Gulfstream G650 Flight Test Crash

What Happened?

On April 2, 2011, during a takeoff performance test for the Gulfstream G650, the aircraft experienced an aerodynamic stall followed by an uncommanded roll, resulting in a crash at the Roswell International Air Center, New Mexico. All four onboard personnel—two pilots and two flight test engineers—were fatally injured, and the aircraft was destroyed by the impact and a subsequent fire. The crash occurred during a one-engine-inoperative (OEI) takeoff test, with aggressive attempts to meet target speeds and maintain schedule pressure.

Why Did It Happen?

1. **Inadequate Development and Validation of Takeoff Speeds:** Gulfstream failed to account for accurate aerodynamic stall data in ground effect, leading to unachievable target speeds and inappropriate assumptions during testing.
2. **Mismanagement of Previous Roll Incidents:** Two uncommanded roll events during earlier flight tests were not investigated thoroughly. These incidents should have signaled the need for a deeper analysis of stall characteristics and potential hazards.
3. **Aggressive Program Schedule:** The company's focus on obtaining certification within a tight timeframe pressured the team to prioritize speed over safety, compounding technical and procedural errors.
4. **Deficiencies in Safety Management:** Gulfstream's safety management system lacked proper oversight, hazard identification, and risk mitigation controls, especially for high-risk test scenarios like OEI takeoffs.
5. **Technical Misjudgments:** The predicted in-ground-effect stall angle of attack (AOA) was overestimated, and stick shaker warning thresholds were set too high, preventing timely pilot warnings before the stall.

What Lessons Were Learned?

1. **Importance of Accurate Aerodynamic Data:** Ground-effect stall behavior must be rigorously analyzed and validated before incorporating into operational and test plans.
2. **Criticality of Investigating Anomalies:** Thorough analysis of unusual events during testing is essential to prevent escalation into accidents.
3. **Safety vs. Schedule Balance:** Aggressive schedules should not compromise the robustness of engineering and safety management processes.

4. **Enhanced Risk Identification:** Test hazard analyses must include comprehensive identification of risks, such as stalls, and establish clear mitigation strategies.
5. **Adopting Safety Management System (SMS) Standards:** Integration of SMS principles into flight testing can improve oversight, hazard identification, and overall safety culture.

What Changed for the Future?

1. **Implementation of SMS:** Gulfstream adopted SMS principles and practices into their flight test operations.
2. **Reevaluation of Test Procedures:** Gulfstream conducted an extensive review and update of its flight test procedures to ensure safe and realistic operational limits.
3. **Industry-Wide Recommendations:** The NTSB issued recommendations to Gulfstream, the FAA, and the Flight Test Safety Committee to improve flight test guidelines and ensure better coordination among stakeholders.
4. **Development of Best Practices:** Guidance documents incorporating best practices in aviation safety management were proposed for adoption across manufacturers and the flight test industry.

Could It Happen Again?

The likelihood of recurrence has been significantly reduced due to:

- **Revised Procedures:** Implementation of lessons learned, such as realistic aerodynamic assumptions and improved safety oversight.
- **Stronger Safety Culture:** Adoption of SMS ensures a structured approach to hazard identification and risk management.
- **Regulatory Oversight:** Enhanced FAA guidelines and audit recommendations further safeguard against similar incidents.

However, risks remain if these measures are not adhered to or updated as technology and testing methods evolve. Ongoing vigilance, coupled with a commitment to safety over scheduling, is critical to maintaining long-term prevention.

Here are the **NTSB recommendations** based on the Gulfstream G650 flight test crash investigation:

Recommendations to the FAA:

1. **Communicate Lessons to Manufacturers:**

- Inform domestic and foreign manufacturers of airplanes certified under 14 CFR Parts 23 and 25 about the circumstances of this accident.

2. Advise them to consider that an airplane's maximum lift coefficient in ground effect may be lower than its maximum lift coefficient in free air, to reduce the risk of ground effect stalls
3. **Develop Detailed Flight Test Operating Guidance:**
    - Collaborate with the Flight Test Safety Committee to issue detailed flight test operating guidance that addresses deficiencies found during this
4. **Establish Flight Test Safety Guidelines:**
    - Work with the Flight Test Safety Committee to develop and promote flight test safety program guidelines based on best practices in aviation safety management
5. **Incorporate Guidelines into FAA Orders:**
    - Integrate these flight test safety guidelines into FAA Order 4040.26, Aircraft Certification Service Flight Test Risk Management Program
6. **Improve High-Risk Test Coordination:**
    - Inform Part 139 airports with current or potential flight test activity of the importance of coordinating high-risk flight tests with test operators and ensuring adequate rescue and firefighting readiness

Recommendations to the Flight Test Safety Committee:

1. **Develop Flight Test Guidance:**
    - In collaboration with the FAA, issue flight test operating guidance to address deficiencies found in flight test policies and procedures
2. **Encourage Coordination of High-Risk Tests:**
    - Urge members to provide advance notice of high-risk flight tests and coordinate them with airport operations and firefighting personnel

Recommendations to Gulfstream:

1. **Conduct External Safety Audits:**
    - Commission independent safety audits before major certification flight test programs to evaluate the company's flight test SMS and address identified concerns

2. **Share Lessons Learned:**
    - Share insights from implementing its flight test SMS with other manufacturers, industry groups, and stakeholders to enhance flight test safety industry-wide

These recommendations aim to prevent similar accidents by improving safety management, enhancing technical practices, and fostering better coordination for high-risk flight tests.