Airbag Performance in General Aviation Restraint Systems

Safety Study

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Abstract: In 2003, airbags were first certificated for pilot and copilot seats on general aviation (GA) aircraft, and as of August 2010, they have been installed in nearly 18,000 seats in over 7,000 GA aircraft. In 2006, the National Transportation Safety Board (NTSB) initiated an exploratory case series study to consider airbag performance in GA accidents. The goals of the study were (1) to examine the effectiveness of airbags in mitigating occupant injury in GA accidents, (2) to identify any unintended consequences of airbag deployments, and (3) to develop procedures to assist investigators in documenting airbag systems in future investigations. During the 3-year data collection period, researchers tracked 145 notifications of events involving airbag-equipped airplanes which yielded 10 airbag-equipped GA airplane accidents that met the study criteria and were subjected to a full review and analysis by a multidisciplinary team. There were no unexpected deployments or unintended consequences identified during the study period. When adjusted correctly, the deployment of the airbag systems did not result in any negative outcomes, and in certain cases, deployment mitigated the severity of occupant injuries. The NTSB concluded that aviation airbags can mitigate occupant injuries in severe but survivable crashes in which the principal direction of force is longitudinal. During the course of the study, the study team also became aware of several potential issues that may compromise occupant safety associated with use, adjustment, or design of restraint systems. The report discusses steps that could be taken to address these safety issues and suggests future research directions in the area of GA occupant protection. Finally, as a result of the study, guidance for NTSB investigators was developed and disseminated, including a formal process for gathering data about airbag installations and deployments in accident aircraft.

The National Transportation Safety Board (NTSB) is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Acronyms and Abbreviations

AmSafe	AmSafe Inc.
ATD	anthropomorphic test dummy
Aviat	Aviat Aircraft Inc.
Avidyne	Avidyne Corporation
BMI	body mass index
CAB	Civil Aeronautics Board
CAMI	Civil Aerospace Medical Institute
CAPS	Cirrus Airframe Parachute System
Cessna	Cessna Aircraft Company
CFI	certified flight instructor
CFR	*Code of Federal Regulations*
CI	confidence interval
CIREN	Crash Injury Research and Engineering Network
Cirrus	Cirrus Aircraft
EAM	energy absorption module
EMA	electronics module assembly
FAA	Federal Aviation Administration
FSI	fatal or serious injury
GA	general aviation
GAMA	General Aviation Manufacturers Association
GPS	global positioning system
HIC	head injury criterion
LB	lap belt

LOC	loss of control
MFD	multifunction flight display
ms	millisecond
msl	mean sea level
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PFD	primary flight display
RPM	revolutions per minute
RR	risk ratio
SDT	System Diagnostic Tool
SH	lap belt/shoulder harness combination
T	time
TAS	traffic advisory system
TRC	transmitter receiver computer
USPA	United States Parachute Association
VIN	vehicle identification number

Executive Summary

In 2003, airbags were first certificated for pilot and copilot seats on general aviation (GA) aircraft, and as of August 2010, they have been installed in nearly 18,000 seats in over 7,000 GA aircraft. Unlike automotive airbags that typically deploy from the steering wheel, instrument panel, or above the window, airbags in GA aircraft are installed in the lap belt or shoulder harness portions of the restraint system and are designed to deploy outward from the pilot or occupant. Sled tests conducted under controlled conditions have suggested that aviation airbags may increase survivability and reduce injury in actual aviation accidents; however, no systematic evaluations have been conducted to evaluate their efficacy in real world scenarios. Therefore, in 2006, the National Transportation Safety Board (NTSB) initiated an exploratory case series study to assess airbag performance in GA accidents. The goals of the study were (1) to examine the effectiveness of airbags in mitigating occupant injury in GA accidents, (2) to identify any unintended consequences of airbag deployments, and (3) to develop procedures to assist investigators in documenting airbag systems in future investigations.

During the 3-year data collection period, researchers tracked 145 notifications of events (including 88 accidents) involving airbag-equipped airplanes and conducted field investigations of 18 of those events. Ten airbag-equipped GA airplane accidents involving 25 occupants met the study criteria and were subjected to a full review and analysis by a multidisciplinary team. The accidents represented a range of crash severities and included survivable accidents with and without airbag deployments. There were no unexpected deployments or unintended consequences identified during the study period. Overall, when adjusted correctly, the deployment of the airbag systems did not result in any negative outcomes, and in certain cases, deployment may have mitigated the severity of occupant injuries.

Of the 88 accidents involving airbag-equipped airplanes that were identified during the study period, about two-thirds (66 percent) had no airbag deployment and no occupant injuries. An additional 22 percent had reductions in survivable space or crash forces that were not survivable. Therefore, airbags would only have been expected to yield a benefit in a relatively small (12 percent) proportion of accidents. Within that window of accident severity, the NTSB concludes that aviation airbags can mitigate occupant injuries in severe but survivable crashes in which the principal direction of force is longitudinal.

During the course of the study, the study team also discovered several potential issues that may compromise occupant safety associated with the use, adjustment, or design of restraint systems. The report discusses steps that could be taken to address these safety issues and suggests future research directions in the area of GA occupant protection.

Finally, as a result of the study, guidance for NTSB investigators was developed and disseminated, including a formal process for gathering data about airbag installations and deployments in accident aircraft.

Chapter 1: Introduction

General aviation[1] (GA) continues to have the highest accident rates within civil aviation. In 2009, GA accident[2] rates per 100,000 flight hours were 4.7 times higher than those for small commuter and air taxi (14 CFR Part 135) operations and over 40 times higher than those for large transport category (14 CFR Part 121) operations.[3] Of the 1,478 GA accidents that occurred in 2009, 465 (31.5 percent) were classified as serious or fatal, resulting in 475 fatally injured and 278 seriously injured occupants.

There are two fundamental ways to reduce the number of injuries and fatalities in GA accidents. The first way is to reduce the number of accidents by making improvements to the aircraft, the flying environment, or pilot performance. The second way is to improve the likelihood that airplane occupants will survive or avoid injury when a crash does occur. As shown in figure 1, rates of both fatal[4] and nonfatal GA accidents per 100,000 flight hours have declined over the past 35 years. Between 1975 and 2009, the fatal accident rate declined by 39.3 percent and the nonfatal accident rate declined by 48.1 percent. In 2009, there were 1.3 fatal and 5.9 nonfatal accidents per 100,000 flight hours.

Although accident rates have decreased, the *proportion* of occupants killed or seriously injured in those GA accidents that occur, shown in figure 2, has changed very little since the early 1980s. In 2009, 18.6 percent of all occupants in GA accidents died, 11.0 percent were seriously injured,[5] 13.4 percent had minor injuries, and 56.9 percent were uninjured.

[1] General aviation is defined as any civil aircraft operation that is *not* covered under Title 14 *Code of Federal Regulations* (CFR) Parts 121, 129, and 135, commonly referred to as commercial air carrier operations.

[2] An accident is defined as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death, or serious injury, or in which the aircraft receives substantial damage. The definition of "aircraft accident" includes "unmanned aircraft accident." See 49 CFR 830.2.

[3] Information obtained from the NTSB website <http://www.ntsb.gov/aviation/Table1.htm> (accessed October 15, 2010).

[4] An accident is considered fatal if it involves a fatal injury, which is defined in 49 CFR 830.2 as any injury that results in death within 30 days of the accident.

[5] Serious injury is defined in 49 CFR 830.2 as any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

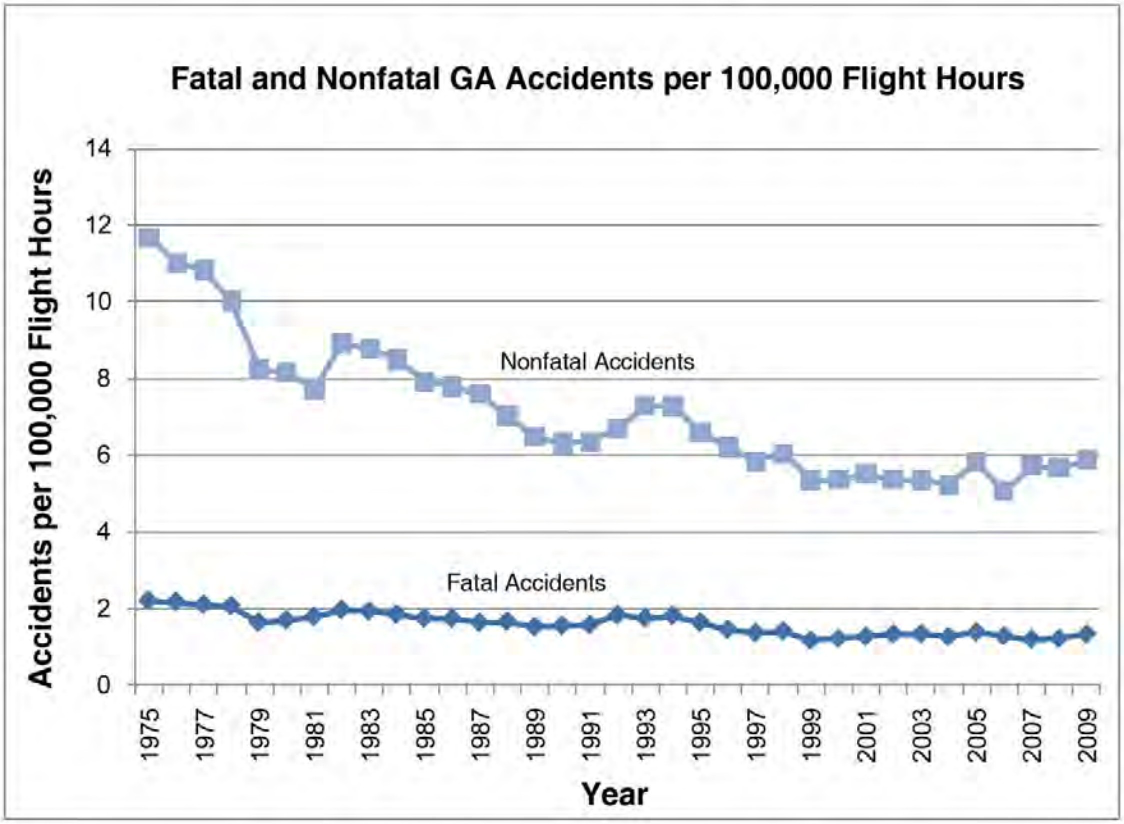

Figure 1. A chart showing fatal and nonfatal GA accidents per 100,000 flight hours for the years 1975 through 2009. (Accident data source: NTSB; flight hour data source: FAA.)

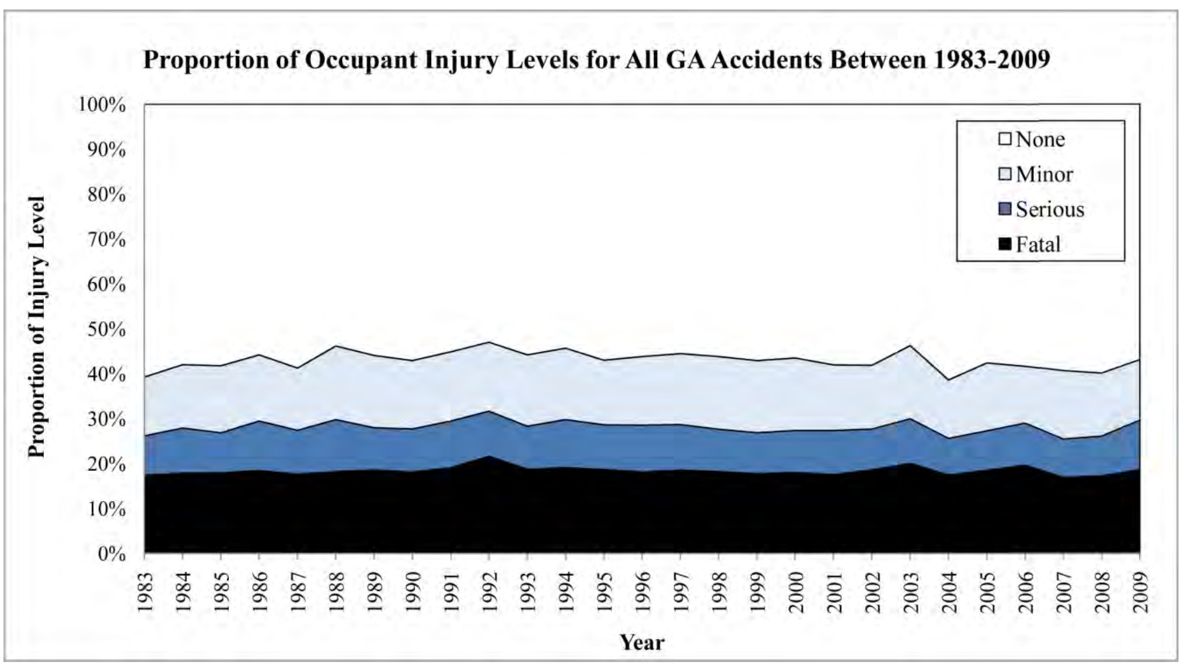

Figure 2. A chart showing the proportion of injury levels, by occupant, for all GA accidents between 1983 and 2009. (Accident data source: NTSB.)

History of GA Occupant Protection Systems

The first efforts to improve occupant survival in airplane crashes began not long after the advent of aviation. In his book chapter on the history of crash injury prevention in civil aviation, Richard Chandler, former head of the Federal Aviation Administration's (FAA) Civil Aerospace Medical Institute (CAMI) Protection and Survival Laboratory, states that as early as World War I, lap belt/shoulder harness combinations were used by military aviators.[6] However, according to Chandler, they were primarily designed to keep aviators in place during maneuvers and offered little safety benefit during a crash. By 1928, seatbelts were required in all aircraft, and in 1933, the civil aviation regulations were modified to require seatbelts to be "capable of withstanding a load of 1,000 pounds applied in the same manner as a passenger's weight would be applied in a crash."[7]

Military research conducted in the 1930s suggested that occupants could survive much greater crash forces when using a lap belt/shoulder harness combination;[8] however, shoulder harnesses were not seriously considered in aircraft design until many years later, partly because of public perceptions that seatbelts were hazardous, and partly because of early designs that were uncomfortable for occupants.[9]

In the 1940s and 1950s, the U.S. Department of Agriculture funded a project to develop an airplane for agricultural uses. The design included several crashworthiness features, including a tubular structure that would bend and fall outwardly away from occupants, space between the instrument panel and firewall to permit forward displacement of the panel, removal of sharp or rigid edges from the instrument panel, and lap and shoulder restraints and seat anchorages sufficient to resist failure up to the point of cabin collapse.[10]

In 1969, the FAA required that newly type-certificated GA aircraft must have seatbelts and shoulder harnesses for each occupant.[11] However, this requirement did not have a wide impact because it only applied to new type certificates. Manufacturers could continue producing aircraft without shoulder harnesses under existing type certificates. In 1977, the FAA published two regulatory amendments that affected GA aircraft and operations.[12] Title 14 CFR Part 23, which governs the airworthiness standards for GA aircraft, was modified to require shoulder harness installations in all newly *manufactured* GA aircraft starting in 1978, but only for front seats. Title 14 CFR Part 91, which covers general operating and flight rules, was modified to state that

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[6] R. Chandler, *Accidental Injury: Biomechanics and Prevention* (New York: Springer-Verlag, 1993), pp. 151–185.

[7] U.S. Department of Commerce, Aeronautics Branch, Aeronautics Bulletin No. 7-F, effective March 1, 1933.

[8] H.G. Armstrong, *Principles and Practice of Aviation Medicine*, (Baltimore: Williams and Wilkins, 1939).

[9] Chandler, pp. 151–185.

[10] F.E. Weick and J.R. Hansen, *From the Ground Up: The Autobiography of an Aeronautical Engineer* (Washington and London: Smithsonian Institution Press, 1988).

[11] Alternately, manufacturers could meet the regulatory requirement by installing lap belts and eliminating injurious objects within the striking radius of the head or by installing lap belts and an energy-absorbing rest to support the arms, shoulders, head, and spine.

[12] See Amendment 23-19 to 14 CFR Part 23 and Amendment 91-139 to 14 CFR Part 91. *Federal Register*, vol. 42, no. 116 (June 16, 1977), p. 30601.

"required flight crewmembers" must use available shoulder harnesses during takeoff and landing.

In the 1980s, the National Transportation Safety Board (NTSB) and the FAA engaged in several efforts to improve GA safety. The FAA requested the formation of an independent General Aviation Safety Panel to suggest regulatory and non-regulatory ways for the FAA to promote GA safety. Similarly, the NTSB initiated a GA crashworthiness program with the goal of persuading the FAA to improve regulations regarding the crashworthiness of GA aircraft.[13] In 1985, the NTSB conducted a study of 535 accidents in which at least one occupant was fatally or seriously injured.[14] The NTSB found that shoulder harnesses were available for only 40 percent of occupants in those accidents and that only 40 percent of occupants used the shoulder harnesses that were available, resulting in a total usage rate of 16 percent. The report estimated that if all occupants in the study had worn shoulder harnesses, fatalities in all crashes would have decreased by 20 percent and that 88 percent of seriously injured persons in survivable crashes would have experienced significantly fewer life-threatening injuries.

The final phase of the NTSB's crashworthiness study, published in 1985, examined survivable accidents in which occupants died or were seriously injured to identify improvements needed for GA aircraft crashworthiness.[15] The NTSB defined a survivable accident as

> one in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided throughout the crash sequence.[16]

The study found that more than half of the seats in the accidents investigated became detached. The report called existing seat design requirements inadequate and supported the use of dynamic seat tests, energy absorbing seats, rip-stop seat pans, and shoulder harnesses to reduce occupant injuries.

In 1985, the FAA modified the regulations to require shoulder harnesses in all seating positions of GA airplanes manufactured after December 12, 1986, and amended 14 CFR Part 91 to require all occupants to wear them during takeoff and landing. In 1988, the FAA issued a final rule outlining performance-based dynamic crash test standards for all aircraft carrying no more than nine passengers. Those tests standards remain today and are described in more detail in the

[13] *The Status of General Aviation Aircraft Crashworthiness,* Safety Report NTSB/SR-80/02 (Washington, DC: National Transportation Safety Board, 1980).

[14] *General Aviation Crashworthiness Project: Phase Two—Impact Severity and Potential Injury Prevention in General Aviation Accidents,* Safety Report NTSB/SR-85/01 (Washington, DC: National Transportation Safety Board, 1985).

[15] *General Aviation Crashworthiness Project: Phase 3—Acceleration Loads and Velocity Changes of Survivable General Aviation Accidents,* Safety Report NTSB/SR-85/02 (Washington, DC: National Transportation Safety Board, 1985).

[16] *General Aviation Crashworthiness Project: Phase 1,* Safety Report NTSB/SR-83/01 (Washington, DC: National Transportation Safety Board, 1983).

section later in this chapter, titled "Standards and Certification of GA Restraint and Airbag Systems."

NTSB Recommendation History

In 1964, the Civil Aeronautics Board (CAB) Bureau of Safety (predecessor of the NTSB) recommended that the Federal Aviation Agency (predecessor of the FAA) require shoulder harnesses for each occupant on newly certified GA aircraft; shoulder harnesses and crash helmets for those aircraft involved in "hazardous flight," such as aerial applications or aerial surveys; and education for all pilots stressing the desirability of using safety equipment.[17]

Since its inception as an independent agency, the NTSB has continued to push for changes to improve occupant survival in aviation and has issued more than 40 recommendations concerning occupant protection in GA aircraft.[18] The majority of those recommendations were issued to the FAA in the 1970s and 1980s and called for the installation, testing, and use of shoulder harnesses in GA aircraft. For example, in response to the FAA's 1977 rulemaking[19] to require shoulder harnesses for pilot and copilot seats beginning in 1978, the NTSB issued Safety Recommendations A-77-70 and -71, which respectively recommended that the FAA strengthen the rules to require installation of shoulder harnesses at all seat locations and require their installation on all GA aircraft, including those manufactured earlier than 1978. In 1985, the FAA modified 14 CFR 91.33 to require shoulder harnesses in all seats of GA airplanes manufactured after December 12, 1986, and amended 14 CFR Part 91 to require all occupants to wear shoulder harnesses, when available, during takeoff and landing. However, the FAA never modified its regulations to require retrofitting of aircraft manufactured before the 1978 and 1986 regulatory changes.[20]

The NTSB also made several recommendations concerning shoulder harnesses and improved survivability in GA aircraft as a result of its GA crashworthiness program in the 1980s. As a result of its 1985 safety report,[21] the NTSB issued four recommendations to the FAA calling for increased performance standards for occupant protection systems and dynamic testing of seat restraint systems, a requirement that all occupants use shoulder harnesses during takeoffs and landings, an advisory circular on GA aircraft occupant protection, and airworthiness directives to address component failures identified in the study.[22] An additional recommendation was issued to the General Aviation Manufacturers Association (GAMA) to encourage its members to identify weaknesses in seat restraint systems that could be easily corrected.[23]

[17] NTSB/SR-80/02.

[18] See appendix A for a list of NTSB safety recommendations concerning occupant protection in GA.

[19] *Federal Register*, vol. 50, no. 219 (November 13, 1985), p. 46872.

[20] Safety Recommendation A-77-70, which called for shoulder harnesses at all seat locations, was classified "Closed—Acceptable Action" on March 25, 1986. Safety Recommendation A-77-71, which called for the installation of shoulder harnesses on aircraft manufactured before 1978, was classified "Closed—Unacceptable Action" on July 1, 1986.

[21] NTSB/SR-85/02.

[22] See Safety Recommendations A-85-122 through A-85-125.

[23] See Safety Recommendation A-85-126.

Nearly all of the NTSB recommendations concerning GA occupant protection were closed in an acceptable status as a result of the aforementioned revisions to 14 CFR Parts 23 and 91 that took place in the late 1980s, with the exception of Safety Recommendation A-77-71, which called for the retrofit installation of shoulder harnesses in aircraft manufactured before 1978. Open NTSB recommendations concerning GA occupant protection include recommendations to the FAA and to the United States Parachute Association (USPA) that call for research and actions to improve restraint systems for parachutists.[24] Additionally, in August 2010, NTSB made two recommendations to the FAA calling for regulatory amendments (1) to require separate seats for every aircraft occupant and (2) to require that each person who is less than 2 years of age be restrained in a separate seat position by an appropriate child restraint system during takeoff, landing, and turbulence.[25]

Research on the Effectiveness of Aviation Airbags and Other Occupant Protection Systems

According to one study, the most common cause of death noted on autopsies for pilots in GA airplane accidents is blunt trauma, accounting for 86.0 percent of all GA pilot fatalities.[26] The next highest were thermal burns (3.9 percent), drowning (3.6 percent), inhalation of smoke and toxic gases (2.0 percent), and bleeding to death (2.0 percent). Another study analyzed injuries recorded on death certificates for aviation accident–related fatalities and determined that 42 percent of fatalities were noted to result from multiple injuries, 22 percent resulted primarily from head injuries, and 12 percent resulted primarily from internal injuries.[27] The researchers suggested that about 20 percent of aviation deaths would be preventable if occupants were protected by better restraint systems.

Early airbag-related research sponsored by the FAA Civil Aeromedical Institute[28] compared an inverted-Y yoke harness to an instrument-panel-mounted airbag using sled tests with animal (baboon) subjects.[29] With respect to the airbag condition, the authors remarked that

> all subjects moved within 10 seconds of impact and were alert and active within 20 seconds. In comparison, no other system tested to date resulted in such immediate subject recovery post impact. This may have important implications

[24] As of December 6, 2010, Safety Recommendations A-08-71 through A-08-74 are all classified as "Open—Acceptable Response."

[25] As of December 6, 2010, Safety Recommendations A-10-121 and A-10-122 are both classified as "Open—Initial Response Received."

[26] D.A. Weigmann and N. Taneja, "Analysis of Injuries Among Pilots Involved in Fatal General Aviation Airplane Accidents," *Accident Analysis and Prevention*, vol. 35, no. 4 (2003), pp. 571–577.

[27] G. Li and S. Baker, "Injury Patterns in Aviation-Related Fatalities: Implications for Preventative Strategies," *American Journal of Forensic Medicine and Pathology*, vol. 18, no. 3 (1997), pp. 265–270.

[28] Later renamed the Civil Aerospace Medical Institute.

[29] Subjects had lap belts in both conditions. See R.G. Snyder, J.W. Young, and C.C. Snow, *Experimental Impact Protection With Advanced Restraint Systems: Preliminary Primate Tests With Air Bag and Inertia Reel/Inverted-Y Yoke Torso Harness*, AM-69-4 (U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1969), p. 18.

where immediate evacuation is important, provided that the deflated bag does not become an obstacle.

An FAA review described other early conceptual research, comparing various airbag system configurations including floor-mounted, instrument panel-mounted, seat-mounted, and restraint-mounted designs, all of which included two airbags for both longitudinal and vertical impacts.[30] The review suggested that restraint-mounted airbags were superior to other configurations, especially with respect to retrofitting aircraft.

Subsequent research using an anthropomorphic test dummy (ATD) in catapult-and-track crash simulations compared levels of crash protection offered by lap belts alone compared to lap belt/shoulder harness combinations and lap belt/airbag combinations.[31] Both the lap belt/shoulder harness combination and the lap belt/airbag combination conditions were superior to lap belt alone in reducing head and chest accelerations. At the time, the potential risks associated with inadvertent airbag deployment and the challenges in developing a reliable crash sensor made the lap belt/shoulder harness combination the most practical approach. However, the report also recommended that “developments in inflatable restraint systems… be closely monitored for new technology which would further improve occupant protection. When such technology is established, further evaluation testing should be conducted.”[32] Other laboratory sled tests using ATDs compared lap belts with and without aviation airbags and found that airbag systems were associated with a reduction in head and pelvis accelerations and in head injury criterion (HIC)[33] in head-on crashes.[34]

Military research using actual pilots in helicopter simulators has shown that pilots were able to regain aircraft control after an average of 4 seconds following an inadvertent airbag deployment.[35] Similar research conducted to evaluate emergency egress from a water impact scenario employed a mock-up helicopter cockpit in a “dunker” simulator with actual helicopter pilots.[36] The study showed that deployed airbags did not significantly hinder pilots’ egress from the cockpit.

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[30] R.W. Carr and N.S. Phillips, *Inflatable Restraint Concept for General Aviation Aircraft*, FAA-RD-73-3 (Washington, DC: Beta Industries, Inc. Prepared for U.S. Department of Transportation, Federal Aviation Administration, 1973).

[31] J.A. Sommers, *Comparison of General Aviation Occupant Restraint Systems*, FAA-RD-73-114 (Washington, DC: National Aviation Facilities Experimental Center Prepared for U.S. Department of Transportation, Federal Aviation Administration, 1973).

[32] Sommers, p. 16.

[33] The HIC was proposed by the National Highway Traffic Safety Administration (NHTSA) in 1972 and is a measure of the likelihood of head injury, with higher values indicating an increased likelihood.

[34] L.W. Roemke, “The Inflatabelt Occupant Restraint System,” pp. 52–65 in *Proceedings of the Technical Cooperative Program Workshop: Inflatable Restraints in Aviation*, TTCP/HUM/00/009 (Huntsville, Alabama: Technical Cooperation Program, 2000).

[35] F. Brozoski and others, “Effect of Airbag Deployment on Helicopter Flight Control,” pp. 72–80 in *Proceedings of the Technical Cooperative Program Workshop: Inflatable Restraints in Aviation*, TTCP/HUM/00/009 (Huntsville, Alabama: Technical Cooperation Program, 2000).

[36] M.R. Schultz, A.C. Schoenbeck, and G. Wittlin, “Airbag Performance and Design Issues for Naval Aircraft Applications,” pp. 26–34 in *Proceedings of the Technical Cooperative Program Workshop: Inflatable Restraints in Aviation*, TTCP/HUM/00/009 (Huntsville, Alabama: Technical Cooperation Program, 2000).

Research Methods and NTSB Research

Research methods that are used to evaluate a safety technology vary depending on its stage of implementation. During the developmental stages of a new safety technology, a considerable amount of research is performed using simulators and laboratory testing. The benefits of this type of research are many. It allows for strict control of test variables, rapid results, and is far less likely to put human subjects at risk of injury. However, the main drawback is that such research cannot replicate the complexity of the applied environment.

During the early implementation stage of a new safety technology, the research methods shift toward observational, descriptive case studies. This approach, employed in the present study, is useful for developing an initial understanding of how users interact with the system, for identifying any unintended problems, for generating hypotheses that can be tested in future studies, and for establishing the data elements that could be used to test those hypotheses. The case study approach has been successfully applied by the NTSB in evaluating lap belts,[37] lap/shoulder belts,[38] and airbags[39] in highway passenger vehicles and shoulder harnesses and energy-absorbing seats in GA.[40]

Once a technology has been implemented on a wider scale, empirical research can be used to quantify the effectiveness of a countermeasure. The NTSB conducted such an empirical analysis on the efficacy of lap belt/shoulder harness combinations in GA during the course of this study. Using its extensive database of aviation accidents, the NTSB analyzed over 37,000 single engine airplane accidents between 1983 and 2008, and found that the risk of death or serious injury for pilots who used lap belts only was nearly 50 percent higher when compared to pilots who wore lap belt/shoulder harness combinations. Previously, these analyses had only been performed on specialty groups,[41] with findings that were limited by small sample sizes and an exclusive focus on fatalities as an outcome measure. This NTSB analysis, described in detail in Appendix B, definitively shows the benefit of shoulder harnesses in reducing injuries and fatalities in GA accidents.

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[37] *Performance of Lap Belts in 26 Frontal Crashes*, Safety Study NTSB/SS-86/03 (Washington, DC: National Transportation Safety Board, 1986).

[38] *Performance of Lap/Shoulder Belts in 167 Motor Vehicle Crashes (Volume 1)*, Safety Study NTSB/SS-88/02 (Washington, DC: National Transportation Safety Board, 1988).

[39] *The Performance and Use of Child Restraint Systems, Seatbelts, and Air Bags for Children in Passenger Vehicles Volume 1: Analysis*, Safety Study NTSB/SS-96/01 (Washington, DC: National Transportation Safety Board, 1996).

[40] NTSB/SR-85/01.

[41] D.M. Bensyl, K. Moran, and G.A. Conway, “Factors Associated With Pilot Fatality in Work-Related Aircraft Crashes: Alaska, 1990–1999,” *American Journal of Epidemiology*, vol. 154, no. 11 (2001), pp. 1037–1042; L.G. Gillis, G. Li, and S.P. Baker, “General Aviation Crashes Involving Military Personnel as Pilots,” *Aviation Space and Environmental Medicine*, vol. 72, no. 11 (2001), pp. 1001–1005.; S.P. Baker and M.W. Lamb, “Hazards of Mountain Flying: Crashes in the Colorado Rockies,” *Aviation Space and Environmental Medicine*, vol. 60, no. 6 (1989), pp. 531–536; G. Li and S.P. Baker, “Correlates of Pilot Fatality in General Aviation Crashes,” *Aviation Space and Environmental Medicine*, vol. 70, no. 4 (1999), pp. 305–309; P.S. Rostykus, P. Cummings, and B.A. Mueller, “Risk Factors for Pilot Fatalities in General Aviation Airplane Crash Landings,” *JAMA*, vol. 280, no. 11 (1998) pp. 997–999.

Automotive Airbag Systems

Airbags have been used in the automotive fleet for more than three decades, and the history of their adoption and associated research to evaluate them can inform the study of aviation airbags. Initially introduced as standard equipment as early as the mid-1970s, automotive airbags were mandated by Congress for front seats in all passenger vehicles by 1998. The efficacy of automotive airbags has been evaluated in numerous large-scale empirical research studies. Early studies showed that fatalities were about 11 percent lower in airbag-equipped vehicles for both drivers[42] and right front passengers.[43]

Beginning in 1993, the NHTSA Special Crash Investigations program[44] and the NTSB[45] conducted investigations and documented cases in which certain occupants, particularly children and infants, seated in the right front passenger seat had been killed by airbags in survivable low-speed crashes. Concern about airbag-induced fatalities led to a large-scale education campaign to educate caregivers about proper child seatbelt and safety seat use; it also prompted amendments to vehicle design regulations and the development of a new generation of "depowered" airbags to reduce the aggressivity of the bag.[46] More recent studies have demonstrated that the use of the depowered airbags has led to a significant reduction in risk of dying in frontal collisions among right front seat passengers under age 10, with no reduction in protection for other occupants.[47]

In the case of automotive airbags, there has been a continuous cycle of testing, design, iteration, and field research with the goal of improving survivability among all occupants. The cycle has continued with the development and introduction of new technologies, such as rear seat airbags that deploy between rear seated passengers[48] and inflatable rear seatbelts designed to increase the surface area of the seatbelt and disperse crash loads across the body.[49]

[42] C.J. Kahane, *Fatality Reduction by Air Bags: Analyses of Accident Data Through Early 1996*, DOT HS 808 470 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1996).

[43] E.R. Braver and others, "Reductions in Deaths in Frontal Crashes Among Right Front Passengers in Vehicles Equipped with Passenger Air Bags," *Journal of the American Medical Association*, vol. 278, no. 17 (1997), pp. 1437–1439.

[44] *Special Crash Investigations: First Generation Frontal Air Bags—A Model for Future Corrective Action*, DOT HS 811 261 (U.S. Department of Transportation, National Highway Traffic Safety Administration, 2010).

[45] See NTSB/SS-96/01.

[46] S.A. Ferguson and L.W. Schneider, "An Overview of Frontal Air Bag Performance With Changes in Frontal Crash-Test Requirements: Findings of the Blue Ribbon Panel for the Evaluation of Advanced Technology Air Bags," *Traffic Injury Prevention*, vol. 9, no. 5 (2008), pp. 421–431.

[47] E.R. Braver and others, "Deaths Among Drivers and Right-Front Passengers in Frontal Collisions: Redesigned Air Bags Relative to First-Generation Air Bags," *Traffic Injury Prevention*, vol. 9, no. 1 (2008), pp. 48–58.

[48] Information obtained from AutoWeek website <http://www.autoweek.com/article/20090311/CARNEWS/903119979> (accessed May 20, 2010).

[49] Information obtained from Wired website <http://www.wired.com/autopia/2009/11/ford-inflatable-seatbelts/> (accessed May 20, 2010).

Description of Current GA Airbag Systems

Although airbag systems are now standard in the automotive industry, their use in aviation is relatively new. In addition, unlike most automotive applications, aviation airbags are incorporated into the lap belt or shoulder harness portions of the restraint system rather than mounted in the vehicle. Airbags were introduced into commercial aircraft at bulkhead positions in 2001 as a means of complying with certification standards promulgated in 1988 relating to emergency landing dynamic conditions described in 14 CFR 25.562. In 2003, airbags were first certificated for use on GA aircraft, and in 2005, GA airplane manufacturers began offering airbags as standard equipment on pilot and copilot seats. Figure 3 depicts the number of installations grouped by manufacturer. As of August 2010, airbags have been installed in nearly 18,000 seats in over 7,000 GA aircraft. Airbags are now included as standard equipment in the pilot and copilot seats of over half of all newly manufactured single-engine GA airplanes; however, because airplanes remain in service for many years, airbag-equipped airplanes currently account for less than 5 percent of the active GA fleet.[50] Appendix C contains a list of airplane models that have been approved to have airbags installed as standard equipment.

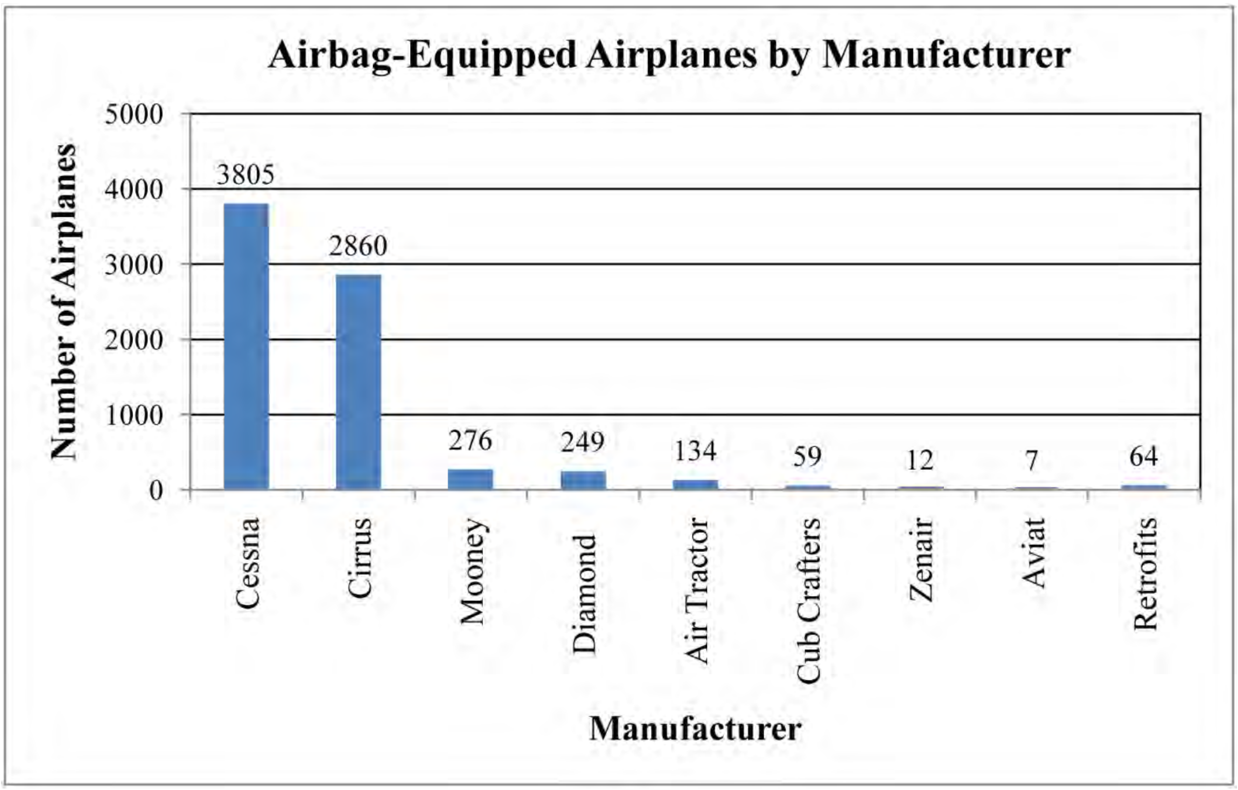

Figure 3. A chart showing the number of airplanes with airbags installed as original equipment grouped by manufacturer (as of August 2010).

[50] According to the FAA's General Aviation and Part 135 Activity Survey for calendar year 2008, there were 177,096 active GA airplanes that year.

Currently, AmSafe Inc. (AmSafe) is the only company certified to manufacture aviation airbag systems for commercial and private aircraft. The AmSafe Aviation Inflatable Restraint System, Version 23, is described by the manufacturer as a

> self-contained, modular airbag restraint system… specifically designed to improve occupant protection from serious head-impact injury during an otherwise survivable aircraft accident, thus enhancing the occupant's ability to exit the aircraft.[51]

As previously discussed, the airbag is installed in the lap belt or shoulder harness portions of the restraint system and deploys outward from the pilot or occupant. For 2- and 3-point restraint systems,[52] the airbag is embedded in the lap portion of the restraint; for 4- and 5-point restraint systems, the airbag is typically embedded in the outboard shoulder harness. Figure 4 displays examples of 3- and 4-point airbag-equipped restraint systems. The airbag restraint systems employ attachment points that are identical to restraint systems without airbags. As such, few design changes have been necessary to equip GA aircraft with airbag systems.

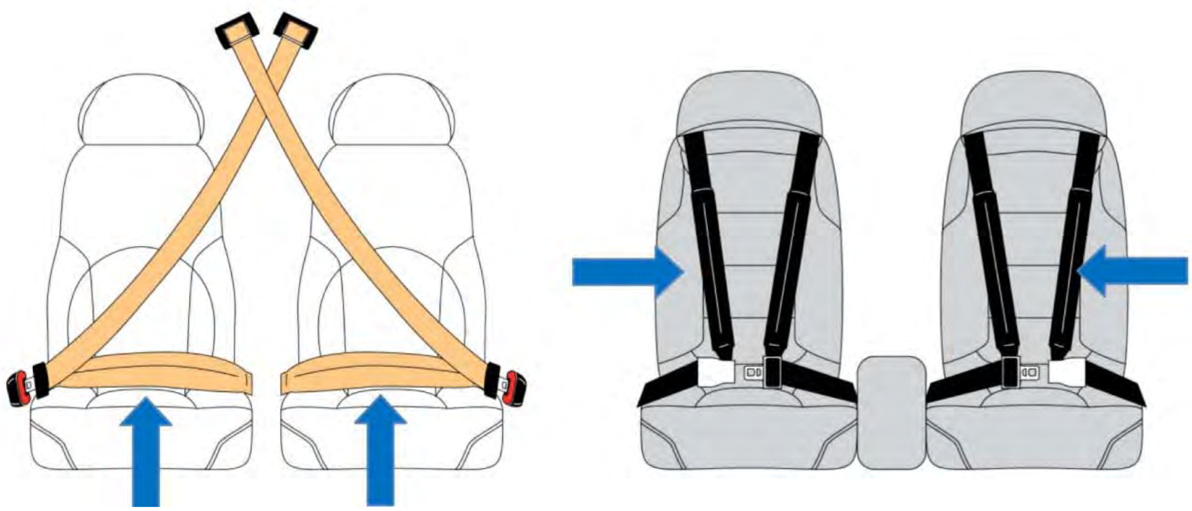

Figure 4. A pair of drawings showing airbag systems integrated into a 3-point restraint system (left) and a 4-point restraint system (right). The blue arrows indicate the location of the airbag embedded in the restraint.

Airbag Deployment

Figure 5 depicts a series of photographs showing a typical airbag deployment during a laboratory sled test with a 3-point restraint system. A device known as the electronics module assembly (EMA) contains the crash sensor that provides the signal to deploy the airbag system.

[51] Information obtained from AmSafe website <http://www.amsafe.com/news/pressreleases/detail.php?id=85> (accessed January 6, 2010).

[52] When referring to a seatbelt as a 2- or 3- point restraint system, this refers to the number of anchor points for the seatbelt. For example, a 2-point restraint system is typically a lap belt, and a 3-point restraint system is typically a lap belt with a single diagonal shoulder harness. Two-point systems are primarily used in air transport category aircraft.

Unlike automotive airbags, which use electronic sensors, the crash sensor used in GA aircraft is a mechanical, spring-mass-damper type sensor that is mounted to the structure of the aircraft beneath the floor in the vicinity of the seats. The EMA connects to a cable harness that then splits to each seat's airbag system. One EMA is capable of controlling airbags for up to three seats.

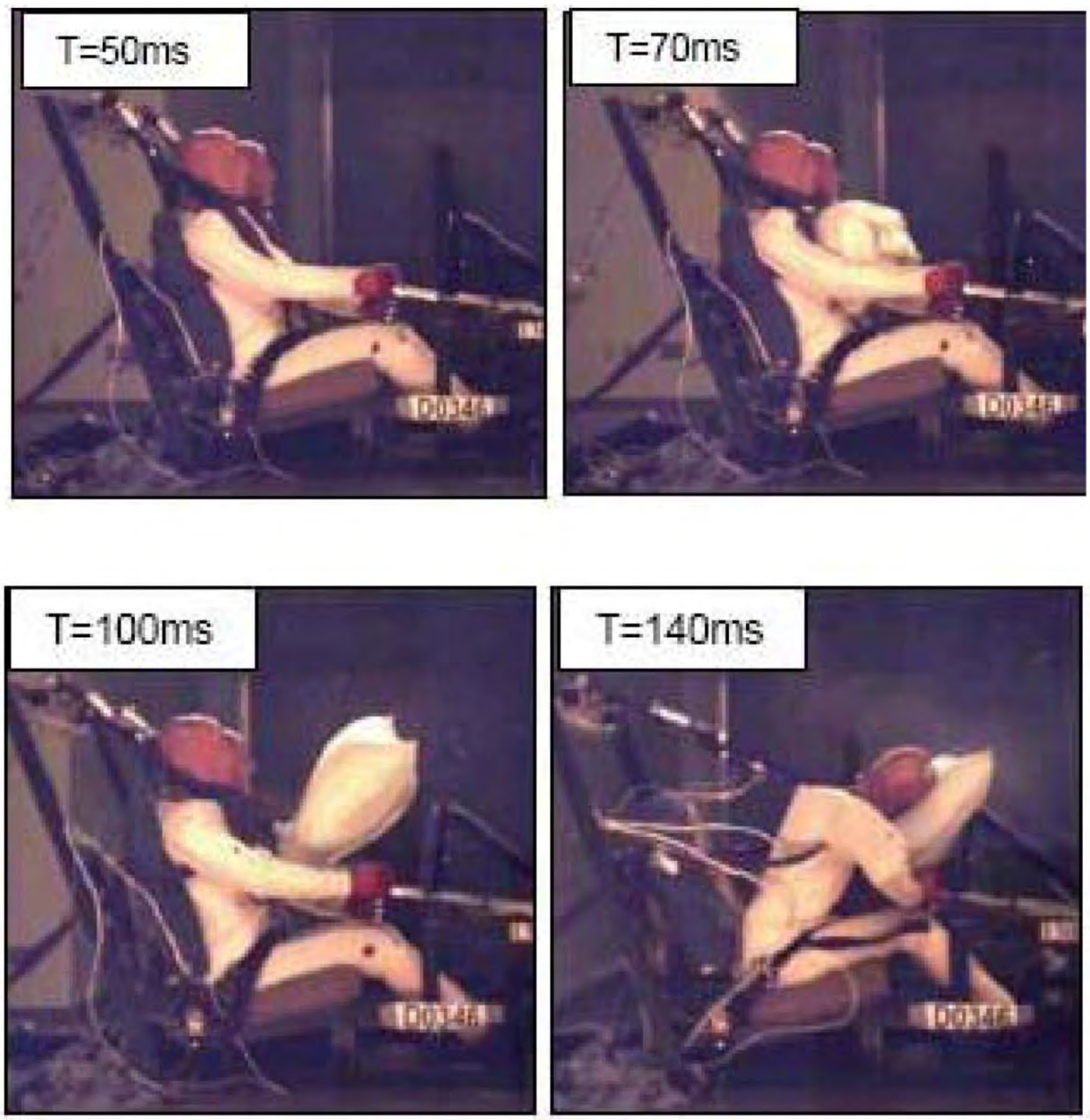

Figure 5. A series of images taken from a high-speed video showing the deployment sequence of the AmSafe airbag system in a laboratory sled test.[53] (T refers to time, and ms refers to milliseconds of elapsed time.)

[53] Photographs provided by AmSafe.

The sensor is designed to close a circuit when the aircraft decelerates rapidly in the longitudinal direction and reaches a predetermined activation threshold, thereby deploying the airbag.[54] Unlike automobile airbag control modules, which store data on vehicle speed, engine speed, and deceleration over time, the AmSafe control modules do not store data.[55]

Certain restraint systems, such as the 3-point restraint system installed in Cessna Aircraft Company (Cessna) airplanes, have an internal activation circuit that prevents the airbag from deploying if the restraint is not latched. Other systems, such as the 4-point restraint system installed in Cirrus Aircraft Corporation (Cirrus) airplanes, do not have such a circuit, and are active at all times regardless of whether the restraint is latched.[56]

When the airbag deployment threshold is met, an inflator assembly mounted near each airbag-equipped restraint attachment point releases nonheated, helium gas to fill the airbag.[57] The inflated airbag is designed to reduce head injuries by distributing impact energy and reducing the likelihood of contact with the instrument panel. It is also designed to dissipate the kinetic energy of the occupant and reduce the peak force of the restraint upon the occupant.

Figure 6 depicts two common airbag designs. A rectangular airbag is used in most 3-point restraint systems, and an L-shaped airbag is employed in most 4-point restraint systems. One or more vent holes on the instrument panel side of the airbag allow the gas to escape from the inflated bag during impact. The venting mechanism is designed to dissipate the kinetic energy, prevent rebound injuries, and allow deflation so that the airbag does not interfere with occupant egress from the airplane.

[54] The fixed wing airplane sensor is designed for predominantly longitudinal decelerations. The sensor activation threshold is a function of the impact force and the impact energy. Severe impacts deploy the airbag earlier in time and at higher deceleration forces than more gradual impacts. The lowest theoretical impact force capable of deployment is produced by about 5 G deceleration. (A G is a unit of measurement of force on a body undergoing acceleration as a multiple of its weight. The normal load factor for an airplane in straight and level flight is about 1 G.) However, in real crash impacts, airbags typically deploy above 8 G because crash impacts below this level often do not satisfy the impact energy threshold. A typical GA crash pulse will deploy the airbag later in time because the force and energy limits are reached more slowly.

[55] Some of the study airplanes were Cirrus airplanes capable of recording data on primary flight displays (PFDs) or multifunction flight displays (MFDs). Data from those displays were useful in this study, and such data have also been used in numerous other accident investigations. For more information, see the section titled, "Glass Cockpit Display Unit Data" in Chapter 2 of this report.

[56] The restraints were originally designed with the activation circuit as a means to disable the belts during transport to the airplane manufacturer (that is, to avoid unintentional deployments during shipment) and as a safeguard against deployments in unknown unbelted configurations. Later designs did not include the activation circuit partly because of design challenges in including that feature in a 4-point belt. Additionally, AmSafe argued that the likelihood of unintentional deployment was so low as to make such an additional safeguard unnecessary.

[57] By contrast, automotive airbags use a variety of inflation techniques including solid propellant, hybrids of propellant and stored gas, or stored gas.

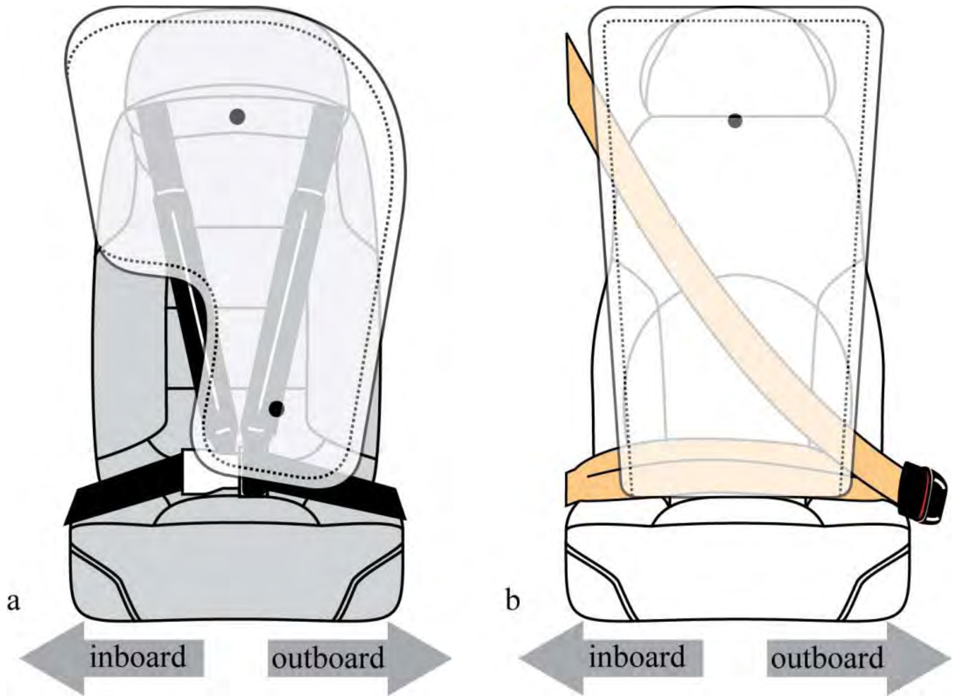

Figure 6. A pair of drawings showing basic airbag shapes for the (a) Cirrus and (b) Cessna systems described in this report.

Standards and Certification of GA Restraint and Airbag Systems

Occupant protection for GA fixed-wing aircraft is regulated under 14 CFR Parts 23 and 91. Title 14 CFR Part 23 contains requirements for aircraft design and 14 CFR Part 91 contains requirements for those who operate GA aircraft. For example, section 23.785 regulates the design of seats, berths, litters, seatbelts, and shoulder harnesses, and section 23.2 requires the installation of shoulder harnesses for all GA aircraft manufactured after December 12, 1986. Section 91.107(3) states that all occupants must wear lap belts and, if available, must wear shoulder harnesses during takeoff and landing.

Although no Federal regulations specifically govern the use of airbags in GA aircraft, section 23.561 states that "the airplane, although it may be damaged in emergency landing conditions, must be designed … to protect each occupant under those conditions." The section goes on to define the loads under which the aircraft should provide protection to the occupant. Section 23.562 outlines two dynamic tests that manufacturers must use to evaluate the crashworthiness of aircraft seats/restraint systems and to determine that the design meets the regulatory requirements. Additional guidance about conducting the tests is documented in FAA Advisory Circular (AC) 23.562-1, issued June 22, 1989, and a figure summarizing the tests is included in appendix D. Both tests must be conducted with an ATD with a nominal weight of 170 pounds and seated in the upright position oriented in the normal position with respect to the airplane.

The first test focuses on the protection provided when the predominant impact load is downward, in combination with a forward component. In this case, the velocity may not be less than 31 feet per second, and the horizontal plane of the airplane must be pitched up 60 degrees with no yaw relative to the impact vector. For crew (front) seats, peak deceleration must occur not more than 0.05 seconds after impact and must have a peak deceleration of at least 19 G.

The second test evaluates protection provided in crashes where the predominant impact is forward, in combination with a lateral component. In this case, the change in velocity may not be less than 42 feet per second. For the crew seats, the peak deceleration must occur in not more than 0.05 seconds after impact and must reach a minimum of 26 G.

Test compliance is demonstrated by meeting several requirements, including the following:

- The seat/restraint attachments must remain intact, although the seat structure may deform.
- The system must restrain the ATD, although seat and restraint system components may experience deformation or crushing intended as part of the design.
- The lap belt/shoulder harness combination must remain on the ATD's pelvis and shoulder respectively during impact, and the ATD's HIC must not exceed 1,000 if the head contacts anything during the test.
- Loads in individual shoulder harness straps may not exceed 1,750 pounds (2,000 pounds for dual straps) and the compression load measured between the pelvis and the lumbar spine of the ATD may not exceed 1,500 pounds.

Each interior certified to include airbags includes "special conditions" published by the FAA because the existing airworthiness regulations do not have appropriate safety standards for airbags as a design feature. The first special conditions for the installation of AmSafe Inflatable Restraints were published in October 2003 for the Zenair CH2000. Subsequently, special conditions were issued to install these restraints on various aircraft including those manufactured by Cessna, Mooney, and Sky International. In June 2006, the FAA published a revised set of special conditions to address a large number of GA airplanes.[58] Subsequent revisions were published in January and November 2008 to add agricultural and several additional normal and utility category airplanes that were not included in the 2006 version. The full text of the most recent version of the special conditions[59] is included in appendix C.

The 2008 special conditions outline additional safety standards necessary for establishing a level of safety equivalent to those provided by the existing airworthiness standards. The FAA stated, in the special conditions, that it had two primary safety concerns with the installation of airbags: that they perform properly as designed and that they do not deploy inadvertently and constitute a hazard, for example, by impeding a pilot's ability to control the airplane. Consequently, several conditions needed to be met before manufacturers could include airbags on their type certificate, such as demonstrating that the airbag would provide protection for each

[58] *Federal Register*, vol. 71, no. 114 (June 14, 2006), p. 34237.

[59] *Federal Register*, vol. 73, no. 217 (November 7, 2008), p. 66163.

occupant, that the design would prevent the restraint from being incorrectly installed or buckled, that inadvertent deployment would be extremely improbable, and that airbag deployment would not impede egress.

Purpose of the Current Study

Laboratory studies suggest that aviation airbags may reduce injury in actual aviation accidents. Additionally, if airbags can preserve consciousness in a crash, it would likely improve the chance that occupants could successfully egress from accidents involving fire, toxic gases, or water immersion. However, no systematic evaluations have been conducted to evaluate the efficacy of aviation airbags in real-world scenarios. Therefore, in 2006, the NTSB initiated an exploratory study to assess airbag performance in GA accidents.

There were three main goals of the study. The first was to examine the effectiveness of airbags in mitigating occupant injury in GA accidents. Although previous research using computer simulations and sled tests has suggested that airbags confer a safety benefit beyond what is provided by conventional restraint systems, no studies have been conducted using real-world accidents. In actual GA accidents, there is a much greater variability than in controlled test environments. For example, actual crashes may involve complex impact sequences with multiple impacts at a variety of speeds and angles. Another potential source of variability is in aircraft design characteristics, such as the airframe, seat structure, seat pans, and restraints.

In addition to differences in the crash sequence and the aircraft design, characteristics of the occupants—including age, sex, height, weight, and torso size—introduce variability. Also, factors such as whether and how occupants utilize restraint systems, how occupants adjust their seat position, and how they respond to crashes could also affect the performance of airbags. For example, if restraints are adjusted incorrectly, this may influence how well occupants are protected in a crash. Finally, if occupants are out of the normal seated position during a crash, for example, because of aircraft motion or bracing for impact, this may also influence their interaction with the airbag system and their resulting injuries. It was anticipated that the study could provide some early insights into factors such as these that may affect airbag performance and effectiveness.

The second goal of the study was to identify any unintended negative consequences of airbag deployments. Examples of possible unintended outcomes include the following:

- Airbags deploying during normal flight due to turbulence, maneuvering, high intensity magnetic fields, lightning, or during hard landings. Such deployments could startle the pilot and/or interfere with a pilot’s ability to use the controls.
- An airbag impeding an occupant’s ability to egress after a crash.
- Airbag deployment adversely affecting users with non-normative anthropomorphics, such as pregnant women or children.
- Airbags inadvertently deploying during installation, maintenance, or rescue operations and causing injury.

During the certification process, AmSafe provided documentation to show that such occurrences would be extremely unlikely.[60] Therefore, the NTSB did not anticipate unintentional airbag deployments; however, investigators were nonetheless vigilant for these or any other unintended consequences of their use.

The third goal of the study was to develop procedures to support investigators in documenting airbag restraint systems during the course of their normal investigations and to assist them in evaluating the effects of airbags on accident survivability in future accident investigations. This type of documentation may be useful at the individual case level in helping to better understand factors that contributed to the severity of crash injuries. Providing guidance to investigators will also likely improve the quality of data in the NTSB aviation accident database for future empirical analyses.

[60] See Appendix B.

Chapter 2: Methodology

Case Series Methodology

This study employed a prospective case series methodology. This methodology involves conducting detailed examinations of individual cases to provide insights into the circumstances surrounding those cases. The methodology is well suited for rare events and is often used in medical and social science research. The case series approach has been used on numerous occasions by the NTSB and others to evaluate safety issues, including previous studies of GA survivability. Historically, the case series approach has been described as a means to generate hypotheses that could then be tested using a more traditional quantitative analysis; however, more recently, researchers have argued for the intrinsic value of the case approach in creating expertise and in developing a deep understanding of a problem.[61]

In the present study, accidents that met the preestablished study criteria were subjected to a full review and analysis by a multidisciplinary team to better understand such issues as accident impact forces, exterior and interior airplane damage, cabin damage, occupant injuries, injury causation, and airbag performance. This approach is similar to that employed by NHTSA's Crash Injury Research and Engineering Network (CIREN). Within the CIREN program, medical clinicians, crash reconstructionists, and engineers work together to conduct in-depth studies of highway crashes with the mission "to improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs."[62]

Study Procedures

Events occurring in the United States were selected for inclusion in the study if they involved an airbag-equipped GA airplane and met any of the following criteria:

[61] B. Flyvbjerg, "Five Misunderstandings About Case-Study Research," *Qualitative Inquiry*, vol. 12, no. 2 (2006), pp. 219–245.

[62] *CIREN Program Report, 2002*, DOT HS 809 564 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 2003).

1. Survivable[63] accident in which an airbag deployed.[64]

2. Accident or incident with occupant injuries but no airbag deployment.[65]

3. Any event involving an inadvertent airbag deployment.

A flow chart depicting the study selection criteria and the procedures used for identifying study cases is presented in figure 7.

To find accidents and incidents involving airbag-equipped airplanes, NTSB staff reviewed all U.S. civil aviation accidents and incidents on a daily basis. Operators are required to report aircraft accidents and certain incidents to the NTSB,[66] and other incidents are reported to the FAA and are published regularly on a public website.[67] AmSafe provided NTSB with a list of registration numbers for all aircraft with airbag systems and updated the list at regular intervals. NTSB staff used this list to determine whether aircraft involved in accidents and incidents were equipped with airbag systems.

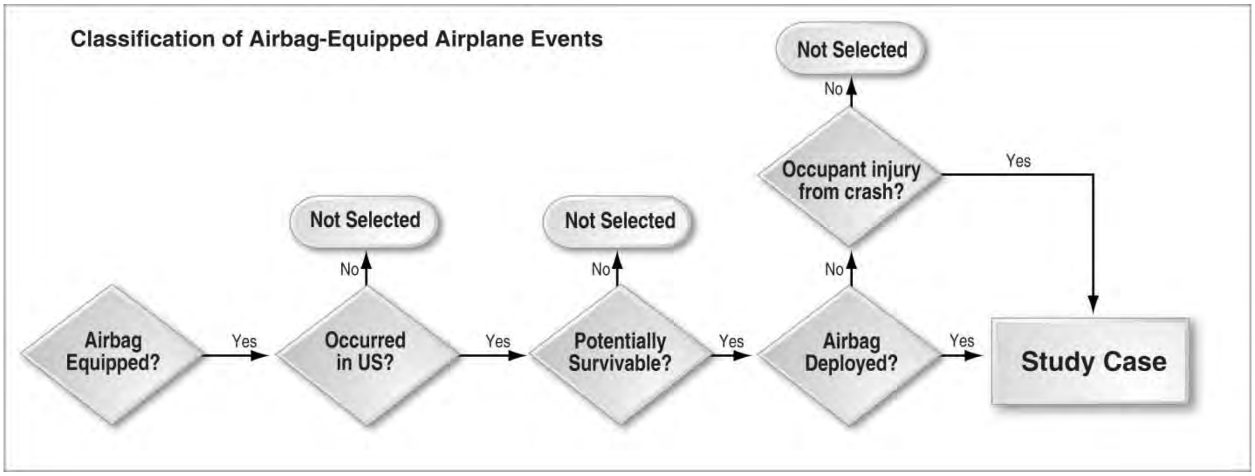

Figure 7. A chart showing the selection criteria for accidents and incidents that were included in the study.

When an airbag-equipped airplane was involved in an accident or incident, members of the study team worked with NTSB regional air safety investigators to determine whether the

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[63] A survivable crash was defined as one in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided throughout the crash sequence.

[64] Airbag deployment or nondeployment was confirmed visually by either an NTSB investigator or an FAA designee.

[65] During the initial months of the study data collection period, staff launched on several incidents with no airbag deployment and no occupant injuries. The launch criteria were later refined because of a lack of meaningful data from these incidents.

[66] See 49 CFR 830.5 for regulations governing which aviation events must be reported to the NTSB.

[67] Information obtained from FAA website <http://www.faa.gov/data_research/accident_incident/preliminary_data/> (December 1, 2010).

event met the study launch criteria. Accidents that met the criteria were subjected to a detailed investigation by an NTSB investigative team that included a study manager, a survival factors expert, and an investigator-in-charge. Party members[68] to the investigation typically included the airbag manufacturer, the airplane manufacturer, and the FAA.

A data collection form, based on NTSB forms used to generate aviation survival factors field notes, guided the team's data collection efforts. The form, shown in appendix E, contains sections for documenting the aircraft exterior, aircraft cabin, seats, restraints, and airbags, as well as occupant demographics and injuries. The form was modified over the course of the study as the team gained additional knowledge about documenting the airbag restraint systems.

Accident Scene

For certain accidents, the team was able to document the airplane within the context of the accident scene, and on other occasions, the airplane was relocated to a secure space before the team arrived. When the team members were able to collect data at the scene of the crash, they gathered evidence that would help to determine the nature of the impact, such as the airplane's final resting position and markings on impacted objects and terrain. When they could not collect this information firsthand, they obtained analogous photographic evidence and documentation from NTSB and FAA investigators who were on scene. Additionally, when available, witness accounts of the accident or photographs capturing the accident were used to complement data gathered at the scene.

Airplane Damage

Overall damage to the airplane was documented using photography, measurements, and written descriptions. Particular emphasis was placed on documenting the airplane cabin for signs that the occupant space had been compromised or that the occupants' bodies had made contact with the airplane interior. The team also documented the airplane seats, including their dimensions, positions, adjustment, and any damage or deformation. After the seats were initially measured and photographed, the team removed the seat covers to allow for a detailed examination of the seat pan and structure. For example, in the front seats of Cirrus airplanes, the team documented any deformation of the aluminum honeycomb-shaped energy absorption module (EAM), which often retained evidence of compression.

Restraint Systems and Airbags

The restraint systems for each occupant were documented, including their design, adjustment, appearance, and condition. Parts such as the inertia reels[69] and buckles were checked

[68] NTSB designates other organizations or corporations as parties to the investigation. Other than the FAA, which by a combination of law and regulation is provided participation as a party, the NTSB has complete discretion over which organizations it designates as parties to the investigation. Only those organizations or corporations that can provide expertise to the investigation are granted party status and only those persons who can provide the NTSB with needed technical or specialized expertise are permitted to serve on the investigation.

[69] Inertia reels take up the slack of the webbing for stowing the restraint and also can lock up in the event of a sudden deceleration to secure the occupant.

for functionality, and the entire system was checked for any damage including stretched or torn seatbelt webbing or deformations of attachment points or buckle materials. The seatbelts were also examined for markings, particularly the presence of "load marks" or indentations on the seatbelt webbing that suggest that the seatbelt experienced loading and stretching during the accident. Load marks were typically found beneath the load bar[70] portion of the buckle, shown in figure 8.

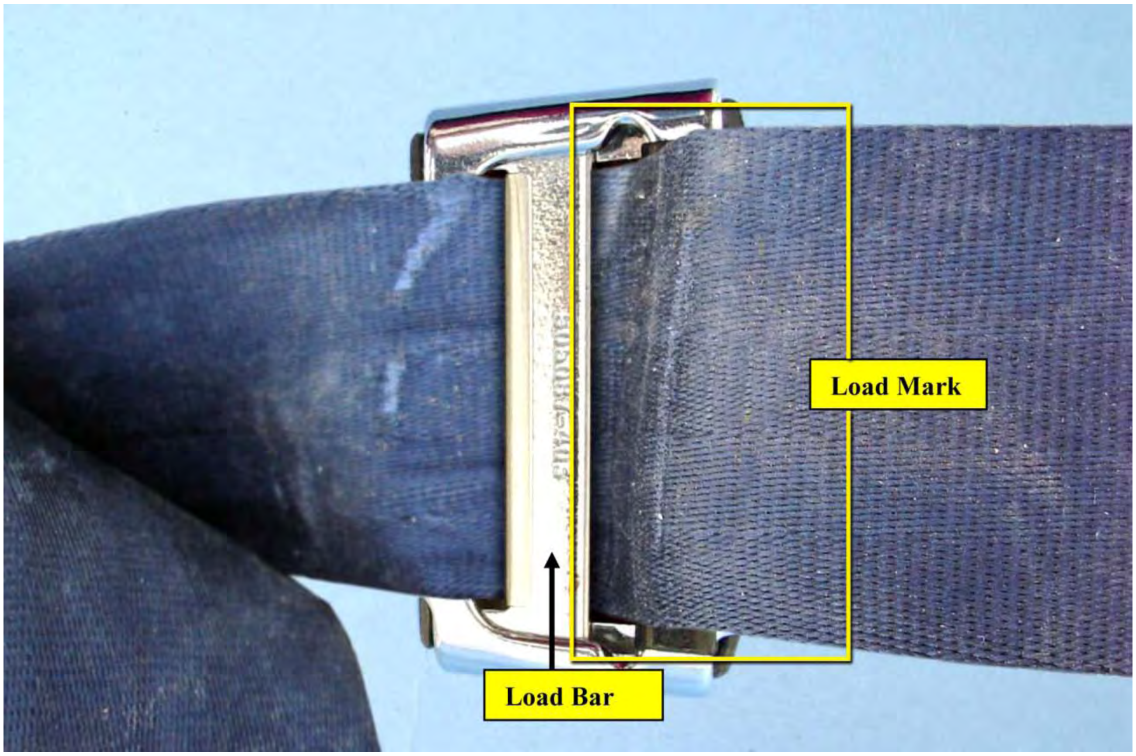

Figure 8. A photograph showing seatbelt webbing, load bar, and load mark.

Typically airbag-equipped restraint systems were only in the front row seats; however, occasionally they were found in all four seats. For airbag-equipped restraint systems, the team documented whether the airbag deployed as a result of the crash. Deployed airbags were measured and photographed and inspected for signs of damage including fraying, stretching, or tearing of the airbag seams or fabric. Any scuff marks or blood transfer on the airbags were also carefully documented so that they might provide information about the surfaces that the airbag contacted upon deployment.

Finally, the airbag vent holes were examined for damage. The airbag fabric is woven in a cross-hatch pattern, and the circular vent hole occasionally exhibited signs of "squaring" or fraying in a square-shaped pattern. (See figure 9.) Similar squaring of the vent holes had been documented during controlled laboratory tests under various loading conditions.[71] Those tests

[70] Buckles function by running webbing through a frame. The frame guides the webbing in a manner that crimps or locks it in place. The term *load bar* refers to a structure that locks down on the webbing, transferring the tension load onto the frame.

[71] *Study on the Effects of Pressure on Aviation Airbag Vent Hole Fraying*, <http://www.ntsb.gov/Events/2011/ga_airbag_study/docket/450736.pdf> (Washington, DC: National Transportation Safety Board).

suggested that although the absence of vent hole fraying in a deployed airbag should not be interpreted to mean that no load was applied to the bag, the presence of heavy fraying or squaring is likely an indicator that the bag underwent more pressure than that encountered by simply deploying the airbag without an external load. As such, investigators routinely documented the number of frayed threads and whether there was squaring of the vent holes and considered these to be potential indicators of whether the airbag had sustained load during the accident.

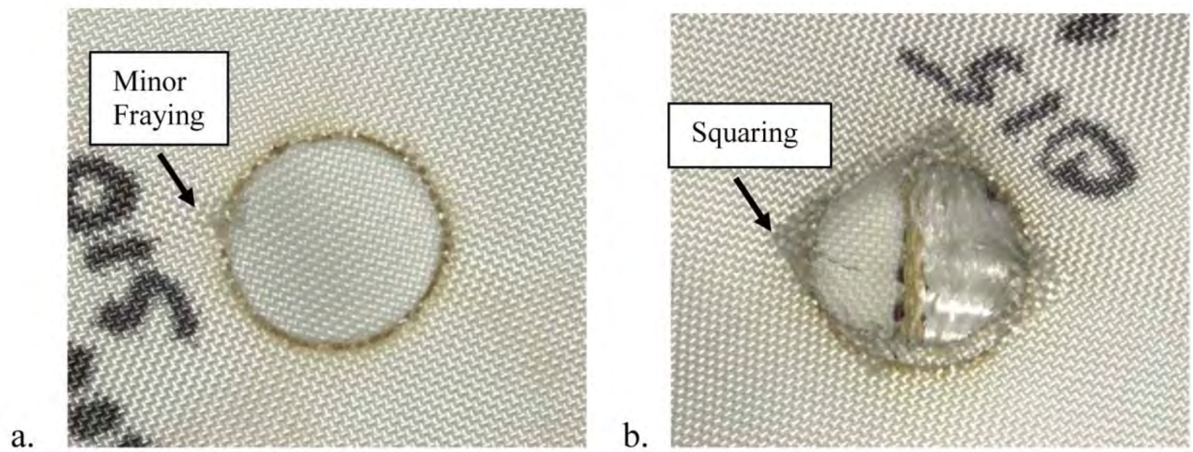

Figure 9. A pair of photographs showing vent holes from a Cirrus airbag. Photograph a. shows minor fraying, and photograph b. shows squaring. Squaring of the vent hole was used as one indicator that the airbag had sustained loads during the accident.

For airbag systems that did not deploy during a crash, the study team employed a System Diagnostic Tool (SDT), designed by AmSafe, to test whether the airbag system was functional. The SDT is a portable, hand-held device designed for use by maintenance personnel to test functionality and integrity of the airbag system. Specifically, the SDT tests the electronic module's battery, sensor, and inflator.

Additional diagnostic tests were conducted at an AmSafe testing facility and witnessed by FAA representatives. The tests were conducted to verify that the parts were manufactured in accordance with production requirements and functioned properly at the time of the accident. The tests were conducted in two parts. The first test inspected the circuitry of the assembly to determine the output voltage and open circuits required by the system to perform correctly. The second test inspected the trigger timing or "time to fire" using a thruster, a machine that applies impact acceleration to the EMA. The test evaluated whether the EMA would send a signal to the system when subjected to a 21 G/60 ms or 26 G/50 ms crash pulse, which is consistent with the dynamic seat testing requirements stated in 14 CFR 23.562(b)(2).

Glass Cockpit Display Unit Data

Glass cockpit displays, displays that use computer screens rather than analog gauges, were introduced to the GA fleet about the same time as airbag restraint systems. Data from

GAMA indicate that by 2006, more than 90 percent of new piston-powered, light airplanes had been equipped with full glass cockpit displays.[72] The typical glass cockpit consists of at least two displays: a primary flight display (PFD) and a multifunction flight display (MFD). A PFD replaces individual flight instruments to display the airspeed, altitude, attitude, and rate information that pilots use for airplane control. On an MFD, a wide range of supplementary and status information can be selected for display. Typical MFDs supplement or replace discrete navigation, communication, weather displays, and system status information, such as engine and fuel gauges. They can also display navigational charts, airport diagrams, and electronic checklists.[73]

In certain aircraft, data from the PFD and MFD are stored and can be read out to produce information about an accident flight. For accidents included in this study, the recording capability was only available on Cirrus airplanes, which use PFDs and MFDs manufactured by Avidyne Corporation (Avidyne). Whenever they were available, the study team secured the Avidyne PFD and MFD memory cards and shipped them to the NTSB Recorder Laboratory to be read out. The PFD unit includes a solid-state Air Data and Attitude Heading Reference System and displays aircraft and navigation data including altitude, airspeed, attitude, vertical speed, and heading to the pilot. Each PFD contains two flash memory devices that store information that the PFD needs to generate the various primary flight data displays. Additionally, the PFD has a data logging function, which is used by the manufacturer for maintenance and diagnostics. The PFD samples and stores several data streams in a sequential fashion; when the recording limit of the PFD is reached, the oldest record is dropped and a new record is added. Data from the attitude and heading reference system, such as pitch, roll, heading, and accelerations,[74] are recorded at a rate of 5 samples per second.[75] Air data information, such as pressure altitude, indicated airspeed, and vertical speed, is recorded once per second. Global positioning system (GPS) data, as well as navigation data and settings, are recorded every 4 seconds, and information about pilot settings of heading, altitude, and vertical speed references are recorded when changes are made.

Like the PFD, the Avidyne MFD also has a data logging function that stores periodic information such as engine parameters and flight track data. Specifically, the MFD records GPS position; engine performance data, such as RPM, manifold pressure, cylinder head and exhaust temperature, outside air temperature, and fuel flow; some electrical bus conditions; and weather service communication logs. Some MFD software versions also store pressure and density altitude. The MFD generates a new data file for each power-on cycle. Similar to the PFD, the oldest record is dropped and a new record is added when the storage limit has been reached. MFD data are sampled every 6 seconds. The sampled data are accumulated in a temporary memory buffer that is written to the memory card once every minute.

[72] *General Aviation Airplane Shipment Report, End-of-Year 2006* (Washington, DC: General Aviation Manufacturers Association, 2007) indicates that 92 percent of the 2,540 piston airplanes delivered during 2006 were equipped with glass cockpit electronic flight displays.

[73] *Introduction of Glass Cockpit Avionics into Light Aircraft*, Safety Study NTSB/SS-10/01 (Washington, DC: National Transportation Safety Board, 2010).

[74] The accelerometer is located within the PFD unit on the instrument panel.

[75] Because this is a relatively slow sampling rate, it is unlikely that peak crash accelerations would be captured on the PFD.

It is important to note that PFD and MFD systems are only available in certain airplane models, are not designed to capture crash data, and have substantial limitations. First, because their sampling rates are relatively slow, it is likely that peak accelerations will occur between sampling intervals and thus not be captured. Second, if an abrupt power interruption occurs, the data that are being accumulated in the temporary storage buffer are lost. As a result, the captured data are often truncated before the end of the impact sequence. Finally, the systems do not document values that exceed certain thresholds. For example, in the case of longitudinal, vertical, and lateral accelerations, the recording ceilings are about 4.5 G in all axes. Despite these limitations, and because these airplanes are not required to have event recorders, these data were very useful, when available, to help inform the team's understanding of the speed and orientation of the airplane prior to and at the time of impact.

Occupant Interviews and Injury Documentation

Whenever possible, interviews were conducted with surviving occupants to document their first-hand accounts of the accident flight, accident sequence, and airbag deployment, and of the occupants' egress from the airplane. The interviews also allowed the team to document occupant demographics, such as height, weight, and age, and occupant's general knowledge of and experience with the restraint system.

Self-reported injury information and medical treatment were also gathered during the interview process. Additionally, medical records and/or autopsy reports were obtained when available and were reviewed and summarized by the NTSB medical officer and survival factors staff.

NTSB Team Case Reviews

For each accident, one or more factual reports were generated to document survival factors, vehicle dynamics, and recorded data. A study team, which included the investigative team members as well as the NTSB medical officer, a biomechanics expert, and, when appropriate, a vehicle recorders expert, then met for a formal case review. During the case review, the team reviewed the factual data and came to consensus on several factors, including airplane crash forces, airplane damage, cabin damage, occupant injuries, injury causation, and airbag effectiveness. The purpose of this multidisciplinary group activity was to determine whether the airbags mitigated injury, had no affect on injury, or contributed to injury. The discussions focused on airplane motion at impact, airplane crush, occupant motion, occupant injuries, and potential injury causing mechanisms.

To facilitate communication about the directions of crash forces applied to airplane occupants, the team employed a human body coordinate system and accelerative terminology similar to that used in the U.S. Army Aircraft Crash Survival Design Guide.[76] The terms used to describe directions of force on the human body, illustrated in figure 10, are as follows:

[76] J.W. Coltman and others, *Aircraft Crash Survival Design Guide, Volume I–Aircraft Design Crash Impact Conditions and Human Tolerance,* USAAVSCOM TR 89-D-228 (Simula, Inc. Prepared for Aviation Applied Technology Directorate, U.S. Army Aviation Research and Technology Activity [AVSCOM], 1989).

- Longitudinal: forward or rearward.
- Vertical: upward or downward.
- Lateral: right or left.

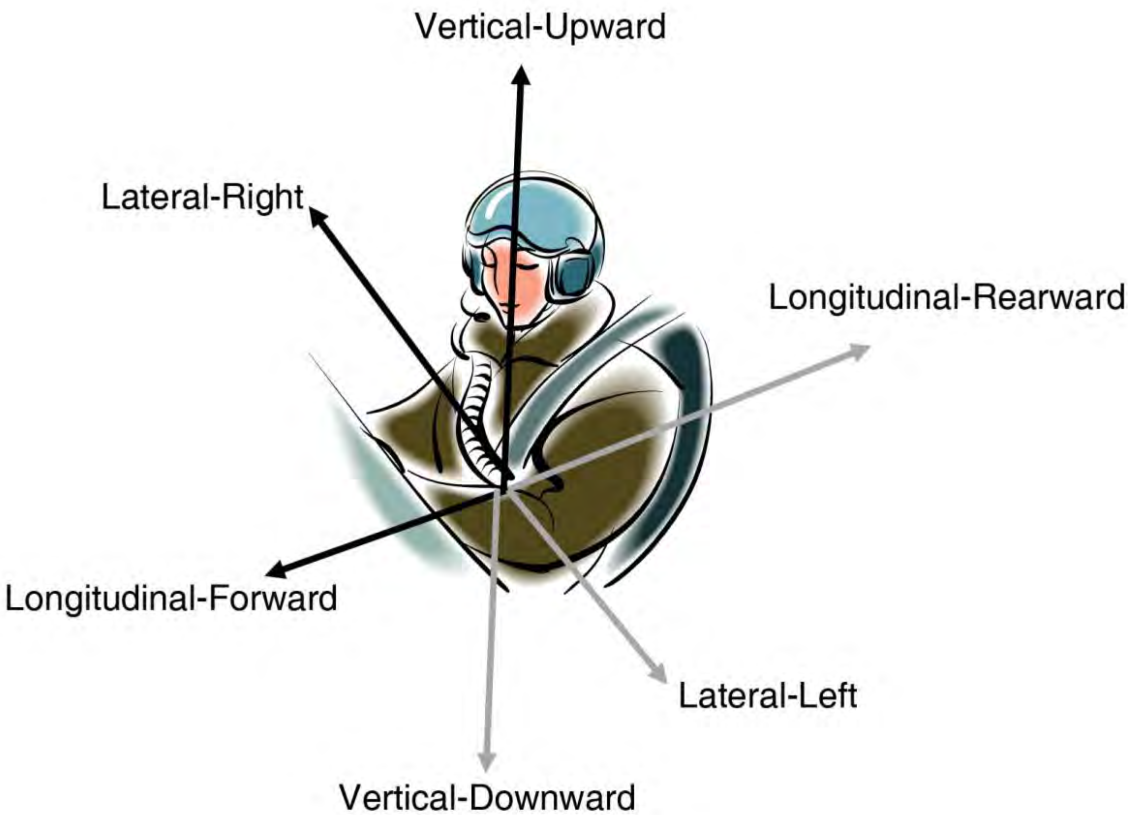

Figure 10. A drawing showing various directions of crash forces as applied to aircraft occupants.

Study Limitations

The investigative team was not always able to document the airplane in its final resting position. Although the team typically arrived within 1 to 3 days of the accident, in many cases, airplanes had been relocated or repositioned before the team's arrival. Moving the airplane, in some cases, may have altered the shape of the cabin or seats. In each case, the team was able to obtain photographic documentation of the airplane in its final resting position, but these photographs did not always provide the detail that would be necessary to fully understand the effects of the crash on the interior cabin space. Similarly, the assessment of whether an occupant's injuries would have been more or less severe without the airbag system depended upon the review of sometimes limited medical and physical evidence by the multidisciplinary team.

Although the range of occupant body types was quite diverse given the small number of accidents in the study, there were no children under age 13 (in airbag-equipped seats or in child safety seats). Also, to the best of the team's knowledge, there were no pregnant occupants or occupants with physical disabilities. Therefore, no conclusions can be made about airbag performance for these groups. Additionally, certain airbag types, such as the 5-point restraint system installed in certain agricultural aircraft, were not included because there were no crashes involving these aircraft that met the study inclusion criteria during the 3-year study period. These limitations were anticipated and are inherent in case study approaches in general. It is important to note that although the number of cases reviewed for this study was relatively small, they composed the entire population of airbag-equipped airplane accidents that occurred during the 3-year study period. Continued surveillance will be necessary to determine whether the proportion of cases in which occupants benefitted from airbags in this study will remain consistent within a larger sample of cases.

Chapter 3: Results

Summary of Airbag-Equipped Events During the Study Period

Data collection began in August 2006 and ended in July 2009. There were 145 notifications of accidents or incidents[77] involving airbag-equipped airplanes during the 3-year study period, with 41 notifications in the first year, 40 in the second year, and 64 in the third year. As shown in figure 11, the majority of events involved Cessna and Cirrus airplanes, the two manufacturers that had the highest numbers of airbag installations at the time of the study. Of the 138 events that occurred in the United States, there were 50 incidents and 88 accidents. The accident group represented all accidents involving airbag-equipped airplanes that occurred during the study time period. Within that group, 21 accidents (23.9 percent) were classified as fatal, meaning at least one occupant was fatally injured. The proportion of injury levels by occupants in the accidents was also calculated. (See figure 12.) There were 161 occupants involved in the 88 accidents; about one-third of these occupants were fatally or seriously injured.

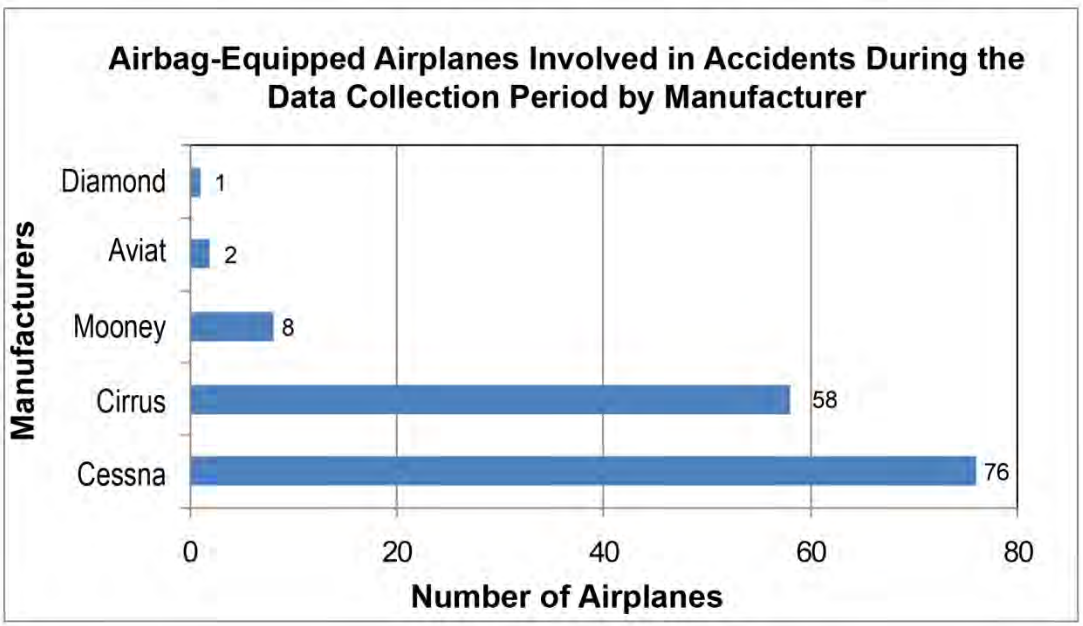

Figure 11. A chart showing the manufacturers of all airbag-equipped airplanes involved in accidents or incidents during the data collection period.

[77] Incidents are defined in 49 CFR 830.2 as an occurrence other than an accident associated with the operation of an aircraft that affects or could affect the safety of operations.

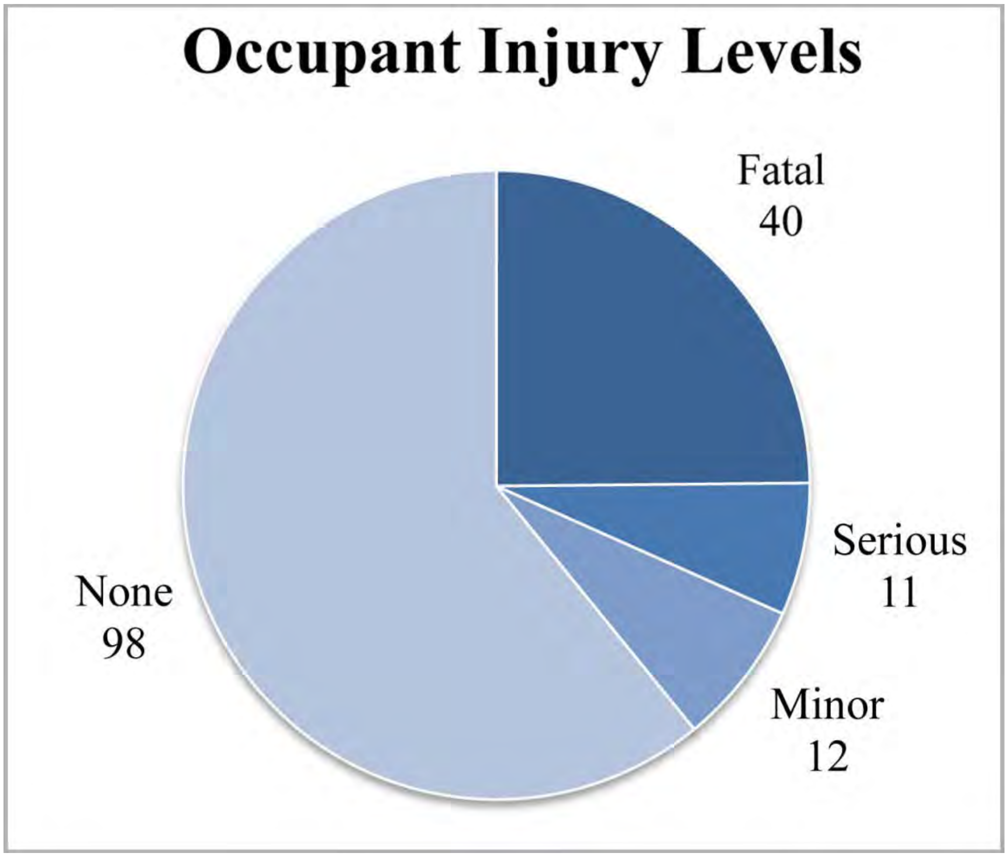

Figure 12. A chart showing injury levels among the 161 occupants involved in 88 accidents in airbag-equipped airplanes.

The proportion of fatal accidents and the proportion of fatally and seriously injured occupants in the study sample are somewhat higher than those cited earlier from the overall GA population; however, the overall GA population represents a much wider range of aircraft types and operations.[78]

Figure 13 depicts the classification of the 145 airbag-equipped event notifications by whether they occurred in the United States, whether the event was survivable, by airbag deployment, and by occupant injury. Of the 138 events that occurred in the United States, 19 were excluded from the study sample because they were determined to be non-survivable, and 3 were excluded because of missing evidence.[79] Among the 117 survivable events, there were 7 accidents with airbag deployments, and there were 3 accidents with no airbag deployments but in which occupants sustained injuries due to the crash. These 10 accidents met the study criteria and were subjected to a full review and analysis.

[78] The proportion of fatal accidents and the proportion of fatally and seriously injured occupants in this study were similar to a more representative sample of accidents involving newly manufactured single-engine piston aircraft described in a recent NTSB safety study report concerning light aircraft with and without glass cockpit avionics. (See NTSB/SS-10/01).

[79] In two cases, the airplane wreckage was missing or had been destroyed by postcrash fire, and it could not be evaluated to determine survivability of the accident. In one additional case, wreckage documentation was incomplete because the accident was reported late to the NTSB.

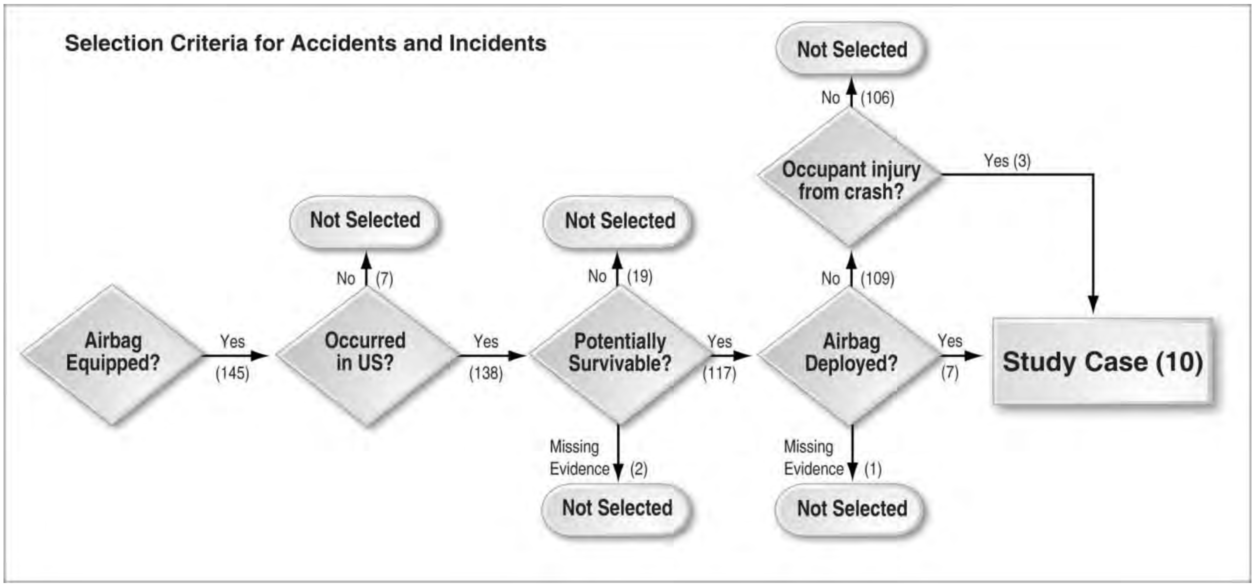

Figure 13. A chart summarizing the classification of all airbag-equipped airplane events tracked during the study period.

The study accidents are summarized in table 1 and described in further detail in the following sections. Detailed injury information is provided in appendix F. The selected accidents included five airplanes manufactured by Cessna, four airplanes manufactured by Cirrus, and one airplane manufactured by Aviat Aircraft Inc. (Aviat). The following sections provide an overview of the airplane models that were included in the study with an emphasis on occupant-related design features.

Table 1. A summary of the accidents that met the study selection criteria.

Date	City, State	NTSB Number	Make/Model	Total Seats	Restraint Type	Airbag-Equipped Seats
05-Aug-06	Boyceville, WI	CHI06FA218	Cirrus SR22	4	4-point	Front
27-Aug-06	Owyhee, OR	SEA06FA168	Aviat A-1B	2	5-point	Front and Rear
28-Aug-06	Indianapolis, IN	CHI06FA245	Cirrus SR22	4	4-point	Front
27-Feb-07	Athens, TX	DFW07LA078	Cessna T182T	4	3-point	Front and Rear
30-Sep-08	Fullerton, CA	LAX08FA301	Cessna 172S	4	3-point	Front
19-Nov-08	Groton, CT	ERA09LA064	Cessna 172S	4	3-point	Front
19-Nov-08	Green Cove Springs, FL	ERA09LA062	Cirrus SR20	3	4-point	Front
15-Feb-09	Steamboat Springs, CO	CEN09LA165	Cirrus SR22	4	4-point	Front
09-Apr-09	Stigler, OK	CEN09LA247	Cessna 182T	4	3-point	Front and Rear
14-July-09	Boyd, TX	CEN09LA442	Cessna 172S	4	3-point	Front

Cessna Skyhawk and Skylane

The Cessna airplane models included in the study were the Skyhawk 172S and the Skylane 182S, 182T, and T182T. All of these models are single-engine, high-wing, four-seat airplanes constructed primarily of metal, such as aluminum alloy. The original type certificates for the Skyhawk and Skylane models were issued by the FAA in 1955 and 1956 respectively. The supplemental type certificates for the models included in the study were issued in 1996 (182S), 1998 (172S), and 2001 (182T and T182T). The airplane models are required to meet some, but not all, of the requirements in 14 CFR 23.562.[80]

The Skyhawk and Skylane control yokes are located directly in front of occupants seated in the two front seats. All four airplane seats are designed with a foam cushion in between the surface of the seat and the underlying structure of the seat itself. Both the Skyhawk and Skylane airplanes have 3-point restraint systems. On the front seats, the buckles are on the outboard side of the seats. On the rear seats, the buckles are on the inboard side. Airbag systems are included in the front seats of all Skyhawk and Skylane models manufactured beginning in 2005 and are optional for the two rear seats. The airbags are mounted in the lap portion of the restraint and deploy outward and up. The airbag systems are active only when the buckle is fastened. The airbag is rectangular in shape and has one vent hole located on the instrument panel side of the bag. A photograph showing an exemplar instrument panel appears in figure 14. Figure 15 shows a photograph of an exemplar 3-point restraint system.

[80] Specifically, the certification basis requires that the airplanes meet 14 CFR 23.562(a), 23.562(b)2, 23.562(c)1, 23.562(c)2, 23.562(c)3, and 23.562(c)4, but it does not require that the airplanes meet sections 23.562(c)5, 23.562(c)6, or 23.562(c)7.

Figure 14. A photograph of the Cessna 172 Skyhawk instrument panel.[81] The Skylane panel has a similar glass cockpit panel with dual control yokes.

Figure 15. A photograph of an exemplar Cessna airplane seat with a lap belt-mounted airbag system.[82]

[81] Photograph obtained from Garmin website <http://www8.garmin.com/HiRes/cessnaSkyhawkPanel.jpg> (accessed April 1, 2010).

Cirrus SR20 and SR22

The Cirrus airplane models included in the study were the SR20 and SR22. Both airplanes are single-engine, low-wing airplanes constructed primarily of composite materials. The original type certificates for the SR20 and SR22 models were issued by the FAA in 1998 and 2000, respectively, and they were required to meet the dynamic seat-testing requirements described in 14 CFR 23.562. The SR20 and SR22 models differ from other airplanes in this study in that they are equipped with an airplane parachute system known as the Cirrus Airframe Parachute System (CAPS),[83] which is designed to protect occupants in the event of an emergency by lowering the airplane to the ground after deployment.

In contrast to control yokes on the Cessna, the SR20 and SR22 control yokes are smaller and are located on the outboard sides of the instrument panel. The seat pans in the front seats are designed with a foam layer, an aluminum seat pan, an aluminum EAM, and a carbon fiber seat pan that is attached to the seat frame structure. The rear seats have three layers of foam separated by thin sheets of aluminum. The SR20 and SR22 have a 4-point restraint system for each seat. (There are four seats in these models.) Airbag systems are included in the front seats of all SR20 and SR22 models manufactured beginning in 2005. The airbag system is active at all times, regardless of whether the restraint is buckled. The airbag is mounted in the outboard shoulder harness and has an inverted L-shape with a vent hole on each lobe of the bag on the instrument panel side. A photograph showing an exemplar instrument panel is shown in figure 16. Figure 17 shows an exemplar seat/restraint configuration.

Figure 16. A photograph of the Cirrus SR22 instrument panel. (Photograph obtained from BJA website <http://www.bja.com.au/blog/wp-content/uploads/2009/02/cirrus_sr20_panel1.jpg> [accessed April 5, 2010]).

[82] Photograph provided by AmSafe.

[83] The CAPS system is manufactured by BRS Aviation.

Figure 17. A photograph of exemplar Cirrus airplane seats with airbags mounted in the outboard shoulder harnesses.

Aviat Husky A-1B

The Aviat Husky is a two-seat (front and rear), single-engine, high-wing airplane with a floor-mounted control stick located in front of each occupant and a tail wheel landing gear configuration. The original type certificate for the Aviat Husky was issued in 1987, and the supplemental type certificate for the Husky A-1B was issued in 1998. This airplane was required to meet the dynamic seat testing requirements described in 14 CFR 23.562. The Husky A-1B has a 5-point restraint system (with either a lift latch or rotary buckle). Airbags are optional, as are glass cockpit avionics. The airbag, which is active at all times regardless of whether the restraint is buckled, is mounted in the right shoulder harness. A photograph showing an exemplar instrument panel appears in figure 18. Figure 19 shows an exemplar seat/restraint configuration.

Figure 18. A photograph of the exemplar Aviat Husky A-1B instrument panel. (Radio Package 2 panel shown.)[84]

Figure 19. A photograph of exemplar Aviat Husky airplane seats with airbags mounted in the right shoulder harness.[85]

[84] Photograph obtained from Aviat Aircraft website <http://www.aviataircraft.com/husky_aircraft_radio_options.html> (accessed April 8, 2010).

[85] Photograph provided by AmSafe.

Chapter 4: Accident Analyses

The following section provides a more detailed description and analysis of each of the 10 accidents that were included in the study. In each case, details about the accident, airplane damage, restraint system, airbags, and occupant injuries are included; the crash dynamics and forces are analyzed; and conclusions are made with respect to the effectiveness of the airbag system. A full factual report of each accident can be found on the NTSB website at <http://www.ntsb.gov/ntsb/query.asp>.[86]

Boyceville, Wisconsin, August 5, 2006, Cirrus SR22

On August 5, 2006, at 1140 central daylight time, a Cirrus SR22, N658CD, received substantial damage on impact with terrain to the right of the approach end of runway 26 at Boyceville Municipal Airport in Boyceville, Wisconsin. The private pilot receiving instruction, seated in the left front seat, sustained serious injuries. The certified flight instructor (CFI), seated in the right front seat, and passenger, seated in the right rear seat, sustained minor injuries. Figure 20 shows a seating chart that summarizes occupant injury and demographic information.

The pilot was on the final day of a 4-day training curriculum for new Cirrus SR22 owners. During a simulated total loss of engine power, the pilot flew to an airport and entered the left downwind traffic pattern for a landing on runway 26. During the base to final turn, the pilot banked “steeply,” and when the airplane exceeded a 30-degree left bank, the CFI verbally warned the pilot. The pilot “banked [the airplane] steeper,” the stall horn sounded, and the left wing “dropped.” The CFI then “grabbed the controls to prevent [the airplane] from entering a spin” and applied full power. The CFI reported that the airplane was “losing altitude in the stall with the left and right wing alternately dropping.”

The NTSB determined that the accident was caused by the pilot’s failure to maintain adequate airspeed and the certified flight instructor’s delayed remedial action and inadequate supervision of the flight training, which resulted in an inadvertent stall during a base to final turn to the landing runway. An additional cause was the pilot’s lack of total experience in the Cirrus SR22. A factor in the accident was the low altitude at which the stall occurred.

[86] This is the NTSB Aviation Accident Database and Synopses webpage. Users can type in basic information about an accident, such as the date, the location, and the accident number, to obtain factual and probable cause reports.

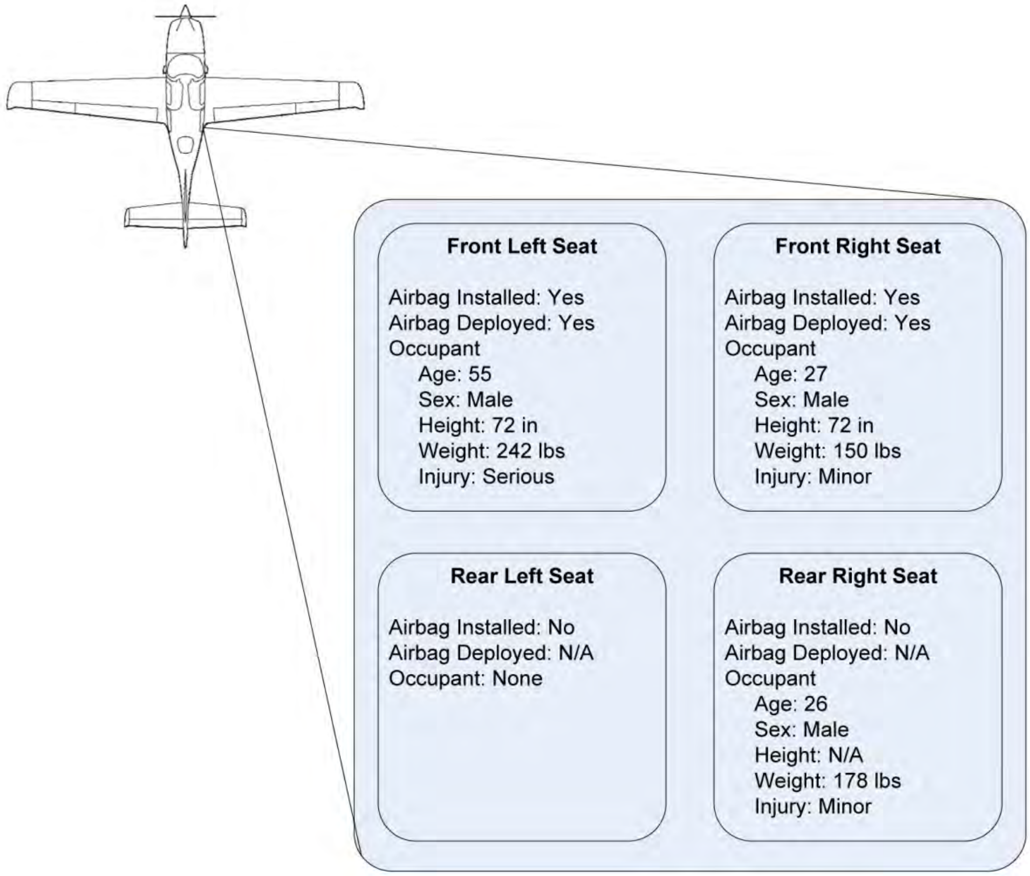

Figure 20. A seating chart from Cirrus SR22, N6568CD, which crashed in Boyceville, Wisconsin. (NTSB accident identification number is CHI06FA218.)

The airplane was located about 350 feet to the right of the approach end of the runway in a soybean field. The main wreckage, shown in figure 21, which consisted of the fuselage, wings, empennage, and engine, was at the western edge of a 150-foot-long ground scar located on a 270-degree azimuth from the point of impact. There were three depressions along the length of the ground scar. The eastern end of the ground scar was near an area of debris from the left wing tip and pieces of the upper wing skin, followed by a second depression about 50 feet from the first ground scar along the 270-degree heading. The second depression was about 10 feet by 15 feet and contained pieces of engine cowling. Adjacent to the second depression were tree branches cut approximately 60 degrees relative to horizontal. The westernmost depression contained the main wreckage oriented on a tail to nose heading of about 150 degrees with the attached engine, fuselage, wings, and empennage.

Figure 21. A photograph showing the final resting position of Cirrus SR22, N658CD, which crashed in Boyceville, Wisconsin. The photograph was taken facing the nose of the airplane. The two front row seats are denoted with yellow arrows.

Data from the last sample captured by the PFD indicated a forward deceleration of the airplane structure of +1.36 G and a downward deceleration of –2.17 G.[87] For the lateral (side-to-side) forces, the final three samples, captured at a rate of 5 hertz, were at 0, –1.2 G (left) and +1.48 G (right), which would suggest an oscillation about the lateral axis. The final samples also represented the maximum accelerations recorded in all three axes.[88]

Evaluation of the impact marks left on the plants and ground, damage to the airplane, and data from the PFD suggested the initial impact was made when the left wing cut into the soybean field but did not hit the ground, followed by the left wingtip impacting the ground and soybeans. The plane then rotated from left wing low and impacted nose down, with impact damage to the right side of the nose and propeller, leaving the third mark. Finally, the airplane slid to a rest

[87] All reported vertical accelerations include gravity. As such, a vertical acceleration of –2.17 G would be –1.17 G beyond gravity. Additionally, these accelerations represent motion recorded on the airframe and may not represent the accelerations experienced by the occupants.

[88] The peak accelerations on the airplane were likely greater than what was recorded because of the relatively low sampling rate of the system. Also, the system likely stopped recording prior to final rest, which resulted in an additional loss of data.

position with wings parallel to ground and the upper portion of the fuselage rotated onto its right side.

The front seats stayed attached to the wing spar, but the top part of the cabin was torn open with the tear continuing around the left seat side window/door area. The initial separation likely occurred when the airplane's nose hit the ground, and the tearing continued as the airplane slid to its final resting position. The rear seats were found near the wreckage but disconnected from the fuselage; they were still attached to the airplane floor.

Examination of the EAMs of both front seats showed mild to moderate compression across the leading edge. The right rear seat that was occupied by the passenger showed some signs of damage. Specifically, the outboard fitting that attaches the seat base to the airplane floor had been torn from the aluminum seat pan, and the energy-absorbing foam on that seat showed evidence of crushing. According to the flight instructor who occupied the right front seat, he unfastened his harness and was able to walk away from the wreckage. He also reported that the passenger in the right rear seat was able to remove his restraint and egress from under some debris, but that the pilot in the left front seat was unable to egress because of the extent of his injuries.

The airplane had a 4-point restraint system in each seat that was manufactured by AmSafe. There was evidence that the two front seat restraints and the right rear seat restraint were in use and were loaded during the crash, based on load marks on the seatbelt webbing. The load marks were more pronounced on the right side webbing compared to the left side, indicating that the right side was loaded more severely. The airplane had airbags installed in the outboard shoulder harnesses of the 4-point restraint systems for both front seats. An airbag was not available for the right rear occupant. Both airbags deployed in the accident. The left front seat airbag was undamaged except for very slight fraying of the upper vent hole. On the right front seat, the top circular vent showed minor fraying, and the bottom vent showed more significant fraying and squaring. Fraying of the fibers around the circular vent holes was likely associated with increased pressurization on the airbag due to occupant contact with the airbag. All other components of the airbag inflation system were examined and found to be in normal condition.

The left front occupant, a 55-year-old male pilot, was 6 feet tall and weighed 242 pounds. His left ankle was seriously injured, likely caused either by contact with the left rudder pedal at impact or by a combination of rudder pedal intrusion, force against the rudder pedal, and the deceleration along the axis of his leg. He also suffered a left wrist fracture and a contusion on his left forearm, likely as the result of holding the side yoke at the time of impact. The occupant also suffered multiple bilateral rib fractures with scattered contusions on his right chest that may have resulted from ribcage compression, caused by an impact between his right chest and the throttle and/or radio stack area. Finally, the occupant had small abrasions and contusions on his face and scattered contusions on his right shoulder, right shin, and right knee, with undetermined contacts.

The right front occupant and CFI, a 27-year-old male, was 6 feet tall and weighed 150 pounds. According to medical records, he suffered superficial lacerations and abrasions on his left forehead, left upper arm, and left hip.[89] The right rear occupant, a 26-year-old male passenger, who weighed 178 pounds, also experienced minor abrasions on his left shin and right hip. The exact causes of the right front and right rear occupants' injuries could not be established.

Primary occupant motion in this crash was likely forward and to the right. In the case of the right front occupant, this motion likely pushed him toward the side yoke and the right door interior. The airbag deployed from the right shoulder harness. The right front occupant's chest and head likely made contact with the airbag, based on the fraying around the airbag vent holes, indicating loading of the airbag, and the lack of significant right-sided injuries to this occupant. In the absence of an airbag, the occupant would likely have sustained injuries to his right side from contact with the instrument panel or right door interior. Therefore, the evidence suggests that the front right airbag provided occupant protection beyond that of the restraint system alone.

In the case of the left front occupant, there did not appear to be a similar benefit from the airbag. The left front airbag displayed almost no signs of loading, and the occupant's torso injuries were largely attributable to impacting the throttle and/or the radio stack area on the occupant's right side. One possible explanation for this outcome is that the airbags are mainly designed for frontal loads. In this accident scenario, with occupant motion forward and to the right, the airbag, which deployed from the left shoulder harness, likely did not prevent the occupant's motion to the right, and injuries were sustained as a result of direct contact.

In sum, the right front occupant's injuries were mitigated by the presence of the airbag system. However, the left front occupant's airbag did not prevent his serious chest injuries.

Owyhee, Oregon, August 27, 2006, Aviat Husky A-1B

On August 27, 2006, about 1326 Pacific daylight time, an Aviat Husky A-1B, N94HY, sustained substantial damage during landing at the Owyhee State Reservoir Airport, Owyhee, Oregon. The private pilot/registered owner of the airplane was the sole occupant; he sustained minor injuries during the accident sequence. The flight had originated in Ontario, Oregon, about 30 minutes prior to the accident. Figure 22 shows a seating chart that summarizes occupant injury and demographic information.

The NTSB determined that the accident was caused by the pilot's inadvertent landing with the parking brake engaged, which resulted in a nose over. In a written report submitted to the NTSB, the pilot stated that he had completed three to four "water ski" runs (a maneuver accomplished by setting the airplane's parking brake, touching down on the water, and skiing on the main landing gear tires) on the reservoir and was transitioning to the airport for a full-stop landing. The pilot stated that after he completed the maneuvers, he climbed to 1,000 feet above ground level and entered a left downwind for the intended runway. He stated that when the airplane touched down (a wheel landing[90] about 43 mph) he felt the right main tire[91] drag and

[89] This occupant self-reported additional injuries that he termed "trivial". These injuries included a bruise above his right eye, a bruise on his right shoulder and right hip that he attributed to the restraint, and bruising to his backbone. He also noted bumps on his legs and right arm.

[90] A *wheel landing* involves landing on the two front (left and right main) wheels before the rear/tail wheel touches down.

attributed it to the soft runway condition. He reported that the airplane skidded down the runway and when the left main tire touched down, the airplane's tail "came up" and the airplane nosed over. The pilot estimated that when the airplane nosed over, it was traveling about 5 knots (5.8 mph).

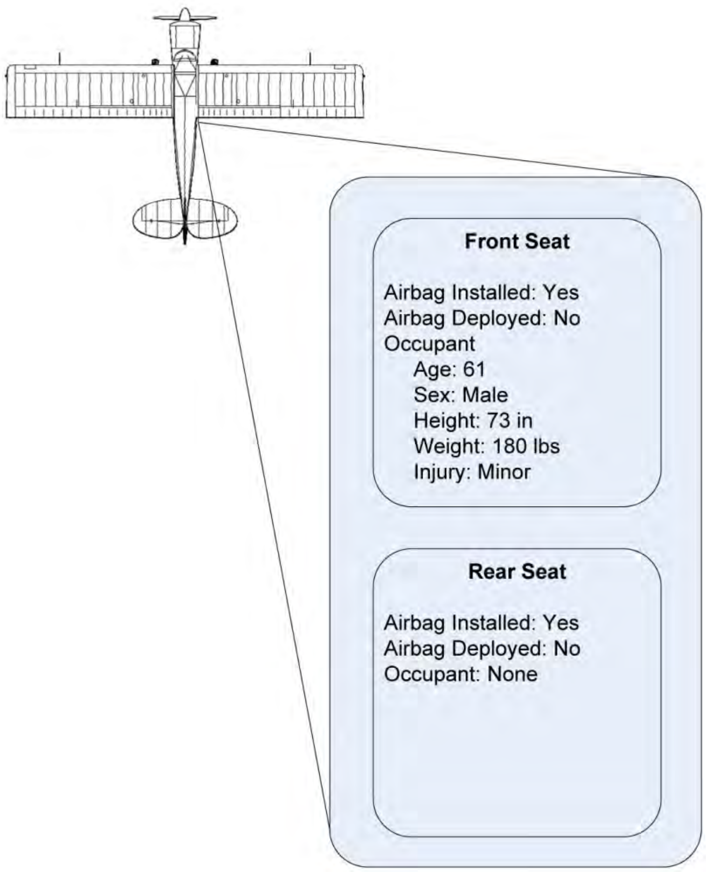

Figure 22. A seating chart from Aviat Husky A-1B, N94HY, which crashed in Owyhee, Oregon. (NTSB accident identification number is SEA06FA168.)

The airplane came to rest inverted on the dirt/sod runway. The pilot stated that the airplane's parking brake had been engaged prior to the water ski maneuver; however, he failed to release it after completing the maneuver and inadvertently landed with the brake set. After the crash, the pilot exited through the airplane door.

There was substantial damage to the airplane, shown in figure 23, including a bent propeller, dented spinner and engine cowling, damage to the leading edge of the left wing, bent right wing ribs, bent right wing strut, and deformation of the vertical stabilizer and rudder. The forward windscreen was broken, the forward left diagonal post (A-pillar) was compressed outward and downward about 3 inches, and the roof of the cockpit was deformed toward the cabin about 1 inch. There was a black smudge on the metal support tube that was located directly

[91] The airplane had *tundra tires*, which are about four times larger than normal tires and may affect ground handling and braking.

above the occupant's head, and the tube was compressed upward about 1/16 inch. There was no damage to the instrument panel.

Figure 23. A photograph of the wreckage of Aviat Husky A-1B, N94HY, which crashed in Owyhee, Oregon. (The wings were removed postcrash during the recovery of the airplane.)

Both the forward and rear seats were intact and undamaged. The airplane had an airbag-equipped 5-point restraint system with lift latch buckles on each seat. The pilot was wearing his restraint system at the time of the crash. The restraint systems were undamaged, and neither the pilot's airbag nor the unoccupied rear seat airbag deployed during the accident sequence. Examination of both systems revealed that the inflator, the cable harness to the buckle switch, and the gas inflator hose were all connected. Two EMAs were present in this plane, one for the front seat and another for the rear seat. The EMAs, inflator assembly, squib connectors, and associated lines were intact, and no damage was noted.

The SDT was used to check the functional status of the airbag system. The system check, which was conducted by the investigator-in-charge, was completed, and no system anomalies were noted. Additional testing and evaluation of the EMAs were completed at the AmSafe manufacturing facility in Phoenix, Arizona, under the supervision of a representative from the FAA's Manufacturing Inspection District Office. The circuitry, trigger timing, and overall condition of the unit were evaluated, and according to the post examination report, "no anomalies were found and the unit performed as designed."

The pilot, a 61-year-old male, was seated in the front seat. He was 6 feet 1 inch tall and weighed 180 pounds. During the nose over, the occupant was likely initially pushed slightly downward into his seat and then upwards toward the roof of the airplane as it came to rest inverted. The airplane speed had diminished significantly before it started to nose over. Therefore, the longitudinal deceleration was probably well below the threshold for airbag deployment.

Initially, the pilot did not document any injuries in a written report. However, during a subsequent interview, the pilot reported that he had sustained a minor laceration on his head and bruising to his head, right hip, and left shin. The head laceration did not require stitches. The pilot self-reported that he had been cut by his headset when his head impacted the roof of the airplane during the crash. A black smudge on the support beam above the pilot's head indicated possible transfer of material from the headset during the accident. His hip and shin bruises were likely due to seatbelt loading and impacts with the instrument panel, respectively.

Therefore, in the Owyhee, Oregon, accident, because the impact severity was likely below the threshold, the airbag would not have been expected to deploy. Further, because the pilot's head injury was not related to forward motion toward the instrument panel, the airbag's deployment would not have mitigated any of the minor injuries that the occupant sustained.

Indianapolis, Indiana, August 28, 2006, Cirrus SR22

On August 28, 2006, a Cirrus SR22, N91MB, was destroyed when it impacted a water retention pond located about 2.4 miles from the Eagle Creek Airpark in Indianapolis, Indiana, after a loss of control during cruise climb. (See figure 24.) According to the front right seat passenger, when the airplane reached about 4,000 feet of altitude, he noticed that the sound of the engine had changed and saw that the pilot was struggling to control the airplane. The passenger stated that the airplane then entered a "counterclockwise spin" and that the pilot instructed him to pull the emergency parachute.[92] At that time, the passenger pulled the throttle back to idle and then pulled the parachute handle. The airplane impacted the pond less than 9 seconds later.[93] The pilot sustained fatal injuries, and the three passengers sustained serious injuries. All four occupants were removed or assisted from the wreckage by individuals who lived in homes surrounding the pond. Figure 25 shows a seating chart that summarizes occupant injury and demographic information.

[92] The SR22 is equipped with a CAPS.

[93] Evidence of aerodynamic loads on the parachute, the angle of the front attachment points, and the condition of the rear attachment harness indicated that the parachute was activated while the airplane was airborne but that the airplane impact occurred prior to a full sequence of the CAPS deployment.

Figure 24. Photograph of Cirrus SR22, N91MB, as it was lifted from the water retention pond where it crashed in Indianapolis, Indiana. (NTSB accident identification number is CHI06FA245.)

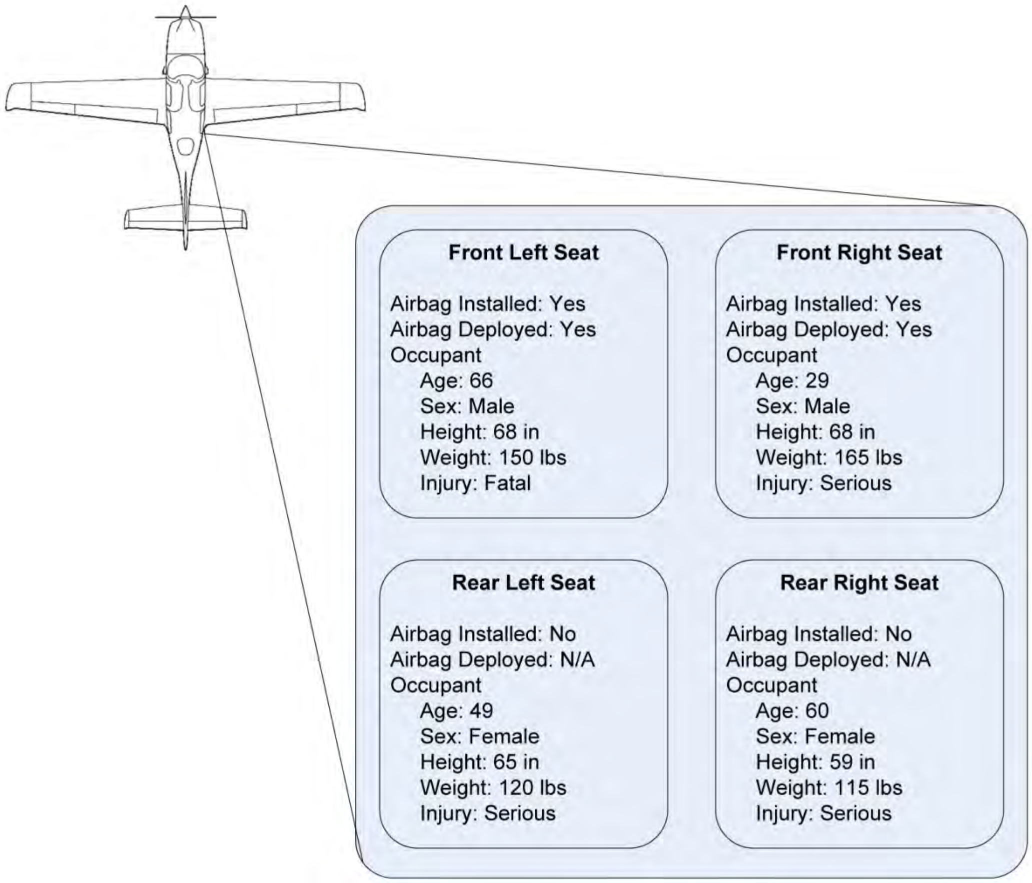

Figure 25. A seating chart from Cirrus SR22, N91MB, which crashed in Indianapolis, Indiana.

The NTSB determined that the accident was caused by the pilot's failure to maintain sufficient airspeed, which resulted in a stall and subsequent spin. Contributing to the accident were the pilot's inadequate preflight planning, the overloaded condition of the airplane, and the center of gravity aft of the center of gravity limit. Witnesses observed the airplane descending through the clouds with a partially deployed parachute. Data extracted from the PFD indicated that the airplane's airspeed decayed until the stall angle of attack of the wing was exceeded. The airplane was in a stalled condition for about 30 seconds and then entered a spin. About 4 seconds prior to impact, the PFD recorded a large decrease in longitudinal acceleration consistent with CAPS deployment. The altitude at that moment was about 1,340 feet mean sea level (msl) (528 feet above ground level). Based on the PFD data and the wreckage of both the airplane and the CAPS system, it was estimated that the airplane impacted the water with a 60-degree nose down attitude, the left wing down, and a vertical descent rate of about 56 mph (or 82 feet per second). Upon hitting the water, the fuselage likely continued downward and forward resulting in a cracking around the fuselage forward of the wing spar. The impact on the nose and the crushing of the fuselage toward the nose may have resulted in a reduction in the occupant space for both front seat occupants; this reduction likely occurred in the upper body region and on the left side.

The maximum recorded accelerations captured on the PFD in the seconds prior to the end of the recording were 1.2 G longitudinal (forward), 1.65 G vertical (down), and 0.2 G lateral (right). The recorded maximum longitudinal acceleration is lower than the minimum threshold for airbag deployment, but the severe damage to the airplane suggested that there had been much greater accelerations that were not captured on the PFD. For example, there was evidence of severe longitudinal loading based on the deformation to the propeller spinner, the cracking around the fuselage, the vertical descent rate, and the 60-degree nose down attitude at impact. Severe vertical loading was evidenced by the deformation and compression of the seat pan energy absorbing materials for all of the seating locations. For the front seats, shown in figure 26, the forward, left quadrant of both EAMs exhibited the greatest amount of crushing. The left seat EAM indicated a more distributed and complete crushing. The deformation to the right seat EAM was more localized. The localized loading of the right seat EAM may have been intensified by the presence of the air conditioning unit positioned beneath the seat.

Figure 26. A photograph showing the seat pan and aluminum EAMs from the two front seats. The left front seat pan and EAM block are on the left side of the photograph. The front of both seat pans is toward the top of the photograph.

A 4-point restraint system manufactured by AmSafe was present in each seat. Load marks were documented on all four restraint systems, indicating that the restraints were in use at the time of the crash. However, the lap belt load marks were not as pronounced as observed in other accidents, likely because the primary impact vector was downward with significant but secondary components in the forward and left direction. Both PFD data and injuries to the occupants supported this direction of primary impact force.

The front passenger seats were equipped with airbags mounted in the outboard shoulder harnesses, and both airbags deployed during the crash. The airbags were undamaged, but differences in loading were documented based on the squaring of the vent holes. Each airbag had two vent holes on the instrument panel side of the airbag. The left airbag showed squaring in both the upper and lower vent holes. The right airbag showed squaring in the lower vent hole and slight fraying in the upper vent hole. The amount of squaring indicated that the left airbag sustained higher pressures than the right airbag.

Based on information from the wreckage and the PFD, it was determined that the occupant motion was forward, downward, and to the left. Some components of counterclockwise rotational velocity (about 180 degrees per second) may have affected occupant motion but were less significant than the vertical descent rate at impact. The impact on the nose and the crushing of the fuselage toward the nose may have resulted in a reduction in the occupant space for both front seat occupants; especially in the upper body region and on the left side. It is likely that the initial parachute deployment placed the airplane into a 60-degree nose down attitude, causing the occupants to lean forward out of their normal seated positions. Although there was sufficient time prior to impact for occupants to readjust, it is unknown whether they did so.

The left front seat occupant, a 66-year-old male, was fatally injured. He was 5 feet 8 inches tall and weighed 150 pounds. He suffered severe head and chest trauma, and his cause of death was listed as multiple blunt force injuries. The head contact likely occurred on the left side instrument panel from intrusion into the occupant's space as a result of crushing of the front of the airplane. His chest injuries were also likely due to direct contact with the instrument panel resulting from intrusion into the occupant's space. The left front occupant also had lower spinal injuries that resulted from the vertical deceleration of the airplane. The spinal injuries may have been more severe because of the location of a traffic advisory system (TAS) transmitter receiver computer (TRC) box[94] installed below the seat, which may have reduced the total stroking distance[95] or deformation of the seating system. Such injuries would not require a large vertical deceleration if the occupant were bent forward, as would likely result from the nose-down position of the airplane.[96] In the case of this occupant, there is no evidence that the airbag mitigated injuries; however, airplane airbags are not currently designed to prevent injuries caused by severe intrusion or large vertical impacts.

[94] This is part of the SkyWatch system, which monitors airspace by interrogating transponder-equipped aircraft in the area and determining if a collision threat exists.

[95] The stroking distance is defined as the distance between the seat assembly and the underlying airplane structure.

[96] A National Aeronautics and Space Administration (NASA) summary noted that there were German and British pilot ejection studies with subjects restrained by a lap belt only in which severe spinal fractures occurred with as little as 3 to 4 vertical Gs. See A.M Eiband, "Human Tolerance to Rapidly Applied Accelerations: A Summary of the Literature," NASA-MEMO-5-19-59E (NASA Lewis Research Center, Cleveland, 1959).

The right front seat occupant, a 29-year-old male, was 5 feet 8 inches tall and weighed 165 pounds. He suffered serious injuries to his head, chest, and spine. It is likely that his head injuries resulted from direct contact between the right side of his head and the MFD unit in the instrument panel. The nature of his facial injury suggested that the occupant was likely turning his head to the left side at the time of impact. His lower spinal injuries resulted from the vertical deceleration of the airplane and may have been more severe because of the location of the air conditioning unit below the seat. Like the TAS TRC box under the left seat, the air conditioning unit may have reduced the total stroking distance or deformation of the seating system. The occupant also suffered a sternal fracture that likely resulted from direct contact between his chest and the GPS/radio control knobs or the throttle. As with the front left occupant, the airbag did not likely affect his injuries because there was airplane intrusion into the occupant space and direct contact of airplane structure to the head and chest. Airbags are not expected to mitigate injury caused by severe intrusion.

The left back seat occupant, a 49-year-old female, was 5 feet 5 inches tall and weighed 120 pounds. She suffered serious injuries including spinal injuries and sternal and rib fractures. Her spinal injuries resulted from the vertical deceleration of the airplane. Her sternal and rib fractures likely resulted from direct contact; however, the impact source was undetermined. Potential impact sources included the recessed armrest region on the left side wall or the seatbelt if it were in direct contact with the sternum.

The right back seat occupant, a 60-year-old female, was 4 feet 11 inches tall and weighed 115 pounds. She suffered serious injuries including spinal injuries, rib fractures, and burns. Similar to the other occupants, her spinal injuries resulted from the vertical deceleration of the airplane. The source of her rib fractures was again undetermined and may have resulted from seatbelt loading. The severity of her rib fractures was likely influenced by relative bone fragility associated with her small stature and age. The sources of the burns to her shoulder, back, and foot could not be determined.

In conclusion, the majority of occupant injuries were caused by the vertical deceleration of the airplane, and for the front seat occupants, intrusion of the instrument panel into the occupant space. The airbags, as they are currently designed, did not, and would not be expected to, mitigate these types of injuries. The front seat occupants' spinal injuries may have been more severe because of the substantial vertical deceleration, the occupants' positions, and the presence of a TAS TRC box under the left seat and an air conditioning unit under the right seat, which reduced the stroking distance of those seats. However, because the SR22 seats were able to meet the type certification basis specified in 14 CFR 25.562 without stroking, no additional testing d been required prior to their installation.

Athens, Texas, February 27, 2007, Cessna T182T

On February 27, 2007, about 1506 central daylight time, a single-engine Cessna T182T airplane, N14685, was substantially damaged during a forced landing to a field near Athens, Texas, following a loss of engine power. No flight plan was filed for the cross-country flight that originated at a private airstrip near Berryville, Texas, about 1455, and was destined for the Midland International Airport, near Midland, Texas. The pilot in the front right seat and the passenger in the rear left seat were seriously injured, and the passenger in the front left seat sustained minor injuries. Figure 27 shows a seating chart that summarizes occupant injury and demographic information.

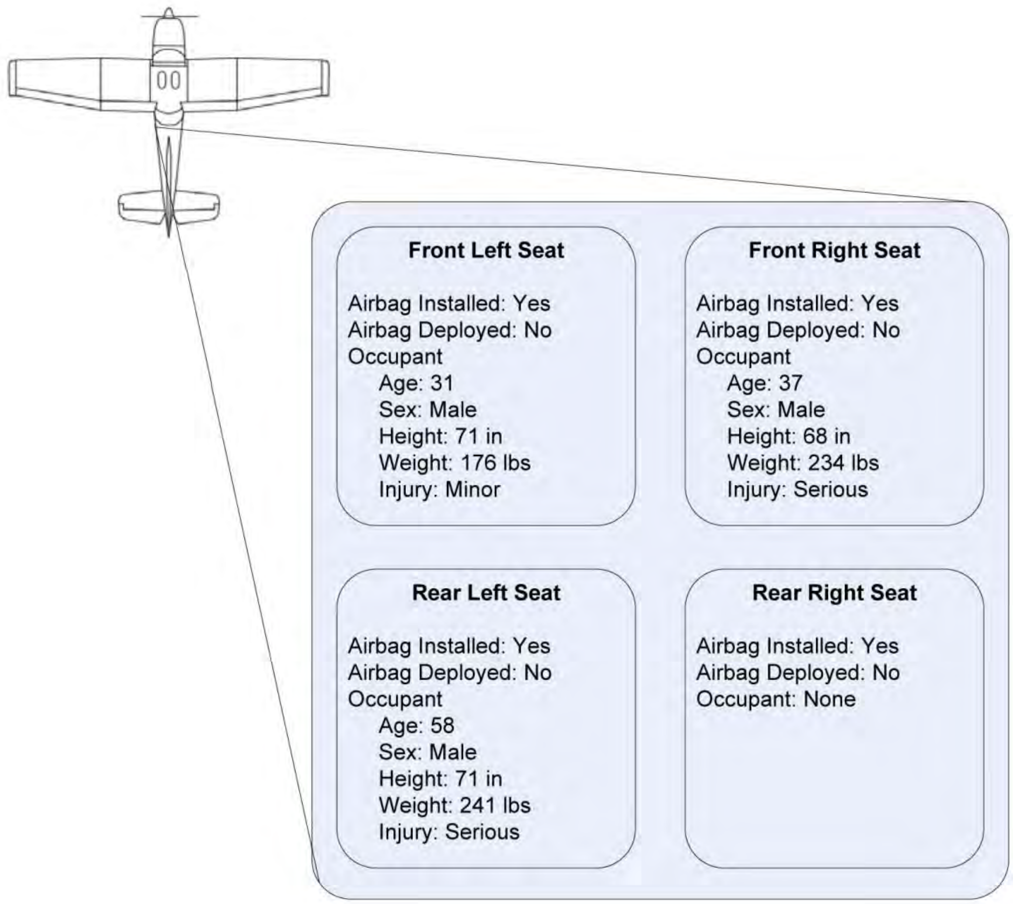

Figure 27. A seating chart from Cessna T182T, N14685, which crashed in Athens, Texas. (NTSB accident identification number is DFW07LA078.)

The NTSB determined that the accident was caused by a loss of engine power as a result of the failure of a mechanic to properly check the torque on the input and output fuel lines to the fuel transducer during the manufacturing process. A contributing factor was the lack of suitable terrain for the forced landing.

According to the pilot in the front right seat, the airplane was operating normally until it reached an altitude of 5,000 feet, and the turbine-inlet-temperature warning light illuminated on the MFD unit, followed by a sudden loss of engine power. The pilot reduced the engine throttle setting and adjusted the pitch of the airplane to establish the best glide speed and attempted to reach the Athens Municipal Airport, near Athens, Texas. When the pilot realized that he would not be able to reach the Athens Municipal Airport, he elected to execute a forced landing in a grass field southeast of the airport. The pilot stated that the airplane was traveling about 50 knots (57.6 mph) when it touched down in the field. The pilot reported that the left main landing gear dug into the ground and the airplane nosed over, coming to rest in an inverted position. (See figure 28.) The pilot stated that he unfastened his seatbelt, fell onto the ceiling of the airplane, and slid out onto the wing on his back. The pilot also stated that the front left seat passenger and rear left seat passenger were able to release their seatbelts easily[97] and that they exited the airplane through the left door.

Figure 28. A photograph of the wreckage of Cessna T182T, N14685, which crashed in Athens, Texas.

The airplane came to rest inverted in a flat grassy pasture with a magnetic heading of 70 degrees at a field elevation of about 461 feet msl. At the initial impact point there was a series of ground scars that were located about 120 feet from the resting place of the airplane. The airplane sustained structural damage to the vertical stabilizer and to both wings, with the greatest damage to the right wing. In addition, the left main wheel was separated from the strut, and the nose-wheel assembly had been sheared from the airplane.

No deformation was noted on any of the airplane's four seats. There was a 3-point restraint system in every seat. There was no damage observed to the restraint systems, and the inertia reels for all three occupied restraint systems were functional after the accident. Load marks were documented on the seatbelts indicating that all three occupants were wearing their restraints at the time of the accident.

[97] However, in a subsequent interview with the left rear seat passenger, the passenger reported that he was unable to unbuckle his restraint after the crash and needed assistance from the left front seat passenger to do so.

The airplane had an airbag installed in the lap portion of the 3-point restraint system in every seat, and none of the airbags deployed during the crash. All four restraints, the four seats, and the two EMAs used to deploy the front and rear seat airbags were properly installed. On-scene diagnostic testing of the EMAs using the SDT did not reveal any anomalies. The EMAs were removed and tested at AmSafe in Phoenix, Arizona, on May 16, 2007, under the supervision of the FAA. Both EMA units performed as designed during the tests.

Based on the damage to the airplane and the ground scars, it appeared that, after the left landing gear touched down, the airplane rolled to the right while skidding and bouncing forward across the ground for about 100 feet. The airplane had likely decelerated considerably by the time it nosed over. The damage to the right wing suggested that the airplane may have nosed over with the right wing touching the ground.

The pilot, a 37-year-old male, was in the front right seat. He was 5 feet 8 inches tall and weighed 234 pounds. He sustained three compression vertebral fractures near the base of his neck (C-7, T-1, and T-2). He also had a laceration on his head that did not require stitches. The occupant, who also reported that he had training as an emergency medical technician, believed that his neck injury occurred as a result of his head hitting the ceiling of the airplane during the crash. He reported that after the crash, he was hanging from the seatbelt and that the vertebral fractures affected sensation in his arm.

The front left seat passenger was 5 feet 11 inches tall, weighed 176 pounds, and was 31 years old. The rear left seat passenger was 5 foot 11 inches tall, weighed 241 pounds, and was 59 years old. Based on a questionnaire completed by the pilot, both passengers suffered bruises and sprains, and the rear left seat passenger sustained rib injuries. In a subsequent interview with the rear left seat occupant, he reported that two of his ribs (the 4th and 5th ribs) had cracked on the right front side of his body.

The study team determined that the front right occupant’s vertebral fractures likely resulted from his head striking the ceiling of the airplane as it became inverted. For the rear left side occupant, the team determined that the deceleration of the airplane was probably not sufficient to have led to a seatbelt-induced rib fracture, and there was no clear injury source. Consequently, the team was unable to determine the source of the rear left seat passenger’s rib injuries. The sources of the front left seat occupant’s bruises and sprains were also undetermined.

Overall, because the primary impact was along the vertical axis when the airplane inverted, the airbags would not have been expected to deploy and their deployment would likely not have mitigated the injuries that were sustained by the occupants.

In his interview, the pilot noted that at the beginning of the flight, the front left seat passenger had incorrectly attempted to use the restraint for the right seat. In the Cessna T182T, both of the front seatbelts hang from the ceiling between the two seats. The pilot, who was also a certified flight instructor, noted that there had been other occasions when his students had inadvertently used the wrong restraint in either the Cessna 172 or Cessna 182.

The study team documented the fact that in Cessna-manufactured airplanes, it is possible to cross the restraints in such a way that the incorrect airbag system can become activated. For example, as shown in figure 29, if an occupant in the left seat fastens the right seat restraint to his or her outboard buckle, the airbag system in the unused restraint would be active while the airbag in the buckled restraint would be inactive.

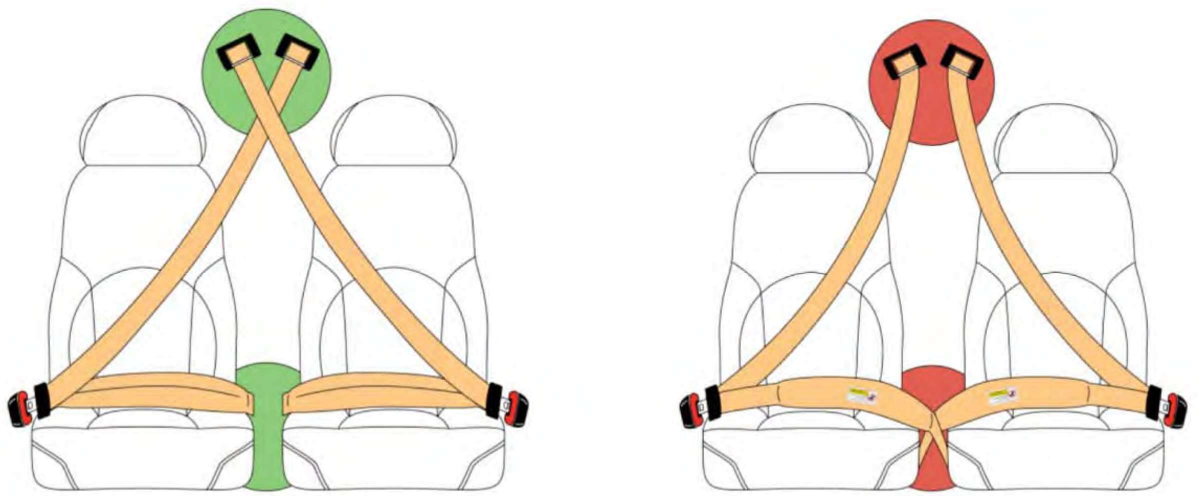

Figure 29. A pair of drawings showing pilot and front passenger seats and restraint configurations of a Cessna 172S. The correct latch configuration is shown on the left, and the incorrect configuration is shown on the right.

In issuing special conditions for the installation of GA airbags, the FAA stated that the airbag restraint design should prevent the restraint from being incorrectly buckled such that the airbag would not properly deploy. (See appendix C.) After becoming aware of the possibility of inadvertent inactivation of the airbag via crossing the restraints in the manner described above, the NTSB brought it to the attention of AmSafe, Cessna, and the FAA.

In response, AmSafe issued a supplement to the pilot's operating handbook for Cessna Skyhawk (172R, 172S), Skylane (182S, 182T, T182T), and Stationair (206H, T206H) models to include a reference to a warning label on the lap portion of the restraint.[98] On October 22, 2007, Cessna issued a service bulletin to owners of airbag-equipped Cessna aircraft to document the changes to the Pilot Operating Handbook.[99] The label, referenced in the above documents and shown in figure 30, is primarily designed to warn users that child safety seats should not be used in seats with airbag-equipped restraints because of the risks they pose to children in such seats. The label also contains a secondary bullet that informs users that the label side of the seatbelt should face the occupant.

[98] FAA Approved Airplane Flight Manual Supplement to *Pilot's Operating Handbook and FAA Approved Airplane Flight Manual for Cessna Aircraft Company Skyhawk Models (172R, 172S), Skylane Models (182S, 182T, T182T) and Stationair Models* (206H, T206H), issued June 28, 2007.

[99] Cessna Service Bulletin, SB07-11-02, for *Pilot's Operating Handbook—AmSafe Aviation Inflatable Restraints (AAIR) Supplement Revision*, issued October 22, 2007.

Figure 30. A photograph of the label placed on the occupant-facing side of the lap belt portion of Cessna airbag-equipped restraints.

With respect to the possibility of crossing the restraints, Cessna has also noted that its pilot's operating handbook contains a picture of the seat and seatbelt installation showing which inertial reel goes with which front seatbelt. (See figure 31.) However, the NTSB is concerned that some airplane occupants may not fully review or understand this information, particularly passengers. Furthermore, the warning label on the lap portion of the 3-point restraint system is currently designed in a way that suggests its message is solely geared toward potential child safety seat users. Discussions with Cessna pilots have indicated that several occupants have unknowingly crossed the restraints, putting them at risk of not having the full benefit of the restraint or airbag in a crash.

Certain older Cessna models included a design feature that allowed the seatbelt webbing to be threaded through a bracket attached to the seatback. Such a design feature would likely have prevented confusion about which seatbelt was designed to be used with which seat. However, this design feature was eliminated, and no additional design changes have been made or proposed to address this issue.

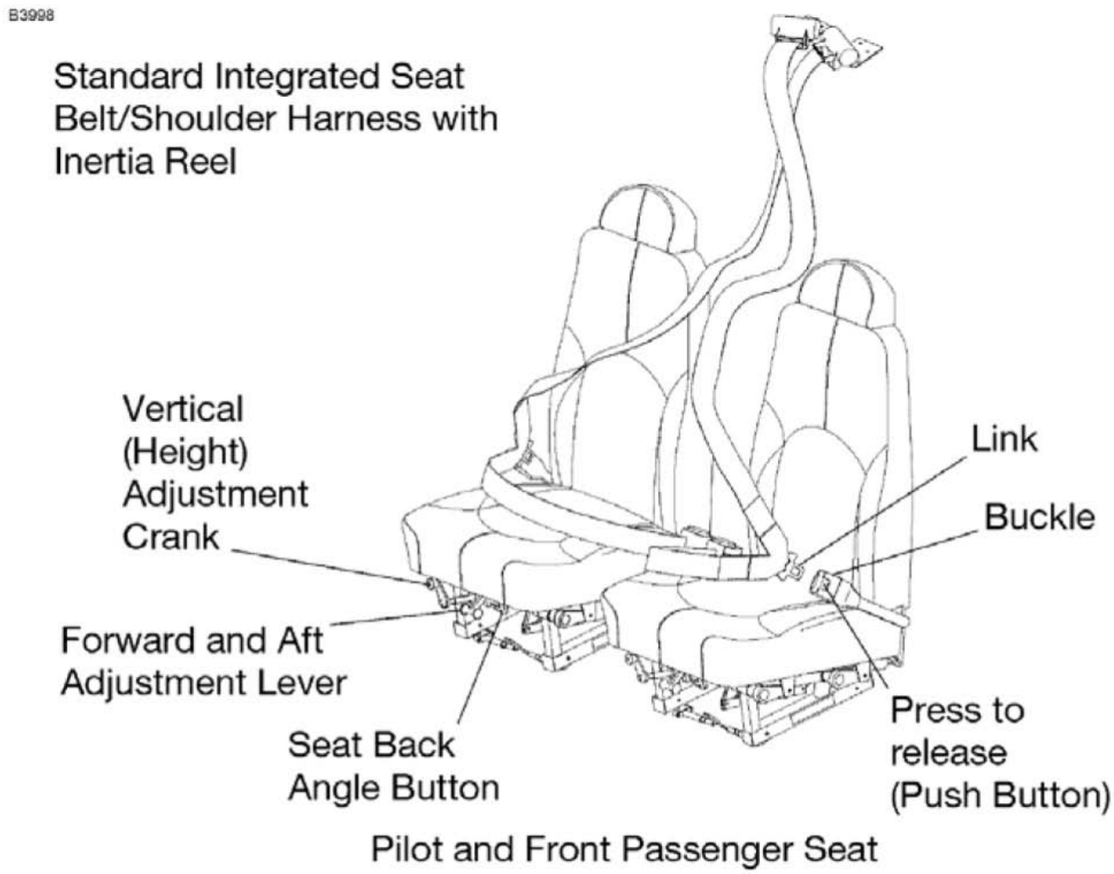

Figure 31. A drawing showing the front seats and seatbelts/shoulder harnesses of the Cessna 172S.[100]

The NTSB concludes that the 3-point restraint systems in certain Cessna airplanes can be crossed in such a way that the airbag and restraint systems are not used as designed and certified. Although the NTSB is not aware of any accidents in which occupants have crossed the restraints, the findings from this investigation suggest that crossing the restraints is not an unusual error and that doing so could result in a reduction of protection from the restraint system. Efforts thus far to address the problem, including labeling the seatbelt and adding text to the pilot's operating handbook, are unlikely to mitigate the problem of misuse, especially among passengers who are less familiar with aviation restraint systems. A more effective solution would be to redesign the restraint system to prevent occupants from using the incorrect restraint entirely (for example, by keying the buckle in such a way that only the correct restraint would fasten).

Therefore, the NTSB recommends that the FAA require Cessna and other manufacturers whose restraint system designs permit an occupant to use an inactive airbag restraint system not intended for use in his or her seat to modify their restraint system designs to eliminate that possibility, and require them to modify restraint systems in existing airplanes to eliminate the possibility of misuse.

[100] *Cessna Pilot's Operating Handbook and FAA Approved Flight Manual, Revision 1,* issued January 12, 2009.

Fullerton, California, September 30, 2008, Cessna 172S

On September 30, 2008, about 1835 Pacific daylight time, a Cessna 172S, N2190W, impacted terrain following a loss of control on takeoff from runway 24 at Fullerton Municipal Airport, Fullerton, California. The student pilot, the sole occupant, was seated in the left seat and sustained serious injuries, but he maintained consciousness and exited the airplane through the left cabin door.[101] Figure 32 shows a seating chart that summarizes occupant injury and demographic information.

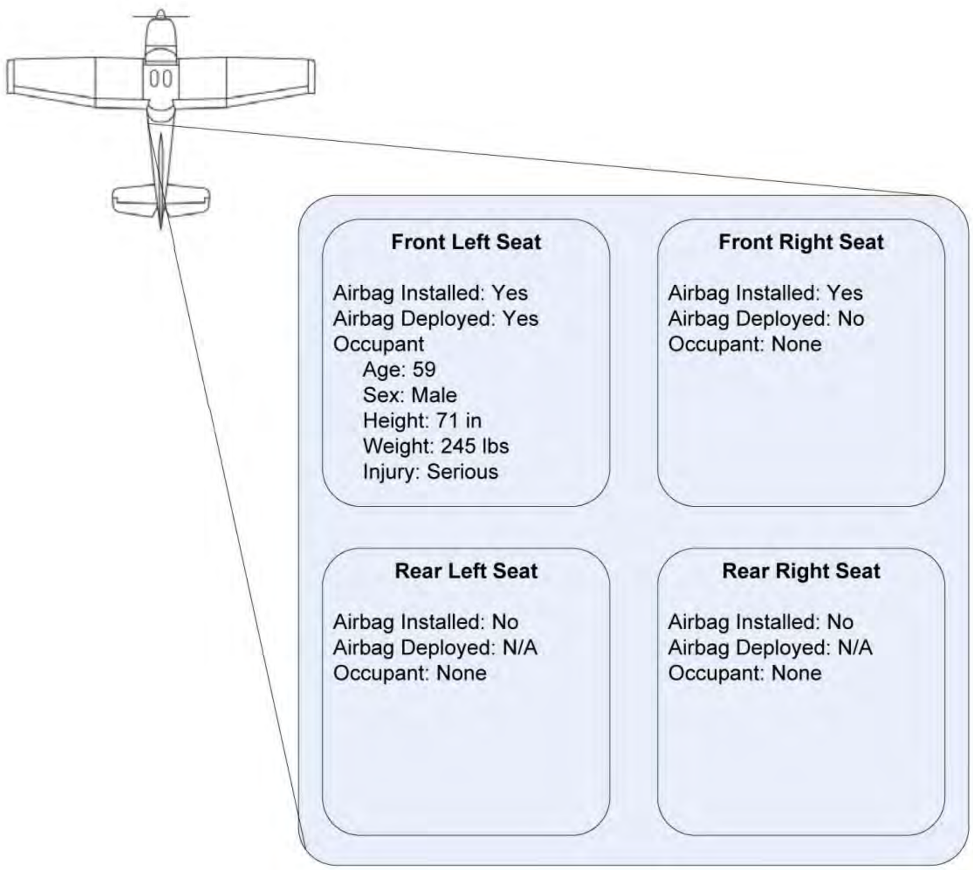

Figure 32. A seating chart from Cessna T172S, N2190W, which crashed in Fullerton, California. (NTSB accident identification number is LAX08FA301.)

The NTSB determined that the accident was caused by the pilot's failure to follow the takeoff checklist and verify the proper flap setting before takeoff. A security camera on the airport's tower with a frame rate of one frame per second captured several images of the accident airplane during its flight. The camera was positioned toward the airplane's impact location but did not capture the actual moment of impact because of the low sampling rate. An image approximately 1.5 seconds before impact showed a large roll angle to the right. The last image before impact shows the plane in an approximate 90-degree right bank. Based on the video

[101] The pilot was also involved as a passenger in the Athens, Texas, accident, during which he was seated in the left rear seat.

evidence,[102] airspeed at impact was estimated to be between 40 to 70 knots (80.6 mph). The pitch attitude at impact was estimated to be 90 + 15 degrees. The roll attitude was estimated to be 90 + 15 degrees, and the yaw attitude at impact was estimated to be –20 + 10 degrees.

Examination of the wreckage suggested that the first impact was on the right wing tip and the propeller spinner. A witness said that the right wing tip strike occurred as the airplane was perpendicular to the runway, and on-scene evidence indicated that the right wing tip dragged from the far edge of the runway to the center of the runway. Based on the wreckage and markings on the runway, it appears that the airplane impacted the runway with the right wing tip followed shortly thereafter by the nose. The right wing tip dragged from the far edge of the runway to the center when the nose hit. The airplane continued sliding off the runway and came to rest slightly off the runway inverted on its roof. (See figure 33.)

Figure 33. A photograph showing the final resting position of Cessna 172S, N2190W, which crashed in Fullerton, California.

The engine and instrument panel were displaced aft, upward, and to the left; the control yokes were displaced aft and to the left. There was also significant deformation of the foot well aft and to the left. The impact on the nose and the resulting airplane crush and intrusion into the

102 *Fullerton, California, Video Study*, <http://www.ntsb.gov/Events/2011/ga_airbag_study/docket/447756.pdf> (Washington, DC: National Transportation Safety Board).

cabin may have resulted in a reduction in the occupant space for the front seated occupant, both at chest level and in the region of the lower extremities.

No noticeable deformation of the seat pan was found. In addition, there was no indication of vertical loading to the seat structure. There was, however, a slight displacement of the seat frame to the right.

Each of the four seats was equipped with a 3-point restraint system manufactured by AmSafe, and the front two seats were also equipped with an airbag in the lap portion of the restraints. The front left airbag deployed, indicating that the restraint system was latched correctly during the crash sequence. Additionally, the position of the load marks on the seatbelt webbing suggested that the seatbelt was nearly fully extended, consistent with a large-sized occupant. Because of the design of the 3-point restraint system and the placement of the airbag on the lap portion of the restraint, when a person with a large waist size occupies the airbag-equipped seat, the portion of the lap belt that contains the airbag will shift toward his or her inboard side.[103] The left front seat airbag exhibited squaring of the single vent hole, indicating that the airbag sustained loads. There were also contact marks on the instrument panel side of the airbag corresponding to scuff marks on the left control yoke. The marks indicated that there was contact between the airbag and the yoke on the upper left hand corner of the pilot's yoke and further suggested that the airbag was positioned between the pilot and the control yoke.

In a postaccident interview, the pilot reported having difficulty extricating himself from the restraint system after the accident. This was most likely due to the inverted position of the airplane at final rest. As a result, the pilot's body would have placed additional weight on the restraint system latch, requiring additional force from the occupant to release it. The occupant's difficulty in reaching and releasing the seatbelt may also have been exacerbated by his size, his injuries, and the airplane damage.

At the time of impact, occupant motion was forward and to the right because of the about-90-degree pitch attitude, the about-90-degree roll attitude, and the wingtip and nose strike on the runway. The pilot, a 59-year-old male, was the sole occupant. He was 5 feet 11 inches tall and weighed 245 pounds. He survived the crash with multiple serious injuries. His right femur was fractured in two places. One fracture likely resulted from bending loads placed on the leg from the combined forces of a right rudder input, instrument panel intrusion, and seat deformation. The second femoral fracture may have resulted from the direct load applied by the intruding instrument panel.

The pilot's right knee was also fractured likely from direct impact with the instrument panel and also because of the intrusion of the instrument panel into the passenger compartment. He also experienced a right forearm fracture that was likely the result of contact between his right hand and the throttle at the time of impact. Because the accident occurred during takeoff, his right hand was likely on the throttle at impact. The pilot also had a bruised right lung, which likely resulted from impact with the control yoke centered in front of him through the airbag.

[103] In the front seats of Cessna airplanes, the restraint buckle is on the outboard side. In the rear seats, the restraint buckles are inboard. Therefore, for individuals with a large waist size who are seated in the rear seats, the airbag would be shifted toward their outboard side.

The pilot also suffered a nasal bone fracture and laceration across the bridge of the nose and right eyebrow. Most of his facial injuries were on the right side of his head. These injuries likely resulted from direct impact between the pilot's head and the right side of the instrument panel near or on the MFD and/or the glare shield. The pilot had abrasions across the right upper and lower quadrants of his abdomen. These abrasions likely resulted from the lap belt loading. Finally, the pilot had an abrasion and bruising on his left chest with uncertain source of impact.

Overall, in this accident, it appeared that the airbag mitigated the severity of the pilot's injuries, especially in the region of his torso. In spite of his bruised right lung, the airbag yielded a possible benefit by cushioning the impact between the occupant's chest and the control yoke. However, it was uncertain how the airbag was positioned at the time of head impact. Based on the laceration across the bridge of the pilot's nose and the nasal bone fracture, there was no clear evidence for protection of the head. One possible reason for the lack of head protection may be that, given the pilot's above average waist size, the airbag was initially positioned off to the pilot's right side. Although the pilot likely moved forward and to the right during the crash sequence, the airbag's interaction with his right arm may have prevented the airbag from fully deploying toward his head, thereby reducing its effectiveness for head protection.

Groton, Connecticut, November 19, 2008, Cessna 172S

On November 19, 2008, a Cessna 172S, N2337F, was substantially damaged when it impacted trees during night flight instruction at Groton-New London Airport in Groton, Connecticut. The certificated flight instructor (right seat occupant) and the student pilot (left seat occupant) incurred minor injuries. Figure 34 shows a seating chart that summarizes occupant injury and demographic information.

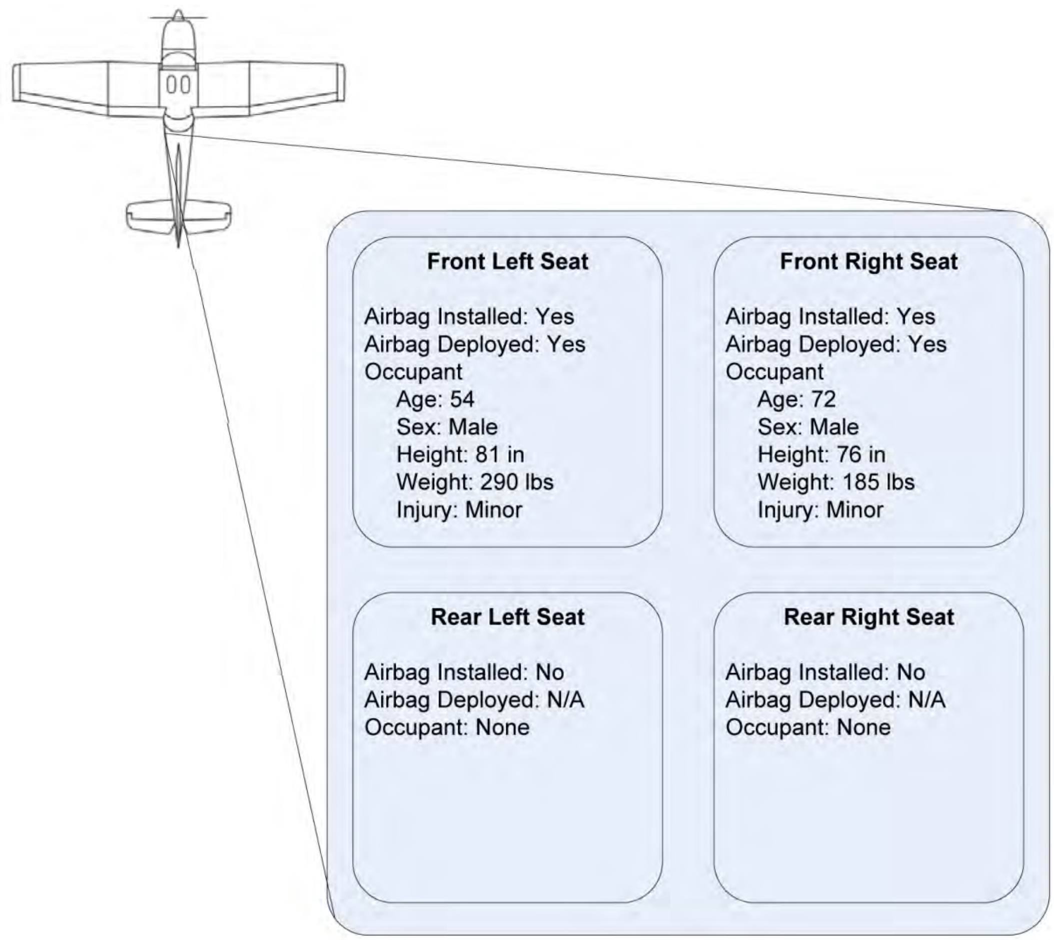

Figure 34. A seating chart from Cessna 172S, N2337F, which crashed in Groton, Connecticut. (NTSB accident identification number is ERA09LA064.)

The NTSB determined that the accident was caused by the student pilot's failure to maintain a proper descent profile to avoid trees during the night visual approach and the flight instructor's inadequate oversight. Interviews with the pilots and scene documentation revealed that the airplane impacted 30- to 40-foot tall trees about 1/4 mile from the runway during a practice landing. The trees were located in a hilly, heavily wooded area at an elevation of about 200 feet msl. Tree damage extended for about 100 feet and was generally aligned with the runway.

The airplane, shown in figure 35, impacted the ground at the forward left side of the engine compartment and came to rest with the nose down and the left wing tip crushed against the ground. The nose gear had collapsed and the engine had partially separated from its mounts. The glare shield was cracked across the upper window pane, and the tail of the empennage was bent to the right. The right cabin door was compressed inboard about 1 inch and the door was stuck in the closed position. Reportedly, the left cabin door was also stuck after the crash. The occupants stated that they were unable to open the doors manually, so the student pilot in the left front seat turned his body to the left and pushed the left door open with his feet. Both occupants then exited through the left side door. The left cabin door was separated from the airplane and the hinges were sheared where the door mounted to the upper and lower hinges.

Figure 35. A photograph showing the final resting position of Cessna 172S, N2337F, which crashed in Groton, Connecticut.

Except for some minor damage to the instrument panel, there was little damage inside the cabin. The airplane had a 3-point restraint system manufactured by AmSafe, and the front seats were equipped with lap belt-mounted airbags that deployed during the accident. Both occupants had their seats adjusted fairly far back,[104] likely due to their tall stature. There was no damage to the seats or the restraints. Load marks on the seatbelt webbing suggested that the seatbelts had been worn and sustained some stress during the accident impact. However, there was no damage to the airbags or stitching, and the vent holes for both airbags were round and intact.

The left front occupant, a 54-year-old male, was 6 feet 9 inches tall and weighed 290 pounds. He experienced a minor left thumb injury, likely as a result of contact with the control yoke. He also had a bruised right knee that was likely due to an impact with the throttle control and rib soreness that may have resulted from contact with the shoulder harness. The right front occupant, a 72-year-old male, was 6 feet 4 inches tall and weighed 185 pounds. He had a minor knee laceration and bruised knuckles on both hands possibly from contacting the instrument panel. He also experienced some back pain and rib soreness that may have resulted from contact with the shoulder harness.

[104] The left seat was in the 11th position back from full forward, and the right seat was in the 9th position back. There are 13 total adjustment positions on the Cessna 172S.

In this accident, the evidence of loading on the seatbelt webbing, the rearward position of the occupants, and the lack of obvious loading on the airbags suggested that the majority of occupant protection was provided by the seatbelts/shoulder harnesses. Therefore, the airbags performed as designed but did not appear to yield benefit beyond that conferred by the 3-point restraint system.

Green Cove Springs, Florida, November 19, 2008, Cirrus SR20

On November 19, 2008, a Cirrus SR20, N389CP, operated by the Commercial Airline Pilot Training Program, experienced a stuck throttle control and was substantially damaged during a subsequent forced landing near Reynolds Airpark in Green Cove Springs, Florida. The student pilot in the left front seat sustained a minor injury. The certified flight instructor in the right front seat and the observer in the right rear seat were not injured. Figure 36 shows a seating chart that summarizes occupant injury and demographic information.

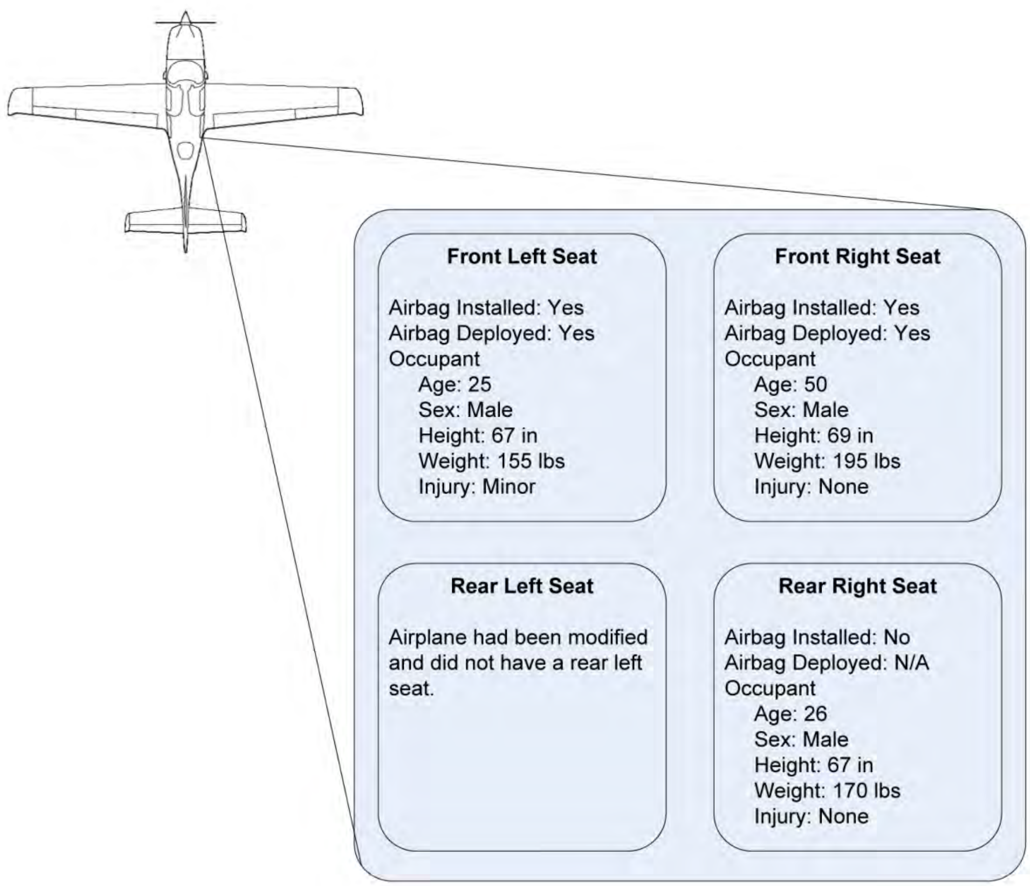

Figure 36. A seating chart from Cirrus SR20, N389CP, which crashed in Green Cove Springs, Florida. (NTSB accident identification number is ERA09LA062.)

The NTSB determined that the accident was caused by the fusing of an electrical cable from the No. 2 (standby) alternator with the throttle cable resulting in the flight crew's inability to move the throttle control. Contributing to the accident was the failure of maintenance personnel to detect inadequate clearance and chafing of the alternator output cable against the throttle cable housing during the 100-hour inspections.

As a result of the stuck throttle, the instructor declared an emergency with air traffic control, trimmed the airplane to maintain best glide airspeed, and proceeded to the nearest airport. According to the instructor, while descending near the airpark, the airplane clipped tree tops, and then it impacted soft ground, nosed over, and remained inverted. (See figure 37.) The occupants were unable to open the doors, so the rear seat occupant broke a rear cabin window using the emergency egress hammer,[105] and the occupants exited through the window.

Figure 37. A photograph showing the final resting position of Cirrus SR20, N389CP, which crashed in Green Cove Springs, Florida.

The airplane was substantially damaged. The left wing was damaged by a tree branch, which impacted the leading edge of the wing at about the midpoint of the wing. The right wing remained intact. There was a small area of fuselage damage at the wing's right aft attach point. The left and right main gear remained intact, and the nose gear remained attached to the nose of the airplane and was bent to the right. The upper weldment for the nose landing gear was

[105] According to Cirrus, an egress hammer is included with their aircraft to fulfill 14 CFR 23.807 emergency exit requirements that the exits should allow egress in any probable crash attitude.

fractured midway between the bulkhead and the nose gear. The top of the vertical tail fin was scraped, and the horizontal stabilizer remained intact. The propeller blades were curled rearward at the tips, and the spinner was dented. The MFD and PFD were recovered with recorded data. Maximum recorded accelerations were –4.0 G in the longitudinal (forward) axis, –2.8 G in the lateral (left) axis, and 2.9 G (1.9 G plus the gravitational force of 1.0 G) in the vertical (downward) axis. As the longitudinal deceleration reached its maximum value, the vertical acceleration reversed and moved from 2.9 G to –1.0 G over the course of about 3 seconds. The PFD data were consistent with the pilot's statements and indicated that the airplane flipped over and came to rest on its roof. At final rest, the PFD registered about 0 G in the longitudinal and lateral direction and –1 G in the vertical direction.

There was little damage to the cockpit, cabin, seats, and restraints. The left visor was fractured at its inboard end, and a small area of the bolster panel in front of the right front seat had separated at the outboard upper attachments. The left and right front seats were found adjusted one and four positions forward of the complete aft positions, respectively.[106] The front seats were undamaged with the exception of some minor compression (between 0.25 and 0.50 inches) of the front right region of the EAMs. The right rear seat had damage to the forward edge of the lower seat pan, which had separated from the forward cross tube at the rivets. The airplane did not have a left rear seat.

The airplane had a 4-point restraint system manufactured by AmSafe in each of the three seats, and the front seats were equipped with airbags in the outboard shoulder harnesses that deployed during the accident. The seatbelts and inertia reels operated correctly postaccident, and load marks on all three seatbelts suggested that they were being worn and sustained some stress at the time of the accident. Similarly, minor fraying of the vent holes on both airbags suggested that some load had been applied to them during the crash; however, there was no other damage, and minimal marking was visible on the airbags.

The left front occupant, a 25-year-old male, was 5 feet 7 inches tall and weighed 155 pounds. He hit his head during the impact and sustained a cut on the upper left side of his forehead near his hairline, likely due to contact with the sun visor, which was found broken in the wreckage. He was taken to the hospital, examined, and released. The right front seat occupant, a 50-year-old male, was 5 feet 9 inches tall and weighed 195 pounds. The right rear seat occupant, a 26-year-old male, was 5 feet 7 inches tall and weighed 170 pounds. Neither the right front seat occupant nor the right rear seat occupant sustained injuries.

In this accident, the airbags performed as designed. They did not have a negative effect, and they did not appear to yield benefit beyond that of the 4-point restraint system. Although there was some evidence that the airbags sustained some loads during the accident, the accident did not result in crush into the cabin compartment. Also, the occupants were of small stature and their seats were positioned far from the instrument panel. Finally, the rear seat occupant, whose restraint was not equipped with an airbag, was uninjured.

[106] There are 11 total adjustment positions.

Steamboat Springs, Colorado, February 14, 2009, Cirrus SR22

On February 14, 2009, about 1115 mountain standard time, a Cirrus SR22, N486CD, registered to and operated by Vector Resources LLC, Denver, Colorado, was substantially damaged when it crashed during an attempted go-around at Bob Adams Field in Steamboat Springs, Colorado. The cross-country flight originated from Centennial Airport in Englewood, Colorado, about 1015, and the SR22 was en route to Bob Adams Field. The pilot and two rear seat passengers were not injured; the front right seat passenger sustained minor injuries. Figure 38 shows a seating chart that summarizes occupant injury and demographic information.

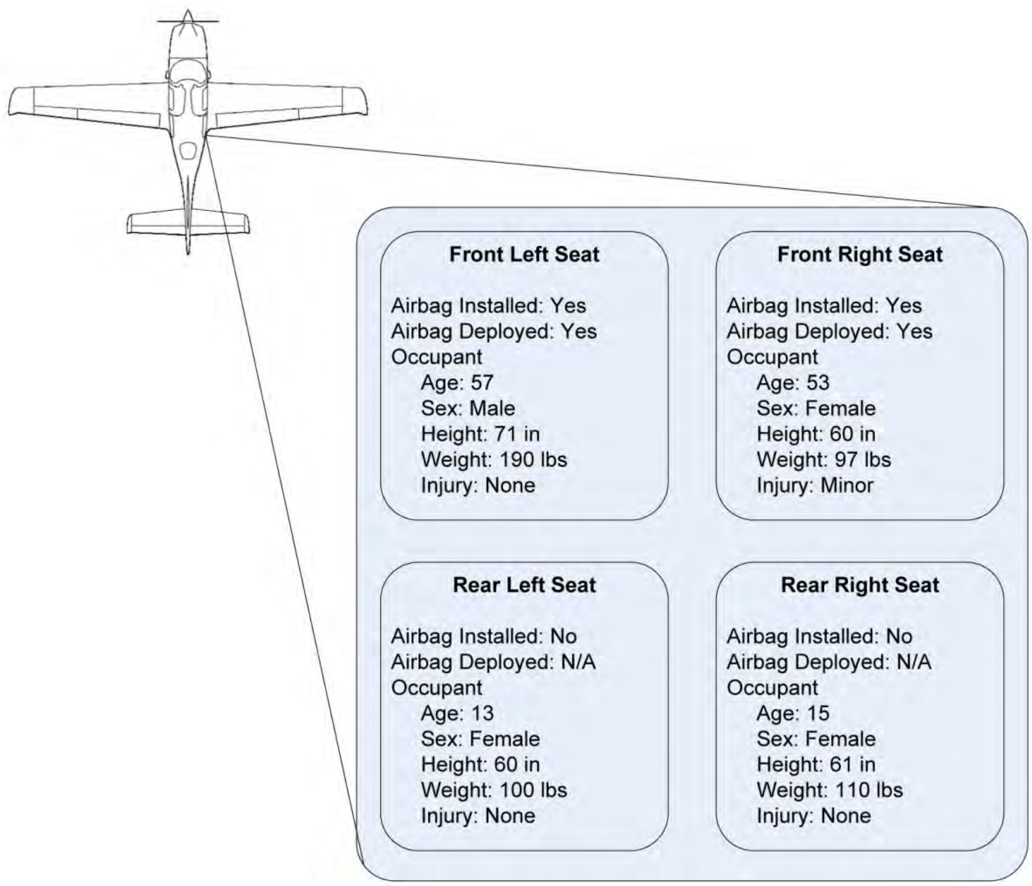

Figure 38. A seating chart from Cirrus SR22, N486CD, which crashed in Steamboat Springs, Colorado. (NTSB accident identification number is CEN09LA165.)

The NTSB determined that the accident was caused by the pilot's failure to apply brakes in a timely manner while landing on a snow-packed, ice-covered runway and his delay in executing a go-around. The pilot reported that during the landing roll, the airplane hit a patch of ice and began turning sideways. As a result, the pilot decided to initiate a go-around. According to airport staff, as the airplane lifted off, the landing gear struck a 19-inch snow berm 49 feet past the end of the runway, and the airplane nosed over. (See figure 39.) The pilot used the egress hammer to break a hole in the right front window. The four occupants then released their seatbelts and exited through the window.

Figure 39. A photograph showing the final resting position of Cirrus SR22, N486CD, which crashed in Steamboat Springs, Colorado.

The vertical stabilizer was torn off the airplane, and the horizontal stabilizer buckled. The nose of the airplane was slightly damaged and was displaced to the left. Little damage was noted to the landing gear, possibly indicating that the impact with the snow berm acted more as a "trip mechanism" than as a substantial impact incurred by the landing gear. The vertical stabilizer was broken, likely due to impact with the ground after the airplane flipped over.

Data from the airplane's PFD were available for the entire landing and crash sequence. The PFD data showed that the airplane experienced a change in velocity in all three axes. Initially, the plane began to show a positive longitudinal acceleration, possibly indicating the pilot's attempt at a go-around. A little over a second later, the longitudinal acceleration changed direction indicating that the plane was rapidly slowing down, likely from impacting the snow berm and striking the nose into the snow. As the longitudinal acceleration reached its most extreme recorded value of –2.6 G, the vertical acceleration reversed showing an acceleration of –2.3 G, indicating that the plane was accelerating upwards in the direction of the roof. This acceleration is consistent with the airplane flipping tail over nose at this time. At final rest, the PFD registered 0.2 G in the longitudinal, 0 G in the lateral direction, and –1.0 G in the vertical direction.

The evidence suggested that initial occupant motion was likely forward and slightly to the right. During the overturn sequence, the occupants would have been pushed downward into their seats relative to the airplane, and at final rest, the occupants were hanging upside down inside the airplane. Although the airbags did deploy, the recorded accelerations in the longitudinal direction were lower than anticipated for an airbag deployment, likely because the low sampling rate on the PFD did not capture the true peak accelerations.

Overall, the airplane cabin and interior were predominantly intact. There was a slight displacement of the center console and bolster. The left sun visor was broken, and the right side headliner and right door were blood-stained. The seats were also predominantly intact, with the exception of some slight deformation along the leading edge of the EAMs of the two front seat pans.

The pilot reported that all of the occupants had their seatbelts belted at the time of the crash. Additionally, load marks were observed under the load bars on the seatbelt webbing at all four seats suggesting that they were in use during the crash. However, the load marks on both rear seats' webbing indicated that the lap portion of the seatbelts were extended much farther than anticipated for proper fit on the occupants, two small teenage girls.[107]

The pilot, a 57-year-old male, was in the front left seat. He was 5 feet 11 inches tall and weighed 190 pounds. Neither he nor the two rear seated occupants sustained any injuries. The front right seat occupant, a 53-year-old female, was 5 feet tall and weighed 97 pounds. She was a physician and stated that her injuries included a chin abrasion, a bloody nose, a sprained left hand and wrist, and bruising near her 3rd and 4th ribs around the midpoint of her chest. She indicated that the chest bruise location was where the harness buckle rested. A subsequent interview with the occupant confirmed that she typically adjusted the restraint so that the buckle rested at the base of her sternum.

The right front seat occupant's minor facial injuries were likely caused by direct contact of the airbag with her face during the airbag deployment. Her improper use of the restraint system, which positioned the buckle too high on her chest, may have contributed to these injuries because the occupant's face would have been in closer proximity to the shoulder harness-mounted airbag at initial deployment. Similarly, her chest bruising likely resulted from direct loading to the chest from the improperly positioned buckle. The occupant's sprained left hand and wrist likely resulted from direct impact; however, the source could not be determined. It may have resulted from the occupant bracing herself during the impact sequence.

The extended position of the lap portion of the seatbelt webbing for the two occupants in the rear seats and the account from the occupant in the front right seat indicated that the 4-point restraint systems were likely worn incorrectly. When unbuckled and not in use, the 4-point restraint systems on the Cirrus SR22 appear as shown in figure 40. The buckle portion rests at the midpoint of the seatback because when they are unfastened, the inertial reel retracts and takes up the slack in the shoulder harness portion of the restraint.

[107] The rear seat occupants may have adjusted their restraints looser than normal because they were wearing ski jackets.

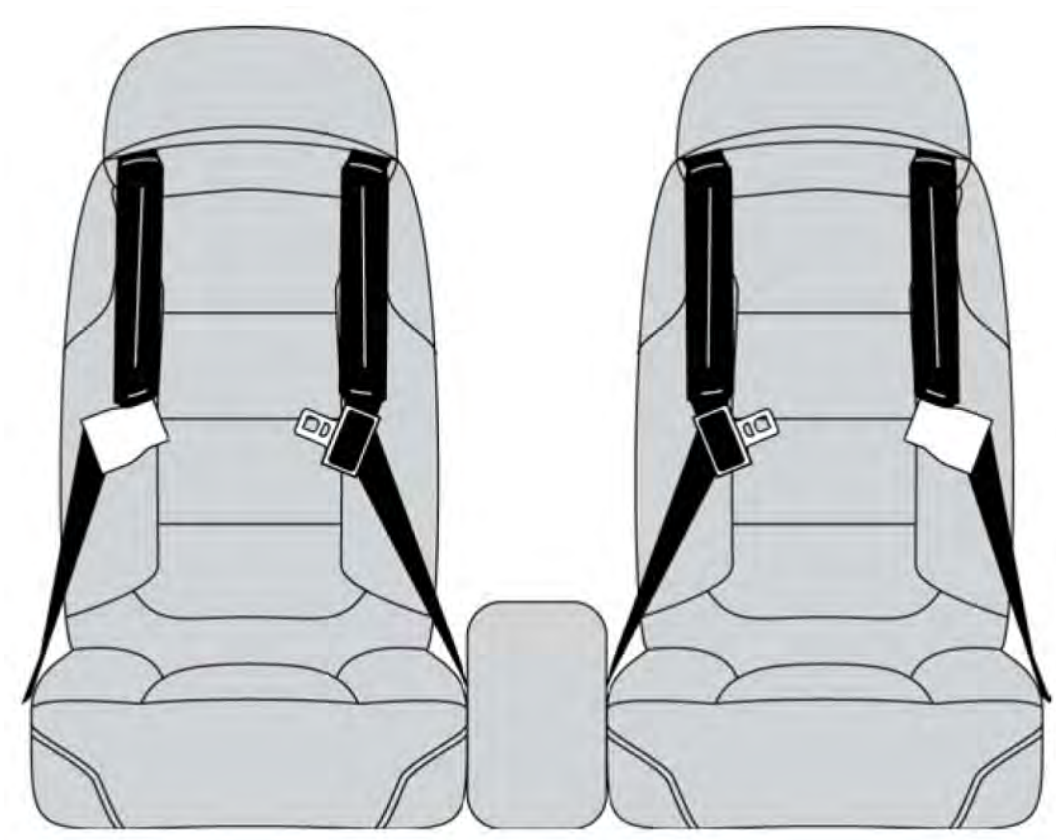

Figure 40. A drawing showing a pair of unbuckled Cirrus SR22 4-point restraint systems.

The pilot's operating handbook for the Cirrus SR22[108] provides the following instructions to users regarding restraint use:

To use the restraints:

1. Slip arms behind the harness so that the harness extends over shoulders.
2. Hold the buckle and firmly insert the link.
3. Grasp the seat belt tabs outboard of the link and buckle and pull to tighten. Buckle should be centered over hips for maximum comfort and safety.
4. Restraint harnesses should fit snug against the shoulder with the lap buckle centered and tightened around the hips.

However, in the Steamboat Springs accident, it appears that the rear-seated occupants and front right seat occupant fastened the buckles of the restraints across their chests, rather than pulling down on the shoulder harness, fastening the buckle low on the hips, and then tightening each side of the lap belt portion of the seatbelt.

[108] *Pilot's Operating Handbook and FAA Approved Airplane Flight Manual for the Cirrus Design SR22,* issued October 10, 2003.

The two front seat restraints had airbag systems, which deployed during the crash. The top vent hole on the left front airbag showed slight fraying, as did both the upper and lower vent holes of the right front airbag. Minor fraying of the airbag vent holes indicated that they sustained some loading during the crash. However, for the left front seat occupant, there was likely no additional benefit of the airbag beyond the benefit gained from the 4-point restraint system.

For the right front seat occupant, the airbag likely contributed to the minor injuries she sustained, but these injuries may have been exacerbated by the improper use of the restraint system. If the restraint had been worn properly, likely there would not have been an additional benefit of the airbag above the benefit gained from the 4-point restraint system.

Overall, the airbag system did not appear to yield benefit beyond that conferred by the 4-point restraint system. For the front right seat occupant, the airbag likely contributed to the occupant's minor injuries, but these injuries may have been exacerbated by the improper use of the restraint system. Although the pilot reportedly provided guidance to the passengers about how to use the restraint systems, there is evidence that all three passengers incorrectly latched the restraints so that the buckle was positioned at chest level, rather than at pelvis level.

Stigler, Oklahoma, April 9, 2009, Cessna 182T

On April 9, 2009, a Cessna 182T, N1491D, was substantially damaged upon collision with terrain following a loss of control during initial takeoff from a private airfield near Stigler, Oklahoma. One of the passengers told an FAA inspector that during takeoff, the airplane encountered a gust of wind. The pilot lost control of the airplane, which collided with terrain and nosed over, coming to rest in an inverted position. The pilot, seated in the left front seat, suffered serious injuries, and the right front and left rear passengers suffered minor injuries as a result of the crash. Figure 41 shows a seating chart that summarizes occupant injury and demographic information.

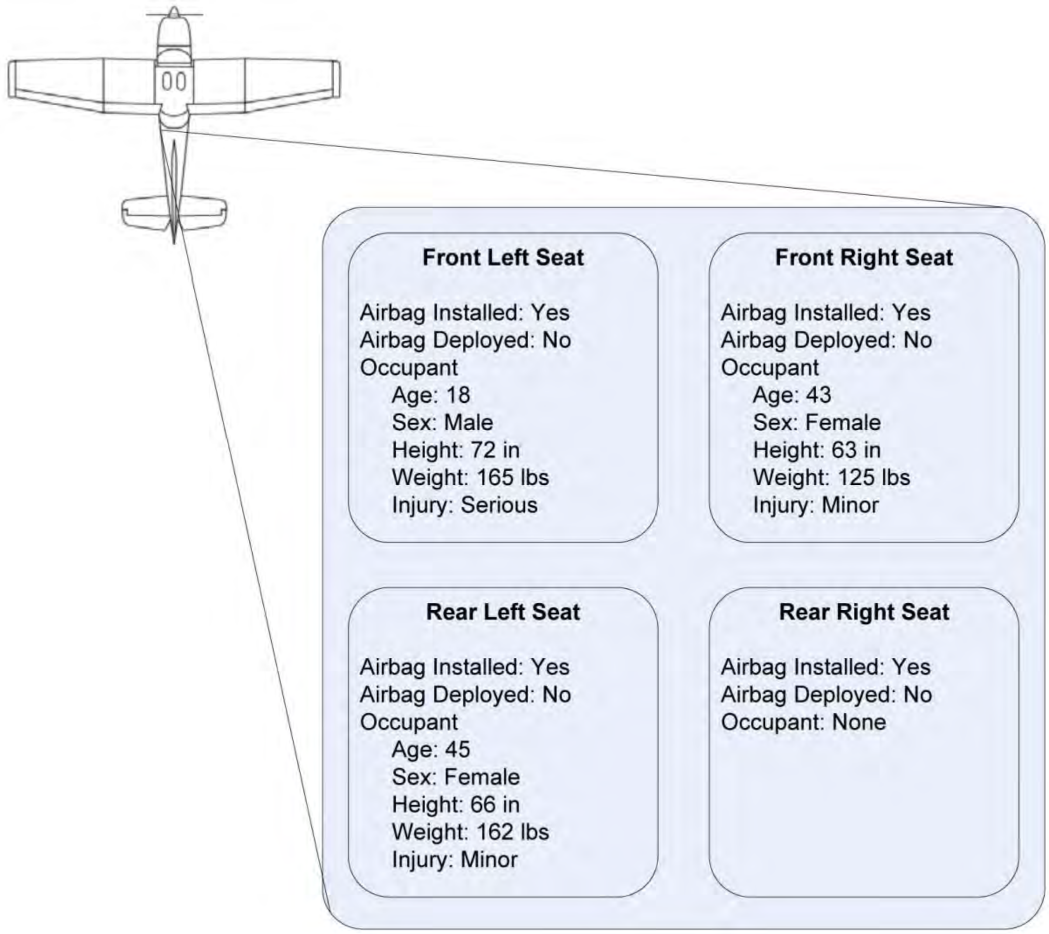

Figure 41. A seating chart from Cessna 182T, N1491D, which crashed in Stigler, Oklahoma. (NTSB accident identification number is CEN09LA247.)

The NTSB determined that the accident was caused by a loss of directional control during takeoff. Contributing to the accident was the pilot's decision to take off with 40 degrees of flaps and with a tailwind. The accident occurred during a soft field takeoff from a 2,000-foot downhill private grass runway. With winds gusting from the southeast, the private pilot elected to depart to the north. During the takeoff sequence, the airplane likely became airborne at about 40 knots (46.1 mph) because of the incorrect flap setting. At this airspeed, there was likely insufficient rudder authority to counteract the winds, and the airplane was pushed to the left.

Based on ground scars, it appeared that the airplane landing gear touched down on a heading of 315 degrees about 219 feet west of the estimated point of takeoff and became airborne again. About 660 feet west of the landing gear ground scars was additional evidence of the airplane contacting the ground aligned on a heading of 300 degrees. Three ground scars consistent with propeller strikes were not aligned with the larger ground scar, which was consistent with the airplane being yawed during the ground contact.

The airplane came to rest in the inverted position. (See figure 42.) The nose and engine were found about 30 feet past the final resting position of the airplane, and the tail was broken and twisted. The outboard 4 feet of the left wing displayed signs of rearward crushing, and this section was found folded on top of the wing. Based on the ground scars and airplane damage, it appeared that the right wing tip, nose, and left wingtip then impacted the ground sequentially. The airplane then likely pitched nose over into the final resting position.

Figure 42. A photograph showing the final resting position of Cessna 182T, N1491D, which crashed in Stigler, Oklahoma. Two major impacts of the nose into the ground are visible in the foreground.

The evidence gathered at the scene of the accident indicated that the primary impact pushed the nose of the airplane upward, and much of the observed airplane damage was consistent with a vertical impact. Specifically, the engine was sheared off vertically, and the deformation forward of the cabin was upwards toward the airplane ceiling. The instrument panel and the rudder pedals were also displaced upward but not aft in the direction of the occupants.

Each of the four seats was equipped with a 3-point restraint system with an airbag in the lap portion of the restraint. There were two sets of buckles in the rear seat area, as shown in figure 43. The additional set was designed for use with child safety seats with labels that advised users that “the use of the child seat buckle will deactivate the airbag.”

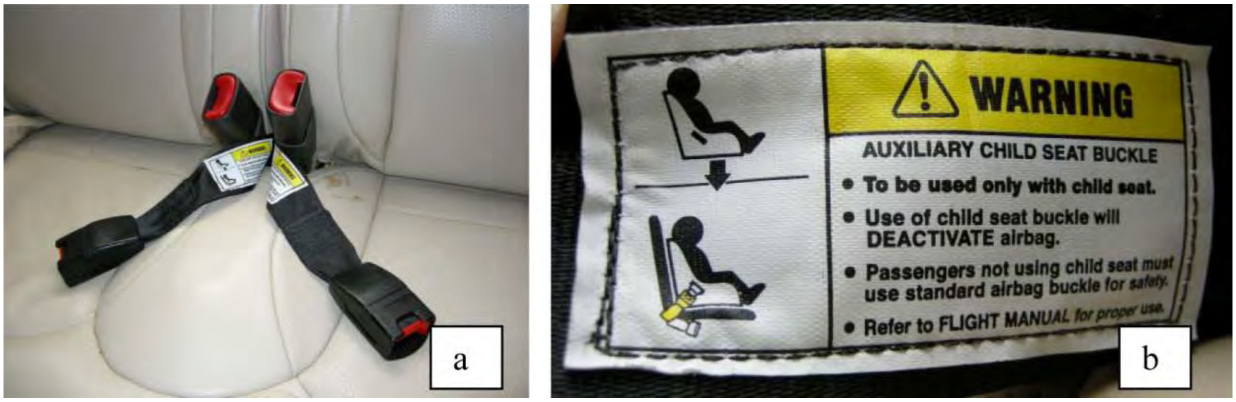

Figure 43. A pair of photographs showing seat belt buckles and a buckle label. Photograph a, on the left, shows the primary (top) and child seat (bottom) buckles for the rear seat occupants. Photograph b, on the right, shows the label stitched to the child seat buckles.

After the accident, both the left and right front seat inertia reels were functional, but the right front seatbelt webbing would not fully retract into the reel. The inertia reels were functioning properly for the two rear seats. Load marks were found under the load bar on the seatbelt webbing in all occupied seats, indicating that the restraints were worn during the accident. The front seatbelts exhibited heavier load marks than those on the left rear seatbelt. Load marks on the left rear seatbelt suggested that the seatbelt was extended further than would be consistent with the small-sized passenger who occupied the seat. It was not known whether these marks were from another instance or actually reflected the use at the time of this crash.

None of the four airbag systems deployed during the crash. Examination of all four systems revealed that the inflator, the cable harness to the buckle switch, and the gas hose were all connected. There were two EMAs in the airplane: one for the front seats and another for the rear seats. Each EMA connects to a cable harness that then splits to each seat's airbag system. This connection was intact for both the front and rear seats.

The SDT was connected to each airbag system to assess whether the system was active and enabled. For all four airbags, the SDT showed a green light indicating that the system was active and enabled. When the restraint was fastened into the auxiliary child seat buckles, neither rear seat airbag was enabled. The EMAs for the front and rear seats were removed and were shipped to AmSafe in Phoenix, Arizona, for further testing to verify that they were within design specifications. Both EMAs performed as designed, indicating that the crash sensors and firing signals performed within approved tolerances.

The occupants were upside down at final rest. The front right seat passenger stated that she released her seatbelt with difficulty and assisted the pilot and the rear left seat passenger with unfastening their restraints. The right front seat passenger and the left rear seat passenger then assisted the pilot in exiting the wreckage.

The pilot, an 18-year-old male, was in the front left seat. He was 6 feet tall and weighed 165 pounds. His seat was in the full forward position. His injuries included several facial fractures (including an orbital wall fracture, zygomatic fracture, and maxillary sinus fracture), lacerations, and contusions. He also experienced fractures to his left fibula and lateral maleolus (ankle) and abrasions to both knees. The pilot's facial fractures probably occurred from an impact on the control yoke as the engine was sheared off and the control yoke and instrument panel were displaced upwards. Because of the nose-down orientation of the airplane, the pilot's head was likely facing the floor during the impact. This facial position would account for a hard impact of the yoke near the pilot's right eye. The occupant's lower extremity injuries resulted from the damage and upward displacement of the rudder pedals and foot well.

The occupant in the right front seat was a 43-year-old female. She was 5 feet 3 inches tall and weighed 125 pounds. Her seat was in the 9th pin position from full forward, indicating that her body was farther from the control surfaces than the pilot's at the time of the crash. This occupant sustained minor seatbelt-induced injuries consisting of contusions and abrasions on the right hip and contusions on the left shoulder near the neck. No additional injuries were sustained, likely because of the occupant's position away from the instrument panel and her small size.

The occupant in the left rear seat was a 45-year-old female. She was 5 feet 6 inches tall and weighed 162 pounds. She experienced minor lower extremity contusions and lacerations that likely resulted from flailing during the crash sequence or occurred during egress.

In this accident, the airbags did not deploy and they were not designed to do so. Deployment of the airbag system is triggered by longitudinal (forward) deceleration, whereas the primary forces in this accident were in the vertical direction. In this particular accident, if the airbag had deployed, it might have cushioned the impact between the pilot's head and the yoke and mitigated his injuries by dissipating the impact forces. Deployment in this case would have required a vertical deployment trigger, and it is unclear how such a trigger might perform under more common crash scenarios. The timing of such a trigger in an accident with multiple impacts might be problematic. For example, an initial vertical impact followed by a more severe longitudinal impact could cause the airbag to deploy prematurely and not provide optimal protection for the occupant during the more critical longitudinal impact. A vertical deployment threshold could also pose problems for inadvertent deployment in severe turbulence.

Boyd, Texas, July 14, 2009, Cessna 172S

On July 14, 2009, at 1746 central daylight time, a single-engine Cessna 172S, N2446F, was substantially damaged during a forced landing following a loss of engine power 2 miles west of Boyd, Texas. The solo student pilot, seated in the left front seat, sustained minor injuries. The local flight originated from Fort Worth Meacham International Airport in Fort Worth, Texas. Figure 44 shows a seating chart that summarizes occupant injury and demographic information.

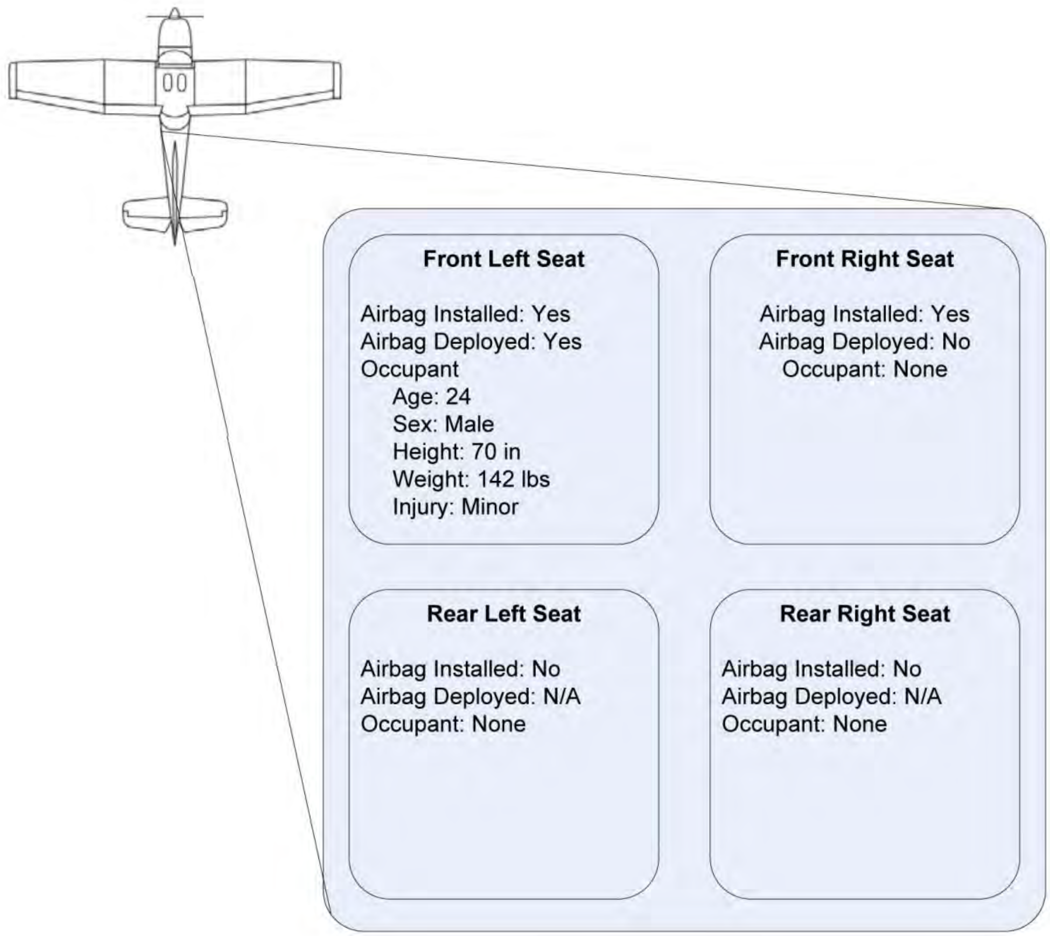

Figure 44. A seating chart from Cessna 172S, N2446F, which crashed in Boyd, Texas. (NTSB accident identification number is CEN09LA442.)

According to an FAA inspector, the airplane, shown in figure 45, came to rest in an upright position in a pasture after hitting a cattle fence, becoming airborne again, hitting a tree, and then hitting a man-made embankment of a stock water pond. The pilot stated that, after the airplane came to a stop, he remained seated on the forward left seat and was able to open his door to exit the airplane.

Figure 45. A photograph of the final resting position of Cessna 172SP, N2246F, which crashed in Boyd, Texas.

The forward fuselage firewall and engine were displaced downward about 30 degrees from the instrument panel forward and about 5 degrees to the right. The nose gear had collapsed and intruded into the airplane between the two forward seats. The nose had articulated forward, separating the glare shield at its bottom edge where it attaches to the engine cowlings. The firewall was buckled, but the engine mounts and mounting tubes were not bent or cracked. The roof over the cabin exhibited compression wrinkles, which were more pronounced on the right side of the roof. The left door had been ripped from its hinges and oil canning[109] was found on both the left and right door frames. The left wing had compression wrinkles on both the top and bottom sides. The right wing exhibited small dents on the leading edge and compression wrinkles on the underside.

There was little damage inside the cabin, except for the nose landing gear intrusion and the left foot well deformation inward and toward the left side foot well area. The rudder pedals and flooring below the pedals were bent and displaced. The center trim control tab and fuel selector valve console were deformed. The instrument panel was intact, with the exception of some cracking of the paneling between the throttle and primer levers. Hair remnants were found in the doorframe molding screw, and the left visor was broken.

[109] *Oil canning* is a waviness across the flat areas of thin-gauge sheet metal panels.

The airplane had a 3-point restraint system manufactured by AmSafe in each of the four seats, and the front seat restraints were equipped with lap belt-mounted airbags. There was no damage to the seats or the restraints. Load marks on the left front seatbelt indicated that it had been worn and sustained some stress during the accident impact.

The left front seat airbag deployed during the accident. The airbag displayed green colored scuff marks, minor damage to the stitching of the airbag cover, and slight fraying to the vent hole on the instrument panel side of the bag.

The airplane damage suggested that initial occupant motion was likely forward and to the left side. There were several impacts during the sequence of events when the airbag may have deployed. The airplane impacted a cattle fence with the right horizontal stabilizer, impacted a huisache tree,[110] and then impacted an embankment on the far side of a pond. Given the frangibility of the fence and the tree and considering the pilot's statement that the airbag deployed after the "violent" impact with the ground, it is likely that the airbag deployed during the airplane's impact with the pond embankment after crossing over the water.

The pilot, a 24-year-old male, was in the left front seat. He was 5 feet 10 inches tall and weighed 142 pounds. His injuries included a 3-centimeter laceration to the left side of his head, which required staples. This minor injury was likely the result of the pilot hitting his head on the doorframe molding screw on the inside of the left doorframe or from impacting the visor. The occupant also experienced a sprained right ankle and a contusion on the right heel, which were likely the result of the foot well deformation in front of the left seat. Finally, the occupant suffered back strain, which likely resulted from the downward motion during the impact sequence.

Overall, although there was slight fraying of the vent hole indicating some loading on the airbag by the left front seat occupant, the airbags did not appear to yield benefit beyond that conferred by the 3-point restraint system. Additionally, because the instrument panel was displaced forward and away from the occupant, contact with the instrument panel was less likely.

Summary of Results

There were 10 accidents investigated for the study. Seven of the accidents had airbag deployments. Three of the accidents did not have airbag deployments, but they did have occupant injuries. As shown in table 2, all of the airplanes sustained substantial damage or were destroyed.[111] In more than half of the accidents, the principal direction of accident force was in the forward longitudinal axis, the direction required for airbag deployment. For a graphical depiction of the directions referenced in table 2, please see figure 10.

[110] The *huisache* is a variety of the acacia tree that is native to the southern United States. It has very brittle wood.

[111] Notably, none of the seats in this study became detached. By contrast, in NTSB's 1985 study of survivable GA accidents with fatal or serious injuries (see NTSB/SR-85/01), over half of the seats became detached in the accidents analyzed.

Table 2. Summary data concerning the 10 accidents that met the safety study criteria.

City, State	Make/Model	Airplane Damage	Airbag Deployed	Principal Direction of Force	Secondary Direction of Force
Boyceville, WI	Cirrus SR22	Substantial	Yes	Longitudinal-Forward	Lateral-Right
Owyhee, OR	Aviat A-1B	Substantial	No	Vertical-Upward	Longitudinal-Forward
Indianapolis, IN	Cirrus SR22	Destroyed	Yes	Vertical-Downward	Longitudinal-Forward
Athens, TX	Cessna T182T	Substantial	No	Vertical-Upward	Longitudinal-Forward
Fullerton, CA	Cessna 172S	Substantial	Yes	Longitudinal-Forward	Lateral-Right
Groton, CT	Cessna 172S	Substantial	Yes	Longitudinal-Forward	Vertical-Downward
Green Cove Springs, FL	Cirrus SR20	Substantial	Yes	Longitudinal-Forward	Vertical-Upward
Steamboat Springs, CO	Cirrus SR22	Substantial	Yes	Longitudinal-Forward	Vertical-Upward
Stigler, OK	Cessna 182T	Substantial	No	Vertical-Downward	Vertical-Upward
Boyd, TX	Cessna 172S	Substantial	Yes	Longitudinal-Forward	Lateral-Left or Vertical-Downward

The 10 accidents that met the study criteria involved 25 occupants: 18 males and 7 females. The occupants ranged in age from 13 to 72 and represented a wide range of body sizes. Occupant heights ranged from 4 feet 11 inches to 6 feet 9 inches and weights ranged from 97 to 290 pounds. All 25 occupants were using lap belt/shoulder harness combinations at the time of the crash. Seventeen of the 25 occupants were in seats that had airbag-equipped restraint systems, and 12 airbags deployed. Overall, there was 1 fatality, 7 occupants with serious injuries, 12 occupants with minor injuries, and 5 occupants with no injuries. See table 3 for a summary of occupant demographics.

Table 3. Occupant demographics.

Accident	Occupant Position	Age	Sex	Height (in)	Weight (lbs)	BMI	Classification[a]	Injury[b]	Airbag Benefit/ Harm
Boyceville	Left front	55	M	74	242	31.1	Obese	Serious	Null
Boyceville	Right front	27	M	72	150	20.3	Normal	Minor	Benefit
Boyceville	Right rear	26	M	—	—	—	—	Minor	No airbag
Owyhee	Left front	61	M	73	180	23.7	Normal	Minor	No deployment
Indianapolis	Left front	66	M	68	150	22.8	Normal	Fatal	Null
Indianapolis	Right front	29	M	68	165	25.1	Overweight	Serious	Null
Indianapolis	Left rear	45	F	65	120	20.0	Normal	Serious	No airbag
Indianapolis	Right rear	60	F	59	115	23.2	Normal	Serious	No airbag
Athens	Left front	31	M	71	176	24.5	Normal	Minor	No deployment
Athens	Right front	37	M	68	234	35.6	Obese	Serious	No deployment
Athens	Left rear	59	M	71	241	33.6	Obese	Minor	No airbag
Fullerton	Left front	59	M	71	245	34.2	Obese	Serious	Benefit
Groton	Left front	54	M	81	290	31.1	Obese	Minor	Null
Groton	Right front	72	M	76	185	22.5	Normal	Minor	Null
Green Cove Springs	Left front	25	M	67	155	24.3	Normal	Minor	Null
Green Cove Springs	Right front	50	M	69	170	25.1	Overweight	None	Null
Green Cove Springs	Right rear	26	M	67	170	26.6	Overweight	None	No airbag
Steamboat Springs	Left front	57	M	71	190	26.5	Overweight	None	Null
Steamboat Springs	Right front	53	F	60	97	18.9	Normal	Minor	Minor harm
Steamboat Springs	Left rear	13	F	60	100	19.5	Normal	None	No airbag
Steamboat Springs	Right rear	15	F	61	110	20.8	Normal	None	No airbag
Stigler	Left front	18	M	72	165	22.4	Normal	Serious	No deployment
Stigler	Right front	43	F	63	125	22.1	Normal	Minor	No deployment
Stigler	Left rear	45	F	66	163	26.3	Overweight	Minor	No airbag
Boyd	Left front	24	M	70	142	20.4	Normal	Minor	Null

[a] Body mass index (BMI) classifications are based on guidelines from the World Health Organization. Information obtained from World Health Organization website <http://apps.who.int/bmi/index.jsp?introPage=intro_3.html> (accessed December 8, 2010).

[b] Injury definitions are taken from 49 CFR 830.2. Fatal injury means any injury that results in death within 30 days of the accident. Serious injury is defined as any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface. Minor injury is defined as any injury less than serious injury.

Chapter 5: Discussion

Impact energy management is an important factor in GA crash survivability. In aviation crashes, the aircraft fuselage, landing gear, and seats can all serve to dissipate impact energy that might otherwise be borne by the aircraft occupants. Restraints couple the occupant to the aircraft allowing the occupant to benefit from the structural energy dissipation during the impact. In the smaller aircraft used in GA operations, there is less structure, so a greater emphasis must be placed on the design of seats and restraints for this occupant protection. The addition of airbag systems has the potential to provide another means to dissipate kinetic energy and mitigate injury.

AmSafe, currently the sole manufacturer of GA airbag systems, has stated that its system is designed to preserve consciousness and reduce head injury in the event of a survivable crash. This study applied a case series methodology to survivable crashes involving airbag-equipped airplanes with the goals of evaluating the efficacy of GA airbag systems at mitigating occupant injury in real-life accident cases, identifying any potential unintentional negative consequences associated with airbag use, and developing methods to assist investigators in documenting airbag systems in future accidents. The study team collected data from multiple sources to provide the best possible understanding of crash dynamics and their effects on the airplane, cabin, seats, restraints, and occupants. The study team tracked 145 events involving airbag-equipped airplanes, 88 of which were accidents that comprised the entire population of accidents involving airbag-equipped airplanes in the United States during the 3-year study period.

Ten of the 88 GA airbag-equipped airplane accidents, involving 25 occupants, met the study criteria.[112] Seventeen of the 25 occupants were seated in seats with airbag-equipped restraint systems, and 12 of those occupants experienced airbag deployments as a result of the crash.

During the study period, it was important to establish whether these airbag systems caused any unintended harm as previously mentioned with the early introduction of airbags in the automotive fleet. Based upon investigations of 10 accidents, the NTSB concludes that there were no cases in which the airbags were expected to deploy but did not. The NTSB further concludes that there were no cases that involved airbags deploying under unexpected circumstances, and there was no evidence of airbags hindering egress, fueling postcrash fires, or interfering with rescue attempts. The discussion will therefore focus on (1) the efficacy of the airbag systems in mitigating occupant injury, (2) potential safety issues associated with misuse of restraint systems, and (3) future research concerning GA airbag systems and GA aircraft crashworthiness.

[112] As previously stated, events occurring in the United States were selected for inclusion in the study if they involved an airbag-equipped GA airplane and met any of the following criteria: (1) survivable accident in which an airbag deployed, (2) accident or incident with occupant injuries but no airbag deployment, (3) any event involving an inadvertent airbag deployment.

Effectiveness of GA Airbag Systems in Mitigating Occupant Injury

The aviation airbag systems evaluated in this safety study are designed to reduce head injury during a survivable crash. Furthermore, these restraint-mounted airbags are designed to provide protection primarily in forward impacts. In order to assess the effectiveness of airbag systems, it is important to take into consideration the fairly narrow range of crash types in which airbags might be expected to convey a safety benefit, specifically survivable accidents severe enough to cause injury.

In the current study, there were 88 accidents involving airbag-equipped airplanes and the team was able to make a definitive determination about both survivability and airbag deployment in 85 of those cases.[113] Within that sample, 19 of those cases (or about 22 percent) were determined to be nonsurvivable, meaning either that the forces transmitted to the occupants exceeded the limits of human tolerance or that the livable space within the cabin was compromised to a degree that did not allow for occupant survival. In an additional 56 accidents (about 66 percent) the crash forces were not severe enough to either deploy the airbag systems or to cause any crash-related injury. Therefore, there were only 10 accidents, or about 12 percent of those accidents tracked during this study, in which the crashes were severe enough to cause injury and/or to deploy the airbag, yet not so severe as to preclude survival. Those 10 accidents were subjected to a full investigation and case review by the study team.

Of the 10 accidents investigated and reviewed in this study, there were 3 accidents in which the airbag systems did not deploy, and the occupants sustained injuries ranging from minor to serious. In all three of those cases, the study team determined that the principal direction of force was vertical, either upward or downward, with insufficient deceleration in the longitudinal direction to deploy the airbags based on the airbag deployment criteria. Furthermore, in two of those cases, the team determined that the injuries that were sustained would likely not have been mitigated even if the airbags had deployed. However, in one case (Stigler, Oklahoma), the study team determined that although the airbag was not expected to have deployed, its deployment might have mitigated the left front occupant's facial injuries by cushioning the impact between his head and the vertically displaced control yoke.

There were 18 occupants involved in the 7 remaining survivable accidents in which the airbag systems deployed. Twelve of the 18 were seated in airbag-equipped seats in which the airbag systems deployed during the crash. For 9 of the 12 occupants, the team determined that the airbag systems did not do any harm and did not yield protection beyond what was provided by the restraint systems alone. In one case, in Steamboat Springs, Colorado, the airbag may have caused some minor facial injuries (a bloody nose and bruised chin); however, those injuries were likely a result of the occupant's incorrect adjustment of the 4-point restraint system. The other three occupants in the airplane were uninjured.

For 2 of the 12 occupants, the team determined that the airbag system likely mitigated injuries. The first case was the right front occupant in the Boyceville, Wisconsin, accident. In

[113] In two cases, the airplane wreckage was missing or had been destroyed by postcrash fire and could not be evaluated to determine survivability of the accident. In one additional case, wreckage documentation was incomplete because the accident was reported late to the NTSB.

that accident, the principal direction of force of the airplane was in the forward-longitudinal direction, resulting in occupant motion that was likely forward and to the right, which would have pushed the right front occupant toward the side yoke of the Cirrus SR22 airplane. The team determined that the occupant's chest and head likely made contact with the airbag and that this contact reduced the occupant's potential for injury from impacts on the yoke and interior surfaces. The occupant suffered minor injuries, none of which were on the right side of his body. The second case, which involved a Cessna 172S that crashed during takeoff in Fullerton, California, resulted in an airplane principal direction of force that was forward-longitudinal and occupant motion that was forward and to the right due to the approximately 90-degree pitch attitude and 90-degree right bank angle at the time of impact. The pilot sustained multiple serious injuries, but he maintained consciousness and was able to, with difficulty, egress from the airplane after the accident. The team determined that in the Fullerton accident, the airbag likely mitigated the severity of the pilot's injuries, especially in the region of his torso. Although there were some concerns that the airbag may have been offset to the pilot's right side due to his large waist size, the team determined that overall the airbag system likely benefitted the occupant.

Overall, based upon investigations of 10 accidents, the NTSB concludes that when occupants adjusted the restraint systems correctly, the airbag systems did not cause any negative outcomes, and in some cases with airbag deployment, they were associated with reductions in the severity of occupant injuries. The NTSB further concludes that aviation airbags can mitigate occupant injuries in severe but survivable crashes in which the principal direction of force is longitudinal.

Issues Associated With Restraint Systems

In the present study, the team discovered several potential safety issues associated with restraint design and/or the incorrect usage or adjustment of restraint systems. Some issues, such as improper use or adjustment of restraint systems, would be more likely to affect passengers who are less likely to be exposed to information about restraint adjustment during formal training. Other restraint design issues were more likely to affect large occupants, such as obese individuals or pregnant women.

Incorrect Usage or Adjustment of Restraint Systems

During the course of its investigations, the study team discovered two potential safety issues associated with the misuse or incorrect adjustment of restraint systems. One issue, mentioned previously, was documented during the Athens, Texas, investigation. In his interview, the pilot noted that at the beginning of the flight, the left front seat passenger had attempted to use the restraint for the right seat. In the Cessna T182T, both of the front seatbelts hang from the ceiling between the two seats. The pilot, who was also a certified flight instructor, noted that there had been other occasions when his students had inadvertently used the wrong restraint in either the Cessna 172 or Cessna 182. The study team documented the fact that in Cessna-manufactured airplanes, it is possible to cross the restraints in such a way that the incorrect airbag system can become activated. For example, if a left-seated occupant fastened the right seat shoulder harness to his or her outboard buckle, the airbag system in the unused restraint would be active while the airbag in the buckled restraint would be inactive.

The second issue, discovered during the Steamboat Springs, Colorado, investigation, involved restraint- and airbag-related minor injuries that likely resulted from improper adjustment of the 4-point restraint system in a Cirrus airplane. In that case, the right front occupant, a 5 foot tall, 97 pound female, experienced a bloody nose and chin bruises, likely due to contact with the airbag. The occupant also had bruises on her chest between her 3rd and 4th ribs near her sternum. The occupant reported that the bruise occurred in the location of the restraint buckle. The buckle of a properly adjusted 4-point restraint system should rest low on the pelvis, not at the sternum. In the accident, both rear seat restraints, which were not airbag-equipped, had load marks that suggested that they may also have been adjusted incorrectly because the load marks were inconsistent with the very small size and stature of the occupants. A subsequent interview with the front right seat occupant from this accident confirmed that she believed that the buckle was supposed to rest at the mid-chest region rather than at the pelvis.

Title 14 CFR 91.107 states that before each takeoff, the pilot must brief occupants on how to correctly fasten and unfasten their safety belts and, if installed, shoulder harnesses. Before moving the aircraft, pilots must also notify all occupants to fasten the restraints. Additionally, some manufacturers include guidance about proper use of restraint systems in their pilot operating handbook, or with a placard; however, this study suggested that in spite of the regulations and guidance, some occupants still used their restraints incorrectly.

The NTSB concludes that some GA occupants have misused or incorrectly adjusted their restraints in ways that could reduce the protection conveyed by the restraints or lead to injuries. Therefore, the NTSB recommends that the FAA revise the guidance and certification standards concerning restraint systems to recognize and prevent potential misuse scenarios, including those documented in this safety study. For example, the FAA should consider modifying the Technical Standard Order (TSO) C114, issued March 27, 1987, for restraints to include a usability evaluation component for any newly proposed designs.

Restraint Design Issues Affecting Nonnormative Populations

In the Fullerton, California, accident, the airbag embedded in the lap portion of the 3-point restraint system may have been out of optimal position because of the occupant's large waist size. If the size of an occupant causes the airbag to be positioned off to one side, the airbag may not provide full protection for the occupant's head and torso. Although it is unlikely that the offset airbag position would lead to any harmful outcomes in itself, it may reduce airbag effectiveness for large-sized individuals or pregnant women.

Another restraint-related safety issue concerned egress from inverted airplanes. In several cases, egress from inverted airplanes was reported to be problematic, likely due to the additional weight being placed on the restraints by the occupants' bodies. In the case of 3-point restraint systems, the difficulty may be exacerbated for large or obese individuals because of having to reach to the buckle located near the occupant's hip.

More than one-third of the occupants involved in the study accidents had body mass indices (BMIs) of 25 or higher and were classified as either overweight or obese. In the introduction to the special conditions set by the FAA for the certification for airbag-equipped restraints, the following is noted:

> It is possible a wide range of occupants will use the inflatable restraint. Thus, the protection offered by this restraint should be effective for occupants that range from the fifth percentile female to the ninety-fifth percentile male.

Neither the introduction nor the special conditions explain how the restraint effectiveness should be evaluated for the range of occupants noted, and the range is not adequately defined. No testing is mandated, and no written guidance is provided for manufacturers to comply with the statement above. The average age of the GA accident-involved pilot in 2005 was 50; it was higher for pilots engaged in noncommercial operations.[114] The 95th percentile weight for 50- to 59-year-old males in the United States is 260 pounds, and the 95th percentile waist circumference for that same group is 51 inches.[115] The NTSB questions whether the airbag-equipped restraints were designed or tested with this population in mind. The required emergency landing conditions testing in 14 CFR 23.562 was established in 1988. Anthropometric data gathered around that same time indicated the average weight for adult males (of all ages) was just over 180 lbs, and the average waist circumference was 37.5 inches;[116] more recent data indicate that average weight and waist circumference for that population has increased to just under 195 pounds and more than 39.5 inches.[117] The testing in 14 CFR 23.562 refers only to a NHTSA- or FAA-approved ATD with a nominal weight of 170 pounds. That weight is 20 pounds less than the average flight crewmember weight cited in the FAA Advisory Circular (AC) 120-27D, issued August 11, 2004, regarding aircraft weight and balance control, which derived its average from weights listed on all first and second class FAA medical certificates.[118]

The NTSB concludes that certain aviation airbag restraint configurations do not provide optimal protection for occupants whose anthropomorphic characteristics are substantially dissimilar to those of the ATD required for restraint testing. Given the lack of guidance in the special conditions, and the lack of a clear definition of the 5th percentile female and 95th percentile male referenced therein, the NTSB recommends that the FAA modify the special conditions for the installation of inflatable restraints on GA airplanes (at *Federal Register*, vol. 73, no. 217 [November 7, 2008], p. 66163) to provide specific guidance to manufacturers as to how they should demonstrate that the protection is effective for occupants that range from the 5th percentile female to the 95th percentile male. As part of that process, the FAA should consider gathering and evaluating the anthropometric data as a means to provide additional guidance to manufacturers about the anthropometric distribution of the GA occupant population.

[114] *Annual Review of Aircraft Accident Data: U.S. General Aviation, Calendar Year 2005*, Annual Review of U.S. General Aviation NTSB/ARG-09/01 (Washington, DC: National Transportation Safety Board) <http://www.ntsb.gov/publictn/2009/ARG0901.pdf>.

[115] M.A. McDowell and others, "Anthropometric Reference Data for Children and Adults: United States, 2003–2006," *National Health Statistics Reports*, October 22, no. 10 (2008) <http://www.cdc.gov/nchs/data/nhsr/nhsr010.pdf>.

[116] M.A. McDowell and others, "Anthropometric Reference Data for Children and Adults: United States, 1988–1994," *Vital and Health Statistics*, April, Series 11, no. 249 (2009) <http://www.cdc.gov/nchs/data/series/sr_11/sr11_249.pdf>.

[117] M.A. McDowell and others, "Anthropometric Reference Data for Children and Adults: United States, 2003–2006," *National Health Statistics Reports*, October 22, no. 10 (2008) <http://www.cdc.gov/nchs/data/nhsr/nhsr010.pdf>.

[118] GA pilots are only required to have a third class medical certificate.

Small children are another group of occupants that could be affected by restraint and airbag designs in GA airplanes. Although there were no children under age 13 in the accidents investigated for this study, in the Cessna aircraft involved in the Stigler, Oklahoma, accident, auxiliary buckles were available for fastening child restraint systems. In Cirrus aircraft, use of child restraint systems is prohibited in seat locations with airbags. Additional compatibility issues may exist between child restraint systems and GA restraint systems. Child restraint compatibility issues and several other child passenger safety issues were recently discussed at an NTSB Public Forum on Child Passenger Safety in the Air and in Automobiles.[119] During that forum, participants discussed areas for future improvements for child passenger safety, including panel discussions specifically addressing child passenger safety onboard GA aircraft.

Shoulder Harness Use

Although the current study showed that airbags in GA airplanes can mitigate occupant injury in certain cases, because of the small number of accidents analyzed and the even smaller number of cases in which beneficial effects were noted, the study does not provide strong enough support to recommend that airbags be installed on all GA aircraft. However, as discussed previously, a new NTSB analysis has provided definitive evidence that lap belt/shoulder harness use consistently reduces the risk of pilot fatal or serious injury when compared to lap belt use alone.[120] The risk of fatal or serious injury with a lap belt alone was nearly 50 percent higher than with lap belt/shoulder harness combination. The benefits conveyed by shoulder harnesses were significant for multiple subgroups within the larger sample.

In terms of flight characteristics, there were several interaction effects found in which risk of fatal or serious injury was varied as a function of another variable. For example, in accidents that occurred during takeoff or landing, for those that did not involve in-flight or postcrash fires, and for those that did not involve a loss of control in flight, the benefits conferred by shoulder harness use was significantly higher than in accidents that occurred in flight, involved fires, or involved a loss of control in flight. The likely reason for this finding is that those accidents that involve fire or loss of control or that occur when in flight are more likely to be extremely severe, nonsurvivable accidents. However, it is important to note that even within those severe categories, the significant benefit of shoulder harness use in reducing fatal or serious injury was still present, as denoted by the fact that the confidence intervals in all categories were greater than 1. Based on these findings, the NTSB concludes that lap belt/shoulder harness combinations provide significant protection beyond a lap belt alone, and fatalities and injuries would be reduced if lap belt/shoulder harness combinations were used in all GA airplanes.

In 1977, the NTSB recommended that the FAA require the installation of shoulder harnesses on aircraft manufactured before 1978;[121] however, the FAA never took steps to require

[119] See www.ntsb.gov/children

[120] See section titled "Research Methods and NTSB Research" in Chapter 1 of this report.

[121] See Safety Recommendation A-77-71.

retrofitting of aircraft not equipped with shoulder harnesses. In its final correspondence[122] to the FAA concerning the recommendation, the NTSB noted that the FAA had used, as its explanation for not requiring retrofits, the argument that there was insufficient justification to impose additional cost on owners of older aircraft. In response, the NTSB stated:

> Since the benefits of shoulder harnesses have been proven, the position that there is insufficient justification to impose the additional cost of modification on the owners of pre-1978 general aviation airplanes is unreasonable, and exposes the occupants of these airplanes to undue risk.
>
> We are aware that the FAA is preparing an Advisory Circular to discuss shoulder harness installation criteria and installation guidelines. Although this action may foster shoulder harness retrofit in some pre-1978 airplanes, it does not satisfy the intent of this old recommendation which we are now classifying in a "Closed—Unacceptable Action" status.

On June 4, 1993, the FAA issued Advisory Circular (AC) 21-34[123] to provide information and guidance for the "installation of shoulder harness and safety belt restraint systems at all seat locations on all previously type certificated aircraft." The advisory circular emphasizes the safety benefits associated with installing lap belt/shoulder harness combinations, stating that "they can prevent serious head, neck and upper torso injuries in what may be relatively minor accidents in terms of aircraft damage, and they can prevent irreversible or fatal injuries in more severe accidents."

Despite the guidance provided in the advisory circular and FAA's promotion of shoulder harnesses,[124] there are a substantial number of GA airplanes flying today that have not been retrofitted with shoulder harnesses. A detailed review of NTSB pilot reports[125] from accidents involving nonamateur built airplanes with single reciprocating engines for the calendar year 2008 revealed that 122 of 923 (13 percent) did not have shoulder harnesses installed. This proportion likely underestimates the total number of airplanes without shoulder harnesses installed because pilot reports were missing or incomplete in an additional 123 cases (13 percent). Therefore, the NTSB recommends that the FAA require the retrofitting of shoulder harnesses on all GA airplanes that are not currently equipped with such restraints in accordance with Advisory Circular (AC) 21-34, issued June 4, 1993.

For airplane owners who would like to voluntarily retrofit their airplanes to have shoulder harnesses, the FAA provides resources on its website,[126] including links to shoulder harness kit

[122] P.A. Goldman, National Transportation Safety Board, letter (regarding Safety Recommendation A-77-71) addressed to D.D. Engen, Federal Aviation Administration, July 1, 1986.

[123] FAA Advisory Circular (AC) 21-34, issued June 4, 1993.

[124] See, for example, the pamphlet titled *Seat Belts and Shoulder Harnesses: Smart Protection in Small Airplanes*, AM-400-91/2 (Oklahoma City, OK: U.S. Department of Transportation, Federal Aviation Administration, Aeromedical Education Division, 1991).

[125] See NTSB Form 6120.1, "Pilot/Operator Aircraft Accident/Incident Report." A copy of the form may be obtained from the NTSB website at <http://www.ntsb.gov/aviation/6120_1.pdf>.

[126] See information on the FAA website <http://www.faa.gov/aircraft/gen_av/harness_kits/> (accessed November 26, 2010).

manufacturers as well as several policy and advisory circulars to provide support to those who wish to install shoulder harnesses. In addition, since 2007, AmSafe has offered retrofit kits for its airbag-equipped restraint systems.[127]

Future Aviation Occupant Protection Research

Future research efforts should focus on protecting occupants under a broader range of circumstances. For example, in 4 of the 10 accidents detailed in this study, the principal direction of force was vertical. In vertical-downward impacts, the landing gear, airplane floor, crushable seat cushions/pans, and stroking space beneath the seat are currently the primary means of absorbing vertical energy. In vertical-upward impacts, the airplane roof is the only structure between the occupants and the exterior impact surface. As shown in this study, such impacts can result in serious head, neck, and spinal injuries. For example, in the Indianapolis, Indiana, investigation described previously, the majority of occupant injuries, including spinal injuries for all four occupants, resulted from the vertical deceleration of the airplane. Further, for the front seat occupants, the placement of a skywatch box and an air conditioning unit under the respective seats likely exacerbated the occupants' spinal injuries by reducing the stroking space for the seats.

Additional protection from vertical or lateral impacts could also be addressed through efforts to minimize accelerations applied to the occupants. For example, the CAPS aircraft parachute system, described earlier, is designed to slow the descent of an airplane when manually deployed in emergency situations. Additionally, it should be noted that airbag systems that are designed to provide occupant protection from nonfrontal impacts are currently available in the automotive environment.

Occupant safety in the automotive environment has benefited greatly from technology that captures and stores information such as precrash data, crash data, and airbag deployment data. As early as 1974, General Motors production vehicles equipped with airbags have had the ability to record airbag status and crash severity for deployment events.[128] More recent General Motors vehicles capture information both preceding and during a deployment or near-deployment event. By studying this real-world crash information alongside occupant injury data and other postcrash observations, automotive manufacturers have been able to improve many aspects of occupant safety including airbag design, vehicle crashworthiness, and advanced restraint systems.

Like early automotive airbags, the GA airbag systems observed in this study employed a mechanical mass-spring-damper type sensor, a design that does not capture and record crash severity or airbag deployment information. However, having recorded airbag data in the aviation environment could not only provide detailed information about airbag performance, but could also lead to advances in GA occupant safety by enhancing our understanding of aircraft crash dynamics and survivability of aviation accidents in general.

[127] Information obtained from AmSafe website <http://www.amsafe.com/products/detail.php?id=68&type=categories> (accessed November 26, 2010).

[128] A. Chidester and others, "Recording Automotive Crash Event Data," *International Symposium on Transportation Recorders*, National Transportation Safety Board, Arlington, Virginia, May 3–5, 1999.

In addition to studying detailed recorded information that can be gathered in individual crashes, automotive safety research has also benefitted from conducting larger scale aggregate comparisons of vehicles with various safety features. Such research, which employed crash data from Federal databases and vehicle information from public and private vehicle databases, was used to evaluate the effectiveness of automotive frontal airbags in general and to determine that second generation airbags, or “depowered” airbags, mitigated injury risk for children without adversely affecting other occupants.[129] The NTSB’s recent analysis evaluating the efficacy of shoulder harnesses in GA accidents over a multiyear period showed that shoulder harnesses have had a significant effect on reducing injuries sustained by GA pilots.

As the GA fleet becomes increasingly equipped with airbag systems, future research should continue to track the efficacy of such systems, both through detailed investigations and through larger controlled studies. With respect to improving the detailed information that could be gathered in individual investigations, the NTSB concludes that the understanding of aircraft crash dynamics and occupant safety would be improved if airbag-equipped aircraft recorded, at a minimum, data concerning crash dynamics and airbag deployment criteria. Although existing airbag system designs do not support this capability, the NTSB believes that such capability should be considered in future airbag designs to facilitate postcrash airbag evaluations. Therefore, the NTSB recommends that the FAA evaluate the potential safety benefits and feasibility of requiring airbag-equipped aircraft to have the capability to capture and record, at a minimum, data concerning crash dynamics and airbag deployment criteria that can be reviewed after a crash to determine whether the system performed as designed.

During the present study, the NTSB relied on AmSafe, the airbag manufacturer, to provide lists of airbag-equipped aircraft. AmSafe similarly relies on individual airplane manufacturers to provide it with information, such as serial and registration numbers of airplanes that have airbag systems installed. When an owner decides to retrofit an airbag system to his or her aircraft, the installer is required to report the installation to the FAA; however, the NTSB is aware that this information is not always shared or recorded accurately. As new inflatable restraint manufacturers come into the market, it will become even more challenging to track which aircraft are equipped with such systems. Although the inability to track the installation of safety equipment on individual aircraft is unlikely to present a safety hazard, tracking such information may lead to a better understanding of the use and efficacy of such systems.

In the automotive industry, a unique identifier, known as the vehicle identification number (VIN), is given to each motor vehicle. The VIN is a code that provides information about the vehicle year of manufacture, manufacturer, model, and other vehicle attributes. Using this information and information from state and Federal crash databases, researchers have been able to conduct studies about the relationship between certain automotive design features and the likelihood of crashes or crash outcomes. Such a database for aviation could greatly improve understanding of the effectiveness of emerging aviation safety features, particularly if it is linked to the FAA’s existing aircraft registry database. The NTSB concludes that future evaluations of

[129] See, for example, (a) C.J. Kahane, *Fatality Reduction by Air Bags: Analyses of Accident Data Through Early 1996*, DOT HS 808 470 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1996). (b) E.R. Braver and others, “Reductions in Deaths in Frontal Crashes Among Right Front Passengers in Vehicles Equipped with Passenger Air Bags,” *Journal of the American Medical Association*, vol. 278, no. 17 (1997) pp. 1437–1439.

the effectiveness of occupant protection features, such as restraint systems, airbags, and parachutes, would benefit from the establishment of a system to provide information about what aircraft safety equipment is installed on individual aircraft. Therefore, the NTSB recommends that the FAA develop a system to track individual aircraft information about aircraft safety equipment, such as restraint systems, airbags, aircraft parachutes, and other specific aircraft equipment, designed to improve crash outcomes.

Guidance for Documenting Airbag Systems in Future Investigations

One of the goals of this study was to develop procedures to assist investigators in documenting airbag systems in future investigations. Based on the work that was conducted in this study, the team created a short data collection form to assist investigators with this documentation. The form includes fields to document information about the aircraft cabin, seats, restraints, airbag deployment, and airbag condition. It also guides investigators in collecting information about occupant demographics and injuries. Finally, it provides contact information so that investigators can contact subject matter experts for additional tests and documentation as necessary.

In addition to creating this form to aid investigators in documenting airbag systems, the NTSB has also modified its aviation accident/incident database to include data on whether an accident aircraft was equipped with airbags and whether the airbags deployed in the accident. The form that pilots fill out after an accident (NTSB Form 6120.1) has also been modified to elicit similar information about airbag systems.

Conclusions

Findings

1. Based upon investigations of 10 accidents, there were no cases in which the airbags were expected to deploy but did not.

2. There were no cases that involved airbags deploying under unexpected circumstances. Based upon investigations of 10 accidents, there was no evidence of airbags hindering egress, fueling postcrash fires, or interfering with rescue attempts.

3. Aviation airbags can mitigate occupant injuries in severe but survivable crashes in which the principal direction of force is longitudinal.

4. Based upon investigations of 10 accidents, the airbag systems did not cause any negative outcomes when occupants adjusted the restraint systems correctly, and in some cases with airbag deployment, they were associated with reductions in the severity of occupant injuries.

5. Some general aviation occupants have misused or incorrectly adjusted their restraints in ways that could reduce the protection conveyed by the restraints or lead to injuries.

6. The 3-point restraint systems in certain Cessna Aircraft Company airplanes can be reversed by occupants in such a way that the airbag and restraint systems are not used as designed and certified.

7. Certain aviation airbag restraint configurations do not provide optimal protection for occupants whose anthropomorphic characteristics are substantially dissimilar to those of the anthropomorphic test dummy required for restraint testing.

8. Lap belt/shoulder harness combinations provide significant protection beyond a lap belt alone, and fatalities and injuries would be reduced if lap belt/shoulder harness combinations were used in all general aviation airplanes.

9. The understanding of aircraft crash dynamics and occupant safety would be improved if airbag-equipped aircraft recorded, at a minimum, data concerning crash dynamics and airbag deployment criteria.

10. Future evaluations of the effectiveness of occupant protection features, such as restraint systems, airbags, and parachutes, would benefit from the establishment of a system to provide information about what aircraft safety equipment is installed on individual aircraft.

Recommendations

As a result of this safety study, the National Transportation Safety Board makes the following recommendations:

To the Federal Aviation Administration:

Require Cessna Aircraft Company and other manufacturers whose restraint system designs permit an occupant to use an inactive airbag restraint system not intended for use in his or her seat to modify their restraint system designs to eliminate that possibility, and require them to modify restraint systems in existing airplanes to eliminate the possibility of misuse. (A-11-1)

Revise the guidance and certification standards concerning restraint systems to recognize and prevent potential misuse scenarios, including those documented in this safety study. (A-11-2)

Modify the special conditions for the installation of inflatable restraints on general aviation airplanes (at *Federal Register*, vol. 73, no. 217 [November 7, 2008], p. 66163) to provide specific guidance to manufacturers as to how they should demonstrate that the protection is effective for occupants that range from the 5th percentile female to the 95th percentile male. (A-11-3)

Require the retrofitting of shoulder harnesses on all general aviation airplanes that are not currently equipped with such restraints in accordance with Advisory Circular (AC) 21-34, issued June 4, 1993. (A-11-4)

Evaluate the potential safety benefits and feasibility of requiring airbag-equipped aircraft to have the capability to capture and record, at a minimum, data concerning crash dynamics and airbag deployment criteria that can be reviewed after a crash to determine whether the system performed as designed. (A-11-5)

Develop a system to track individual aircraft information about aircraft safety equipment, such as restraint systems, airbags, aircraft parachutes, and other specific aircraft equipment, designed to improve crash outcomes. (A-11-6)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: January 11, 2011

Appendix A: National Transportation Safety Board Safety Recommendation Status Key and Safety Recommendations Concerning General Aviation Occupant Protection

National Transportation Safety Board Safety Recommendation Status Key	
Status	**Status Definition**
C-EX	*Closed—Exceeds Recommended Action:* Response by recipient indicates action on the safety recommendation has been completed. The action taken surpasses what the NTSB envisioned.
C-AA	*Closed—Acceptable Action:* Response by recipient indicates action on the safety recommendation has been completed. The action complies with the safety recommendation.
C-AAA	*Closed—Acceptable Alternate Action:* Response by recipient indicates an alternate course of action has been completed that meets the objective of the safety recommendation.
C-UA	*Closed—Unacceptable Action:* Response by recipient expresses disagreement with the need outlined in the recommendation. There is no further evidence to offer, and the NTSB concludes that further correspondence on, or discussion of, the matter would not change the recipient's position. This status can also be used when the timeframe goals outlined in this order have not been met.
C-UAN	*Closed—Unacceptable Action/No Response Received:* No response to the recommendation was ever received.
C-R	*Closed—Reconsidered:* Recipient rejects the safety recommendation and supports this rejection with a rationale with which the Board concurs. Reasons for the "Reconsidered" status would include situations where the recipient is able to convince the Board that the proposed action would not be effective or that it might create other problems. This status is also assigned when the recipient of a recommendation was in compliance before the recommendation was issued or when the recipient was incorrectly chosen and cannot perform the recommended action.
C-NLA	*Closed—No Longer Applicable:* The recommended action has been overtaken by events. For example, if technology and/or regulatory action has eliminated the reason for the recommendation or if a company has gone out of business.
C-S	*Closed—Superseded:* Applied to recommendations held in an open status when a new, more appropriate safety recommendation is issued that includes the necessary elements of the recommendation to be closed.
C-AAS, C-AAAS, C-UAS	*Closed—Acceptable/Acceptable Alternate/Unacceptable Action Superseded:* Applied to recommendations held in an open status when a new, more appropriate safety recommendation is issued that includes the necessary elements of the recommendation to be closed. The Board determines the Acceptable/Acceptable Alternate/Unacceptable status based on the criteria defined above prior to superseding the recommendation.
O-AA	*Open—Acceptable Response:* Response by recipient indicates a planned action that would comply with the safety recommendation when completed.

National Transportation Safety Board Safety Recommendation Status Key	
Status	**Status Definition**
O-AAR	*Open—Acceptable Alternate Response:* Response by recipient indicates an alternate plan or implementation program that would satisfy the objective of the safety recommendation when implemented.
O-UA	*Open—Unacceptable Response:* Response by recipient expresses disagreement with the need outlined in the recommendation or attempts to convince the Board (unsuccessfully) that an alternative course of action is acceptable. The Board believes, however, that there is enough supporting evidence to ask the recipient to reconsider its position. This status can also be used when the Board believes that action is not being taken in a timely manner.
O-RR	*Open—Response Received:* Response has been received from recipient, but staff evaluation of the response has not been approved by the Board Members.
O-AR	*Open—Await Response:* When a safety recommendation is issued, the status "Open—Await Response" is automatically assigned.

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection

Number	Recipient	Year Issued	Year Closed	Status	Recommendation
A-70-042	FAA	1970	1989	C-AA	Several Recommendations: Shoulder harnesses should be required on all general aviation aircraft at the earliest practical date. Delethalization of aircraft interiors suitable energy absorbing padding required on all interior structures to protect occupants. Dynamic testing of seats. Raise "minor crash landing" inertia forces of FAR 23.561. crash fire protection—materials used in aircraft interiors should not support a self-sustained combustion.
A-73-106	FAA	1973	1984	C-AA	Amend CFR 91 to require the installation of shoulder harnesses at flight deck stations on large aircraft which operate under this part.
A-77-070	FAA	1977	1986	C-AA	Amend 14 CFR 23.785 to require installation of approved shoulder harnesses at all seat locations as outlined in NPRM 73-1
A-77-071	FAA	1977	1986	C-UA	Amend 14 CFR 91.33 and .39 to require installation of approved shoulder harnesses on all general aviation aircraft manufactured before July 18, 1978 , after a reasonable lead time, and at all seat locations as outlined in NPRM 73-1 (retrofit recommendation)

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	Recipient	Year Issued	Year Closed	Status	Recommendation
A-80-125	FAA	1980	1986	C-AA	Require that those GA aircraft manufactured to include attachment points for shoulder harnesses at occupant seats befitted with shoulder harnesses no later than December 31, 1985, and, in the interim, require this modification as a requisite for change in FAA registration.
A-80-126	FAA	1980	1994	C-AA	Develop, in coordination with airframe manufacturers, detailed, approved installation instructions for installing shoulder harnesses at each seat location in current models and types of GA aircraft in which shoulder harness attachment points were not provided as standard equipment. Publish and provide these instructions to owners of these aircraft by December 31, 1982.
A-80-127	FAA	1980	1986	C-AA	Require that those GA aircraft for which FAA-approved harness installation instructions have been developed be fitted with shoulder harnesses no later than December 31, 1985, and, in the interim, require this modification as a requisite for change in FAA registration.
A-80-128	FAA	1980	1986	C-AA	At established intervals, extend the application of all newly established occupant protection provisions of 14 CFR 32 to all newly manufactured general aviation aircraft.
A-80-129	FAA	1980	1984	C-UA	Revise 14 CFR 23.785(J) to incorporate performance standards and test criteria to insure that an acceptable level of occupant safety is achieved through cabin “delethalization”
A-80-130	FAA	1980	1989	C-AA	Revise current standards for seat and restraint systems to incorporate needed crashworthiness improvements indentified in FAA research project reports
A-80-131	FAA	1980	1989	C-AA	Establish standards for the dynamic testing of occupant protection devices required in general aviation aircraft.
A-81-044	FAA	1981	1981	C-AA	Immediately issue a General Aviation Airworthiness Alert warning Decathalon owners of the potential hazards to aerobatic flight when they modify Decathalon Acrobatic restraint systems by attaching the shoulder harness to the seatpan frame and/or route the shoulder straps behind the seatback.
A-81-045	FAA	1981	1981	C-AA	Issue an Airworthiness Directive revising the Bellanca Decathalon FAA approved flight manual for aircraft manufactured prior to 1977 to include the relevant cautionary information of section2.1.9, “occupant restraint systems,” which is contained in subsequent approved flight manuals. An accurate description of the proper installation of the restraint systems should be included.

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	Recipient	Year Issued	Year Closed	Status	Recommendation
A-81-016	FAA	1981	1986	C-AA	Require the Cessna aircraft company to include an adjustment and locking check of front seats, belts, and shoulder harnesses on the “before takeoff” checklists applicable to all Cessna aircraft. This item should be included on new checklists as soon as possible.
A-84-064	Ayres Corp	1984	1987	C-AA	Issue a mandatory service bulletin for Aero Commander, S2R agricultural airplanes.. that would require the installation of a doubler that adequately distributes shoulder harness crash loads to prevent the tearing of the aft cockpit bulkhead structure.
A-85-122	FAA	1985	1989	C-AA	Amend 14 CFR Part 23 to specify performance standards for the seat/restraint systems in small airplanes consistent with the standards proposed by the General Aviation Safety Panel; and require the multiaxis dynamic testing of seat/restraint systems as necessary to demonstrate energy management in the vertical direction and structural adequacy in the longitudinal and lateral directions
A-85-123	FAA	1985	1985	C-AAA	Amend 14 CFR Part 91 and Part 135 to require that all occupants of small airplanes use shoulder harnesses for takeoff and landing when they are available in the airplane.
A-85-124	FAA	1985	1986	C-AA	Issue an Advisory Circular to provide pilots, passengers, and maintenance personnel with information regarding the crash survivability aspects of small airplanes. The Advisory Circular should contain, as a minimum, discussion of the benefits of using lap belts and shoulder harnesses during all phases of flight, discussion of the hazards of modifying seats, appendages to seats, and stowage of articles in space designed or available for energy management, and discussion of the need for regular inspection and maintenance of seats.
A-85-125	FAA	1985	1986	C-UA	Issue a series of airworthiness directives to require modification of seats installed in general aviation airplanes which have identified deficiencies. For example, require the replacement of the 1/8 inch diameter lap belt attachment cable on applicable airplanes with a cable of strength more compatible with the seat design, require replacement of plastic-type seatpans on applicable airplanes with a structural seatpan, and require additional stabilizing support on seats using “S”-shaped springs for the seatpans
A-85-126	GAMA	1985	1986	C-AA	Encourage its members to evaluate the design of the seat/restraint systems in those models of airplanes in wide use to identify additional weaknesses which could be easily correctable. Definitive actions should be taken to implement the corrections, including installing the many modifications and retrofit kits that are presently available for the installation of shoulder harnesses and for the strengthening of seat feet.

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	**Recipient**	**Year Issued**	**Year Closed**	**Status**	**Recommendation**
A-85-117	FAA	1985	1993	C-AA	Amend 14CFR91.7(B) to require that during takeoff and landing each required flight crewmember of a US registered civil aircraft keep the shoulder harness fastened while at his station.
A-85-070	FAA	1985	1993	C-AA	Amend 14 CFR Parts 27 and 29 to require that all helicopters manufactured after 12/31/1987 have shoulder harnesses installed at all seat locations
A-88-008	FAA	1988	1992	C-UA (no response)	Require that shoulder harnesses be installed at all medical personnel and passenger seats on all helicopters when they are newly modified for emergency medical service (EMS) operations or when an existing EMS helicopter undergoes major interior modification or overhaul
A-88-009	FAA	1988	1990	C-UA	Require that those personnel classified as required crewmembers operating emergency medical service helicopters wear protective clothing and equipment to reduce the chance of injury or death in survivable accidents. This clothing and equipment should include protective helmets, flame-and-heat resistant flight suits and protective footwear.
A-88-014	American Society of Hospital Based Emergency Aeromedical Services	1988	1990	C-AA	Encourage members who operate EMS programs to provide medical personnel who routinely fly EMS helicopter missions with protective clothing and equipment to reduce the chance of injury or death in survivable accidents.
A-90-078	FAA	1990	1995	C-UA	Revise 14 CFR 91, 121, and 135 to require that all occupants be restrained during takeoff, landing, and turbulent conditions, and that all infants and small children below the weight of 40 pounds and under the height of 40 inches be restrained in an approved child restraint system appropriate to their height and weight.
A-90-079	FAA	1990	1995	C-AA	Conduct research to determine the adequacy of aircraft seatbelts to restrain children too large to use child safety seats and to develop some suitable means of providing adequate restraint for such children.

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	**Recipient**	**Year Issued**	**Year Closed**	**Status**	**Recommendation**
A-93-106	FAA	1993	1996	C-AA	Amend 14 CFR Parts 91, 121, and 135 to prohibit two or more persons from using a safety belt that is designed for one person, regardless of age.
A-93-107	FAA	1993	1995	C-AA	Begin an education campaign to inform general aviation pilots of the benefits of using child restraint systems, and the danger associated with using a safety belt designed for one occupant to restraint two persons.
A-93-108	GAMA	1993	1998	C-AA	Encourage its members to include information about the use of child restraint systems on general aviation aircraft in passenger briefing cards, pilot operating handbooks, and approved flight manuals.
A-93-108	Aircraft Owners and Pilots Association	1993	1998	C-AA	Inform its membership of the dangers associated with using a seatbelt designed for one occupant to restrain two persons, and the benefits of using FAA-approved child restraint systems on aircraft.
A-94-146	National Agricultural Aviation Association	1994	1995	C-AA	Notify members who operate aerial application aircraft of the Safety Board's findings and recommendations regarding the use of a 4-point or 5-point restraint system that allows the safety belt and shoulder harness straps to fall away simultaneously from the seat occupant when released.
A-94-122	Aviation Insurance Association	1994	1998	C-UA (no response)	Encourage its member aviation insurance underwriters to provide reduced insurance premiums to airplane owners who equip their airplanes with shoulder harnesses at all seats
A-94-123	Aircraft Owners and Pilots Association	1994	1998	C-UA (no response)	Encourage its member aviation insurance underwriters to provide reduced insurance premiums to airplane owners who equip their airplanes with shoulder harnesses at all seats

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	Recipient	Year Issued	Year Closed	Status	Recommendation
A-94-018	FAA	1994	2000	C-AAA	Amend 14 CFR 91.30 to require each parachutist or other passenger who is seated on an aircraft cabin floor to use restraint systems. The restraint system must be designed, tested, and approved to provide a level of occupant protection similar to that provided for passengers in forward and aft facing seats that have a safety belt and shoulder harness
A-94-017	FAA	1994	2001	C-UA	In conjunction with industry, USPA, and CAMI, provide for the seating of parachutists to assure an adequate level of crash energy absorption in the event of a survivable aircraft accident.
A-94-023	USPA	1994	2001	C-UA	Participate in the design, development and testing of seating for parachutists that would provide an adequate level of crash energy absorption in the event of a survivable aircraft accident
A-95-051	FAA	1995	2006	C-UA	Revise 14 Code of Federal Regulations Part 91, 135 and 121 to require that all occupants be restrained during takeoff, landing, and turbulent conditions, and that all infants and small children be restrained in a manner appropriate to their size.
A-08-071	FAA	2008	Open	O-AR	Conduct research, in conjunction with the United States Parachute Association, to determine the most effective dual-point restraint systems for parachutists that reflects the various aircraft and seating configurations used in parachute operations.
A-08-072	FAA	2008	Open	O-AR	Once the most effective dual-point restraint systems for parachutists are determined, as requested in Safety Recommendation A-08-71, revise Advisory Circular 105-2C, Sport Parachute Jumping, to include guidance information about these systems.
A-08-073	USPA	2008	Open	O-AR	Work with the Federal Aviation Administration to conduct research to determine the most effective dual-point restraint systems for parachutists that reflects the various aircraft and seating configurations used in parachute operations.

National Transportation Safety Board Safety Recommendations Concerning General Aviation Occupant Protection					
Number	**Recipient**	**Year Issued**	**Year Closed**	**Status**	**Recommendation**
A-08-074	USPA	2008	Open	O-AR	Once the most effective dual-point restraint systems for parachutists are determined, as requested in Safety Recommendation A-08-71, educate your members on the findings and encourage them to use the most effective dual-point restraint systems.
A-10-121	FAA	2010	Open	O-AR	Amend 14 *Code of Federal Regulations* Part 91 to require separate seats and restraints for every occupant.
A-10-122	FAA	2010	Open	O-AR	Amend 14 *Code of Federal Regulations* Part 91 to require each person who is less than 2 years of age to be restrained in a separate seat position by an appropriate child restraint system during takeoff, landing, and turbulence.

Appendix B. Shoulder Harness Analysis

Injury Reduction from Shoulder Harness Use in General Aviation Airplane Accidents

Background

Since 1970, the National Transportation Safety Board (NTSB) has issued more than 30 recommendations concerning general aviation (GA) occupant safety, many of which have focused on the design, installation, testing, and use of shoulder harnesses. Additionally, a 1985 safety study[1] conducted by NTSB looked at 535 accidents in which at least one occupant was fatally or seriously injured. It found that shoulder harnesses were available for only 40 percent of occupants in those accidents and that only 40 percent of occupants used the shoulder harnesses that were available, resulting in a total usage rate of 16 percent. The report estimated that about 20 percent of the occupants who were fatally injured could have survived if they had worn shoulder harnesses and 88 percent of those who experienced serious injury would have had their injures mitigated by using shoulder harnesses.

In 1977, the Federal Aviation Administration (FAA) published an amendment to Title 14 *Code of Federal Regulations* (CFR) Part 23 that required shoulder harness installations in all newly manufactured GA aircraft starting in 1978, but only for front seats.[2] Concurrently, 14 CFR Part 91 was revised to state that "required flight crewmembers" must use available shoulder harnesses during takeoff and landing.[3] In response, the NTSB issued Safety Recommendations A-77-70 and -71, which respectively recommended that the FAA strengthen the rules to require installation of shoulder harnesses at all seat locations and require their installation on all GA aircraft, including those manufactured before 1978. In 1985, the FAA modified 14 CFR 91.33 to require shoulder harnesses in all seats of GA airplanes manufactured after December 12, 1986, and amended 14 CFR Part 91 to require all occupants to wear shoulder harnesses, when available, during takeoff and landing. However, the FAA never modified its regulations to require retrofitting of aircraft manufactured before the 1978 and 1986 regulatory changes.[4]

Because of the longevity of aircraft, a large proportion of the active GA and air taxi fleet were manufactured before shoulder harnesses were required. For example, the 2008 FAA General Aviation and Air Taxi Survey found that 69 percent of active aircraft were manufactured prior to 1984, and 56 percent were manufactured prior to 1979. Although it is possible that many owners of older aircraft have retrofitted those aircraft to include shoulder harnesses without

[1] *General Aviation Crashworthiness Project: Phase Two—Impact Severity and Potential Injury Prevention in General Aviation Accidents*, Safety Report NTSB/SR-85/01 (Washington, DC: National Transportation Safety Board, 1985).

[2] Amendment 23-19 to 14 CFR Part 23. *Federal Register*, vol. 42, no. 116 (June 16, 1977), p. 30601.

[3] See Amendment 91-139 to 14 CFR Part 91. *Federal Register*, vol. 42, no. 116 (June 16, 1977), p. 30601.

[4] Safety Recommendation A-77-70, which called for shoulder harnesses at all seat locations, was classified "Closed—Acceptable Action" on March 25, 1986. Safety Recommendation A-77-71, which called for the installation of shoulder harnesses on aircraft manufactured before 1978, was classified "Closed—Unacceptable Action" on July 1, 1986.

being required to do so, the NTSB continues to investigate numerous accidents in which shoulder harnesses are not present.

Case control studies have been used to assess the effectiveness of GA shoulder harnesses on reducing pilot fatalities for occupational crashes in Alaska,[5] crashes involving military pilots,[6] crashes in the Colorado Rockies,[7] crashes in Maryland and North Carolina,[8] and crashes during takeoff and landing that involved a loss of engine power.[9] In general, these studies found a protective effect of shoulder harnesses in reducing the risk of pilot fatality. However, in general, their findings were somewhat limited by small sample sizes and an exclusive focus on fatalities as an outcome measure. Furthermore, several studies did not appear to discriminate between pilots who used lap belts and those who used no restraint.

Analysis Purpose

The primary goal of the current analysis was to evaluate the real-world performance of lap belt/shoulder harness combinations (SH) compared to lap belts only (LB) with regard to reducing pilot fatality and serious injury. An additional goal was to look at the relationships between SH effectiveness and other factors that might potentially influence survivability, such as whether there was a fire or a loss of control, whether the accident happened at or away from an airport, the phase of flight when the accident occurred, and pilot factors such as gender and age. For example, it is possible that SH may be less effective when there is an aircraft fire, either due to the higher severity of crashes involving fires or due to potential challenges with releasing restraints and exiting the aircraft during a fire. This analysis also addressed some of the shortcomings of previous research by using a large multiyear sample extracted from the NTSB census of civil aviation accidents.

Method

Data were obtained from the NTSB aviation accident database, a census of all civil aviation accidents in the United States. The sample included pilots involved in GA accidents between 1983 and 2008 that involved nonamateur-built airplanes with single reciprocating engines.

The outcome measure of interest was whether the pilot was fatally or seriously injured (FSI) as a result of the accident. NTSB injury coding levels are defined in 49 CFR 830.2. Fatal injury is defined as any injury that results in death within 30 days of the accident. Serious injury

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[5] D.M. Bensyl, K. Moran, and G.A. Conway, “Factors Associated With Pilot Fatality in Work-Related Aircraft Crashes: Alaska, 1990–1999,” *American Journal of Epidemiology*, vol. 154, no. 11 (2001), pp. 1037–1042.

[6] L.G. Gillis, G. Li, and S.P. Baker, “General Aviation Crashes Involving Military Personnel as Pilots,” *Aviation Space and Environmental Medicine*, vol. 72, no. 11 (2001), pp. 1001–1005.

[7] S.P. Baker and M.W. Lamb, “Hazards of Mountain Flying: Crashes in the Colorado Rockies,” *Aviation Space and Environmental Medicine*, vol. 60, no. 6 (1989), pp. 531–536.

[8] G. Li and S.P. Baker, “Correlates of Pilot Fatality in General Aviation Crashes,” *Aviation Space and Environmental Medicine*, vol. 70, no. 4 (1999), pp. 305–309.

[9] P.S. Rostykus, P. Cummings, and B.A. Mueller, “Risk Factors for Pilot Fatalities in General Aviation Airplane Crash Landings,” *JAMA*, vol. 280, no. 11 (1998) pp. 997–999.

is defined as any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

Other variables that were examined included loss of control in flight (LOC, No LOC), presence of in-flight and/or postcrash fire (Fire, No Fire), accident location (Off Airport, On Airport), phase of flight (Takeoff/Landing, In Flight), pilot gender (Female, Male), and pilot age (14-34, 35-44, 45-54, 55+).

Risk ratios (RR) and 95 percent confidence intervals (CIs) were calculated to compare SH to LB. A risk ratio is the risk of an event (in this case, FSI) relative to exposure (restraint condition).[10] A risk ratio equal to 1 would suggest that different restraint types have a null effect on FSI. Numbers greater than 1 indicate that FSI is more likely to occur in the exposure condition compared to the control group. For this analysis, SH was chosen as the control condition to provide a basis for expressing the relative risk of the LB condition compared to the "gold standard" of SH.

Results

Of the 37,344 pilots in the final sample, 15.2 percent were fatally injured and 8.7 percent sustained serious injuries. Over half (55.3 percent) of the pilots were reported to have used an SH, 23.9 percent used LB, and 0.6 percent used no restraint. Restraint use was unknown in 18.9 percent of cases.

Table B-1 provides a summary of risk ratios for pilot FSI comparing LB to SH. Overall, the risk of FSI for pilots was significantly higher for LB compared to SH (RR = 1.49; 95 percent CI: 1.42, 1.56). There were also significant interaction effects indicating that the risk of FSI with LB relative to SH was significantly higher when there was no loss of control, no in-flight or postcrash fire, when accidents occurred on airport and during takeoff or landing. The increase in FSI risk associated with LB use did not vary significantly by gender, but the risk of FSI associated with LB use was greater for pilots under age 45 compared to those 45 and older.

Figure B-1 provides a graphic depiction of the overall risk ratio and those of the various subgroups. The figure shows that across all levels of all conditions, risk ratio and 95 percent CI was greater than 1, indicating that the risk of FSI was significantly higher in the LB condition compared to SH across all conditions. Further, the figure shows that the effects of restraint type are most pronounced in accidents that occur on airports during takeoff and landing phases of flight and among pilots who are less than 45 years old.

[10] M.J. Gardner and D.G. Altman, *Statistics with Confidence* (London: BMJ Publications, 1994), pp. 51–52.

Table B-1. Pilots fatally or seriously injured (FSI), pilots involved in accidents, and risk ratios (RR) for FSI in U.S. airplane accidents involving single reciprocating engines between 1983 and 2008.

	Pilots Fatally or Seriously Injured		Pilots Involved in Accidents		Risk Ratios for LB relative to SH	
	SH[a]	LB[b]	SH	LB	RR[c]	95% CI[d]
Total	3607	2326	7646	926	1.49	1.42, 1.56
Loss of Control (LOC) in Flight						
LOC	1516	985	478	761	1.28	1.21, 1.35
No LOC	2091	1341	7168	165	1.54	1.44, 1.63
In-Flight or Postcrash Fire						
Fire	857	376	497	78	1.14	1.05, 1.22
No Fire	2733	1942	9072	320	1.63	1.54, 1.71
Accident Location						
Off Airport	2893	1835	912	848	1.30	1.23, 1.35
On Airport	652	461	10290	916	1.86	1.65, 2.08
Phase of Flight						
Take-off/Landing	819	637	10615	4235	1.95	1.76, 2.14
In Flight	2718	1629	8883	4281	1.24	1.18, 1.30
Pilot Gender						
Female	104	53	907	268	1.72	1.27, 2.33
Male	3479	2262	19611	8609	1.48	1.41, 1.55
Pilot Age (years)						
14–34	917	502	5881	1912	1.68	1.52, 1.85
35–44	784	566	4916	2087	1.70	1.54, 1.87
45–54	854	560	4637	2262	1.34	1.22, 1.47
55+	1028	684	5016	2596	1.29	1.18, 1.39

[a] SH refers to shoulder harness.
[b] LB refers to lap belt.
[c] RR refers to risk ratio.
[d] CI refers to confidence interval.

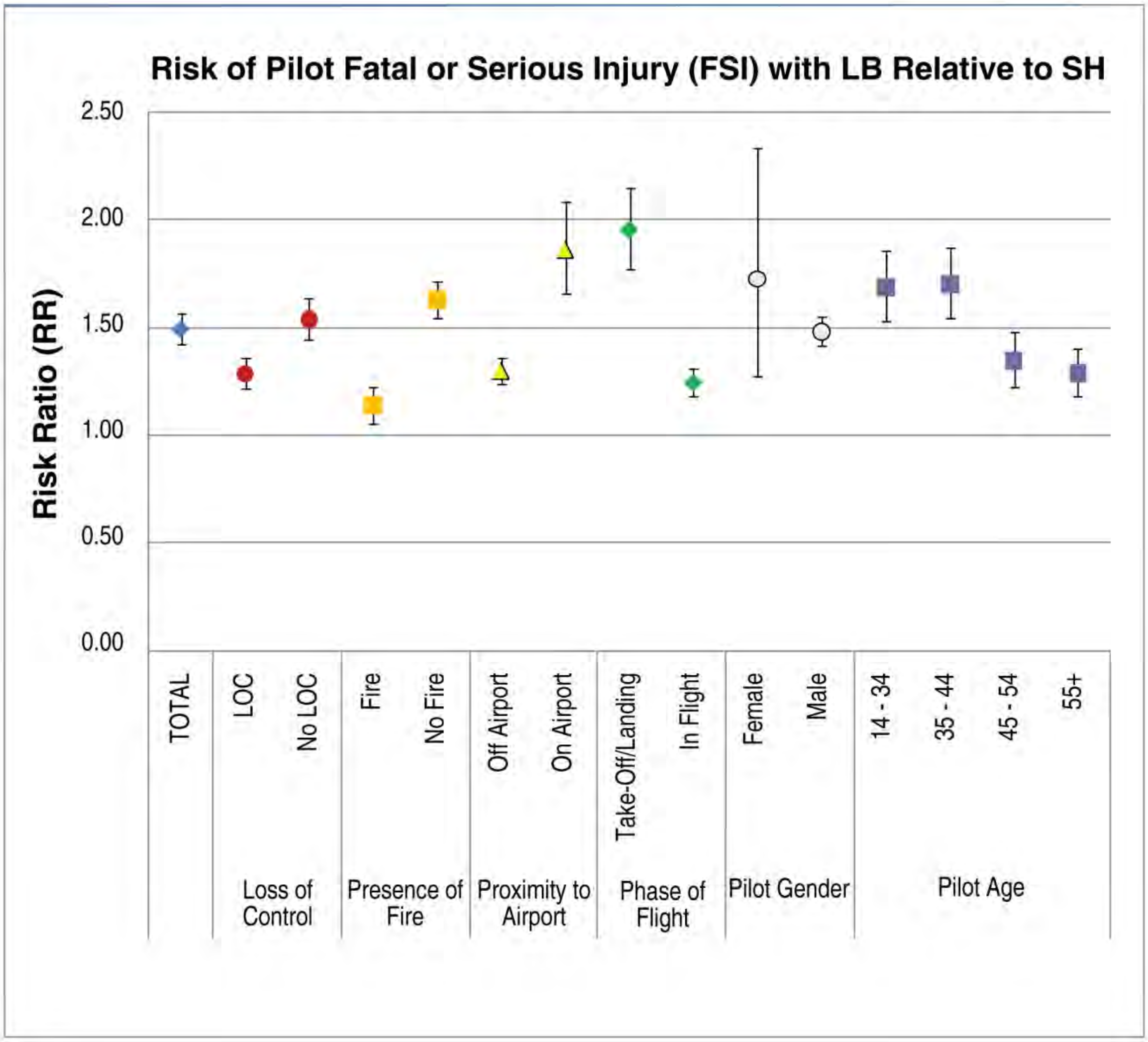

Figure B-1. A chart showing the risk ratios and 95-percent confidence intervals for pilot fatal or serious injury (FSI) when using a lap belt only (LB) relative to a lap belt/shoulder harness combination (SH) across multiple conditions.

Discussion

SH consistently reduced the risk of pilot FSI when compared to LB. The risk of FSI with a lap belt alone was 50 percent higher than with shoulder harnesses. The benefits conveyed by shoulder harnesses were significant for multiple subgroups within the larger sample.

In terms of flight characteristics, there were several interaction effects found in which risk of FSI was varied as a function of another variable. For example, in accidents that occurred during takeoff or landing, for those that did not involve in-flight or postcrash fires, and for those that did not involve a loss of control in flight, the benefits conferred by SH use was significantly higher than in accidents that occurred in flight, involved fires, or involved a loss of control in flight. The likely reason for this finding is that those accidents that involve fire, loss of control, or that occur when in flight are more likely to be extremely severe, nonsurvivable accidents.

However, it is important to note that even within those severe categories, the significant benefit of SH in reducing FSI was still present, as denoted by the fact that the confidence intervals in all categories were greater than 1.

Overall, the findings strongly suggest that lap belt/shoulder harness combinations provide significant protection beyond that offered by wearing only a lap belt and that there would be reductions in pilot fatalities and injuries if lap belt/shoulder harness combinations were installed and used in all GA airplanes.

Limitations

There were two notable limitations in the analysis; however, it is unlikely that the limitations had a substantial effect on the overall findings. First, restraint use was unknown in 18.9 percent of accidents overall, and the proportion of cases in which restraint use was unknown was higher when pilots were fatally injured. This is likely because very severe crashes are more likely to result in evidence being destroyed by fire or explosion, rendering the evidence unobtainable. Second, shoulder harnesses are more likely to be present in newer aircraft, and those aircraft may also have advanced crashworthiness features such as delethalized cabins and crushable seat pans. Due to limitations of the NTSB accident database, it was not possible to know the age of the aircraft involved, therefore the analysis could not control for this variable.

Appendix C. Federal Aviation Administration Special Conditions for the Certification of Aircraft with Inflatable Restraints

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Rules does not affect the collections of information outlined in the Interim Rule nor does it affect the estimated burden set forth in the Interim Rule.

List of Subjects in 12 CFR Part 370

Banks, Banking, Bank deposit insurance, Holding companies, National banks, Reporting and recordkeeping requirements, Savings associations.

■ For the reasons stated above, The Board of Directors of the Federal Deposit Insurance Corporation amends 12 CFR part 370 as follows:

PART 370—TEMPORARY LIQUIDITY GUARANTEE PROGRAM

■ 1. The authority citation for part 370 continues to read as follows:

Authority: 12 U.S.C. 1813(l), 1813(m), 1817(i), 1818, 1819(a) (Tenth); 1820(f), 1821(a); 1821(c); 1821(d); 1823(c)(4).

§ 370.2 [Amended]

■ 2. Amend § 370.2 as follows:
■ A. In paragraph (f), remove "November 12" and replace it with "December 5".
■ B. In paragraph (g), remove "November 12" and replace it with "December 5" and remove "November 13" wherever it appears and replace it with "December 6".

§ 370.3 [Amended]

■ 3. Amend § 370.3 as follows:
■ In paragraphs (b) and (f), remove "November 12" wherever it appears and replace it with "December 5".

§ 370.5 [Amended]

■ 4. Amend § 370.5 as follows:
■ A. In paragraphs (a), (c), (f), and (j), remove "November 12" wherever it appears and replace it with "December 5".
■ B. In paragraph (h), remove "December 1" and replace it with "December 19".
■ 5. Amend § 370.6 by revising paragraphs (a), (b)(1), (b)(2), and (c) to read as follows:

§ 370.6 Assessments under the Debt Guarantee Program.

(a) *Waiver of assessment for certain initial periods.* No eligible entity shall pay any assessment associated with the debt guarantee program for the period from October 14, 2008 through November 12, 2008. An eligible entity that opts out of the program on or before December 5, 2008 will not pay any assessment under the program.

(b) * * *

(1) Any eligible entity that does not opt out of the Debt Guarantee Program on or before December 5, 2008, as provided in § 370.5, and that issues any guaranteed debt during the period from October 14, 2008 through December 5, 2008 which is still outstanding on December 5, 2008, shall notify the FDIC of that issuance via the FDIC's e-business Web site FDIC*connect* on or before December 19, 2008, and the eligible entity's Chief Financial Officer or equivalent shall certify that the issuances outstanding at each point of time did not exceed the guaranteed amount limit as set forth in § 370.3.

(2) Any eligible entity that does not opt out of the program and that issues guaranteed debt after December 5, 2008, shall notify the FDIC of that issuance via the FDIC's e-business Web site FDIC*connect* within the time period specified by the FDIC. The eligible entity's Chief Financial Officer or equivalent shall certify that the issuance of guaranteed debt does not exceed the guarantee limit as set forth in § 370.3.

* * * * *

(c) *Initiation of assessments.* Assessments, calculated in accordance with paragraph (d) of this section, will accrue, with respect to each eligible entity that does not opt out of the debt guarantee program on or before December 5, 2008.

(1) Beginning on November 13, 2008, on all senior unsecured debt, other than overnight debt instruments, issued by it on or after October 14, 2008 that is still outstanding on November 13, 2008;

(2) Beginning on November 13, 2008, on all senior unsecured debt, other than overnight debt instruments, issued by it on or after November 13, 2008 and before December 6, 2008; and

(3) Beginning on December 6, 2008, on all senior unsecured debt issued by it on or after December 6, 2008.

■ 6. Amend § 370.7 by revising paragraphs (a) and (b) to read as follows:

§ 370.7 Assessments under the Transaction Account Guarantee Program.

(a) *Waiver of assessment for certain initial periods.* No eligible entity shall pay any assessment associated with the transaction account guarantee program for the period from October 14, 2008, through November 12, 2008. An eligible entity that opts out of the program on or before December 5, 2008 will not pay any assessment under the program

(b) *Initiation of assessments.* Beginning on November 13, 2008 each eligible entity that does not opt out of the transaction account guarantee program on or before December 5, 2008 will be required to pay the FDIC assessments on all deposit amounts in noninterest-bearing transaction accounts calculated in accordance with paragraph (c) of this section.

* * * * *

Federal Deposit Insurance Corporation.
Robert E. Feldman,
Executive Secretary.

[FR Doc. E8–26569 Filed 11–4–08; 4:15 pm]
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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 23

[Docket No. CE285, Special Conditions No. 23–225A–SC]

Final Special Conditions: AmSafe Aviation; Inflatable Restraints Installation; Approved Model List of Normal and Utility Category Airplanes, and Agricultural Airplanes Certificated in the Normal/Utility/Restricted Category

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions; request for comments.

SUMMARY: These special conditions are issued for AmSafe Aviation to amend the list of approved models. These airplanes, as modified by AmSafe Aviation, will have novel and unusual design features associated with the lap belt or shoulder harness portion of the safety belt, which contains an integrated airbag device. The applicable airworthiness regulations do not contain adequate and appropriate safety standards for this design feature. These special conditions contain the additional safety standards that the Administrator considers necessary to establish a level of safety equivalent to that established by the airworthiness standards.

DATES: The effective date of these amended special conditions is October 31, 2008. Comments must be received on or before December 8, 2008.

ADDRESSES: Mail two copies of your comments on these amended special conditions to: Federal Aviation Administration (FAA), Regional Counsel, ACE–7, Attention: Rules Docket, Docket No. CE285, 901 Locust, Room 506, Kansas City, Missouri 64106, or you may deliver two copies to the Regional Counsel at the above address. Mark your comments: Docket No. CE285. You may inspect comments in the Rules Docket weekdays, except Federal holidays, between 7:30 a.m. and 4 p.m.

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FOR FURTHER INFORMATION CONTACT: Mr. Bob Stegeman, Federal Aviation Administration, Small Airplane Directorate, Aircraft Certification Service, ACE–111, 901 Locust, Kansas City, Missouri, 816–329–4140, fax 816–329–4090, e-mail *Robert.Stegeman@faa.gov*.

SUPPLEMENTARY INFORMATION: The FAA has determined that notice and opportunity for prior public comment hereon are impracticable because these procedures would significantly delay issuance of the approval design and thus delivery of the affected aircraft. In addition, the substance of these special conditions has been subject to the public comment process in several prior instances with no substantive comments received. The FAA, therefore, finds that good cause exists for making these amended special conditions effective upon issuance.

Comments Invited

We invite interested persons to participate in the making of these special conditions by submitting such written data, views, or arguments as they may desire. Identify the regulatory docket or notice number and submit the comments in duplicate to the address specified above. All comments received on or before the closing date for comments will be considered by the Administrator. The special conditions may be changed in light of the comments received. All comments received will be available in the Rules Docket for examination by interested persons, both before and after the closing date for comments. A report summarizing each substantive public contact with FAA personnel concerning this rulemaking will be filed in the docket. Commenters wishing the FAA to acknowledge receipt of their comments submitted in response to this notice must include a self-addressed, stamped postcard on which the following statement is made: "Comments to CE285." The postcard will be date stamped and returned to the commenter.

Background

On June 18, 2008, AmSafe Aviation, 1043 North 47th Avenue, Phoenix, AZ 85043, applied to add several more models to an existing supplemental type certificate. The AML STC allows for the installation of inflatable restraints in airplane models included herein that were certificated prior to the dynamic seat rule specified in 14 CFR part 23, § 23.562.

AmSafe Aviation has previously applied for and obtained an Approved Model List (AML) Supplemental Type Certificate (STC) for the installation of Inflatable Two-, Three-, Four- or Five-Point Restraint Safety Belts with an Integrated Airbag Device in airplanes certificated in the Part 23 Normal/Utility and Restricted-Agricultural categories.

This special condition includes additional normal and utility category aircraft.

The inflatable restraint system is either a two-, three-, four-, or five-point safety belt restraint system consisting of a shoulder harness and a lap belt with an inflatable airbag attached to either the lap belt or the shoulder harness. The inflatable portion of the restraint system will rely on sensors to electronically activate the inflator for deployment. The inflatable restraint system will be made available on the pilot, co-pilot, and passenger seats of these airplanes.

If an emergency landing occurs, the airbag will inflate and provide a protective cushion between the occupant's head and structure within the airplane. This will reduce the potential for head and torso injury. The inflatable restraint behaves in a manner that is similar to an automotive airbag. However, in this case, the airbag is integrated into the lap or shoulder belt. While airbags and inflatable restraints are standard in the automotive industry, the use of an inflatable restraint system is novel for aircraft operations.

The FAA has determined that this project will be accomplished on the basis of not lowering the current level of safety of the airplanes' original certification basis. The FAA has two primary safety concerns with the installation of airbags or inflatable restraints:

- That they perform properly under foreseeable operating conditions; and
- That they do not perform in a manner or at such times as to impede the pilot's ability to maintain control of the airplane or constitute a hazard to the airplane or occupants.

The latter point has the potential to be the more rigorous of the requirements. An unexpected deployment while conducting the takeoff or landing phases of flight may result in an unsafe condition. The unexpected deployment may either startle the pilot, or it may generate a force sufficient to cause a sudden movement of the control yoke. Either action could result in a loss of control of the airplane, the consequences of which are magnified due to the low operating altitudes during these phases of flight. This consideration is of special concern for aircraft designated for agricultural use because these aircraft spend a majority of their flight time at low altitudes. The FAA has considered this when establishing these amended special conditions.

The inflatable restraint system relies on sensors to electronically activate the inflator for deployment. These sensors could be susceptible to inadvertent activation, causing deployment in a potentially unsafe manner. The consequences of an inadvertent deployment must be considered in establishing the reliability of the system. AmSafe Aviation must show that the effects of an inadvertent deployment in flight are not a hazard to the airplane or that an inadvertent deployment is extremely improbable.

In addition, general aviation and agricultural aircraft are susceptible to a large amount of cumulative wear and tear on a restraint system. It is likely that the potential for inadvertent deployment increases as a result of this cumulative damage. Therefore, the impact of wear and tear on inadvertent deployment must be considered. Due to the effects of this cumulative damage, a life limit must be established for the appropriate system components in the restraint system design.

There are additional factors to be considered to minimize the chances of inadvertent deployment. General aviation airplanes are exposed to a unique operating environment, since the same airplane may be used by both experienced and student pilots. The effect of this environment on inadvertent deployment must be understood. Therefore, qualification testing of the firing hardware/software must consider the following:

- The airplane vibration levels appropriate for general aviation and agricultural airplanes; and
- The inertial loads that result from typical flight/ground maneuvers, gusts, hard landings and flight maneuvering unique to both general aviation and agricultural aircraft operations.

Any tendency for the firing mechanism to activate as a result of these loads or acceleration levels is unacceptable.

Other influences on inadvertent deployment include high intensity electromagnetic fields (HIRF) and lightning. Since the sensors that trigger deployment are electronic, they must be protected from the effects of these threats. To comply with HIRF and lightning requirements, the AmSafe Aviation inflatable restraint system is considered a critical system, since its inadvertent deployment could have a hazardous effect on the airplane.

Given the level of safety of the retrofitted airplane occupant restraints,

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the inflatable restraint system must show that it will offer an equivalent level of protection in the event of an emergency landing. If a deployment occurs, the restraint must still be at least as strong as a Technical Standard Order approved belt and shoulder harnesses. There is no requirement for the inflatable portion of the restraint to offer protection during multiple impacts.

The inflatable restraint system must deploy and provide protection for each occupant during crash conditions as specified in the original certification basis. Therefore, the test emergency landing loads identified in the original certification basis of the airplane must be used to satisfy this requirement. It must be shown that the inflatable restraint will deploy and provide protection under crash conditions as specified in the original certification basis. Compliance will be demonstrated using the test condition specified in the original certification basis. It must be shown that the crash sensor will trigger when exposed to a rapidly applied deceleration, like an actual crash event. Therefore, the test crash pulses identified in § 23.562 must be used to satisfy this requirement, although the peak "G" may be reduced to a level meeting the original certification requirements of the aircraft. Testing to these pulses will demonstrate that the crash sensor will trigger when exposed to a rapidly applied deceleration, like an actual crash event.

It is possible a wide range of occupants will use the inflatable restraint. Thus, the protection offered by this restraint should be effective for occupants that range from the fifth percentile female to the ninety-fifth percentile male.

In support of this operational capability, there must be a means to verify the integrity of this system before each flight. As an option, AmSafe Aviation can establish inspection intervals where they have demonstrated the system to be reliable between these intervals.

An inflatable restraint may be "armed" even though no occupant is using the seat. While there will be means to verify the integrity of the system before flight, it is also prudent to require that unoccupied seats with active restraints not constitute a hazard to any occupant. This will protect any individual performing maintenance inside the cockpit while the aircraft is on the ground. The restraint must also provide suitable visual warnings that would alert rescue personnel to the presence of an inflatable restraint system.

In addition, the design must prevent the inflatable seatbelt from being incorrectly buckled and/or installed such that the airbag would not properly deploy. As an alternative, AmSafe Aviation may show that such deployment is not hazardous to the occupant and will still provide the required protection.

The cabins of the various model airplanes identified in these special conditions are confined areas, and the FAA is concerned that noxious gases may accumulate if an airbag deploys. When deployment does occur, either by design or inadvertently, there must not be a release of hazardous quantities of gas or particulate matter into the cockpit.

An inflatable restraint should not increase the risk already associated with fire. Therefore, the inflatable restraint should be protected from the effects of fire, so that an additional hazard is not created by, for example, a rupture of the inflator.

Finally, the airbag is likely to have a large volume displacement, and it may impede the egress of an occupant. Since the bag deflates to absorb energy, it is likely that the inflatable restraint would be deflated at the time an occupant would attempt egress. However, it is appropriate to specify a time interval after which the inflatable restraint may not impede rapid egress. Ten seconds has been chosen as reasonable time. This time limit will offer a level of protection throughout the impact event.

Special conditions for the installation of AAIR systems on other certificated airplanes have been issued and no substantive public comments were received. Since the same special conditions were issued multiple times for different model airplanes with no substantive public comments, the FAA began issuing direct final special conditions with an invitation for public comment. This was done to eliminate the waiting period for public comments and to allow AmSafe Aviation to proceed with the project.

These previous special conditions were typically issued for a single model airplane or for variants of a model from a single airplane manufacturer, and required dynamic testing of each AAIR system installation for showing compliance. Since AmSafe Aviation has previously demonstrated by dynamic testing, and has the supporting data, that the Electronics Module Assembly (EMA) and inflator assembly will function as intended in a simulated dynamic emergency landing, it is not necessary to repeat the test for each airplane model shown in these amended special conditions.

Type Certification Basis

Under the provisions of 14 CFR part 21, § 21.101, AmSafe Aviation must show that affected airplane models, as changed, continue to meet the applicable provisions of the regulations incorporated by reference in the Type Certificate Numbers listed below or the applicable regulations in effect on the date of application for the change. The regulations incorporated by reference in the type certificate data sheet are commonly referred to as the original "type certification basis" and can be found in the Type Certificate Data Sheets for the numbers listed below. The following models are covered by this amended special condition:

LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS

Make	Model	TC holder	TCDS	Certification basis
1 Aerostar	PA–60–600 (Aerostar 600) PA–60–601 (Aerostar 601) PA–60–601P (Aerostar 601P) PA–60–602P (Aerostar 602P) PA–60–700P (Aerostar 700P)	Aerostar Aircraft Corporation.	A17WE, Revision 22	14 CFR PART 23.
1 All American	10A	All American Aircraft, Inc	A–792	CAR 3
1 American Champion (Champion).	402	American Champion Aircraft Corp.	A3CE, Revision 5	CAR 3

LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS—Continued

Make	Model	TC holder	TCDS	Certification basis
1 American Champion (Bellanca) (Champion) (Aeronca).	7AC, 7ACA, 7EC, 7GCB, S7AC, S7EC, 7GCBA (L–16A), 7BCM, 7ECA, 7GCBC (L–16B), 7CCM, 7FC, 7HC, S7CCM, 7GC, 7JC, 7DC, 7GCA, 7KC, S7DC, 7GCAA, 7KCAB.	American Champion Aircraft Corp.	A–759, Revision 67	CAR 4a.
1 American Champion (Bellanca) (Trytek) (Aeronca).	11AC, S11AC, 11BC, S11BC	American Champion Aircraft Corp.	A–761, Revision 17	CAR 4a.
1 American Champion (Bellanca) (Trytek) (Aeronca).	11CC, S11CC	American Champion Aircraft Corporation.	A–796, Revision 14	CAR 3.
1 VARGA (Morrisey)	2150, 2150A, 2180	Augustair, Inc.	4A19, Revision 9	CAR 3.
1 Bellanca	14–13, 14–13–2, 14–13–3, 14–13–3W	Bellanca Aircraft Corporation.	A–773, Revision 10	CAR 4a.
1 Bellanca	14–9, 14–9L	Bellanca Aircraft Corporation.	TC716	CAR 4a.
1 Cessna	120, 140	Cessna Aircraft Company.	A–768, Revision 34	CAR 4a.
1 Cessna	140A	Cessna Aircraft Company.	5A2, Revision 21	CAR 3.
1 Cessna	150, 150J, 150A, 150K, 150B, A150K, 150C, 150L, 150D, A150L, 150E, 150M, 150F, A150M, 150G, 152, 150H, A152.	Cessna Aircraft Company.	3A19, Revision 44	CAR 3.
1 Cessna	170, 170A, 170B	Cessna Aircraft Company.	A–799, Revision 54	CAR 3.
1 Cessna	172, 172I, 172A, 172K, 172B, 172L, 172C, 172M, 172D, 172N, 172E, 172P, 172F (USAF T–41A), 172Q, 172G, 172H, (USAF T–41A).	Cessna Aircraft Company.	3A12, Revision 73	CAR 3.
1 Cessna	175, 175A, 175B, 175C, P172D, R172E (USAF T–41B) (USAF T–41C and D), R172F (USAF T–41D), R172G (USAF T–41C or D), R172H (USAF T–41D), R172J, R172K, 172RG.	Cessna Aircraft Company.	3A17, Revision 45	CAR 3.
1 Cessna	177, 177A, 177B	Cessna Aircraft Company.	A13CE, Revision 24	14 CFR PART 23.
Cessna	177RG	Cessna Aircraft Company.	A20CE, Revision 21	14 CFR PART 23.
Cessna	180, 180E, 180A, 180F, 180B, 180G, 180C, 180H, 180D, 180J, 180E, 180K.	Cessna Aircraft Company.	5A6, Revision 66	CAR 3.
1 Cessna	182, 182K, 182A, 182L, 182B, 182M, 182C, 182N, 182D, 182P, 182E, 182Q, 182F, 182R, 182G, R182, 182H, T182, 182J, TR182.	Cessna Aircraft Company.	3A13, Revision 64	CAR 3.
1 Cessna	185, A185E, 185A, A185F, 185B, 185C, 185D, 185E.	Cessna Aircraft Company.	3A24, Revision 37	CAR 3.
Cessna AgWagon	188, 188A, 188B, A188, A188A, A188B, T188C.	Cessna Aircraft Company.	A9CE, Revision 27	14 CFR PART 23.
1 Cessna	190 (LC–126A,B,C), 195, 195A, 195B	Cessna Aircraft Company.	A–790, Revision 36	CAR 3.
1 Cessna	206, U206B, TP206D, P206, U206C, TP206E, P206A, U206D, TU206A, P206B, U206E, TU206B, P206C, U206F, TU206C, P206D, U206G, TU206D, P206E, TP206A, TU206E, U206, TP206B, TU206F, U206A, TP206C, TU206G.	Cessna Aircraft Company.	A4CE, Revision 43	CAR 3.
1 Cessna	208, 208A, 208B	Cessna Aircraft Company.	A37CE, Revision 12	14 CFR PART 23.
1 Cessna	210, 210K, 210A, T210K, 210B, 210L, 210C, T210L, 210D, 210M, 210E, T210M, 210F, 210N, T210F, P210N, 210G, T210N, T210G, 210R, 210H, P210R, T210H, T210R, 210J, 210–5 (205), T210J, 210–5A (205A).	Cessna Aircraft Company.	3A21, Revision 46	CAR 3.
1 Cessna	310, 310J, 310A(USAF U–3A),310J–1, 310B, E310J, 310C, 310K, 310D, 310L, 310E(USAF U–3B), 310N, 310F, 310P, 310G, T310P, 310H, 310Q, E310H, T310Q, 310I, 310R, T310R.	Cessna Aircraft Company.	3A10, Revision 62	CAR 3.

LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS—Continued

Make	Model	TC holder	TCDS	Certification basis
1 Cessna	320, 320F, 320–1, 335, 320A, 340, 320B, 340A, 320C, 320D, 320E.	Cessna Aircraft Company.	3A25, Revision 25	CAR 3.
1 Cessna	321 (Navy OE–2)	Cessna Aircraft Company.	3A11, Revision 6	CAR 3.
1 Cessna	336	Cessna Aircraft Company.	A2CE, Revision 7	CAR 3.
1 Cessna	337A (USAF 02B), T337E, 337B, 337F, M337B (USAF 02A), T337F, T337B, 337G, 337C, T337G, T337C, 337H, 337D, P337H, T337D, T337H, T337H–SP.	Cessna Aircraft Company.	A6CE, Revision 40	CAR 3/14 CFR PART 23.
1 Cessna	401, 401A, 401B, 402, 402A, 402B, 402C, 411, 411A, 414, 414A, 421, 421A, 421B, 421C, 425.	Cessna Aircraft Company.	A7CE, Revision 46	CAR 3.
1 Cessna	404, 406	Cessna Aircraft Company.	A25CE, Revision 11	14 CFR PART 23.
1 Cessna	441	Cessna Aircraft Company.	A28CE, Revision 12	14 CFR PART 23.
1 Commander Aircraft	Model 112, Model 114, Model 112TC, Model 112B, Model 112TCA, Model 114A, Model 114B, Model 114TC.	Commander Aircraft Company.	A12SO, Revision 21	14 CFR PART 23.
Diamond	DA20–A1, DA20–C1	Diamond Aircraft Industries, Inc..	TA4CH, Revision 14	14 CFR PART 23.
1 Great Lakes	2T–1A, 2T–1A–1, 2T–1A–2	Great Lakes Aircraft Company, LLC.	A18EA, Revision 10	Aeronautical Bulletin No 7–A.
1 Helio (Taylorcraft)	15A, 20	Helio Aircraft Corporation.	3A3, Revision 7	CAR 4a.
1 Learjet	23	Learjet Inc	A5CE, Revision 10	CAR 3.
1 Lockheed	402–2	Lockheed Aircraft International.	2A11, Revision 4	CAR 3.
1 Land-Air (TEMCO) (Luscombe).	11A, 11E	Luscombe Aircraft Corporation.	A–804, Revision 14	CAR 3.
1 Maule	Bee Dee M–4, M–5–180C, MXT–7–160, M–4–180V, M–4 M–5–200, MX–7–180A, M–4C, M–5–210C, MXT–7–180A, M–4S, M–5–210TC, MX–7–180B, M–4T, M–5–220C, M–7–235B, M–4–180C, M–5–235C, M–7–235A, M–4–180S, M–6–180, M–7–235C, M–4–180T, M–6–235, MX–7–180C, M–4–210, M–7–235, M–7–260, M–4–210C, MX–7–235, MT–7–260, M–4–210S, MX–7–180, M–7–260C, M–4–210T, MX–7–420, M–7–420AC, M–4–220, MXT–7–180, MX–7–160C, M–4–220C, MT–7–235, MX–7–180AC, M–4–220S, M–8–235, M–7–420A, M–4–220T, MX–7–160, MT–7–420.	Maule Aerospace Technology, Inc.	3A23, Revision 30	CAR 3.
1 Mooney	M20, M20A, M20B, M20C, M20D, M20E, M20F, M20G, M20J, M20K (Up to S/N 25–2000), M20L.	Mooney Airplane Company, Inc	2A3, Revision 47	CAR 3.
1 Interceptor (Aero Commander) (Meyers).	200, 200A, 200B, 200C, 200D, 400	Prop-Jets, Inc	3A18, Revision 16	CAR 3.
1 Beech	35–33, J35, 35–A33, K35, 35–B33, M35, 35–C33, N35, 35–C33A, P35, E33, S35, E33A, V35, E33C, V35A, F33, V35B, F33A, 36, F33C, A36, G33, A36TC, H35, B36TC, G36.	Raytheon Aircraft Company	3A15, Revision 90	CAR 3.
1 Beech	45 (YT–34), A45 (T–34A, B–45), D45 (T–34B).	Raytheon Aircraft Company.	5A3, Revision 25	CAR 03.
1 Beech	19A, B23, B19, C23, M19A, A24, 23, A24R, A23, B24R, A23A, C24R, A23–19, A23–24.	Raytheon Aircraft Company.	A1CE, Revision 34	CAR 3.
1 Beech	3N, 3NM, 3TM, JRB–6, D18C, D18S, E18S, E18S–9700, G18S, H18, C–45G, TC–45G, C–45H, TC–45H, TC–45J or UC–45J (SNB–5), RC–45J (SNB–5P).	Raytheon Aircraft Company	A–765	Revision 74 CAR 03.
1 Beech	35, A35, E35, B35, F35, C35, G35, D35, 35R.	Raytheon Aircraft Company	A–777, Revision 57	CAR 03.

LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS—Continued

Make	Model	TC holder	TCDS	Certification basis
1 Raytheon	200, A100–1 (U–21J), 200C, A200 (C–12A), 200CT, A200 (C–12C), 200T, A200C (UC–12B), B200, A200CT (C–12D), B200C, A200CT (FWC–12D), B200CT, A200CT (C–12F), B200T, A200CT (RC–12D), 300, A200CT (RC–12G), 300LW, A200CT (RC–12H), B300, A200CT (RC–12K), B300C, A200CT (RC–12P), 1900, A200CT (RC–12Q), 1900C, B200C (C–12F), 1900D, B200C (UC–12M), B200C (C–12R), B200C (UC–12F), 1900C (C–12J).	Raytheon Aircraft Company.	A24CE, Revision 91	14 CFR PART 23.
1 Beech	B95A, D55, D95A, D55A, E95, E55, 95–55, E55A, 95–A55, 56TC, 95–B55, A56TC, 95–B55A, 58, 95–B55B (T–42A), 58A, 95–C55, 95, 95–C55A, B95, G58.	Raytheon Aircraft Company.	3A16, Revision 81	CAR 3.
1 Beech	60, A60, B60	Raytheon Aircraft Company.	A12CE, Revision 23	14 CFR PART 23.
1 Beech	58P, 58PA, 58TC, 58TCA	Raytheon Aircraft Company.	A23CE, Revision 14	14 CFR PART 23.
1 Cessna	CESSNA F172D CESSNA F172E CESSNA F172F CESSNA F172G CESSNA F172H CESSNA F172K CESSNA F172L CESSNA F172M CESSNA F172N CESSNA F172P	Reims Aviation S.A.	A4EU, Revision 11	CAR 10/CAR 3.
1 Socata	TB 9, TB 10, TB 20, TB 21, TB 200	SOCATA-GROUPE AEROSPATIALE.	A51EU, Revision 14	14 CFR PART 23.
1 Pitts	S–1S, S–1T, S–2, S–2A, S–2S, S–2B, S–2C.	Sky International Inc. (Aviat Aircraft, Inc.).	A8SO, Revision 21	14 CFR PART 23.
1 Taylorcraft	19, F19, F21, F21A, F21B, F22, F22A, F22B, F22C.	Taylorcraft Aviation, LLC	1A9, Revision 19	CAR 3.
1 Taylorcraft	BC, BCS12–D, BCS, BC12–D1, BC–65, BCS12-D1, BCS–65, BC12D–85, BC12–65 (Army L–2H), BCS12D–85, BCS12–65, BC12D–4–85, BC12-D, BCS12D–4–85.	Taylorcraft Aviation, LLC	A–696, Revision 22	CAR 04.
1 Taylorcraft	(Army L–2G) BF, BFS, BF–60,BFS–60, BF–65, BFS–65,(Army L–2K) BF 12–65, BFS–65.	Taylorcraft, Inc	A–699, Revision 5	CAR 4a.
1 Luscombe	8, 8D, 8A, 8E, 8B, 8F, 8C, T–8F	The Don Luscombe Aviation History Foundation, Inc	A–694, Revision 23	CAR 4a.
Sierra Hotel Aero, Inc. (Navion).	Navion (L–17A), Navion A (L–17B) (L–17C),Navion B, Navion D, Navion E, Navion F, Navion G, Navion H.	Sierra Hotel Aero, Inc	A–782, Revision 51	CAR 3.
Piper	J–3	Piper Aircraft Inc	ATC 660, Revision 0	Not listed.
Piper	J3C–40, J3C–50, J3C–50S, J3C–65, J3C–65S, PA–11, PA–11S.	Piper Aircraft Inc	A–691, Revision 33	CAR 4a.
FS 2003 Corporation (Piper).	PA–12, PA–12S	FS 2003 Corporation	A–780, Revision 13	CAR 3.
FS 2002 Corporation (Piper).	PA–14	FS 2002 Corporation	A–797, Revision 11	CAR 3.
Piper	PA–15	Piper Aircraft Inc	A–800, Revision 11	CAR 3.
Piper	PA–16, PA–16S	Piper Aircraft Inc	1A1, Revision 13	CAR 3.
Piper	PA–17	Piper Aircraft Inc	A–805, Revision 12	CAR 3.
2 Piper	PA–18, PA–18S, PA–18A, PA–18S "125", PA–18AS "125", PA–18A "135", PA–18S "135", PA–18AS "135", PA–18 "150", PA–18A "150", PA–18S "150", PA–18AS "150", PA–19S.	The New Piper Aircraft, Inc.	1A2, Revision 37	CAR 3.
Piper	PA–20, PA–20–115, PA–20–135, PA–20S, PA–20S–115, PA–20S–135.	Piper Aircraft Inc	1A4, Revision 24	CAR 3.

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LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS—Continued

Make	Model	TC holder	TCDS	Certification basis
Piper	PA-22, PA-22-108, PA-22-135, PA-22-150, PA-22-160, PA-22S-135, PA-22S-150, PA-22S-160.	Piper Aircraft Inc	1A6, Revision 34	CAR 3.
Piper	PA-23, PA-23-160, PA-23-235, PA-23-250.	Piper Aircraft Inc	1A10, Revision 51	CAR 3.
Piper	PA-24, PA-24-250, PA-24-260, PA-24-400.	Piper Aircraft Inc	1A15, Revision 34	CAR 3.
1 Piper	PA-28-140, PA-28-151, PA-28-150, PA-28-161, PA-28-160, PA-28-181, PA-28-180, PA-28R-201, PA-28-235, PA-28R-201T, PA-28S-160, PA-28-236, PA-28S-180, PA-28RT-201, PA-28R-180, PA-28RT-201T, PA-28R-200, PA-28-201T.	The New Piper Aircraft, Inc.	2A13, Revision 47	CAR 3.
1 Piper	PA-30, PA-39, PA-40	The New Piper Aircraft, Inc.	A1EA, Revision 16	CAR 3.
1 Piper	PA-32-260, PA-32R-301 (SP), PA-32-300, PA-32R-301 (HP), PA-32S-300, PA-32R-301T, PA-32R-300, PA-32-301, PA-32RT-300, PA-32-301T, PA-32RT-300T, PA-32-301FT, PA-32-301XTC.	The New Piper Aircraft, Inc.	A3SO, Revision 29	CAR 3.
1 Piper	PA-34-200, PA-34-200T, PA-34-220T	The New Piper Aircraft, Inc.	A7SO, Revision 16	14 CFR PART 23.
1 Piper	PA-31P, PA-31T, PA-31T1, PA-31T2, PA-31T3, PA-31P-350.	The New Piper Aircraft, Inc.	A8EA, Revision 22	CAR 3.
1 Piper	PA-36-285, PA-36-300, PA-36-375	The New Piper Aircraft, Inc.	A9SO, Revision 9	14 CFR PART 23.
1 Piper	PA-36-285, PA-36-300, PA-36-375	The New Piper Aircraft, Inc.	A10SO, Revision 12	14 CFR PART 21/14 CFR PART 23.
Piper	PA-38-112	The New Piper Aircraft, Inc.	A18SO, Revision 4	14 CFR PART 23.
1 Piper	PA-44-180, PA-44-180T	The New Piper Aircraft, Inc.	A19SO, Revision 9	14 CFR PART 23.
1 Piper	PA-31, PA-31-300, PA-31-325, PA-31-350.	The New Piper Aircraft, Inc.	A20SO, Revision 10	CAR 3.
1 Piper	PA-42, PA-42-720, PA-42-1000	The New Piper Aircraft, Inc.	A23SO, Revision 17	14 CFR PART 23.
1 Piper	PA-46-310P, PA-46-350P, PA-46-500TP.	The New Piper Aircraft, Inc.	A25SO, Revision 14	14 CFR PART 23.
Piper	PA-46R-350T	Piper Aircraft, Inc	A25SO, Revision 16	14 CFR PART 23.
1 Tiger Aircraft LLC (American General).	AA-1, AA-1A, AA-1B, AA-1C	Tiger Aircraft LLC	A11EA, Revision 10	14 CFR PART 23.
1 Tiger Aircraft	AA-5, AA-5A, AA-5B, AG-5B	Tiger Aircraft LLC	A16EA, Revision 13	14 CFR PART 23.
1 Twin Commander	500, 500-A, 500-B, 500-U, 520, 560, 560-A, 560-E, 500-S.	Twin Commander Aircraft Corporation.	6A1, Revision 45	CAR 3.
1 Twin Commander	560-F, 681, 680, 690, 680E, 685, 680F, 690A, 720, 690B, 680FL, 690C, 680FL(P), 690D, 680T, 695, 680V, 695A, 680W, 695B.	Twin Commander Aircraft Corporation.	2A4, Revision 46	CAR 3.
1 Univair (Stinson)	108, 108-1, 108-2, 108-3, 108-5	Univair Aircraft Corporation.	A-767, Revision 27	CAR 3.
1 Univair	(ERCO) 415-D (ERCO) E (ERCO) G (Forney) F-1 (Forney) F-1A (Alon) A-2 (Alon) A2-A (Mooney) M10	Univair Aircraft Corporation.	A-787, Revision 33	CAR 3.
1 Univair (Mooney)	(ERCO) 415-C, (ERCO) 415-CD	Univair Aircraft Corporation.	A-718, Revision 29	CAR 4a.

The following aircraft are certified in the restricted category:

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LIST OF ALL AIRPLANE MODELS AND APPLICABLE TCDS

Make	Model	TC holder	TCDS	Certification basis
Air Tractor	AT–250, AT–300, AT–301, AT–302, AT–400, AT–400A.	Air Tractor, Inc	A9SW, Revision 12	14 CFR PART 23.
Air Tractor	AT–401, AT–401A, AT–401B, AT–402, AT–402A, AT–402B, AT–501, AT–502, AT–502A, AT–502B, AT–503, AT–503A.	Air Tractor, Inc	A17SW, Revision 10	14 CFR PART 23.
Air Tractor	AT–802A, AT–802, AT–602	Air Tractor, Inc	A19SW, Revision 4	14 CFR PART 23.
Allied Ag Cat	G–164, G–164A, G–164B, G–164B with 73", G–164B–15T, G–164B–34T, G–164B–20T, G–164C, G–164D, G–164D with 73" wing gap.	Allied Ag Cat Productions, Inc.	1A16, Revision 24	CAR 8.
Gippsland Aeronautics	GA200	Gippsland Aeronautics Pty. Ltd..	A00001LA, Revision 1	14 CFR PART 23.
[2] Piper	PA–18A, PA–18A "135", PA–18A "150"	The New Piper Aircraft, Inc.	AR–7, Revision 11	CAR 8.
LAVIA S.A. (Piper)	PA–25, PA–25–235, PA–25–260	Latino Americana De Aviación (LAVIA) S.A.	2A10, Revision 24	CAR 8.
Thrush Aircraft, Inc. (Snow, Rockwell, Ayres).	S–2B, S–2C, 600–S2C	Thrush Aircraft, Inc	2A7, Revision 16	CAR 8.
Thrush Aircraft, Inc. (Snow, Rockwell, Ayres).	600 S–2D, S–2R, S2R–T34, S2R–T15, S2R–T11, S2R–R3S, S2R–R1340.	Thrush Aircraft, Inc	A3SW, Revision 18	CAR 3.
Thrush Aircraft, Inc. (Snow, Rockwell, Ayres).	600 S2D, S2R–R1340, S2R–G10, S–2R, S2R–R1820, S2R–G5, S2R–T34, S2R–T65, S2R–G1, S2R–T15, S2RHG–T65, S2RHG–T34, S2R–R3S, S2R–T45, S2R–T660, S2R–T11, S2R–G6.	Thrush Aircraft, Inc	A4SW, Revision 28	CAR 8.
Weatherly	620, 620TP, 620A, 620B, 620B–TG	Weatherly Aircraft Company.	A26WE, Revision 7	14 CFR PART 23.
[3] Ximango	AMT–100, AMT–200, AMT–300, AMT–200S.	Aeromot-Industria Mecanico Metalugica Ltd.	TG00004AT, Revision 4	14 CFR PART 23

[1] Aircraft identified with a 1 have special conditions for AmSafe Aviation Inflatable Restraints published under Special Conditions 23–182–SC.
[2] Piper PA–18A, PA–18A "135" and PA–18A "150" (identified with a 2) are type certificated in Normal/Utility Category on TCDS 1A2 and in Restricted Category on TCDS AR–7. The same aircraft may be operated under either TCDS in accordance with the restrictions listed on TCDS AR–7.
[3] Ximango (identified with a 3) is certificated in the Utility Category.

For all the models listed above, the certification basis also includes all exemptions, if any; equivalent level of safety findings, if any; and the other special conditions.

If the Administrator finds that the applicable airworthiness regulations (*i.e.*, part 23 as amended) do not contain adequate or appropriate safety standards for the AmSafe Aviation, inflatable restraint as installed on these models because of a novel or unusual design feature, special conditions are prescribed under the provisions of § 21.16.

Special conditions, as appropriate, as defined in § 11.19, are issued in accordance with § 11.38, and become part of the type certification basis in accordance with § 21.101.

Special conditions are initially applicable to the model for which they are issued. Should the applicant apply for a supplemental type certificate to modify any other model included on the same type certificate to incorporate the same novel or unusual design feature, the special conditions would also apply to that model under the provisions of § 21.101.

Novel or Unusual Design Features

The various airplane models will incorporate the following novel or unusual design feature:

The AmSafe Aviation Inflatable Two-, Three-, Four-, or Five-Point Restraint Safety Belt with an Integrated Airbag Device.

The purpose of the airbag is to reduce the potential for injury in the event of an accident. In a severe impact, an airbag will deploy from the restraint, in a manner similar to an automotive airbag. The airbag will deploy between the head of the occupant and airplane interior structure. This will, therefore, provide some protection to the head of the occupant. The restraint will rely on sensors to electronically activate the inflator for deployment.

The Code of Federal Regulations state performance criteria for seats and restraints in an objective manner. However, none of these criteria are adequate to address the specific issues raised concerning inflatable restraints. Therefore, the FAA has determined that, in addition to the requirements of part 21 and part 23, special conditions are needed to address the installation of this inflatable restraint.

Accordingly, these amended special conditions are adopted for the various airplane models equipped with the AmSafe Aviation, two-, three-, four, or five-point inflatable restraint. Other conditions may be developed, as needed, based on further FAA review and discussions with the manufacturer and civil aviation authorities.

Applicability

As discussed above, these amended special conditions are applicable to the Approved Model List (AML) above. Should AmSafe Aviation apply at a later date for a supplemental type certificate to modify any other model included on the type certificates listed above to incorporate the same novel or unusual

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design feature, the special conditions would apply to that model as well.

Conclusion

This action affects only certain novel or unusual design features on the previously identified airplane models. It is not a rule of general applicability, and it affects only the applicant who applied to the FAA for approval of these features on the airplane.

Under standard practice, the effective date of final special conditions would be 30 days after the date of publication in the **Federal Register**; however, as the certification date for these airplane models, as modified by AmSafe Aviation, is imminent, the FAA finds that good cause exists to make these amended special conditions effective upon issuance.

List of Subjects in 14 CFR Part 23

Aircraft, Aviation safety, Signs and symbols.

Citation

■ The authority citation for these amended special conditions is as follows:

Authority: 49 U.S.C. 106(g), 40113 and 44701; 14 CFR 21.16 and 21.101; and 14 CFR 11.38 and 11.19.

The Amended Special Conditions

The FAA has determined that this project will be accomplished on the basis of not lowering the current level of safety of the occupant restraint system for the airplane models listed in these special conditions. Accordingly, the FAA is issuing the following amended special conditions as part of the type certification basis for these models, as modified by AmSafe, Aviation.

Inflatable Two-, Three-, Four-, or Five-Point Restraint Safety Belt with an Integrated Airbag Device Installed in an Airplane Model.

1a. It must be shown that the inflatable restraint will provide restraint protection under the emergency landing conditions specified in the original certification basis of the airplane. Compliance will be demonstrated using the static test conditions specified in the original certification basis for each airplane.

1b. It must be shown that the crash sensor will trigger when exposed to a rapidly applied deceleration, like an actual emergency landing event. Therefore, compliance may be demonstrated using the deceleration pulse specified in § 23.562, which may be modified as follows:

I. The peak longitudinal deceleration may be reduced; however, the onset rate of the deceleration must be equal to or greater than the emergency landing pulse identified in § 23.562.

II. The peak longitudinal deceleration must be above the deployment threshold of the sensor, and equal or greater than the forward static design longitudinal load factor required by the original certification basis of the airplane.

2. The inflatable restraint must provide adequate protection for each occupant. In addition, unoccupied seats that have an active restraint must not constitute a hazard to any occupant.

3. The design must prevent the inflatable restraint from being incorrectly buckled and/or incorrectly installed such that the airbag would not properly deploy. Alternatively, it must be shown that such deployment is not hazardous to the occupant and will provide the required protection.

4. It must be shown that the inflatable restraint system is not susceptible to inadvertent deployment as a result of wear and tear or the inertial loads resulting from in-flight or ground maneuvers (including gusts and hard landings) that are likely to be experienced in service.

5. It must be extremely improbable for an inadvertent deployment of the restraint system to occur, or an inadvertent deployment must not impede the pilot's ability to maintain control of the airplane or cause an unsafe condition (or hazard to the airplane). In addition, a deployed inflatable restraint must be at least as strong as a Technical Standard Order (C22g or C114) restraint.

6. It must be shown that deployment of the inflatable restraint system is not hazardous to the occupant or will not result in injuries that could impede rapid egress. This assessment should include occupants whose restraints are loosely fastened.

7. It must be shown that an inadvertent deployment that could cause injury to a sitting person is improbable. In addition, the restraint must also provide suitable visual warnings that would alert rescue personnel to the presence of an inflatable restraint system.

8. It must be shown that the inflatable restraint will not impede rapid egress of the occupants 10 seconds after its deployment.

9. For the purposes of complying with HIRF and lightning requirements, the inflatable restraint system is considered a critical system since its deployment could have a hazardous effect on the airplane.

10. It must be shown that the inflatable restraints will not release hazardous quantities of gas or particulate matter into the cabin.

11. The inflatable restraint system installation must be protected from the effects of fire such that no hazard to occupants will result.

12. There must be a means to verify the integrity of the inflatable restraint activation system before each flight or it must be demonstrated to reliably operate between inspection intervals.

13. A life limit must be established for appropriate system components.

14. Qualification testing of the internal firing mechanism must be performed at vibration levels appropriate for a general aviation airplane.

Issued in Kansas City, Missouri on October 31, 2008.

James E. Jackson,

Acting Manager, Small Airplane Directorate, Aircraft Certification Service.

[FR Doc. E8-26663 Filed 11-6-08; 8:45 am]

BILLING CODE 4910-13-P

DEPARTMENT OF HOMELAND SECURITY

U.S. Customs and Border Protection

19 CFR Part 102

[CBP Dec. 08-42]

Technical Corrections Relating to the Rules of Origin for Goods Imported Under the NAFTA and for Textile and Apparel Products

Correction

In rule document E8-25734 beginning on page 64518 in the issue of Thursday, October 30, 2008, make the following correction:

§102.21 [Corrected]

On page 64539, in §102.21, in the table, in the first column, in the firstentry, "6209.20.1000...."should read "6209.20.1000–".

[FR Doc. Z8-25734 Filed 11-6-08; 8:45 am]

BILLING CODE 1505-01-D

DEPARTMENT OF LABOR

Mine Safety and Health Administration

30 CFR Parts 56, 57, and 71

RIN 1219-AB24

Asbestos Exposure Limit

AGENCY: Mine Safety and Health Administration, Labor.

ACTION: Final rule, technical amendment.

Appendix D. Summary of Dynamic Seat/Restraint Tests Required for Title 14 *Code of Federal Regulations* Part 23 Aircraft

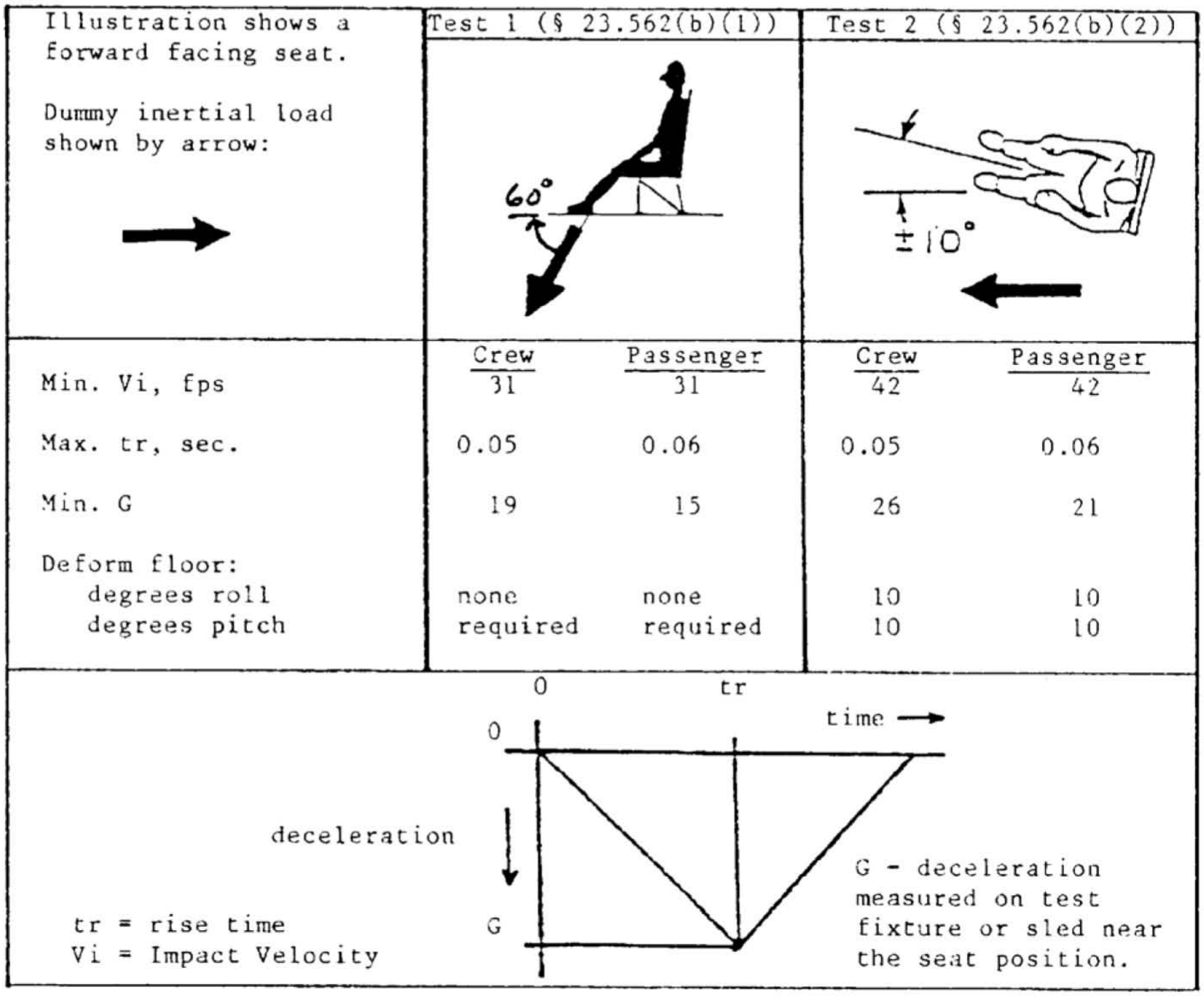


Illustration shows a forward facing seat. Dummy inertial load shown by arrow:	Test 1 (§ 23.562(b)(1))		Test 2 (§ 23.562(b)(2))	
	Crew	Passenger	Crew	Passenger
Min. Vi, fps	31	31	42	42
Max. tr, sec.	0.05	0.06	0.05	0.06
Min. G	19	15	26	21
Deform floor: degrees roll	none	none	10	10
degrees pitch	required	required	10	10

Figure 2 - SEAT/RESTRAINT SYSTEM DYNAMIC TESTS
NORMAL, UTILITY, OR ACROBATIC CATEGORY AIRPLANES

Appendix E. Airbag Data Collection Form

Survival Factors

Field Notes for Airbag Performance in General Aviation Restraint Systems Safety Study

[Insert date.]

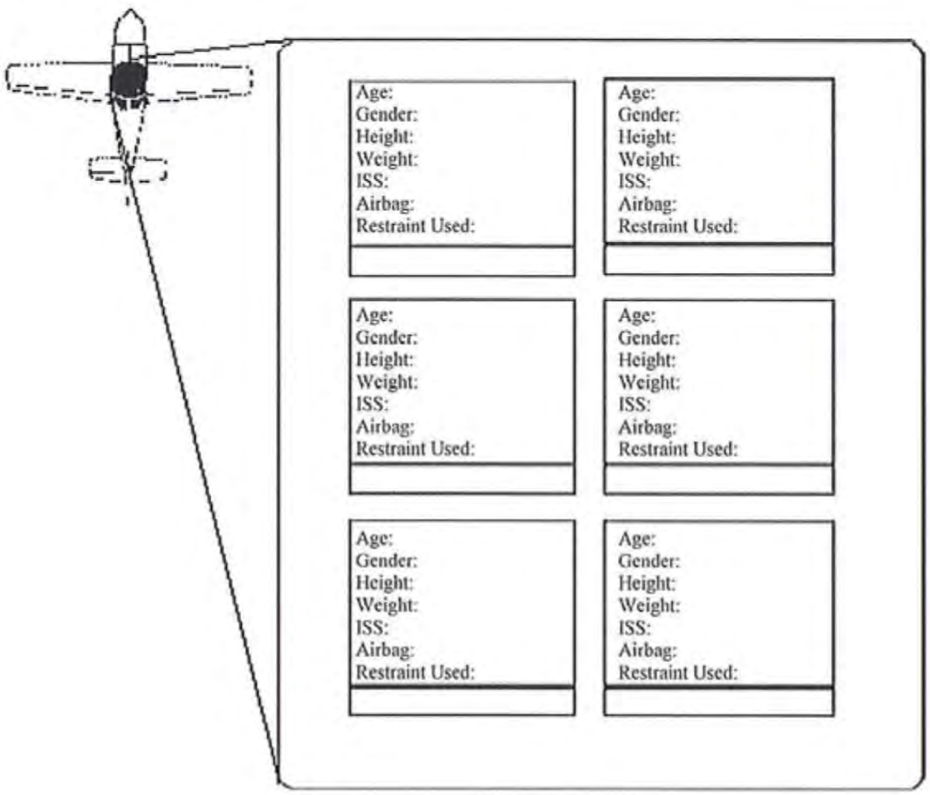
Location:
Aircraft Type:
Accident Date:
Accident Time:
Accident Number:
Airbag Equipped:

Group Members

NTSB Group Chairman:

Additional Members:

Seating Chart



Documentation

Write a brief description of the overall condition of the airplane and any exterior damage that may help explain occupant position, motion, and injuries.

Insert photograph.

Figure x. A photograph showing the damage to the airplane.

Document any impact marks found in the airplane, such as on the instrument panel, windshield, side windows, doors, canopy, etc. Note condition of foot wells.

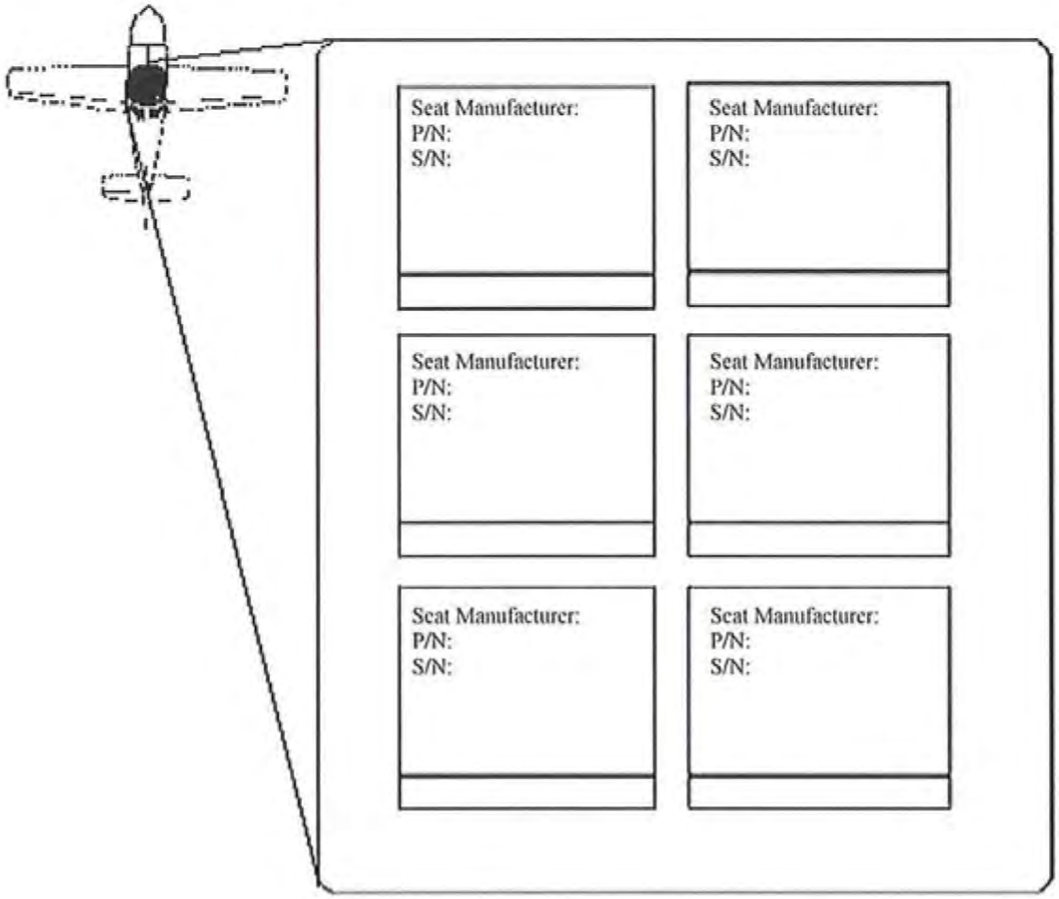
Seats

Write a brief description addressing the condition of the seats. Note any damage to the exterior seat coverings. Document current seat positions. For example, count the number of seat pins back from full forward position. Measure the length and width of each seat pan and the width and height of each seat back. (Examine restraints and airbags prior to removal of seat coverings.) Remove exterior coverings and foam padding. Note differences in construction between front and rear seats. Note differences in the energy absorbing structure in the front and rear seats. Document deformation patterns on seat pan, seat pan energy absorbing material, and seat backs. Measure amount of deformation, note patterns of deformation, and photograph if possible. Note any loss of space under seats due to deformation or equipment storage.

Insert photograph. (Example shown below.)

Figure x. Dimensions of the seats.

Seat Numbers



Insert photographs to highlight the condition of the seating systems.

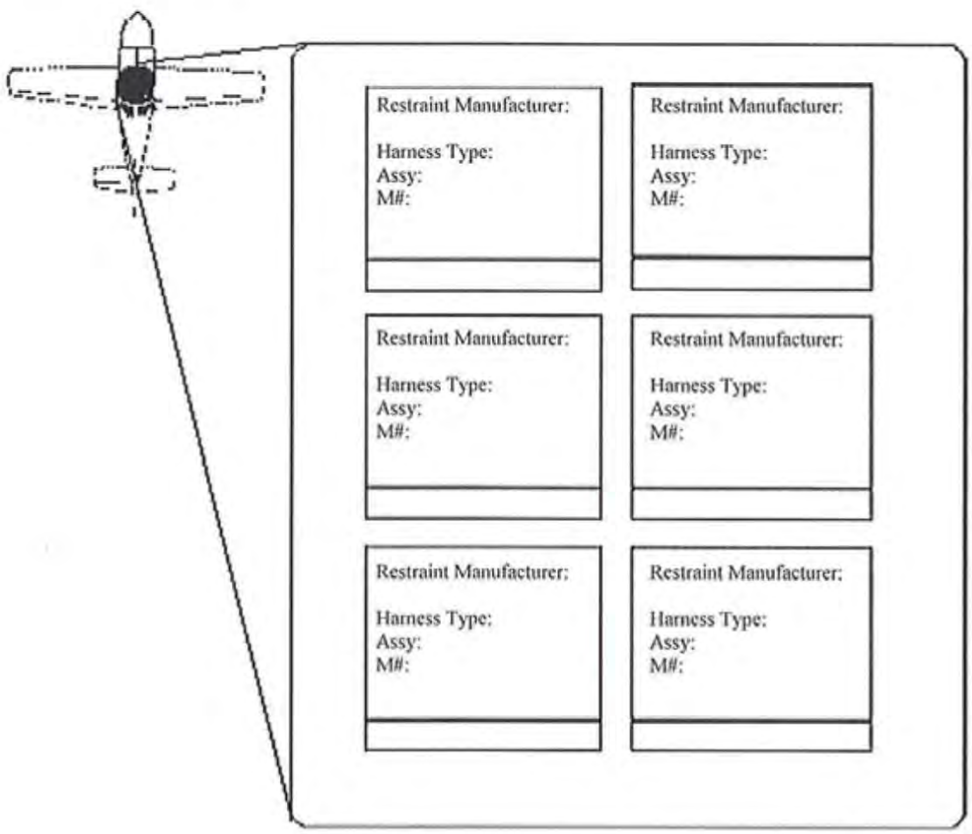
Figure x. [Add descriptive caption.]

Restraints

Condition of Restraints

Note if the seat has a 2-point, 3-point, or 4-point restraint system. Note impact/loading marks in webbing, damage to webbing, latches, retractors, damage from emergency response, etc. Note if retractors function properly. Note location of any marks on webbing using the attachment point as a reference point for measurements.

Restraint Numbers



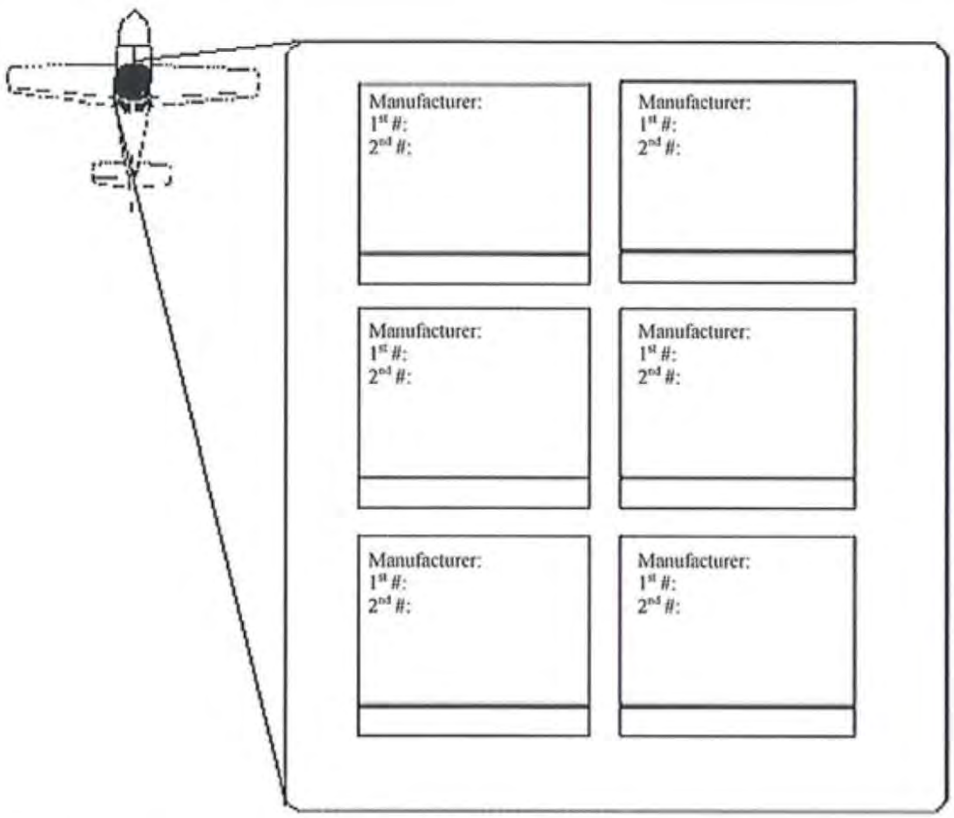
Insert photographs to highlight the condition of the restraint systems.

Figure x. [Add descriptive caption.]

Airbags

Note the location of the airbag (lap belt portion or shoulder harness.) The 2- and 3-point restraint systems typically have a latch sensor so that the airbag only fires if the latch is connected. Note the condition of this sensor. Note the labels on all airbag inflators. Document and photograph any witness marks found on the airbags. Document and photograph the vent holes on all airbags.

Airbag Labels



Insert photographs to highlight the condition of the airbags and associated vent holes.

Figure x. [Add descriptive caption.]

Medical/Autopsy Information

Provide a description of the type of data obtained and where it was obtained. Note the hospital names and locations, the dates of treatment, and the dates of any autopsies conducted. This will likely be completed after the initial investigation. Most of the fields in the table below will be automatically completed from the seating chart data, but the detailed description of injuries will need to be filled in manually for each occupant.

Occupant Location	Gender	Age	Height	Weight	Description of Injuries	Injury Classification
First Row, Left						
First Row, Right						
Second Row, Left						
Second Row, Right						
Third Row, Left						
Third Row, Right						

Insert other photographs as appropriate.

Figure x. [Add descriptive caption.]

Appendix F. Injury Details

Boyceville, Wisconsin (CHI06FA218)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 55 Height: 6 feet Weight: 242 pounds Injury Classification: Serious	Open left pilon fracture with associated fibula fracture Left nondisplaced radial head fracture Fracture of posterior medial aspect of right 3rd, 4th, 5th and possibly 2nd ribs Mildly displaced fractures of the right 2nd, 4th, 5th and 7th ribs Mildly displaced anterolateral fractures of the left 4th and 5th ribs Small abrasions and contusions to right temple; bruising over left eyelid 3 centimeter laceration to chin Small contusions scattered on right chest wall Contusion on left forearm
Position: Front row, right seat Sex: Male Age: 27 Height: 6 feet Weight: 150 pounds Injury Classification: Minor	Left forehead laceration Left upper arm abrasion Left posterior iliac abrasion Lower cervical neck strain[a]
Position: Second row, right seat Sex: Male Age: 26 Height: Not available Weight: 178 pounds Injury Classification: Minor	Left anterior tibial abrasion Right iliac crest abrasion

[a] This occupant self-reported additional injuries that he termed “trivial”. These injuries included a bruise above his right eye, a bruise on his right shoulder and right hip that he attributed to the restraint, and bruising to his backbone. He also noted bumps on his legs and right arm.

Owyhee, Oregon (SEA06FA168)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 61 Height: 6 feet 1 inch Weight: 180 pounds Injury Classification: Minor	Minor laceration and bruising on head Bruise on right hip Bruise on left shin

Indianapolis, Indiana (CHI06FA245)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 66 Height: 5 feet 8 inches Weight: 150 pounds Injury Classification: Fatal	Subgaleal hemorrhage Left orbital roof fracture Left sided subdural hemorrhage Bilateral subarachnoid hemorrhage (diffuse) Bilateral frontal and left temporal contusion 2 sternal fractures; nondisplaced posterior left 1st–3rd, 6th, 7th, 9th, 12th rib fractures; lateral left 3rd–8th rib fractures Aortic lacerations (2 centimeters in length and 1.5 centimeters in length); Moderate right homothorax Small left hemothorax Bilateral pulmonary contusions Transverse fracture through body of C2 Burst fracture of L1, L4 Bilateral L1 and L2 transverse process fractures Left transverse process fracture at L3 and L4 Nondisplaced L4 laminar fractures Nondispalced fracture of the coccyx Multiple contusions and abrasions on extremities 2–3 centimeter laceration in the left parietal scalp
Position: Front row, right seat Sex: Male Age: 29 Height: 5 feet 8 inches Weight: 165 Injury Classification: Serious	Right side small subdural hematoma Right subarachnoid hemorrhage Mild right mid-lobe pulmonary contusion Sternal fracture L2 burst fracture Bilateral L1 and L2 transverse process fracture Nondisplaced right side L5 vertebral body fracture Small chin laceration Contusion to the right temporal lobe and right frontal lobe Abrasion to right lateral neck Abrasion to the right forehead and left mandibular region
Position: Back row, left seat Sex: Female Age: 49 Height: 5 feet 5 inches Weight: 120 pounds Injury Classification: Serious	Blunt trauma to chest and abdomen L1 burst fracture T12 posterior element fractures Nondisplaced sternal fracture; minimally displaced left 2nd, 4th, and 5th rib fractures Mildly displaced right anterior 2nd rib fracture Nondisplaced posterior left 11th rib fracture Nondisplaced right posterior 1st rib fracture Severe left mid-foot sprain Fracture anterior nasal spine of the maxilla Minimally depressed medially angulated incomplete fracture of the right nasal bone Chin lacerations Small right frontal scalp hematoma
Position: Back row, right seat Sex: Female Age: 60 Height: 4 feet 11 inches Weight: 115 pounds Injury Classification: Serious	T12 burst fracture Transverse process fracture of right L1, L3 and L5 and left L1, L2, and L3 Nondisplaced left 2nd–6th rib fractures Nondisplaced posterior left 9th, 10th, and 11th rib fractures Minimally displaced right 4th rib fracture Nondisplaced right 7th rib fracture

	Left upper back superficial burn Partial thickness burns to the back and left foot

Athens, Texas (DFW07LA078)

Occupant Information	Injury Details
Position: Front Row, Left Seat Sex: Male Age: 31 Height: 5 feet 11 inches Weight: 176 pounds Injury Classification: Minor	Bruises and Sprains
Position: Front Row, Right Seat Sex: Male Age: 37 Height: 5 feet 8 inches Weight: 234 pounds Injury Classification: Serious	Compression fractures of C-7, T-1, and T-2 vertebrae Minor head laceration
Position: Back Row, Left Seat Sex: Male Age: 58 Height: 5 feet 11 inches Weight: 241 pounds Injury Classification: Serious	Fractured and dislocated 4th and 5th ribs on the right side Bruises and sprains

Fullerton, California (LAX08FA301)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 59 Height: 5 feet 11 inches Weight: 245 pounds Injury Classification: Serious	Right proximal femoral shaft fracture Left tibial plateau fracture Right distal nondisplaced femoral shaft fracture Right open ulnar fracture Right anterior pulmonary contusion Nasal bone fracture Stellate laceration across bridge of nose (6 centimeters) Right eyebrow laceration (3 centimeters) Abrasion, hematoma on left chest Abrasions across right upper and lower quadrant

Groton, Connecticut (ERA09LA064)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 54 Height: 6 feet 9 inches Weight: 290 pounds Injury Classification: Minor	Bruised right knee Left thumb abrasion
Position: Front row, right seat Sex: Male Age: 76 Height: 6 feet Weight: 185 pounds Injury Classification: Minor	Bruised knuckles on both hands Minor knee laceration

Green Cove Springs, Florida (ERA09LA062)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 25 Height: 5 feet 7 inches Weight: 155 pounds Injury Classification: Minor	Cut to upper left side of forehead
Position: Front row, right seat Sex: Male Age: 50 Height: 5 feet 9 inches Weight: 195 pounds Injury Classification: None	None
Position: Back row, right seat Sex: Male Age: 26 Height: 5 feet 7 inches Weight: 170 pounds Injury Classification: None	None

Steamboat Springs, Colorado (CEN09LA165)

Occupant Information	Injury Details
Position: Front Row, Left Seat Sex: Male Age: 57 Height: 5 feet 11 inches Weight: 190 pounds Injury Classification: None	None
Position: Front Row, Right Seat Sex: Female Age: 53 Height: 5 feet Weight: 97 pounds Injury Classification: Minor	Bloody nose Small chin bruise Small chest bruise between 3rd and 4th rib Sprained left hand/wrist
Position: Back Row, Left Seat Sex: Female Age: 13 Height: 5 feet Weight: 100 pounds Injury Classification: None	None
Position: Back Row, Right Seat Sex: Female Age: 15 Height: 5 feet 1 inch Weight: 110 pounds Injury Classification: None	None

Stigler, Oklahoma (CEN09LA247)

Occupant Information	Injury Details
Position: Front row, left seat Sex: Male Age: 18 Height: 6 feet Weight: 165 pounds Injury Classification: Serious	Left fibula fracture Right lateral malleolus fracture Right orbital wall fracture Right zygomatic fracture Right maxillary sinus fracture Facial lacerations Right eye contusion Upper and lower lip contusions Bilateral knee abrasions
Position: Front row, right seat Sex: Female Age: 43 Height: 5 feet 3 inches Weight: 125 pounds Injury Classification: Minor	Contusions on left shoulder and left side of neck Contusions and abrasions on right hip
Position: Back row, left seat Sex: Female Age: 45 Height: 5 feet 6 inches Weight: 162 pounds Injury Classification: Minor	Left knee contusion Anterior left ankle laceration

Boyd, Texas (CEN09LA442)	
Occupant Information	**Injury Details**
Position: Front row, left seat Sex: Male Age: 24 Height: 5 feet 10 inches Weight: 142 pounds Injury Classification: Minor	Laceration (3 centimeters) to left side of head (staples) Sprained right ankle Contusion on right heel Back strain