National Transportation Safety Board
Washington, DC 20594

Response to Petition for Reconsideration

February 26, 2024

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[redacted]

In accordance with Title 49 *Code of Federal Regulations* (*CFR*) 845.32, the National Transportation Safety Board (NTSB) has reviewed the petition for reconsideration and modification of the probable cause of the accident involving a Cessna 525 airplane in Memphis, Indiana, on November 30, 2018 (CEN19FA036). The petitioner has met the requirements for the NTSB's review of his petition; specifically, as the representative of Tamarack Aerospace Group, a party to the investigation, he has a direct interest in the investigation and has claimed that the NTSB's findings were erroneous. On the basis of its review of the petition, dated January 3, 2022, the NTSB grants the petition in part.

Background

On November 30, 2018, about 1028 central standard time, a Cessna 525 airplane, N525EG, was destroyed when it was involved in an accident near Memphis, Indiana. The pilot and two passengers were fatally injured. The airplane was operated as a 14 *CFR* Part 91 business flight that originated from Clark Regional Airport, Jeffersonville, Indiana.[1]

The airplane was climbing through 3,000 ft mean sea level at an airspeed between 230 and 240 knots with the autopilot on. The airplane then began to bank to the left at a rate of about 5° per second. About 3 seconds later, the autopilot disconnected, and the airplane continued to climb. The airplane reached a maximum altitude of about 6,100 ft mean sea level before it began to rapidly descend; during this time, the left bank angle reached about 90°. About 23 seconds after the autopilot disconnected, the pilot made a mayday call, stating that the airplane was "in an

[1] Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case no. CEN19FA036). Use the CAROL Query to search safety recommendations and investigations.

emergency descent" and that he was "unable to gain control of the aircraft." The airplane subsequently impacted a wooded area about 8.5 miles northwest of the departure airport.[2]

The airplane was modified with wing tip extensions and winglets according to a supplemental type certificate. The wing tip extensions included the Tamarack Aerospace Group Active Technology Load Alleviation System (ATLAS), which operated independently of other airplane systems. The load alleviation system included Tamarack Active Camber Surfaces (TACS), which are aerodynamic control surfaces that either (1) hold their position in trail with the wing or (2) symmetrically deploy trailing edge up or down to relieve structural loads. The TACS were attached to each wing tip extension and were actuated by TACS control units (TCU).[3]

The NTSB's original investigation found that the accident airplane's left rolling moment resulted from the asymmetric deployment of the TACS, with the left TACS likely in a position consistent with trailing edge up and the right TACS likely in a position consistent with neutral. The NTSB determined that the probable cause of the accident (issued on November 1, 2021) was "the asymmetric deployment of the left-wing load alleviation system for undetermined reasons, which resulted in an in-flight upset from which the pilot was not able to recover."

The petitioner acknowledged that the NTSB would not consider petitions that repeated "positions previously advanced," as stated in 49 *CFR* 845.32(b). However, the petitioner stated that this provision was not applicable in this case because the NTSB did not consider information in Tamarack's supplemental party submission, dated October 26, 2021. The petitioner also stated that the NTSB issued its final report "without even acknowledging the existence of [Tamarack's] supplemental [party] submission" and that "there is nothing in the public docket or the Final Accident Report that addresses any information contained in the Tamarack supplemental submission."

The NTSB notes that the supplemental party submission was evaluated during the original investigation by the investigative team members, their supervisors, and senior management. They determined that the concerns in Tamarack's supplemental submission had already been considered by the investigative team.[4] Nevertheless,

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[2] The total time from the beginning of the left bank to ground impact was about 35 seconds.

[3] The TACS' nominal operational travel was 20° trailing edge up and 9° trailing edge down. Mechanical stops were located in a bellcrank assembly.

[4] The information in Tamarack's supplemental party submission presented the petitioner's position that a failure of the airplane's attitude heading reference system (AHRS) led to the uncommanded roll, autopilot disconnection, and in-flight upset. The team determined that a dual AHRS failure would be extremely unlikely given that each AHRS input source is relatively independent. The team also determined that, if one of the two AHRS units had failed, the pilot should have known to select the operating AHRS.

the NTSB considered this petition for reconsideration given the petitioner's claims of erroneous findings. The NTSB's response discusses the assertions on pages 3 and 4 of the petition and presents system-related information first.[5]

Petitioner's Claims and NTSB's Response

The petitioner asserted that the NTSB's final aviation accident report contained "key erroneous findings" and "factual errors," noting that "each error is significant" and that "the cumulative effect of the errors is to clearly demonstrate that there is no evidence that Tamarack's ATLAS was in any way responsible for the November 30, 2018 accident."[6] The "key erroneous findings" that the petitioner described are presented in the sections below along with the NTSB's response to each claim.

Witness Marks

The NTSB's final report stated that, according to witness mark evidence, "the left TACS was in a position consistent with full trailing edge up position at the time of ground impact." The petitioner disagreed with this statement and provided the following rationale:

> The report fails to acknowledge that the referenced damage is consistent with the entire TACS control system being over-deflected. The report also fails to consider that, because the TACS can be easily moved by hand when the system is not powered, it is extremely probable that the TACS moved significantly postimpact, as violent forces acted on the various components. Physical limitation of the movement of components within ATLAS makes it impossible for the witness marks relied on by the Board to conclude that a malfunction of ATLAS caused them. Rather, all the referenced damage and witness marks were likely the result of the high impact forces over-extending the TACS control system just after the aircraft struck the ground.
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> The report clearly misinterprets at-impact witness marks found within the left and right actuators that could only have been caused by impact forces with the ground. These at-impact witness marks are evidence that

[5] The petitioner did not provide any evidence to support assertions related to the pilot's training and experience; as a result, those issues are not discussed in this response.

[6] On March 24, 2022, the petitioner provided a letter to the NTSB, stating that an aviation expert who was familiar with NTSB investigations had reviewed the petition for reconsideration and the information in the accident docket. According to the aviation expert's comments, dated March 22, 2022, "the scenario contained in the NTSB Final Report and the accompanying Probable Cause statement contain several inconsistencies which rule out a failure of the ATLAS system as the cause of the accident."

> the left and right actuators were at a symmetric deployment at an intermediate position consistent with a 2-G flight condition, which matches the final flight condition reported in the NTSB's Performance Study.

During the original investigation, the NTSB's examination of the airplane's left TACS control linkage assemblies revealed a witness mark on the bellcrank that was consistent with contact with the trailing-edge-up mechanical stop. The original investigation also found that additional damage on the TACS inboard hinge fitting was consistent with the TACS being in a trailing-edge-up position at the time of ground impact. These findings contributed to the NTSB's position that the asymmetric deployment of the TACS (with the left TACS in a trailing-edge-up position at the time of ground impact and the right TACS in a position consistent with neutral) led to the left rolling moment during the accident sequence.

As part of our review of this petition, the NTSB re-examined the photographs of the left TACS control linkage assemblies, including the witness mark on the bellcrank and hinge fitting. This re-examination confirmed that the witness mark on the bellcrank was consistent with contact with the trailing-edge-up mechanical stop (21°), which was beyond the 20° soft-stop limit of the left TCU. Further, damage to the hinge fitting could only occur with significant travel beyond the TCU and bellcrank mechanical stop limits.

The petitioner asserted that the damage to the hinge fitting would only have been possible if the overdeflection of the TACS was about 55° (almost three times the 20° trailing-edge-up limit). The NTSB could not confirm this assertion with the available evidence for the investigation. However, the NTSB recognizes that the TCU would not be able to move the TACS to that position during normal operations. Although the final report acknowledged that the damage observed on the TACS inboard hinge fitting was consistent with overdeflection in the trailing-edge-up direction, the report did not indicate the magnitude of the overdeflection, which was well beyond the operational travel of the TACS.

The NTSB's examination of the left TCU ram guide (as part of the original investigation) showed two sets of witness marks on the upper and lower surfaces; one set corresponded to the intermediate extension position of the actuator, and the other set corresponded to the full-extension position.[7] During the examination of photographs of the ram guide as part of this petition evaluation, the NTSB noted additional marks on one side of the ram guide.

[7] The ram guide is the housing in which the actuator ball nut travels.

The photographs in figures 1 and 2, which were taken after the grease was removed from the ram guide, show a mark that corresponds to a TACS neutral position of the actuator and periodic marks toward the TCU full-extension position; these marks were not discussed in the original report. The periodic marks were consistently spaced at the approximate distance of the pitch of the ball screw (which positions the TACS). It is possible that the ball screw deformed during impact and that subsequent motion of the ball screw could have caused nonlinear motion of the ball nut and the periodic contact marks on the sides of the ram guide.

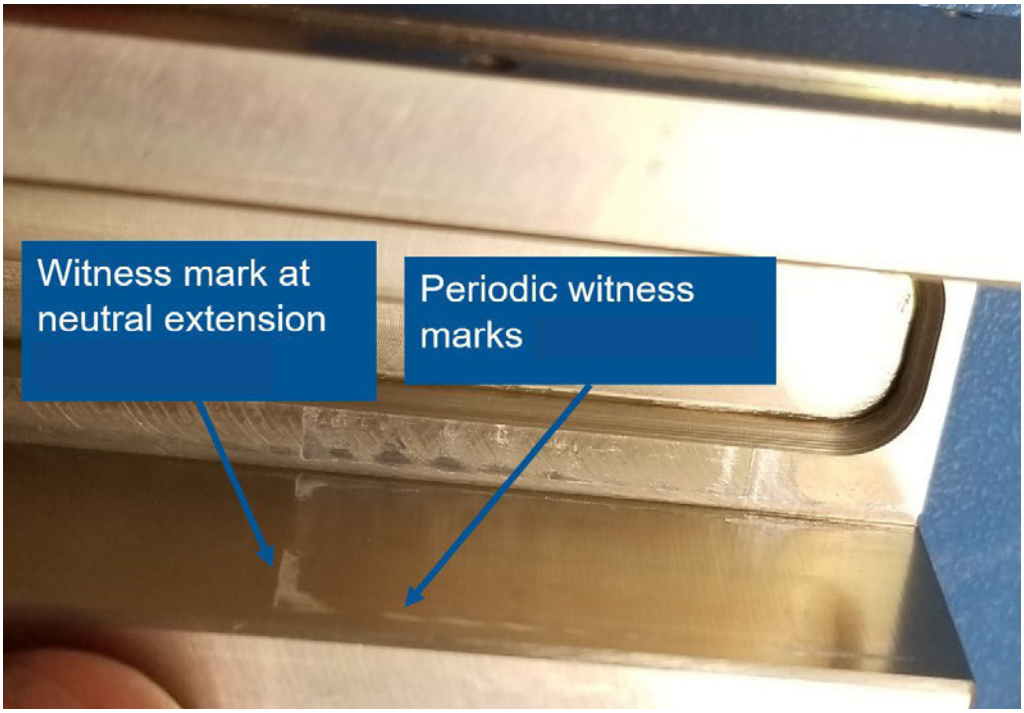

Figure 1. Witness marks on the side of the ram guide housing.

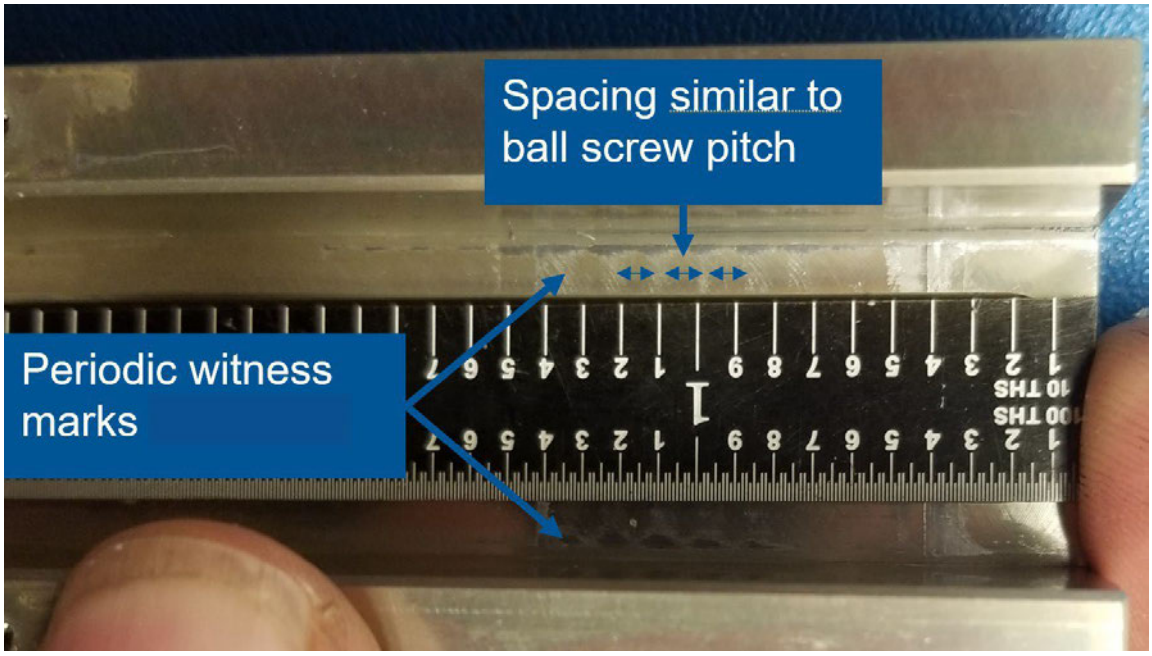

Figure 2. Periodic witness marks on the upper surface of the ram guide housing.

In addition, in May 2023, the NTSB compared the wear marks (resulting from normal operations) on an in-service actuator with the witness marks on the accident left TCU ram guide housing.[8] The comparison showed that the witness marks on the accident TCU were different than the normal wear marks.

In summary, the witness marks on the bellcrank and hinge were outside the normal range of travel and were likely not consistent with the TACS position at the time of initial impact. In addition, although the NTSB's original investigation found witness marks on the TCU ram guide at the intermediate- and full-extension positions, the NTSB's re-examination also found witness marks that corresponded to a TACS neutral position and periodic witness marks on the ram guide. As a result, the available evidence for this accident is insufficient to confirm the petitioner's assertion that the actuator was in an intermediate position at the time of initial impact. However, the NTSB agrees with the petitioner that the evidence is also insufficient to conclude that (1) the left actuator was in an extended position at the time of initial impact and (2) the ATLAS caused the left rolling moment; the NTSB has revised the report accordingly.

[8] As part of the investigation of NTSB accident ERA23FA174, the NTSB examined the left and right TCUs and disassembled the left TCU, and the results of this work were considered in the evaluation of this petition.

TCU Pins

Regarding the six TCU pins described as "curled" in the final report, the petitioner stated the following:

> The bending of six pins within an ATLAS electrical connector could not have existed for about 193 flight hours between the date when two key ATLAS components (both TCUs) were removed and replaced for maintenance on July 13, 2018, and the time of the accident on November 30, 2018. This work was performed to comply with a service bulletin that changed the design of an internal screw assembly within the TCU.[9] Note that the maintenance was performed without any anomaly in the accident aircraft's flight characteristics having presented itself. The cause of the bending was almost certainly impact forces.

The petitioner also stated that "extreme impact forces" caused the TCU circuit board to flex, causing the 40-pin connector to partially disconnect. The petitioner further stated that, when the TCU circuit board "flexed back, the pins were driven back into the sockets" of the connector and that six pins curled because they did not properly seat.

The NTSB's original investigation found that 6 of the left TCU's 40-pin electrical connector were bent (curled) but did not determine how or when those pins became bent. During our evaluation of the petition, the NTSB requested information from Tamarack about the deformation of the TCU circuit board under load. In response, Tamarack conducted impact load testing in spring 2023 and provided the results of to the NTSB. The testing showed that the TCU circuit board (on which the pin portion of the electrical connector was mounted) could deform under loads and that impact forces could have, at a minimum, partially separated the connector pins, resulting in damage to the pins.

Figure 3 is a photograph (from the original investigation) of the bottom cover of the TCU. The figure shows that witness marks had transferred from the TCU circuit board to the bottom cover, which could have only occurred if the circuit board flexed until it contacted the cover. These marks were not noted in the final report for this accident.

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[9] The NTSB's original investigation found that both TCUs had been returned to the manufacturer so that Service Bulletin (SB) CAS/SB1467 could be accomplished. The SB was intended to address the possibility that a metal fastener inside the TCU could become loose and detach. After incorporation of the SB, the TCUs were reinstalled on the airplane on July 13, 2018. The SB is also discussed later in this petition response.

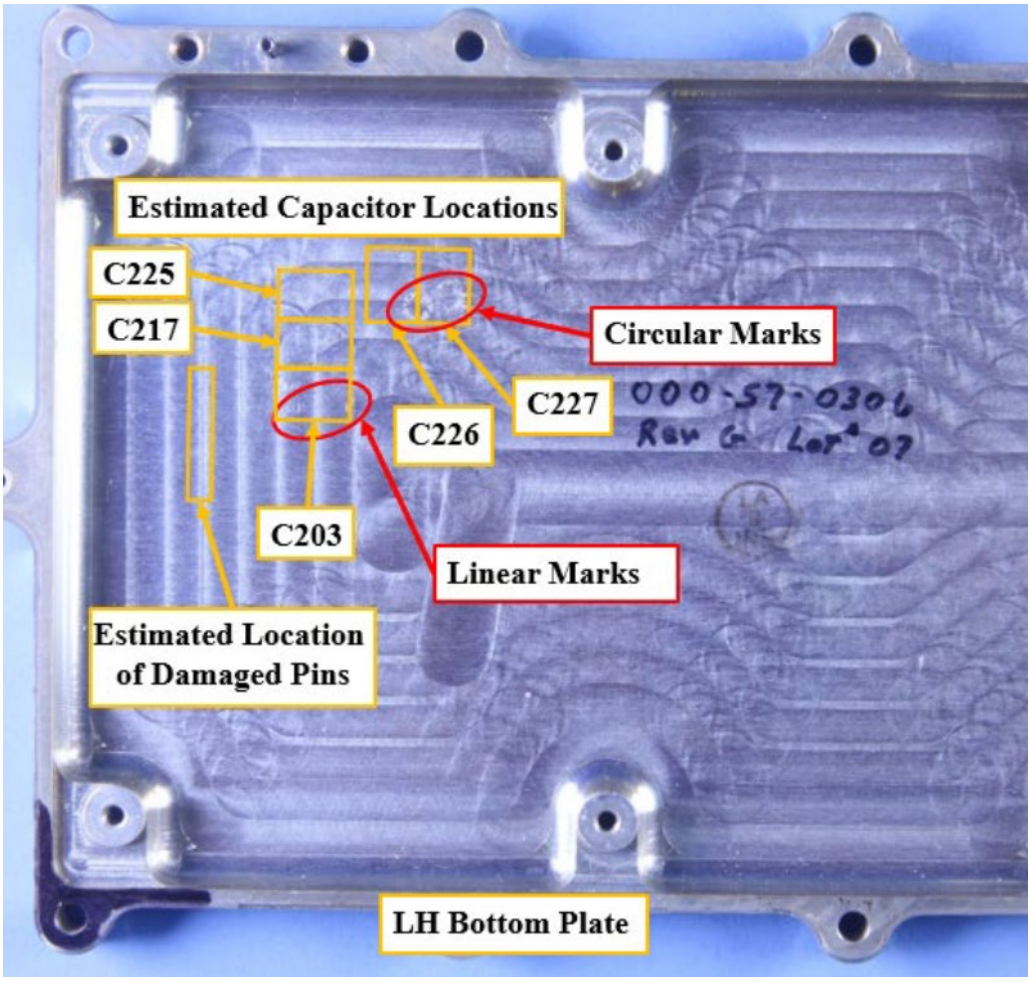

Figure 3. TCU bottom cover showing witness marks that corresponded to capacitor locations.

Note: The labels C203, C217, and C225 through C227 indicate specific capacitors. The linear marks, which cannot be readily seen without magnification, were located in the area under capacitor C203.

Dimensional analysis of the circuit board assembly (performed by the NTSB as part of this petition evaluation) showed that, if the circuit board deflected during impact so that it contacted the bottom cover of the actuator, and if the bottom cover deflected slightly, the pins could disengage from the connector.[10] The analysis also showed that the area of maximum deflection of the circuit card was in line with the area of the 6 bent pins, which could explain why only 6 of the 40 pins were affected.

[10] For the dimensional analysis, the NTSB analyzed computer tomography images that were part of the original investigation. The offset between connectors (0.05 inches) and the maximum distance from the damaged capacitor on the circuit card to the bottom cover of the actuator (0.07 inches) was subtracted from the pin height of the nearest straight pin (0.14 inches). These measurements indicated that the actuator bottom cover needed to deform only about 0.02 inches for the pins to disengage.

The NTSB found that the additional information from the impact load testing and dimensional analysis supported the possibility that the pins became bent during impact. However, the additional information does not eliminate the possibility that the pins had become bent during manufacture or maintenance given that the pins' pre-accident status is unknown.

Regarding the petitioner's position that the bending of six pins within an ATLAS electrical connector could not have existed between the time of the July 13, 2018, maintenance and the accident (about 193 flight hours later), the NTSB notes that, although the pre-accident continuity condition of each pin is unknown, four of the six bent pins had continuity with their respective connectors during postaccident examination. As a result, the final report will not be revised to indicate how or when the pins were bent. However, the final report will be revised to reflect the evidence obtained during this petition evaluation that supported the petitioner's position that the pins could have become bent during impact.

Autopilot Disconnection

Regarding the final report's discussion of the autopilot's disconnection, the petitioner asserted the following:

> The report states that the autopilot prematurely disconnected at a 30° bank angle. The autopilot system disconnect threshold is 45°, which is 15° more than the bank angle at which the accident aircraft's autopilot disconnected. Therefore, the autopilot clearly did not disconnect because of excessive bank angle.
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> The aircraft rolled at 5° per second, but the autopilot disconnect roll rate threshold is 10° per second. Therefore, the autopilot clearly did not disconnect due to excessive roll rate.
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> ATLAS has no connection whatsoever to the autopilot, meaning the only way for an ATLAS failure to disconnect the autopilot is via bank angle or roll rate. If the autopilot did not disconnect due to bank angle or roll rate, ATLAS could not have caused the autopilot to disconnect.

As part of the review of this petition for reconsideration, the NTSB assessed the timing of the autopilot disconnect based on the information from the Performance Study and the Cockpit Voice Recorder (CVR) Factual Report. Because the accident airplane was not equipped (and was not required to be equipped) with a flight data recorder, bank angle and roll rate were not directly measured or recorded. As a result, all airplane performance parameters were calculated from Federal Aviation Administration-provided automatic dependent surveillance-broadcast (ADS-B) data

for GPS latitude and longitude, GPS altitude, and pressure altitude, which were all recorded about once per second.[11]

Calculations of rates of change, including groundspeed, yaw rate, angle of climb, and rate of climb, required numerical analysis of ADS-B position data. Bank angle was calculated using a simplified model of airplane dynamics that determined the lift vector angle necessary to match the calculated yaw rate, pitch angle, pitch rate, and angle of attack. Roll rate was determined using an additional numerical analysis of the calculated bank angle.[12]

The numerical analysis amplified the noise (that is, the random error) inherent in the ADS-B position data. Bank angle, as a function of the rates calculated from the position data, was subject to such noise, and the roll rate calculation amplified the noise further. As a result, smoothing was applied to the data to reduce the noise; however, smoothing can also mask the magnitude and the rate of change in the signal. The NTSB notes that our smoothed and unsmoothed calculations for the airplane's bank angle showed that it was not large enough to cause the autopilot to disconnect when it did.[13]

The petitioner noted that the smoothed roll rate in the Performance Study had a peak value of about -7° per second. The NTSB found that the data, before smoothing, showed a calculated peak value of -13.7° per second about 0.5 seconds before the autopilot disconnected. Thus, given the inherent noise and associated uncertainty in the calculated roll rate, the roll rate could have reached and then surpassed the autopilot disconnect threshold of 10° per second. Thus, although the petitioner stated that the autopilot did not disconnect due to an excessive roll rate, the data are insufficient to support that assertion.

Previous Related Event

The petitioner referenced a roll event mentioned in the NTSB's original report. That event involved another airplane equipped with ATLAS (N680KH). The petitioner stated the following about the inclusion of the roll event in the report:

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[11] The review of the ADS-B data as part of this petition response found no evidence indicating any error in the correlation of the ADS-B time and the CVR time. None of the parameters in the ADS-B data could be directly related to any sound on the CVR, but the data that were recorded were consistent with the final time correlation.

[12] The timing of the bank angle and roll rate data was determined using ADS-B data. The CVR transcript provided the timing of the autopilot disconnect. The air traffic control (ATC) transcript (which was added to the docket) connected the timing from both sources. A comparison of the CVR transcript and the ATC transcript found that the timing was consistent within ± 1 second.

[13] The bank angle and roll rate shown in the NTSB's Performance Study were both smoothed using an algorithm that essentially averaged each data point with the data recorded during the 5 seconds before the data points and the 5 seconds after the data points.

> [The] reference to a roll event in the United Kingdom [UK] on April 13, 2019, involving another aircraft equipped with ATLAS, is completely misleading since the UK incident involved an ATLAS screw that had not been removed and replaced in accordance with the Service Bulletin [SB CAS/SB1467], resulting in a failure. There was no evidence whatsoever of any such screw assembly issue in the [US] accident aircraft.[14]

The NTSB notes that the factual section of the final aviation accident report discussed the Air Accidents Investigation Branch's (AAIB) final report about the uncommanded roll event involving N680KH.[15] According to the AAIB report, shortly after takeoff, "an electrical failure in this system [ATLAS] caused one of these control surfaces [TACS] to deploy separately, causing an uncommanded roll." The report further stated that "the resulting aircraft upset caused the pilot significant surprise and difficulty in controlling the aircraft." Although not discussed in the NTSB's report, the AAIB concluded that "the uncommanded left roll occurred because a short circuit in the left ATLAS Control Unit caused the associated control surface to fail in the fully deflected up position." The AAIB determined that the cause of the TCU failure was likely the result of

> a short circuit within the TCU caused by a loose screw or washer within the unit. The screw and spring washer had become loose because the spring washer had lost load, allowing the screw to unwind and eventually become loose within the unit.

The AAIB report also discussed SB CAS/SB1467, which had not been implemented on N680KH. According to the AAIB report, Tamarack Aerospace issued this SB to recommend the replacement of TCUs to change the screw retention system. As previously stated, this SB was implemented on N525EG (the subject of this petition for reconsideration) on July 13, 2018.

The analysis section of the NTSB's final report stated that five previous uncommanded roll events had occurred on ATLAS-equipped airplanes (including the uncommanded roll event involving N680KH). Although this statement is accurate, the NTSB has decided to remove the statement to ensure that our analysis does not inadvertently imply that the cause of the uncommanded left roll in the UK event was a factor in the subject accident or that a screw assembly issue affected N525EG.

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[14] SB CAS/SB1467, which was not mandatory, was issued about 1 year before the UK event.

[15] The NTSB's final aviation accident report provided a hyperlink to the AAIB's report, which stated that the accident airplane (N680KH) had been modified with ATLAS, a system that was "intended to enhance [the airplane's] performance" and "included supplementary control surfaces designed to deflect symmetrically and automatically to alleviate gust loads."

Disposition

After review of the evidence, the petition for reconsideration of the NTSB's probable cause in connection with the aircraft accident involving a Cessna 525 airplane, N525EG, on November 30, 2018, in Memphis, Indiana, is granted in part because the available evidence for this accident does not sufficiently show that the ATLAS was the cause of the in-flight upset from which the pilot was unable to recover. In addition, the factual and analysis sections of the report and the findings have been revised to reflect the information presented in the petition response sections addressing witness marks, TCU bent pins, and the UK uncommanded roll event.

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

Enclosure
Revised Final Aviation Accident Report