NATIONAL TRANSPORTATION SAFETY BOARD
Public Meeting of September 9, 2015
(Information subject to editing)

Runway Overrun During Rejected Takeoff, Gulfstream Aerospace Corporation G-IV, N121JM, Bedford, Massachusetts
May 31, 2014

This is a synopsis from the NTSB's report and does not include the Board's rationale for the conclusions, probable cause, and safety recommendations. NTSB staff is currently making final revisions to the report from which the attached conclusions and safety recommendations have been extracted. The final report and pertinent safety recommendation letters will be distributed to recommendation recipients as soon as possible. The attached information is subject to further review and editing.

Executive Summary

On May 31, 2014, about 2140 eastern daylight time, a Gulfstream Aerospace Corporation G-IV, N121JM, registered to SK Travel, LLC, and operated by Arizin Ventures, LLC, crashed after it overran the end of runway 11 during a rejected takeoff at Laurence G. Hanscom Field (BED), Bedford, Massachusetts. The airplane rolled through the paved overrun area and across a grassy area, collided with approach lights and a localizer antenna, passed through the airport's perimeter fence, and came to a stop in a ravine. The two pilots, a flight attendant, and four passengers died. The airplane was destroyed by impact forces and a postcrash fire. The corporate flight, which was destined for Atlantic City International Airport, Atlantic City, New Jersey, was conducted under the provisions of 14 *Code of Federal Regulations* (*CFR*) Part 91. An instrument flight rules flight plan was filed. Night visual meteorological conditions prevailed at the time of the accident.

During the engine start process, the flight crew neglected to disengage the airplane's gust lock system, which locks the elevator, ailerons, and rudder while the airplane is parked to protect them against wind gust loads. Further, before initiating takeoff, the pilots neglected to perform a flight control check that would have alerted them of the locked flight controls. A review of data from the airplane's quick access recorder revealed that the pilots had neglected to perform complete flight control checks before 98% of their previous 175 takeoffs in the airplane, indicating that this oversight was habitual and not an anomaly.

A mechanical interlock between the gust lock handle and the throttle levers restricts the movement of the throttle levers when the gust lock handle is in the ON position. According to Gulfstream, the interlock mechanism was intended to limit throttle lever movement to a throttle lever angle (TLA) of no greater than 6° during operation with the gust lock on. However, postaccident testing on nine in-service G-IV airplanes found that, with the gust lock handle in the ON position, the forward throttle lever movement that could be achieved on the G-IV was 3 to 4 times greater than the intended TLA of 6°.

During takeoff, the pilot-in-command (PIC) manually advanced the throttle levers, but the engine pressure ratio (EPR) did not reach the expected level due to the throttles contacting the gust lock/throttle lever interlock. The PIC did not immediately reject the takeoff; instead, he engaged the autothrottle, and the throttle levers moved slightly forward, which allowed the engines to attain an EPR value that approached (but never reached) the target setting.

As the takeoff roll continued, the second-in-command made the standard takeoff speed callouts as the airplane successively reached 80 knots, the takeoff safety speed, and the rotation speed. When the PIC attempted to rotate the airplane, he discovered that he could not move the control yoke and began calling out "(steer) lock is on." At this point, the PIC clearly understood that the controls were locked but still did not immediately initiate a rejected takeoff. If the flight crew had initiated a rejected takeoff at the time of the PIC's first "lock is on" comment or at any time up until about 11 seconds after this comment, the airplane could have been stopped on the paved surface. However, the flight crew delayed applying brakes for about 10 seconds and further delayed reducing power by 4 seconds; therefore, the rejected takeoff was not initiated until the accident was unavoidable.

The safety issues discussed in this report relate to the need for the following:

- **Use of the challenge-verification-response format for checklist execution.** The flight crewmembers' total lack of discussion of checklists during the accident flight and the routine omission of complete flight control checks before 98% of their last 175 flights indicate that the flight crew did not routinely use the normal checklists or the optimal challenge-verification-response format. This lack of adherence to industry best practices involving the execution of normal checklists and other deficiencies in crew resource management eliminated the opportunity for the flight crewmembers to recognize that the gust lock handle was in the ON position and delayed their detection of this error.

- **Analysis of corporate flight operations quality assurance data to define the scope of procedural noncompliance in business aviation.** The National Transportation Safety Board (NTSB) found no data documenting the rate of flight crew compliance with required flight control checks in business aviation for the G-IV or any other airplane, yet checklists, callouts, and other standard operating procedures (SOP) are considered an important "soft" defense against threats and errors in business aviation. If the actual rate of procedural compliance is much lower than assumed, aircraft designers, regulators, and operators may need to help boost compliance or reconsider their assumptions about the reliability of flight crew adherence to routine checks and the level of safety protection afforded by such SOPs.

- **Replacement of nonfrangible fittings with frangible fittings for any objects along the extended runway centerline up to the perimeter fence.** After leaving the paved runway overrun and entering the grass, the airplane collided with structures that were not mounted on frangible supports. These structures were not required to be mounted on frangible supports; only structures inside the runway safety area (RSA) must have frangible supports. The NTSB recognizes that the Federal Aviation Administration

(FAA) already encourages the incorporation of frangible fittings for structures in areas adjacent to RSAs and that it replaced the fittings at BED with frangible fittings after the accident. However, similar nonfrangible structures located outside of an RSA, but inside a perimeter fence and along an extended runway centerline, are likely present at other airports.

- **Retrofit of the gust lock system on all existing G-IV airplanes to comply with the certification requirement that the gust lock limit the operation of the airplane so that the pilot receives an unmistakable warning if the lock is engaged at the start of takeoff.** Performance calculations demonstrated that the interlock mechanism did not perform as intended. If the throttles had remained at the point where they initially contacted the interlock, the airplane would have reached rotation speed about 7 seconds later and about 1,200 ft farther down the runway than it did. In contrast, an interlock that limited TLA to 6° would have prevented the airplane from achieving any significant acceleration, thus constituting an unmistakable warning that would most likely have prevented the accident.

- **Guidance on the appropriate use and limitations of the review of engineering drawings in a design review performed as a means of showing compliance with certification regulations.** The G-IV gust lock/throttle interlock system was based on previously certificated Gulfstream airplane systems, and compliance with the applicable certification regulation (14 *CFR* 25.679, Control System Gust Locks) for the G-IV was demonstrated by a review of engineering drawings. There was no functional test of the design of the G-IV gust lock/throttle interlock system. A drawing review was an insufficient means of demonstrating compliance with 14 *CFR* 25.679 because of the complexities of the G-IV gust lock system. Design review as a means of compliance with a regulation and the specific documentation requirements are not defined in FAA guidance material such as FAA orders or advisory circulars.

Findings

1. The flight crew was qualified to operate the airplane, and the use of alcohol or drugs, fatigue, and medical conditions were not factors in the flight crew's performance.

2. The flight crew failed to disengage the gust lock system as called for in the Starting Engines checklist and failed to conduct a flight control check as called for in the After Starting Engines checklist, during which the crewmembers would have detected that the gust lock system was engaged.

3. Given that the flight crew neglected to perform complete flight control checks before 98% of the crewmembers' previous 175 takeoffs in the airplane, the flight crew's omission of a flight control check before the accident takeoff indicates intentional, habitual noncompliance with standard operating procedures.

4. About the time that the airplane reached a speed of 150 knots, one of the pilots activated the flight power shutoff valve, likely in an attempt to unlock the flight controls, but this action

was ineffective because high aerodynamic loads on the elevator were likely impeding gust lock hook release.

5. The flight crew delayed initiating a rejected takeoff until the accident was unavoidable; this delay likely resulted from surprise, the unsuccessful attempt to resolve the problem through use of the flight power shutoff valve, and ineffective communication.

6. The flight crewmembers' lack of adherence to industry best practices involving the execution of normal checklists eliminated the opportunity for them to recognize that the gust lock handle was in the ON position and delayed their detection of this error.

7. Independent safety audits performed by an industry safety organization did not adequately encourage best practices for the execution of normal checklists.

8. An analysis of flight operational quality assurance data specifically evaluating the rate of noncompliance with flight control checks before takeoff could help define the scope of procedural noncompliance in business aviation and guide the development of strategies to address it.

9. The impact forces from the accident were survivable, but the cabin and cockpit environment quickly deteriorated due to the postcrash fire, which erupted immediately, spread rapidly, and prevented the occupants from escaping.

10. Although it did not affect the survivability of this accident, had a resupply hose been placed at the fire hydrant in the vicinity of the accident site before the aircraft rescue and firefighting vehicles exhausted their water supply, the 14-minute delay in resuming firefighting activities could have been avoided.

11. Had the Laurence G. Hanscom Field airport emergency plan included a gate map, or had the perimeter gates been depicted on the grid map, the aircraft rescue and firefighting personnel's confusion about how to reach the nonairport side of the ravine would likely have been reduced.

12. The replacement of nonfrangible fittings with frangible fittings on structures located outside of, but adjacent to, a runway safety area (RSA), such as the approach lights and localizer antenna struck by the accident airplane, would minimize the potential for damage to an airplane that is unable to stop within the RSA during a runway overrun.

13. Because the gust lock system in Gulfstream Aerospace Corporation G-IV airplanes does not limit the operation of the throttle levers with the gust lock engaged to provide an unmistakable warning at the start of takeoff, as was originally intended when the airplane was certificated, the gust lock system in the G-IV does not comply with 14 *Code of Federal Regulations* 25.679.

14. The Federal Aviation Administration (FAA) missed opportunities to detect the inadequate design of the gust lock system during the Gulfstream Aerospace Corporation G-IV's certification because the FAA relied solely on a review of engineering drawings to determine if the system met certification requirements.

15. Gulfstream Aerospace Corporation's use of a G-IV drawing review alone to show compliance with 14 *Code of Federal Regulations* 25.679 led to a gust lock/throttle interlock system that did not comply with the regulation.

16. If the Gulfstream Aerospace Corporation G-IV's gust lock system had been developed using Gulfstream's current design process, Gulfstream would likely have developed, validated, and verified a gust lock system that would limit the throttle lever movement to 6°.

17. Without clear guidance, the use of drawing reviews as the sole method of compliance determination may not be sufficiently robust to verify that Federal Aviation Administration aircraft type certification requirements have been met.

Probable Cause

The NTSB determines that the probable cause of this accident was the flight crewmembers' failure to perform the flight control check before takeoff, their attempt to take off with the gust lock system engaged, and their delayed execution of a rejected takeoff after they became aware that the controls were locked. Contributing to the accident were the flight crew's habitual noncompliance with checklists, Gulfstream Aerospace Corporation's failure to ensure that the G-IV gust lock/throttle lever interlock system would prevent an attempted takeoff with the gust lock engaged, and the Federal Aviation Administration's failure to detect this inadequacy during the G-IV's certification.

Recommendations

As a result of this investigation, the NTSB makes safety recommendations to the FAA, the International Business Aviation Council, and the National Business Aviation Association:

To the Federal Aviation Administration:

1. Identify nonfrangible structures outside of a runway safety area during annual 14 *Code of Federal Regulations* Part 139 inspections and place increased emphasis on replacing nonfrangible fittings of any objects along the extended runway centerline up to the perimeter fence with frangible fittings, wherever feasible, during the next routine maintenance cycle.
2. After Gulfstream Aerospace Corporation develops a modification of the G-IV gust lock/throttle lever interlock, require that the gust lock system on all existing G-IV airplanes be retrofitted to comply with the certification requirement that the gust lock physically limit the operation of the airplane so that the pilot receives an unmistakable warning at the start of takeoff.

3. Develop and issue guidance on the appropriate use and limitations of the review of engineering drawings in a design review performed as a means of showing compliance with certification regulations.

To the International Business Aviation Council:

4. Amend International Standard for Business Aircraft Operations auditing standards to include verifying that operators are complying with best practices for checklist execution, including the use of the challenge-verification-response format whenever possible.

To the National Business Aviation Association:

5. Work with existing business aviation flight operational quality assurance groups, such as the Corporate Flight Operational Quality Assurance Centerline Steering Committee, to analyze existing data for non-compliance with manufacturer-required routine flight control checks before takeoff and provide the results of this analysis to your members as part of your data-driven safety agenda for business aviation.

The NTSB has also adopted a safety alert about using checklists to ensure procedural compliance.