u>underestimated the seriousness of the initial fuel imbalance warnings</u> because he had not experienced any adverse outcomes from ignoring similar previous warnings.

We note that, in the context of the analysis in the NTSB's report, NTSB finding 13 uses the word "warnings" as a general term to describe the indications presented to the pilot. As stated in the report, the pilot had "previously ignored indications similar to those presented during the accident flight; the report references, specifically, the CAWS fuel boost pump activation advisories, which annunciated an abnormal number of times during the accident flight, the first flight on the day of the accident, and an October 2007 flight (NTSB 2011a, 67).

However, we also note that the words "warning" and "caution" have specific meanings when referring to CAWS annunciations and AFM references. As described in the NTSB's report, CAWS warnings and cautions illuminate in red and amber, respectively, and are accompanied by visual and aural annunciations from the master warning and caution panel; the CAWS fuel pump annunciations are advisories that illuminate in green (NTSB 2011a, 14-16, 19, 31, and 33-34). AFM warnings refer to operating procedures or techniques that, if not followed, may result in personal injury or loss of life, and AFM cautions refer to those that may result in damage to equipment (NTSB 2011a, 68-69).

The NTSB's report uses the words warning and caution in these specific contexts—except in finding 13 and in a paragraph of analysis that precedes it. We believe these exceptions are potentially confusing for the reader and could be interpreted as implying that fuel system low pressure warning annunciations were presented to the pilot at the described times in the accident flight and during the previous flights, which was not the case.

Thus, we concur with the petition's claim that the use of the word "warnings" in NTSB finding 13 is erroneous.

Therefore, we have revised NTSB finding 13 (on page 77 and page 68, paragraph 2), as follows:

> 13. The pilot underestimated the seriousness of the initial fuel imbalance ~~warnings~~ indications because he had not experienced any adverse outcomes from ignoring similar ~~previous warnings~~indications during previous flights.

Likewise, the paragraph of analysis that preceded NTSB finding 13 contains the erroneous use of the word "warnings" and does not identify which indications were "mounting" as the flight progressed.

Therefore, we have also revised the related paragraph of analysis that preceded NTSB finding 13 (on page 67, paragraph 3), as follows:

> The pilot did not change his course of action during the accident flight leg in response to mounting ~~warnings~~ indications to do so. The initial indications were the abnormal number of CAWS fuel boost pump activation advisories, which, as the flight progressed, were followed by the increasing fuel imbalance indications on the fuel quantity indicator and the need for increased opposite aileron deflection to counter the airplane's increasing roll tendency toward the heavier wing. The pilot had likely downplayed the seriousness of the initial ~~warnings~~indications because no adverse outcomes resulted from ignoring ~~the warnings~~similar indications during the first flight of the day and during the October 2007 flight. During the accident flight, ~~R~~rather than divert before the fuel imbalance became more severe, the pilot decided to continue to BZN, and the situation became more difficult to manage as the flight continued.

The petition also proposes a new finding 9 that states that the only caution or warning the pilot received was a "'Fuel Level Low' warning" for the right tank 6 minutes before the crash. (Although the petition's proposed new finding 9 inaccurately describes the CAWS right fuel low caution annunciation as a "warning," we have considered that the petition may have intended to use the word "caution.")

We note that, as described in the NTSB's report, a caution annunciation for low fuel in the right tank (amber "R FUEL LOW") was activated and on continuously beginning about 6 minutes before the final CAWS message (which was a right fuel boost pump advisory) (NTSB 2011a, 32-33, 35, and 54). We note that this is the only CAWS caution or warning annunciation described for the accident flight in the NTSB's report, which specifically stated that "the fuel pressure caution was not logged at any time during the accident flight" (NTSB 2011a, 61).

Thus, we believe that the issues described in the petition's proposed new finding 9 were addressed in the NTSB's report and that our revision to NTSB finding 13 (as described above), which removes the ambiguous language about "warnings," further clarifies the issue.

Therefore, we deny the petition's proposed new finding 9.

3.4 CAWS Design and Certification

As described in the NTSB's report, the CAWS would provide certain warning, caution, or advisory annunciations only if the criteria for their activation continued to be met after a predefined timed delay. The petition claims that the CAWS design suppresses the low fuel pressure caution annunciations (amber "FUEL PRESS" light) such that "a pilot will never receive a LFP [low fuel pressure] warning during a fuel icing event" and that "despite the hundreds of recurring instances of Low Fuel Pressure, the indication for an LFP condition was never illuminated…" (Fraenkel et al. 2017a, 3 and 32). The petition cites a 2001 Pilatus engineering report (which is provided as new evidence) that classifies "Low Fuel Pressure, but No Caution Indication" as a "major" failure condition (Fraenkel et al. 2017a, 34).

Based on these claims, the petition proposes new findings 6, 7, and 8, which state, respectively, that the CAWS was "defectively programmed with a timed delay that suppressed visual and audible indications" for low fuel pressure, that the CAWS design "violates [14 *CFR*] 23.1305 and 23.1332 [sic] because it does not use a red warning means" to indicate low fuel pressure, and that "the pilot would have safely grounded the airplane" before the passengers ever boarded "if he had received visual and audible Low Fuel Pressure warnings on the first flight of the day, indicating an emergency requiring immediate pilot action" (Fraenkel et al. 2017a, 32, 39, and 47). (We note that there is no regulation 14 *CFR* 23.1332; from the context of the petition, we believe it intended to cite 14 *CFR* 23.1322, and we have considered that regulation accordingly.)

Regarding the petition's proposed new finding 6, we note that the CAWS was designed to annunciate a low fuel pressure caution (amber "FUEL PRESS" light) to advise the pilot of a persistent low fuel pressure condition for which an engine flameout could be imminent (Pilatus 2017a, 10). On the day of the accident, the airplane's fuel system was operated—without a FSII added to its fuel—in temperatures far below the 0°C limitation that required the addition of a FSII during both the accident flight and the first flight of the day. (The average outside air temperature at cruise altitude was about -40°C for the accident flight and about -32°C for the first flight. EIS data showed that the exposure to these temperatures exceeded 1 hour 23 minutes during the accident flight and 42 minutes during the first flight.)

Despite prolonged exposure to such adverse operating conditions, during the entirety of each of these flights, each time a low fuel pressure state (below 2 psi) was sensed, the automatic activation of one or both fuel boost pumps restored sufficient fuel pressure within 0.3 seconds to continuously supply fuel to the engine. As a result, no uncorrected low fuel pressure emergency condition (presenting the possibility of imminent engine flameout) ever occurred. Likewise, no CAWS fuel pressure caution ever annunciated.

The programmed time delay that ensured that the CAWS fuel pressure caution (and corresponding master caution) did not annunciate each time a low fuel pressure condition was sensed and then corrected within 0.3 seconds is a normal design feature to ensure that a condition indicated to a pilot is a valid condition (Pilatus 2017a, 10). As described in the NTSB's report, according to the CAWS manufacturer, before annunciating a warning, caution, or advisory, the system evaluates the validity of the event through a series of delay timers and activates the annunciation only if the activation criteria remain valid during that interval (NTSB 2011a, 32 and 34). We note that such features are a common consideration in aircraft alerting system design and are intended to minimize nuisance alerts, which are false alerts for conditions that are not valid (FAA 2010, 9).

Nuisance alerts compromise the integrity of an alerting system and adversely affect flight safety because frequent false or nuisance alerts increases the pilot's workload, reduces the pilot's confidence in the alerting system, and increases the potential for a pilot to ignore a real alert when it is presented (FAA 2010, 9). The AFM described that the electrically driven fuel boost pumps are used for engine start and to provide fuel pressure as a standby system if the normal system cannot maintain adequate pressure (NTSB 2011d, 7).

The system's automatic activations to correct an abnormal, recurring low fuel pressure condition were indicated to the pilot through the abnormally high number of CAWS fuel pump advisories (green "L FUEL PUMP" and "R FUEL PUMP" lights), which were described in the systems information in the AFM for the accident airplane. CAWS data showed that the fuel boost pumps activated 176 times during the first flight of the day and 337 times during the accident flight as they repeatedly corrected the sensed low fuel pressure condition, preventing imminent engine flameout and enabling a descent to warmer air, as described in the low fuel pressure emergency procedures.

Further, although the petition disputes the NTSB report's fuel system icing scenario, the emergency procedures for responding to the fuel imbalance still applied, regardless of the reason the fuel imbalance developed or why it could not be corrected. These procedures included diverting to land the airplane as soon as practical in response to the uncorrectable fuel imbalance.

Thus, the CAWS performed as designed by providing the accident pilot indications for the hundreds of automatic activations of the fuel boost pumps to address the occurrences of low fuel pressure during the flights on the day of the accident. Therefore, we deny the petition's proposed new finding 6.

Regarding the petition's proposed new finding 7, we note that 14 *CFR* 23.1305 and 23.1322 are regulations that pertain to low fuel pressure warnings and the colors for warning, caution, and advisory lights in airplanes; however, the petition quotes versions of those regulations that were current in 2017. At the time of the certification of the Pilatus PC-12 in 1994, the applicable paragraph of 14 *CFR* 23.1305, which had last been modified in 1987, did not specify a requirement of a warning, caution, or advisory for a low fuel pressure condition (Pilatus 2017a, 11).

Thus, the design of the CAWS low fuel pressure annunciations was compliant with the applicable regulations in effect at the time that the airplane was certificated. Further, there was no requirement for the airplane, as previously certificated, to comply with the subsequently revised regulation.

Therefore, we deny the petition's proposed new finding 7 and the first part of its new proposed finding 8, which described the CAWS design as noncompliant with regulations.

Regarding the second part of the petition's proposed new finding 8 (which posits that the accident pilot would not have departed on the accident flight if CAWS low fuel pressure cautions and corresponding master cautions had annunciated during the first flight of the day), the petition makes an unsupported claim regarding the indications available to another pilot who flew a January 30, 2008, flight in another Pilatus PC-12, N666M. During the January 2008 flight in N666M, the airplane sustained fuel system icing after prolonged exposure to a temperature of about -30°C during cruise flight. (The pilot of N666M stated that he had requested that a FSII be added to the airplane's fuel before the flight and that the fixed based operator that last fueled the airplane told him that a FSII was added; however, no fuel records were available to verify whether it had been added.) According to the petition:

> …the CAWS data log for the N666M incident shows a FUEL PRESS data entry, which necessarily means that the pilot of N666M *did* receive a FUEL PRESS Caution light in the cockpit, however briefly. This is not addressed in the Report even though the Report criticizes the accident pilot by emphasizing that the N666M pilot made a precautionary landing under similar conditions. But it is now very significant to note that, without the amber FUEL PRESS light and Master Caution indicating the need for corrective action, the accident pilot's sense of urgency was greatly diminished [emphasis in original (Fraenkel et al. 2017a, 35)].

The petition's claim that the pilot of N666M was briefly provided a CAWS low fuel pressure caution annunciation appears to be based on an assumption that the system logic criteria were programmed similarly to those required for the annunciation of the CAWS caution lights for the stall warning/stick pusher system. (The NTSB's report states that the CAWS for N666M logged a "cleared" low fuel pressure status with no previous "activated" status but did not analyze what corresponding annunciations, if any, may have illuminated [NTSB 2011a, 34 and 44].)

According to the pilot of N666M, he saw the CAWS advisories for both fuel pumps (green "L FUEL PUMP" and "R FUEL PUMP" lights) illuminate steadily and heard a noise that sounded to him as if the fuel boost pumps were "struggling." Based on his assessment of these indications, the pilot of N666M suspected ice in the fuel. He descended the airplane and, about 10 minutes after the event began, he began to maneuver the airplane toward the diversion airport and landed uneventfully about 15 minutes later. A fuel sample taken after landing confirmed the presence of ice in the fuel (NTSB 2011a, 43-44). (Following the event, this pilot placed the airplane in a heated hangar for the night, added FSII to the fuel, and operated it the next day with no abnormalities.)

As described in the NTSB's report (and section 3.2 of this response), the low fuel pressure emergency procedures in the AFM for the accident airplane stated that the automatic operation of the fuel boost pumps normally results from a low fuel pressure condition and that, in such a case, the indication is "both FUEL PUMPS running continuously, cycling OFF/ON every 10-15 secs" (indicated by green "L FUEL PUMP" and "R FUEL PUMP" CAWS advisories). For the cycling fuel pumps condition, the accident airplane's AFM advised descending the airplane to warmer air, noting "[a] possible cause is the fuel filter blocked with **ice crystals**" [emphasis in original].

Although the NTSB's report did not analyze whether the pilot of N666M was provided a low fuel pressure caution annunciation (amber "FUEL PRESS" light), the issue is moot because this pilot stated that he did not notice any illumination of the low fuel pressure caution light (NTSB 2011a, 44). Thus, his assessment of the situation, decision to take action, and sense of urgency was not dependent on a CAWS caution.

Contrary to the petition's claim, the NTSB report's analysis of the accident pilot's decision-making was completely independent of any discussion of the actions of the pilot of N666M; the report in no way "criticizes the accident pilot by emphasizing that the N666M pilot made a precautionary landing under similar conditions." Rather, the NTSB's report used the factual information from the N666M event to emphasize "the importance of adding a FSII to fuel to prevent ice crystals from accumulating in the fuel filter" and to support, in part, nine safety recommendations intended to promote the use of a FSII in aircraft that required it (NTSB 2011a, 61, 62, and 69-71).

We note, however, that compliance with all AFM-specified aircraft limitations is so universally expected that, in response to our recommendations, neither the FAA nor the then-European Aviation Safety Agency (EASA, now European Union Aviation Safety Agency) believed that additional action was needed to amend certification requirements to highlight FSII limitations in the AFM and on fuel filler placards. (The FAA and EASA's responses to our recommendations are discussed further in section 3.7.)

The NTSB is sympathetic to the petitioners' esteem for the accident pilot as a skilled and trusted employee and notes that our investigation did not, as the petition claims, seek to criticize the pilot and his behavior. Rather, the investigation sought to evaluate the human performance considerations that may explain why the accident pilot did not act in accordance with the information provided in the AFM, particularly considering that his skills and abilities were described positively by others who had flown with or trained him. As described previously in this response, the evidence supports that the AFM procedures available to the pilot, which prescribed that the pilot descend the airplane and divert to land as soon as practical, were adequate to have prevented the accident.

Basic FAA human performance guidance notes that most pilots sincerely believe that they will recognize flight safety hazards and take the appropriate action to avoid an accident; however, pilots (like any human) can be susceptible to the development of hazardous attitudes, which can adversely affect their perception of a flight safety hazard, analysis of the potential threat, and performance of an appropriate response (FAA 2003, 16-6; FAA 2008, 17-4; and FAA 2022, 3-1 and 3-2). Invulnerability is one of the five common hazardous attitudes that human performance studies have found affect a pilot's ability to make sound decisions (FAA 2003, 16-6; FAA 2008, 17-4; and FAA 2022, 3-1 and 3-2). Repeated successes—in which no adverse outcomes occur after taking risks—can reinforce a pilot's sense of invulnerability and lead to continued risk-taking.

Thus, as described in the NTSB's report, the lack of any adverse outcomes associated with the accident pilot's previous flight in which an abnormal number of CAWS fuel boost pump activation advisories occurred likely played a role in his underestimation of the risk and influenced his decision to continue the accident flight rather than divert as soon as practical (NTSB 2011a, 66-67). Further, the accident pilot's decisions to delay diverting the flight and to then choose BTM as the destination (in lieu of closer options) may have been influenced by self-induced pressure to complete the flight and his consideration for passenger convenience (NTSB 2011a, 67).

We note that another unsafe condition the pilot allowed for the accident flight (and a previous flight) was also passenger-related. The airplane owner, who organized the accident trip (and is one of the petitioners), was aware that 13 passengers would be transported on board an airplane with only 9 passenger seats. The owner stated that the accident pilot had transported that many people on the airplane before and that he (the owner) believed the scenario was "not pushing the envelope" but acknowledged that "there were just not enough seatbelts" for every passenger (NTSB 2011a, 67 and 72).

As described previously, the design of the CAWS low fuel pressure annunciations was compliant with the applicable regulations in effect at the time that the airplane was certificated. Further, the petition provides no new evidence to suggest that the NTSB report's analysis is erroneous regarding possible influences on the accident pilot's decision-making.

Therefore, we deny the petition's proposed new finding 8.

3.5 Fuel System Icing During Accident Flight

The petition disputes NTSB findings 2 and 3, which state, respectively, that the low fuel pressure state and the restricted fuel supply from the left tank resulted from an accumulation of ice in the fuel system and that, if the pilot had added a FSII to the fuel, as required, the ice accumulation would have been avoided, and a left-wing-heavy fuel imbalance would not have developed.

Specifically, the petition claims that "[t]he lack of a [FSII] would not have caused an imbalance or resulted in any fuel starvation event. The FBPs [fuel boost pumps], coupled with the fuel filter bypass, are designed to handle any fuel icing event" (Fraenkel et al. 2017a, 6). It claims that a restricted fuel supply from the left tank due to ice accumulation (as described in the NTSB's report) is "fundamentally impossible," that "the only 'icing' restriction that could have occurred" during the accident flight "would have been a temporary and passable icing restriction at the airframe fuel filter," and that "[t]here was not, and cannot be, an icing restriction in one wing only" (Fraenkel et al. 2017a, 6).

The petition's claims against the NTSB report's fuel system ice accumulation scenario appear to be based on the unsupported assumptions that, even when the airplane is operated in temperatures far below the 0°C limitation without the addition of a FSII to the fuel, "it is inexplicable why [contaminants or ice in the fuel] would only affect the left side while the same fuel was circulating and being transferred side-to-side" (Fraenkel et al. 2017a, 17). The petition also claims that "there is no evidence to explain why, in real conditions on the accident flight, icing only caused a LFP [low fuel pressure] condition on the left-hand side of the aircraft, while the right-hand system remained perfectly functional" (Fraenkel et al. 2017a, 29).

The petition provides no technical analysis to support its premise that the airplane's fuel system design and the effects of its operational environment during the accident flight were such that the fuel system would inherently accumulate ice only uniformly and simultaneously on both sides (and exhibit identical adverse effects). Such claims and assumptions demonstrate a lack of understanding of not only the design of the fuel system but also the suspension, settling, and accumulation behaviors of contaminants, such as dissolved water, free water, and/or ice, in Jet A fuel at various temperatures.

Further, the petition's claims against the NTSB report's fuel system icing scenario disregard the possibility that differing amounts of contaminants may have been present in the fuel tanks on either or both sides (or elsewhere in the fuel system) before departure. The AFM for the accident airplane describes using the underwing fuel drains to remove water and other contaminants during preflight; however, as described in the NTSB's report, surveillance video at the departure airport showed no evidence that the accident pilot drained any fuel samples after fueling the airplane or any other time before departure (NTSB 2011a, 2 and 12).

In support of its claims related to mechanical defect of the left fuel boost pump (which are discussed in section 3.6 of this response), the petition acknowledges (by citing the deposition of a Pilatus engineer) "[o]ne of the primary purposes of the fuel boost pumps is to provide fuel to the engine in the event of low fuel pressure, such as when the filter becomes blocked with ice" (Fraenkel et al. 2017a, 28). However, in its attempts to dismiss the relevance of the lack of FSII in the airplane's fuel, the petition claims the following:

> [T]he accident could have occurred even if the fuel had FSII….There are a number of contaminants that could block the filter, other than icing. The boost pumps could have been activated due to a filter clogged with another contaminant, even if FSII had been added [Fraenkel et al. 2017a, 28].

Considering that the pilot also did not drain fuel samples from the airplane after fueling, we note that it is possible that contaminants other that water could have been present in the fuel. However, the more compelling scenario for the low fuel pressure condition—which is supported by evidence—is the accumulation of ice in the fuel system; both the pilot's failure to ensure that a FSII was added to the airplane's fuel and his operation of the airplane for an extended period of time in temperatures far below the 0°C limitation strongly support this scenario.

As evidenced by the CAWS data for the day of the accident, the condition that prompted the abnormal number of fuel boost pump activations during the first flight of the day occurred about 1 hour 30 minutes into the flight, did not occur during the second flight (which was a short flight operated at a lower altitude and in warmer conditions), but then recurred about 1 hour 13 minutes into the accident flight. An icing scenario is the most compelling explanation for the type of contaminant that could affect system performance during prolonged operations at cold temperatures, resolve itself during warmer temperature operations, then recur in subsequent cold-temperature operations (NTSB 2011a, 2-3).

Further, the petition contradicts its own claims about the impossibility of a fuel system icing scenario. In its claims against the adequacy of the design and certification of the Pilatus PC-12's fuel system (discussed in section 3.7 of this response), the petition states that Pilatus' hazard assessment for the fuel system "failed to consider that the same condition – icing – could initiate both failures [of the automatic fuel balancing system and the fuel boost pump]" (Fraenkel et al. 2017a, 13). The petition also cites FAA correspondence with Pilatus regarding PC-12 fuel icing events involving a lack of FSII in the fuel, which included a description of "a 2002 incident with an imbalance caused by fuel icing" and another event characterized by "cycling boost pumps with no low fuel pressure light and a 6-bar fuel imbalance" (Fraenkel et al. 2017a, 13).

Thus, the petition provides no evidence or valid technical analysis to support its claims against the fuel system icing scenario determined in the NTSB's report, including the report's determination that the use of FSII in the fuel, as required, would have prevented the ice accumulation that resulted in left-wing heavy fuel imbalance.

Therefore, we deny the petition's claims against NTSB findings 2 and 3.

3.6 Left Fuel Boost Pump Mechanical Condition

The petition claims that the restricted fuel supply from the left tank resulted from a "mechanical defect" of the left fuel boost pump that "caused its failure" during the accident flight. The petition claims that "[i]t is only when a [fuel boost pump] fails that an imbalance will be created" (Fraenkel et al. 2017a, 2 and 6). The petition claims that "the left fuel boost pump failed for a reason completely unrelated to the lack of FSII" and that "the lack of FSII bears no relation to the failure of the boost pump which caused the crash" (Fraenkel et al. 2017a, 28).

These claims are the basis for the petition's proposed new findings 3, 1, and 2, which state, respectively, that the "recurring low fuel pressure condition, the lack of fuel supply from the left fuel tank, the uncorrectable increasing imbalance, and the inability for the system to correct the imbalance were the result of a mechanical defect in the left fuel boost pump;" that the examination of the left fuel boost pump (which included components not previously examined by the NTSB) revealed "mechanical defects that prevented it from operating as designed and intended," and that, "[i]f the left fuel boost pump had operated as designed and intended, it would have maintained sufficient fuel pressure while balancing the fuel…, and a left-wing-heavy fuel imbalance would not have developed" (Fraenkel et al. 2017a, 46). Also, the petition's proposed new finding 4 (discussed, in part, in section 3.2 of this response) claims that "the left fuel boost pump was not operating properly."

Regarding the petition's proposed new finding 3, we note that the assertion that a failed left fuel boost pump could cause the recurring low fuel pressure condition that occurred during the accident flight demonstrates a lack of understanding of the Pilatus PC-12 fuel system and the functions of the fuel boost pumps during both normal and abnormal operations. This lack of understanding is also evident in the petition's summary of the fuel system, which incorrectly states that a fuel imbalance could occur "over time if the two FBPs [fuel boost pumps] have slightly different capacities, or if only one pump is turned on" (Fraenkel et al. 2017a, 20). An imbalance would not occur under the described conditions during normal operations. (We note that an imbalance could occur during abnormal operations, such as following a low fuel pressure condition [and in response to which two fuel boost pumps of differing output are operated for an extended period of time] or through the inappropriate manual operation of only one fuel boost pump when its operation is not needed to balance the fuel.)

As described in the AFM for the accident airplane (and the NTSB's report), during normal operations, fuel is transferred from the fuel tanks to the engine by a motive flow jet pump system that includes a low-pressure engine-driven fuel pump. The motive flow of fuel generated by the low-pressure, engine-driven fuel pump powers both the transfer ejector pumps (which transfer fuel from the aft portion of each main tank to its respective collector tank) and the delivery ejector pumps (which transfer fuel from each collector tank to a common manifold) (NTSB 2011a, 11-12; NTSB 2011d, 7) (see figure 3).

The electrically driven fuel boost pumps provide fuel pressure as a redundant, standby system if the engine-driven fuel pump/motive flow jet pump system cannot maintain adequate pressure to move fuel toward the engine (NTSB 2011a, 11-12; NTSB 2011d, 7). During normal operations (and presuming that the airplane is operated within its limitations), the fuel boost pumps are typically used only during engine startup (by manually turning them ON to supply fuel pressure until the engine-driven pumps are operating) and then set to AUTO, where they remain in standby (that is, they are not actively pumping fuel) unless a fuel imbalance is sensed, in which case, the fuel boost pump on the fuller tank will automatically activate to correct the fuel imbalance (typically for about 4 minutes [NTSB 2011a, 44 and 52]).

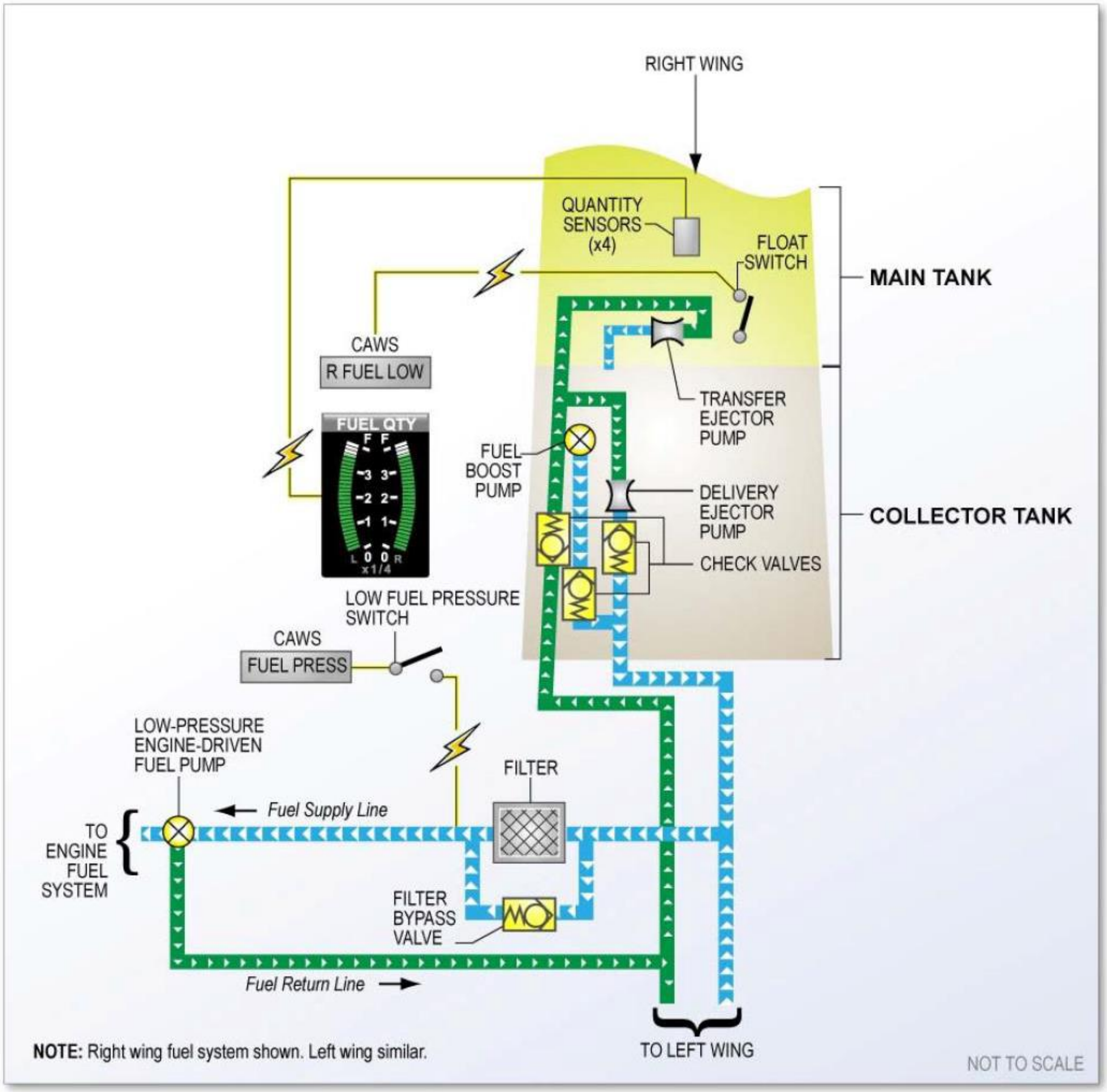

Figure 3. Pilatus PC-12 fuel system (NTSB 2017a, 11).

During abnormal flight operations, such as when a low fuel pressure condition is sensed, the fuel boost pumps provide redundancy by activating automatically to restore adequate fuel pressure to supply the engine with fuel; after fuel system pressure is restored, the fuel boost pumps run for another 10 seconds before turning off (NTSB 2011a, 12).

As described in the NTSB's report, based on the CAWS data for the accident flight, the flight continued normally for about 1 hour 13 minutes before the fuel boost pumps began cycling in response to a sensed low fuel pressure condition (NTSB 2011a, 52). Up until that point (except for the approximate 4-minute operation of the right fuel boost pump to balance the fuel load about 22 minutes into the flight), fuel pressure to supply fuel to the engine was being provided entirely by the engine-driven/motive flow jet pump system, which is consistent with normal operations. That is, at the time that the initial low fuel pressure condition was sensed, both fuel boost pumps were off, with neither supplying any fuel pressure to the system. The low fuel pressure condition preceded (and was the impetus for) the subsequent automatic operation of the fuel boost pumps.

Thus, based on the fuel system design, it was not possible that a mechanical failure of the left fuel boost pump could have created the low fuel pressure condition sensed during the accident flight, as claimed in proposed new finding 3.

Therefore, we deny the petition's proposed new finding 3.

Regarding the petition's proposed new findings 1, 2, and 4, the petition presents new evidence not considered during the NTSB's investigation. Specifically, the petitioners' representatives located and examined the left fuel boost pump's armature assembly (pump motor) and provided their analysis of their findings. The petition claims that a manufacturing defect led to the mechanical failure of the left fuel boost pump, resulting in the development of a left-wing heavy fuel imbalance.

The petition states that, "it is surprising that [fuel boost pump failure] was not at the forefront of the NTSB analysis," and incorrectly claims that the NTSB's report "acknowledged that the left FBP [fuel boost pump] ceased fuel circulation while the right FBP transferred fuel from the right tank to the left, thereby creating the increasing fuel differential" (Fraenkel et al. 2017a, 17).

Contrary to the petition's claim, assessing fuel boost pump performance was integral to our investigation. As described in the NTSB's report, our investigation of fuel boost pump performance included a wreckage examination, laboratory examination of recovered fuel boost pump components, and testing of exemplar fuel boost pumps. Our examination of the recovered left and right fuel boost pump components found no evidence of any preimpact system failures (NTSB 2011a, 28-29 and 48).

The investigation determined that the fuel pressure output of the left-side fuel system had degraded and that the required fuel system pressure could no longer be maintained through the operation of the left fuel boost pump. However, the investigation was unable to identify the source of the restriction of the fuel supply from the left tank, and the investigation drew no conclusions about the left fuel boost pump's performance beyond the observation that ice accumulation in the fuel system could degrade the performance of many fuel system components, including fuel boost pumps (NTSB 2011a, 52 and 62).

According to the petition, its examination of the left fuel boost pump armature assembly “revealed manufacturing defects that created an out-of-round condition, in violation of the manufacturer’s specifications,” and this condition caused the pump “to operate in an unbalanced manner and eventually fail completely” (Fraenkel et al. 2017a, 18). The petition claims that the armature assembly exhibited static impact signatures where the impeller contacted the pump housing in a nonrotating manner and that the pump housing exhibited nonrotational contact damage and stationary impact marks caused by impact of one of the armature shaft flats with the bore of the pump housing. The petition compares impact marks from the right and left fuel boost pump housings, which it claims show that the right fuel boost pump was operating at the time of impact, but the left pump was not (Fraenkel et al. 2017a, 21-22; Fraenkel et al. 2018, 9-10; Fraenkel et al. 2017c, 2-4 and 6).

We note that, although the NTSB did not locate and examine the left fuel boost pump’s armature assembly, the NTSB materials laboratory’s examination of the left fuel boost pump’s housing included an evaluation of the fracture features on the impeller cover, deformation marks on the walls of the housing through-hole (including identification of the location of the marks using an angular reference system), and the fracture features, cracks, and deformation marks on the impeller vanes. Our examination also included a determination of the postcrash orientation of the impeller drive shaft and an evaluation and measurement of polymer transfer marks from the impeller on the step edge around the perimeter of the housing chamber (using scanning electron microscopy and energy-dispersive x-ray spectroscopy, which identified the polymer as consistent with impeller material) (NTSB 2011g, 1-4).

As part of our review of the petition’s claims, we have considered the analysis of the factual evidence provided by the petitioners’ experts, as well as the analysis provided by Pilatus and Crane Company (the manufacturer of the fuel boost pumps). The petition included a labeled diagram of the left fuel boost pump components (see figure 4).

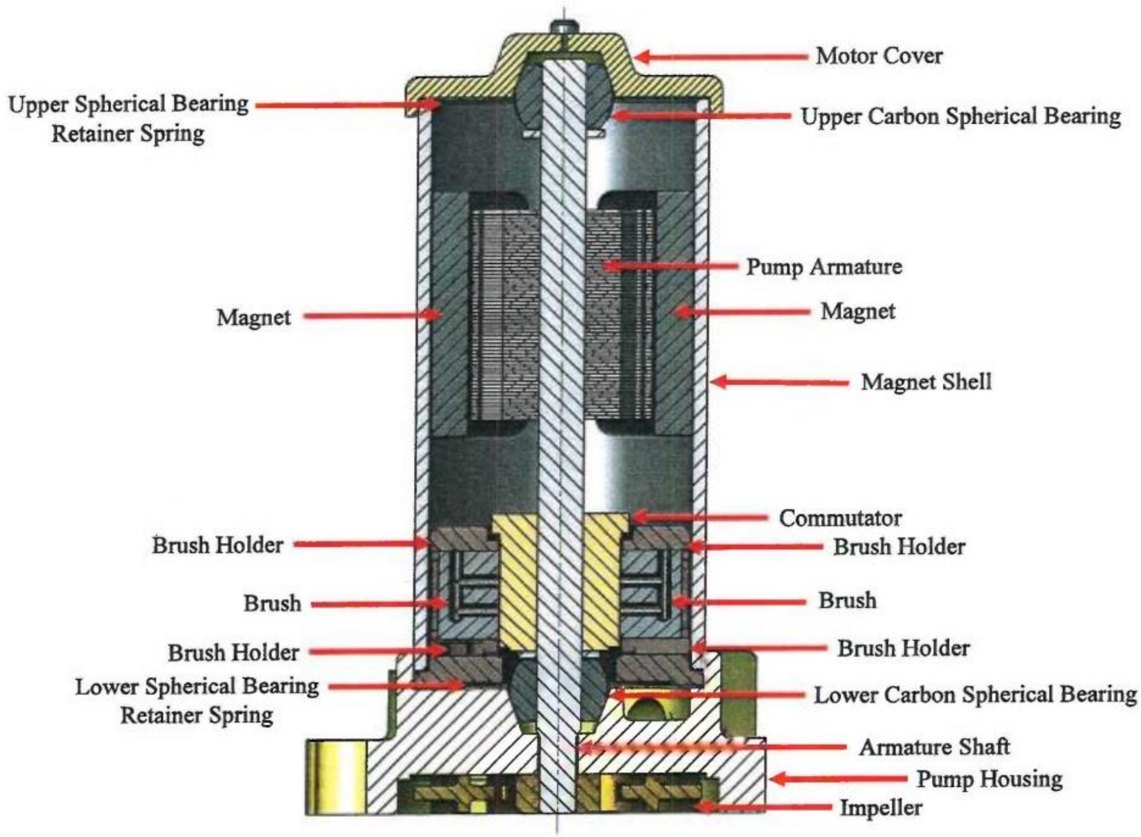

Figure 4. Fuel boost pump components (Fraenkel et al. 2017c, Attachment 1).

We note that the NTSB's factual evidence from the recovered left fuel boost pump components revealed evidence that the impeller from the left fuel boost pump was rotating at the time of impact, consistent with pump operation (Pilatus 2017b, 3-4). Further, we note that the nonrotational contact damage and stationary impact marks on the pump housing described by the petition are secondary witness marks (which occurred as the armature shaft was ejected from the pump housing during the impact sequence) and that these marks lie on top of rotational smearing marks in the shaft bore (Pilatus 2017b, 4-5).The petition's examination of the left fuel boost pump commutator included the use of a coordinate measuring machine to obtain data to "reconstruct" the total indicated runout (TIR) of the commutator, which is the dimensional characterization of deviation from roundness of a rotating component when measured against a reference axis or datum. The evaluation determined that the derived commutator TIR was four times the limit specified for the pump and claims that the value "correlates directly with the runout measurement when the part left the factory" (Fraenkel et al. 2017a, 25).

The petition claims that its derived TIR condition represented a mechanical defect that decreased the performance life of the motor and weakened the left fuel boost pump's performance (pressure and fluid volume). The petition states that carbon buildup from the brushes on the commutator pad precluded the efficient transfer of electrical energy between the brush and the commutator windings. The petition claims that, "[d]ue to this carbon buildup, the left FBP [fuel boost pump] progressively weakened throughout the accident flight, from operating at about 50% capacity to eventually operating very poorly, or perhaps not at all" (Fraenkel et al. 2017a, 27).

We note that the petition does not indicate the source of the capacity estimate and does not clarify the ambiguity between this claim and its claim that the pump armature was not rotating at the time of impact. Further, contrary to its own claims that "the left fuel boost pump failed for a reason completely unrelated to the lack of FSII," the petition claims that the TIR-discrepant left fuel boost pump was "weakened" and sustained greater wear on the commutator and brushes due to the increased viscosity of fuel in "icing conditions, especially without [a FSII]," which increased the demands on the pump (Fraenkel et al. 2017a, 27).

We note that the actual TIR of the commutator recovered from the wreckage could not be measured directly due to the bent armature shaft (Crane 2017, 2). Also, the accident airplane's fuel boost pump was manufactured in 2001, sustained severe impact damage during the accident, and was stored for more than 3 years postaccident within bags of wreckage debris before the examination. Further, although the evaluation technique to "reconstruct" the TIR included the removal of data that corresponded with impact-affected surface areas, we find it unlikely that the results are reflective of the as-manufactured condition of the commutator. We note that large areas of data were subtracted during the evaluation process, with the "reconstructed" TIR value having been derived by subtracting the measurement for the lowest valley or dent in the commutator from the measurement of the highest peak (Crane 2017, 8).

The petitioners' examination of the left fuel boost pump's commutator bars show they were darkened at the brush contact sites and that the surface of the commutator revealed banding of dark and light surface conditions, which the petition claims is indicative of an out-of-balance condition and non-uniform contact between the brushes and the commutator (Fraenkel et al. 2018, 7-8). The petition claims that "the dynamic imbalance of the commutator…combined with the dimensional stack-up condition between the commutator and the brush holder, led to the in-service commutator-to-brush holder contact" (Fraenkel et al. 2017a, 25).

However, we note that the physical evidence does not support such a conclusion. Per the design of the fuel boost pump, brush contact with the commutator is maintained by the brush spring such that the spring pressure forces the brush to follow the surface of the commutator as it rotates; wear of the commutator surface within the brush contact area as measured by the petitioners' representative was generally uniform on all the bars (Pilatus 2017b, 7-8).

We note that, although an imbalanced armature condition would lead to uneven and increased loads on the bearings, it “would not have any effect on the level of contact between the commutator and the brushes or brush holder” (Crane 2017, 3). According to the pump manufacturer, the pump return data for the “K” model pumps (the pump model on the accident airplane) show no pumps having been returned “for an imbalanced armature or because the commutator was eating away at both the brush and brush holder” (Crane 2017, 3-4). Also, the petition claims that the presence of brush holder material deposited between the commutator bars is an indication that the commutator contacted the brush holder during the service life of the fuel boost pump. However, we note the characteristics of the deposit of brush holder material, which is confined to one side of the commutator near the bottom of the shaft, are consistent with a singular contact event (Pilatus 2017b, 8).

As described in the NTSB’s report, the investigation “attempted to determine a possible reason for the restricted fuel supply from the left tank. Although the exact source of the restriction could not be identified, the postaccident testing [of exemplar fuel boost pumps] showed that ice accumulation in the fuel system (as a result of not adding a FSII) could degrade the performance of many fuel system components, including the fuel boost pumps” (NTSB 2011a, 60-62). According to the fuel boost pump manufacturer, ice particles in the fuel “can and will accumulate throughout the fuel system, including on the impeller and discharge port of the boost pump” (Crane 2017, 10).

Further, there is no evidence from the left fuel boost pump’s 8-year operational history, including a lack of any reported maintenance concerns or discrepancies, to support the assertion that it was mechanically defective since leaving the factory. Further, based on the CAWS data for the accident flight, about 15 minutes after the fuel boost pumps began cycling in response to sensed low fuel pressure, operation of the left fuel boost pump alone was sufficient to supply adequate pressure to ensure fuel delivery to the engine for about 3 minutes before the right fuel boost pump began cycling again (NTSB 2011a, 2-3, 32, and 67).

Thus, the petition’s claims that the left fuel boost pump failed due to a mechanical defect are not compelling. Analysis of the evidence examined by the NTSB during the investigation indicated that the left fuel boost pump was likely rotating at the time of impact; the new evidence provided with the petition does not change this determination, and the petition’s claims of evidence of mechanical defect are not persuasive.

Damage sustained by the fuel boost pumps during the accident sequence precludes a determination of the preimpact performance level of each fuel boost pump beyond the conclusive evidence that the operation of one or both fuel pumps restored sufficient fuel pressure to continuously supply fuel to the engine (and prevent engine flameout) after the engine-driven fuel pump/motive flow jet pump system was unable to maintain adequate pressure. The CAWS data for fuel boost pump activation during the three flights on the day of the accident, for which a lack of FSII in the fuel is known, show automatic pump activation patterns consistent with responses to sensed low fuel pressure conditions due to the formation of fuel system icing during the first flight of the day and the accident flight and a lack of pump activation during the second flight, which was operated a lower altitude and in warmer conditions. The possibility that the performance of the fuel system, including one or both fuel pumps, may have degraded due to the accumulation of ice in the fuel system is addressed in the NTSB's report.

Therefore, we deny the petition's proposed new findings 1, 2, and 4.

3.7 Fuel System Design and Certification

The petition makes claims against the adequacy of the design and certification of the fuel system of the Pilatus PC-12. These claims appears to be based on the petition's interpretation of specific wording in Pilatus' fuel system hazard assessment (which is described in the NTSB's report) and FAA e-mail correspondence (provided with the petition as new evidence) between an inspector in the FAA's Recommendations and Analysis Division and the manager of the FAA's Small Airplane Directorate; per the petition, some of this correspondence was forwarded to Pilatus, and the manager of the FAA's Small Airplane Directorate used information provided by a Pilatus engineer in one of his responses (Fraenkel et al. 2017a, 14).

As discussed in section 3.5 of this response, the petition references the NTSB report's fuel system icing analysis (which the petition otherwise disputes when claiming a mechanical fuel boost pump failure scenario) to support its claims that Pilatus' 1993 hazard assessment for the fuel system "failed to consider that the same condition—icing—could initiate both failures [of the automatic fuel balancing system and the fuel boost pump]" (Fraenkel et al. 2017a, 13). (We note that this claim contains an inaccurate summary of the NTSB report's analysis. Our investigation determined that ice accumulation in the fuel system "could degrade the performance of many fuel system components, including the fuel boost pumps" [NTSB 2011a, 60-62]).

The petition claims that Pilatus' fuel system hazard assessment "blatantly predicted and egregiously ignored" a fuel boost pump failure concurrent with a fuel system icing scenario. However, the petition cites the very language in the assessment that directly shows that Pilatus considered such a possibility, as the hazard assessment listed a series of errors that can lead to fuel system icing, including failure to drain the wing tanks (allowing water to accumulate), failure to ensure FSII is properly used, and failure to examine the fuel filter for blockage.

However, our review of Pilatus' fuel system hazard assessment determined that it did consider scenarios involving the adverse effects of a malfunction of the relevant fuel boost pump on the automatic fuel balancing system, a fuel boost pump selector switch failure, and an excessive, uncorrectable fuel imbalance (Fraenkel et al. 2017a, 11-13). In summary, the hazard assessment showed that, in the certification process for the Pilatus PC-12, Pilatus "foresaw [a fuel boost pump] failure scenario, assessed its severity, and demonstrated that the probability of it occurring was sufficiently low to meet certification requirements" (Pilatus 2017a, 2).

Further, although the petition claims that there is no redundancy in the event of a fuel boost pump failure, we note there is no requirement for such a redundancy (Fraenkel et al. 2017a, 3). As discussed in section 3.6, the design of the Pilatus PC-12 fuel system is such that the fuel boost pumps serve as a redundancy to the engine-driven fuel pump/motive flow jet pump system; thus, the fuel boost pumps themselves, are a backup mitigation (Pilatus 2017a, 9). During normal operations (that is, operations in compliance with the limitations prescribed in the airplane's AFM and with both fuel boost pumps set to AUTO), fuel pressure to supply fuel to the engine is provided entirely by the engine-driven fuel pump/motive flow jet pump system, and neither fuel boost pump would be supplying any fuel pressure.

The petition also cites that, in July 2003, an FAA inspector expressed concerns to the FAA's Recommendations and Analysis Division that "a strong potential exists for fuel icing and possible engine failure under certain conditions," referencing a 2002 fuel imbalance incident and "at least two other incidents that point to fuel icing" (Fraenkel et al. 2017a, 13). According to the petition, each event resulted from the inadequate use of a FSII, and one exhibited cycling fuel boost pumps, no CAWS low fuel pressure caution annunciation, and a 6-bar fuel imbalance that caused "serious difficulties" in landing the airplane. (Airplane controllability is discussed in section 3.8 of this response.) The FAA inspector expressed concerns that, although none of the events resulted in injury to property or persons, the potential for a much different outcome existed (Fraenkel et al. 2017a, 13; 2017b, 53-54).

The petition references 2003 correspondence from the FAA to Pilatus containing two recommendations based on the inspector's concerns: one recommendation suggested that Pilatus perform a feasibility study for a fuel heater retrofit for the PC-12, and one suggested requiring direct pilot supervision of the fueling process to ensure adequate use of a FSII additive (Pilatus 2017a, 15; Fraenkel et al. 2017b, 54). Our review of the cited correspondence revealed that the FAA's recommendations were intended to prevent possible fuel starvation due to fuel system icing and included the caveat that, if the airplanes are not retrofitted with a fuel heater, then direct pilot oversight of the fueling process should be required (Fraenkel et al. 2017b, 54).

The petition provides a copy of Pilatus' response to the FAA, includes a history of internal Pilatus correspondence related to the PC-12 fuel system, and implies that the FAA's eventual decision to close its recommendations (without requiring action) in 2003 was based on "misleading representations and inaccuracies" that it claims Pilatus provided to the FAA (Fraenkel et al. 2017a, 14-15). The petition claims that

Pilatus "failed to disclose" to the FAA information about previous fuel system icing events (including a 1993 event involving a PC-12 prototype and 1994 event that occurred during the first flight of the first PC-12, both of which involved inadequate use of FSII), the fuel heater study it had initiated in 1994, or "that the [fuel heater] project was eventually abandoned due to cost" about 1998 (Fraenkel et al. 2017a, 11 and 15).

We note that Pilatus stated in its 2003 response to the FAA's recommendations that it was not aware of any suspected fuel icing events in PC-12 airplanes that were operated in accordance with the AFM limitation for the use of a FSII, and it disclosed to the FAA that, for some reported events, the lack of FSII was assumed because it had insufficient information to fully evaluate the scenario. Pilatus also noted that, for the events cited by the FAA, lack of FSII was presumed as no testing of fuel samples was performed following the events (Fraenkel et al. 2017b, 68). Pilatus noted that PC-12 airplanes in ferry flights alone (such as from the manufacturing facility in Switzerland to the US and other countries) have accumulated thousands of hours in fuel systems icing conditions without incident when operated in compliance with the AFM limitations (Fraenkel et al. 2017b, 68).

Pilatus does not dispute that it has known, since before certification of the Pilatus PC-12 to present, that the airplane's fuel system is susceptible to fuel system icing (Pilatus 2017a, 1). We reviewed the petition's cited discussions among Pilatus engineers about the consequences of a lack of FSII and determined that they underscore the critical importance of adherence to the FSII limitation. Although one Pilatus engineer inquired internally in 2000 about reinstating the fuel heater project, the company's ultimate position that fuel heater retrofits would be very costly was reflected in its 2003 response to the FAA (Fraenkel et al. 2017b, 68, 70, 71, 78, and 80). Thus, contrary to the petition's claims, our review of the petition's cited internal Pilatus correspondence identified no information that contradicts the information that Pilatus provided to the FAA in its 2003 response to the FAA's recommendations.

Pilatus' response to the FAA also addressed the FAA's recommendation for direct pilot supervision of the fueling process, expressing Pilatus' opposition to such a requirement due to concerns that it could have an unintentional adverse effect on safety due to lack of availability of the prescribed FSII at certain fueling facilities (the FAA recommendation specified the use of an aerosol dispenser method when fuel premixed at a bulk supplier was unavailable) (Fraenkel et al. 2017b, 69).

Another aspect of Pilatus' response to the FAA that the petition claims was intentionally "misleading" was Pilatus' assessment of the fuel boost pump cycling phenomena reported in the 2002 fuel imbalance event, which Pilatus stated probably resulted from the airplane having been equipped with a low fuel pressure switch from an identified "faulty batch" (Fraenkel et al. 2017a, 14-15; 2017b, 68). However, our review of the correspondence revealed that Pilatus disclosed to the FAA that it had difficulty in fully assessing the event because it was not provided such information as whether the fuel contained sufficient FSII (Fraenkel et al. 2017b, 68). The petition also takes issue that the internal FAA correspondence from the manager of the FAA's Small Airplane Directorate to the manager of the FAA's Recommendation and Analysis Division (which determined that the recommended actions were not needed) contained information that Pilatus provided to the FAA in its 2003 response. The Pilatus-provided information used by the FAA's Small Airplane Directorate included the following:

> In the event the fuel filter becomes clogged by fuel icing (i.e. no additive in the fuel) fuel pressure would drop, the boost pumps would automatically come on line and the fuel filter by-pass valve would open and supply the engine with (unfiltered) sufficient fuel flow. Therefore, even if the AFM/POH limitation for the addition of [a FSII] is not followed, fuel delivery to the engine will be continued via the by-pass valve…. Additionally, the system is highly tolerant and can cope with fuel mixed incorrectly by the use of the bypass, which is the main element that may be blocked by fuel containing super cooled water or ice crystals. [Fraenkel et al. 2017a, 14].

The petition characterizes the cited information as "intentionally…misleading," and the petition uses the NTSB's fuel system icing analysis (which the petition otherwise disputes when claiming a mechanical fuel boost pump failure scenario) to support its claims that the information, "prepared by Pilatus, is unambiguously designed to assuage the FAA's grave concerns over PC-12 fuel system icing, FBP [fuel boost pump] failures, and fuel imbalance—the exact issues involved in this accident" (Fraenkel et al. 2017a, 14). (We note that our review of the FAA correspondence found no references to or questions about any fuel boost pump failures [Fraenkel et al. 2017b, 35-37, 48-50, and 53-54]. Further, although the letter from the manager of the FAA's Small Airplane Directorate used much of the technical information provided by Pilatus verbatim, the letter drew its own conclusions about the information. The FAA's letter indicated agreement with the information provided by Pilatus and stated that, during its consideration of the issue, the FAA also referenced both the FAA's database of service difficulty reports and the FAA's Small Airplane Directorate's Airworthiness Concerns Process Guide [Fraenkel et al. 2017b, 48-50].)

The petition summarizes the NTSB report's fuel system icing analysis and findings (but inaccurately states that the report determined that fuel system icing initiated a "failure" of the left fuel boost pump), claims that this scenario "certainly does not depict a 'highly tolerant' system that can easily cope," and describes the quoted correspondence as "incredibly unnerving in relation to the safety of this aircraft" (Fraenkel et al. 2017a, 13 and 14).

The petition's claims against the cited information appear to be based on the petition's interpretation that the information implies an assurance that the airplane's fuel system would perform indefinitely while being operated in conditions that far exceed the AFM-specified limitations for its safe operation. Such claims demonstrate a lack of understanding of not only the design of the fuel system but also the behavior of dissolved water, free water, and/or ice in Jet A fuel at subfreezing temperatures. We do not interpret the information provided by Pilatus (as cited in the petition) to imply such performance, and, although we cannot speak for the FAA, we doubt that its personnel did either. Further, the claims disregard the relevance of the aircraft limitation that required the use of a FSII and the AFM emergency procedures for addressing a low fuel pressure condition and a fuel imbalance.

On the day of the accident, the airplane's fuel system was operated—without a FSII added to its fuel—in temperatures far below the 0°C limitation that required the addition of a FSII during both the accident flight and the first flight of the day. During these exposures, both fuel boost pumps began cycling initially, with the eventual continuous operation of the left fuel boost pump during at least portions of the remainder of each flight (NTSB 2011a, 3, 16, and 32).

We note that, during the accident flight, the airplane's fuel system performed in a manner consistent with the descriptions that Pilatus provided the FAA in the correspondence cited by the petition; each time a low fuel pressure state (below 2 psi) was sensed, the automatic activation of one or both fuel boost pumps restored sufficient fuel pressure within 0.3 seconds to continuously supply fuel to the engine, and no engine flameout occurred. The continued operation of the engine provided the pilot with time and opportunity to perform the prescribed AFM procedures; by the time of the accident, about 69 minutes had passed since the fuel boost pumps first began cycling, and about 50 to 61 minutes had passed since the pilot's unsuccessful attempt to balance the fuel.

We note that, as described in the NTSB's report, the AFM for the accident airplane provided a limitation prescribing the use of a FSII to prevent the accumulation of ice in the fuel system, and, in the event that fuel system icing did occur (such as when a FSII was not properly used), the AFM provided emergency procedures with the directive to descend the airplane to warmer air and to land as soon as practical. In no way does the AFM imply that the fuel system, which is designed for the movement of liquid fuel, would be able to endure the accumulation of ice indefinitely.

Although the petition takes issue with Pilatus' decision to use a FSII limitation, rather than a fuel heating device to meet its certification requirements, we note that Pilatus is not unique among airplane manufacturers for opting to incorporate such a limitation, and the PC-12 is not the only FAA-certificated turbine-powered airplane subject to a FSII limitation. As described in the NTSB's report, various models of Cessna, Piper, Socata, Bombardier Learjet, Beechcraft, Hansa, Mitsubishi, Piaggio, and other manufacturers' airplanes require the use of a FSII (NTSB 2011a, 68).

The petition also claims that Pilatus, as party to the NTSB's investigation, withheld information related to "the PC-12's poor fuel system performance in cold temperatures" (Fraenkel et al. 2017a, 10). We note that, based on our review of our report, it is clear that our investigation evaluated the performance of exemplar fuel boost pumps at various temperatures (including subfreezing) and with varying concentrations of a FSII and that our analysis related to the potential adverse effects of fuel system ice accumulation on the performance of fuel boost pumps (and other fuel system components) was based on our own investigation and testing (NTSB 2011a, 30-31, 60, and 62).

Our review of the historical fuel system testing information cited by the petitioners finds no information that conflicts with the factual information and the analysis in our report. Further, we find that the information serves to underscore the critical importance of adherence to the FSII limitation. We note that the petition provided no context for the circumstances of two reported failures of boost pumps to operate in cold temperatures, cited in a 2000 e-mail among Pilatus engineers, or what the company's findings were in investigating the events (Fraenkel et al. 2017a, 10; 2017b, 70).

According to Pilatus, the cold temperature performance issue referenced in the petition was resolved in 2001 with Mandatory Service Bulletin 28-008, which called for inspections of existing fuel boost pumps and amended manufacturing procedures for newly manufactured pumps (Pilatus 2017a, 5). This issue and the service bulletin (mandated in the US by FAA Airworthiness Directive (AD) 2002-01-09, superseded by AD 2004-04-01) were discussed in the NTSB's report, including the evidence of compliance with the inspection for the accident airplane's "K" model fuel boost pumps (NTSB 2011a, 21). (Qualification testing of the "K" model pump was discussed in the NTSB's report [NTSB 2011a, 21].)

Although the petition characterizes the accident pilot's failure to comply with the FSII limitation as a "a foreseeable mistake," we note that a limitation is the strongest directive an aircraft manufacturer can impose on an operator to compel the safe operation of the aircraft (as discussed in section 3.1); generally, noncompliance with any single limitation for any aircraft could result in a fatal outcome. (We note that our database has numerous examples of fatal airplane accidents involving such factors as an inability to become airborne during the takeoff roll because the maximum gross takeoff weight limitation was exceeded, an inability to sustain flight because the minimum airspeed limitation was not maintained, or an inflight breakup following an exceedance of the maximum airspeed limitation.)

A pilot's responsibility to comply with aircraft limitations specified in the AFM is required by regulation and emphasized throughout pilot training and in FAA basic guidance materials. This is because compliance with limitations and knowledge of the performance information and operating procedures contained in the AFM are essential for the safe operation of the aircraft, powerplant, systems, and equipment (FAA 2003, 7-2; FAA 2008, 8-2).

We note that pilot compliance with all AFM-specified limitations is so universally expected that neither the FAA nor EASA (which is the regulator with authority over aircraft certification in Europe) believed that additional fuel system limitation warning or placard requirements were needed as a result of this accident.

Specifically, the NTSB's investigation considered the possibility that the accident pilot may not have fully understood the effects of fuel system icing and concluded that, for certificated aircraft that require the use of a FSII, requirements for including a warning in the limitations section of the AFM and for the installation of fuel filler placards could mitigate the safety hazard involving fuel system ice accumulation (NTSB 2011a, 68-70 and 77). As a result, our report included five safety recommendations to the FAA and four to EASA related to requiring such warnings and placards (Safety Recommendations A-11-70 through -73 and A-11-75 through -78) (NTSB 2011a, 68-70 and 78-79). However, neither the FAA nor EASA agreed to take the recommended action, and we classified all nine recommendations "Closed—Unacceptable Action" within 3 years of having issued them.

In its November 6, 2012, response to our recommendations, the FAA stated that, after a detailed review of the data we provided and its own "comprehensive review of general aviation service history," which included a search of several different accident and incident databases, the FAA found that this accident was the only identified fatal accident with a probable cause involving the pilot's failure to ensure that a FSII was added to the fuel; the FAA concluded that, based on its review, the new certification requirements we recommended were not warranted (FAA 2012a). The FAA's statements included the following:

> A pilot is required by regulation to comply with all limitations specified in the AFM, and as such is expected to be aware of all limitations listed in the AFM before flying an aircraft. We do not believe that undertaking the process to require further highlighting of this current limitation will yield any practical benefit [FAA 2012a].
>
> …The FAA uses data-driven, risk-based decisions to determine if mandatory safety actions are required. Based on actual data, risk analysis considers both the likelihood of an outcome and its severity and uses established guidelines to recommend an appropriate corrective action to maintain an acceptable level of safety. …[The] historical record does not show risk requiring the modification of AFMs for all [14 *CFR* Part] 23 airplanes that require fuel additives….[FAA 2012b].

Similarly, in its November 21, 2012, response to our recommendations, EASA stated that "all limitations [specified in an AFM] are applicable, and there is no basis for mandating some limitations as being more critical than others," such as by highlighting one with a warning (EASA 2012a).

We note that, although neither the FAA nor EASA believed that new requirements were necessary, the FAA noted that "Pilatus voluntarily revised the limitations section of all PC-12 AFMs to highlight a warning" related to procedures for using a FSII, and EASA noted that, "even if this is not considered an unsafe condition, [Pilatus] has decided to introduce a placard on the wing near the fuel filler" (FAA 2012a, EASA 2012b). The FAA stated that other airplane manufacturers "may voluntarily do the same, but we do not plan on making it a requirement" (FAA 2012a). To encourage voluntary participation (in response to our Safety Recommendation A-11-74), on April 17, 2013, the FAA issued a special airworthiness information bulletin to recommend that airplane manufacturers consider highlighting a FSII limitation with an AFM warning and fuel filler placards (FAA 2013).

Thus, none of the petition's claims against the adequacy of the certification of the Pilatus PC-12 fuel system design are supported. Further, as discussed in section 3.4, the CAWS design was compliant with the applicable regulations in effect at the time that the airplane was certificated.

Therefore, we deny the petition's claims against NTSB finding 2.

3.8 NTSB's Statement of Probable Cause

The petition claims that the NTSB's statement of probable cause is erroneous but does not provide any alternative wording. We note that, throughout the petition, there are claims against the following language that we have underlined, as follows:

> The [NTSB] determines that <u>the probable cause of this accident was (1) the pilot's failure to ensure that a fuel system icing inhibitor [FSII] was added to the fuel</u> before the flights on the day of the accident; <u>(2) his failure to take appropriate remedial actions</u> after a low fuel pressure state (<u>resulting from icing within the fuel system</u>) and a lateral fuel imbalance developed, including diverting to a suitable airport before the fuel imbalance became extreme; and <u>(3) a loss of control</u> while the pilot was maneuvering the left-wing-heavy airplane near the approach end of the runway.

We note that sections 3.5 and 3.6 of this response deny the petition's claims that a fuel system icing scenario did not occur, including the claim that the lack of the FSII in the fuel played no role in the circumstances of the accident. Sections 3.1 and 3.2 of this response deny the petition's claims that the AFM procedures related to the remedial action that the accident pilot should have taken in response to the available indications were inadequate. We note that, although we have revised related NTSB findings 9 and 11 (and the corresponding analysis), these revisions do not affect the wording of the probable cause statement for this subject area.

Regarding the loss of airplane control, the petition claims that the airplane "likely would have been uncontrollable and would have crashed" during any landing attempt "with a fuel imbalance far greater than the most severe imbalance ever tested by Pilatus – a 9-bar gauge differential" (Fraenkel et al. 2017a, 8). However, the petition offers no evidence to support this claim beyond an anecdote that one pilot who was faced with an icing-related 6-bar fuel imbalance experienced "serious difficulty in landing" the airplane but did so without damage to property or injury to persons (Fraenkel et al. 2017a, 13).

The NTSB's report described the Pilatus hazard assessment cited by the petition, which considered that a fuel imbalance exceeding 25% of the full tank load would require control column input from the pilot to counter the resulting rolling moment, increasing the pilot workload and decreasing the safety margin for certain airplane maneuvers; the assessment stated that, if the rolling moment became too large to be counteracted by changing the trim setting, the pilot may need to change the original flight plan. As noted in the NTSB's report, the AFM for the accident airplane addressed this situation by indicating that the pilot should land the airplane as soon as practical if a fuel imbalance of 3 or more bars could not be corrected (NTSB 2011a, 59-60).

As described in the NTSB's report (and sections 3.1 and 3.2 of this response), by the time of the accident, about 50 to 61 minutes had elapsed since the pilot's unsuccessful attempt to balance the fuel. Throughout this extended time, the airplane became increasingly difficult to control with the large and worsening left-wing-heavy fuel imbalance. However, we concluded that the airplane's left rolling moment could have been minimized or even avoided if the pilot had followed the required AFM procedures for responding to a fuel imbalance. Pilatus' calculations (which were reviewed as part of an NTSB aircraft performance study) determined that the airplane would have been controllable in static flight with the fuel imbalance that existed at the time of the accident, and an NTSB simulation evaluation determined that the airplane had adequate control authority to partially recover from the roll angle and pitch attitude reported by witnesses (NTSB 2011a, 36, and 56-60; NTSB 2011e).

Thus, none of the petition's claims against aspects of the NTSB's statement of probable cause are supported.

Therefore, we deny the petition's claims against the NTSB's statement of probable cause.

4. Summary of Revisions to the NTSB's Report

In summary, based on the NTSB's review of the petition filed on June 21, 2017, as well as the supplemental information submitted on July 20, 2018, the NTSB grants the petition, in part. The NTSB's final report (attached) has been revised on pages 49, 50, 56, 66, 67, 68, 76, and 77 as described.

Chair HOMENDY, Vice Chairman LANDSBERG, and Members GRAHAM and CHAPMAN concurred in the disposition of this petition for reconsideration.

References

Crane Company. 2017. “Comments of CRANE COMPANY to Petition for Reconsideration and Modification of the National Transportation Safety Board’s Findings and Determination of the Probable Cause of the Crash of Pilatus Pilatus PC-12/45 N128CM – Report No. NTSB/AAR-11/05 PB2011-910405” (with exhibits). October 2, 2017.

FAA (Federal Aviation Administration). 2003. *Pilot’s Handbook of Aeronautical Knowledge*. FAA-H-8083-25. Washington, DC: FAA.

—— 2008. *Pilot’s Handbook of Aeronautical Knowledge*. FAA-H-8083-25A. Washington, DC: FAA.

—— 2010. “Flightcrew Alerting.” Advisory Circular AC 25.1322-1. Washington, DC: FAA.

—— 2011. “System Safety Analysis and Assessment for Part 23 Airplanes.” Advisory Circular AC 23.1309-1E. Washington, DC: FAA.

—— 2012a. Official Correspondence from Michael P. Huerta, Acting Administrator, FAA, to the NTSB in response to Safety Recommendation A-11-70. November 6, 2012. Washington, DC: FAA.

—— 2012b. Official Correspondence from Michael P. Huerta, Acting Administrator, FAA, to the NTSB in response to Safety Recommendation A-11-71. November 6, 2012.

—— 2013. “Aircraft Fuel Systems – Fuel System Ice Inhibitors.” Special Airworthiness Information Bulletin CE-13-29. Washington, DC: FAA.

—— 2016a. *Pilot’s Handbook of Aeronautical Knowledge*. FAA-H-8083-25B. Washington, DC: FAA.

—— 2016b. Official Correspondence from Michael P. Huerta, Acting Administrator, FAA, to the NTSB in response to Safety Recommendation A-11-74. November 6, 2012.

—— 2022. *Risk Management Handbook*. FAA-H-8083-2A. Washington, DC: FAA.

EASA (European Aviation Safety Agency). 2012a. Official Correspondence from John Vincent, Deputy Director for Strategic Safety, Executive Directorate, EASA, to the NTSB in response to Safety Recommendations A-11-75 through -77. November 21, 2012.

—— 2012b. Official Correspondence from John Vincent, Deputy Director for Strategic Safety, Executive Directorate, EASA, to the NTSB in response to Safety Recommendation A-11-78. November 21, 2012.

Fraenkel, Stuart and Nicole Anderson (Nelson & Fraenkel LLP) and Anthony Tariccone (Kreindler & Kreindler LLP) for Irving Feldkamp III, Pamela Feldkamp, Robert Ching, Phyllis Ching, John Jacobson, Judy Jacobson, Louis Pullen, Noellene Pullen, Richard Mautz, and Cheryl Mautz. 2017a. "Petition for Reconsideration and Modification of the National Transportation Safety Board's Findings and Determination of the Probable Cause for the Crash of Pilatus PC-12/45 N128CM – Report No. NTSB/AAR-11/05 PB2011-910405," (with Appendixes 1 through 4). June 21, 2017.

—— 2017b. Appendix 2, Exhibits A through AD, with documentation related to the Stipulated Protective Order, Superior Court of the State of California for the County of Los Angeles, dated April 25, 2012, and confidentiality agreement between the petitioners and Pilatus, dated December 16, 2016.

—— 2017c. Appendix 3, Affidavit of Richard McSwain (with Attachments 1 through 30).

—— 2018. "Supplement to June 2017 NTSB Petition for Reconsideration." July 20, 2018.

NTSB (National Transportation Safety Board). 2011a. *Loss of Control While Maneuvering, Pilatus PC-12/45, N128CM, Butte, Montana, March 22, 2009*. AAR-11/05. Washington, DC: NTSB.

—— 2011b. "Operations 2 - Attachment 3 – PC-12 Limitations." Public Docket item for AAR-11/05.

—— 2011c. "Operations 2 - Attachment 4 – Emergency Procedures – Fuel System." Public Docket item for AAR-11/05.

—— 2011d. "Operations 2 - Attachment 6 – PC-12 Systems." Public Docket item for AAR-11/05.

—— 2011e. "Operations 2 - Attachment 20 – Alternate Airport Flight Track." Public Docket item for AAR-11/05.

—— 2011f. "Aircraft Performance Study." Public Docket item for AAR-11/05.

—— 2011g. "Materials Laboratory Factual Report." Public Docket item for AAR-11/05.

Pilatus Aircraft Ltd (Pilatus). 2017a. "Comments of Pilatus Aircraft Ltd. In Response to Petition for Reconsideration and Modification of the National Transportation Safety Board's Findings and Determination of the Probable Cause for the Crash of Pilatus PC-12/45 N128CM – Report No. NTSB/AAR-11/05 PB2011-910405." October 2, 2017.

—— 2017b. Appendix B, Affidavit of Jamie L. Petty-Galis.