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Surviving an Aircraft Crash with Airbag Restraints

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Inflatable restraint solutions have improved the survivability of commercial transport and civil General Aviation (GA) aircraft by mitigating impact injury and keeping the occupants conscious and able to evacuate quickly. The AmSafe® Aviation Airbag makes advanced occupant crash protection systems feasible for retrofit into existing, and space-constrained, cabins/cockpits. This technology has not been incorporated into military aircraft as it is challenging to configure and qualify the equipment for Department of Defense specifications. A look at the history and field performance of the AmSafe Aviation Airbag illustrates the factors to be considered and the potential benefits for military aircraft.

Transport Aircraft Interiors

The AmSafe Aviation Airbag entered service on commercial aircraft in February 2001. The first use was for transport aircraft that needed to comply with the improved crash safety regulations of FAR 25.562 [1]. These regulations introduced dynamic loading requirements for aircraft seats in 1988. Dynamic impact tests with an Anthropomorphic Test Dummy (ATD) are now common to ensure that all civil aircraft seats and floor attachments comply with the FAR 25.562 regulation. The Head Injury Criteria (HIC), a measure of injury potential from head impact, was introduced with the FAR 25.562 regulation in 1988.



100 ms 140 ms
The AmSafe Aviation Airbag functions during a 16g, 180ms impact. It is installed in the front row economy behind a bulkhead.

Airbags can absorb and distribute high levels of impact energy and were immediately considered for HIC and improving safety. Certifying the technology for aviation use, however, required years of development to satisfy a wide range of requirements including electrical (such as EMI/HIRF and lightning strikes), mechanical (such as vibration and structure), and other environments (such as temperature, humidity, and altitude exposure). A well-planned and novel compliance approach

met the requirement that safety devices on aircraft be extremely reliable. It also showed that the system functions for the full range of occupants and uses without impeding evacuation. All of this had to be done in a package to retrofit into existing interiors and had to meet the aggressive cost and weight targets for commercial aviation.

In the AmSafe Aviation Airbag configuration, the airbag is mounted onto the restraint and has modular components with highly adaptable attachments. This configuration meets the requirements of both design and market acceptance. Aircraft that use this configuration can greatly expand the flexibility of the interior design. Many new premium-class interiors are possible only because the airbag mitigates occupant flailing and because it passes injury prevention requirements.

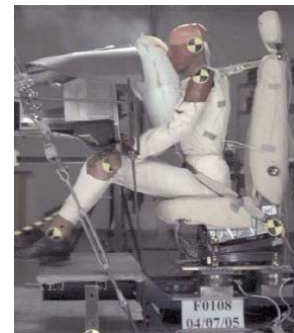


Airbag protection from impact to side-mounted furniture in a premium seat mounted at an angle to the aircraft axis.

General Aviation / Light Sport

Dynamic performance standards were also adopted for GA aircraft in 1988 with FAR 23.562 [2]. The new regulation impacted GA aircraft less than transport aircraft. The FAR

23.785 [3] regulation already required shoulder restraints. The minimum injury prevention requirements for GA aircraft can generally be satisfied without an airbag. Improved crash protection, as opposed to HIC compliance, was the motive for introducing the AmSafe Aviation Airbag in GA and Light Sport aircraft. GA aircraft have a much higher accident and fatality rate than transport aircraft. Accidents are 28 times more frequent and fatalities 26 times higher in GA aircraft based on ten years of statistics from 1997 to 2007. The statistics compare accidents per 1 million miles flown and fatalities sustained for part 121 and 91 operations [4].



The AmSafe Aviation Airbag's four-point configuration used for GA aircraft.

The AmSafe Aviation Airbag was certified both for the pilot/copilot and rear passenger seats on various GA and Light Sport aircraft beginning in 2004. The system is widely used in the production of single-engine GA aircraft. Since 2007, the airbag has been installed as standard equipment on about 80% of new single-engine aircraft.

Pretension / Flail Mitigation

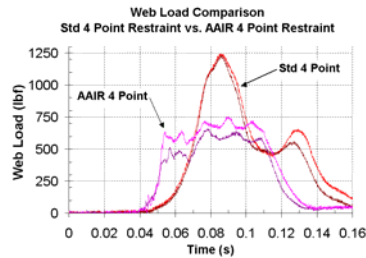
Airbag designs use the energy-absorbing capability differently depending on the interior design. The images from dynamic tests shown previously in this article use the bag predominantly as a barrier between the occupant and the structure. A spring/damper analogy can be applied to the barrier bag concept. The occupant hitting the bag is resisted by increasing air pressure, essentially creating a pneumatic spring. The maximum compression of the bag occurs before the occupant's head hits the interior structure. The venting of the bag acts as a damper, reducing the rebound and dissipating the energy through the air flowing out of the bag.

Other applications use the bag differently. The bag can distribute restraint loads to the occupant early in the event, reducing the momentum caused by the occupant articulating forward. This reduces the peak seatbelt forces, spreading them over a longer time interval.



The tubular AmSafe Aviation Airbag four-point restraint compared to a standard four-point restraint.

Airbag configurations offer two benefits: a reduction of the flailing envelope (zone in which the occupant may contact aircraft structure) thus avoiding potential body impact to the structure; and the reduction of seatbelt force applied to the body.



A restraint web load comparison between the tubular airbag four-point restraint and a standard four-point restraint.

Side-facing seats are used in limited but important configurations. Troop transport, medical evacuation, and other special vehicles require seat positions exposed to lateral impact forces. The body is more susceptible to non-longitudinal impact forces. The same airbag benefits apply for lateral impacts.



A tubular three-point restraint compared with a standard three-point restraint in a lateral impact.

A three-point restraint with a tubular bag incorporated into the shoulder harness eliminates body-to-body contact and head impact with structures just a few inches away from the head, as shown in the above figure.

The benefits and a wide range of applications are not conceptual. Restraint-mounted airbags have been in service for more than a decade. U.S. Army aircraft make limited use of systems such as the Inflatable Body and Head Restraint System (IBAHRS), originally developed in the early 1990's by Simula Inc. (now part of BAE Systems). Early systems used older, solid propellant inflation

technology. The heat generated by the inflators limited bag designs and prevented these systems from reaching a wider market. The AmSafe Aviation Airbag system was first developed in the late 1990s and began revenue service in commercial aircraft in early 2001. The system has since gone through several design iterations and uses a range of modern compressed gas and hybrid (compressed bag/pyrotechnic) inflator technologies.

Experience in the Field

More than 37,000 AmSafe Aviation Airbag systems have been produced and are flying in more than 6,000 aircraft. The airbag is certified on every major transport aircraft platform and is used by over 30 airlines worldwide. The GA and Light Sport aircraft applications are more recent. Standard installations began in late 2005 on aircraft such as Cessna 172/182/206 and Cirrus SR20/SR22. The number of commercial aircraft equipped with AmSafe Aviation Airbags is expanding rapidly. Installations averaged more than 130 GA aircraft per month in 2008. Since the first commercial accident with an air bag-equipped aircraft in late 2005, there have now been over 50 accidents monitored by AmSafe.

Minor Accidents

The accidents can be classified according to the injury potential and if the AmSafe Aviation Airbag system deployed. Minor-injury accidents generally do not have sufficient impact force to cause deployment. A typical example is veering off the runway. These accidents are not always minor from an aircraft damage perspective. The AmSafe Aviation Airbag has demonstrated appropriate activation thresholds

and no inadvertent deployments have been recorded.



Iberia Airlines A340-600 overshot the runway in Ecuador. There were no injuries. AmSafe Aviation Airbags did not deploy [6].

Another example of a more serious accident, but one with only minor injury potential, occurs if the impact is dissipated progressively. The AmSafe Aviation Airbag crash sensor activates only on an impact large enough to threaten serious injury.



The Cirrus SR22 crashed and slowly broke through trees. There were no injuries and the AmSafe Aviation Airbags did not deploy [7].

Major Accidents

Deployments in the field have also indicated the appropriate crash sensor threshold. They have occurred in accidents where the potential for serious injury existed but only minor injury occurred. The AmSafe Aviation Airbag has been deployed in the accidents where serious injuries have occurred. There have also been serious/fatal and non-survivable accidents.



The Cirrus SR22 crashed upon takeoff. There were no serious injuries and the AmSafe Aviation Airbag deployed upon impact [8].

Accidents have occurred with the airbags deployed, and the occupants were able to evacuate the aircraft despite having sustained serious injury.



The Cirrus SR22 crashed upon approach. AmSafe Aviation Airbags deployed and occupants with serious injuries evacuated [9].

Potential Military Applications

The restraint-mounted design and modular components of the AmSafe Aviation Airbag system make it adaptable to a wide variety of cockpit and cabin configurations. Most of the current applications were retrofitted into existing aircraft interiors. The AmSafe Aviation Airbag system has great potential for the constrained space of military applications. The modified restraint eliminates the need to incorporate an airbag module into the cabin or cockpit structure. The bag can be positioned right where it is needed, accommodating a wide range of occupant sizes and personal equipment (such as combat gear). Military specifications have more stringent environmental requirements and impact parameters. The AmSafe Aviation Airbag components can be adapted

for the specifications with upgrades to items such as electrical cables and connectors. The inflation and bag performance of the system can be configured to military impact environments just as the system is currently designed for each unique interior and civil aircraft type. Crash sensing for various military aircraft depends on the aircraft type and the impact environment. Some applications, such as helicopters, require that the sensing system be modified so that it can appropriately discriminate inputs from various directions.

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