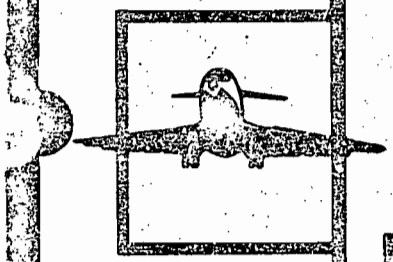

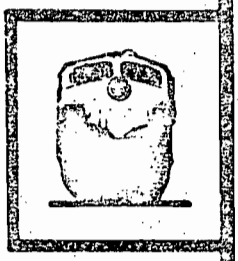

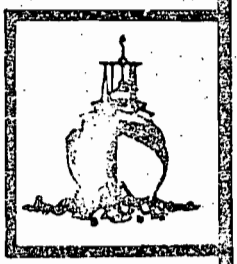

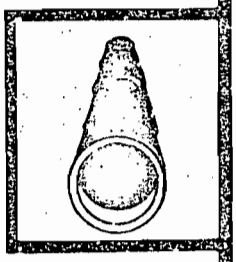

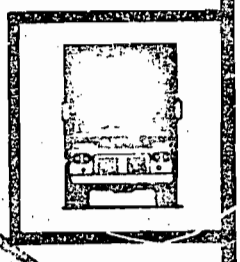

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY REPORT

THE STATUS OF GENERAL AVIATION AIRCRAFT CRASHWORTHINESS

NTSB-SR-80-2

UNITED STATES GOVERNMENT

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16. Abstract

The use of general aviation aircraft in transportation during the past decade has increased rapidly. Possibly more passengers are transported annually in general aviation aircraft than in all commercial air carriers combined. Investigations of general aviation aircraft accidents believed to be survivable indicate that the causes and types of injuries and fatalities are not different from those documented 30 to 40 years ago. However, improvements in the crashworthiness of automobiles during the past decade has been documented through a reduction of the fatality-to-injury ratios. Such improvement in general aviation aircraft crashworthiness has been sought by the National Transportation Safety Board, the Civil Aeronautics Board, and others for more than 35 years.

This report reviews past accident investigations, regulatory developments, and crashworthiness research activities, and assesses the adequacy of current general aviation crashworthiness requirements. As a result of this review, recommendations for improved crashworthiness of general aviation aircraft are made.

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FOREWORD

The mission of the National Transportation Safety Board is to improve transportation safety. This is done by determining the probable causes of accidents through accident investigations and public hearings, through staff review and analysis of accident information, through evaluations of operations, effectiveness, and performance of other agencies, through special studies and special investigations, and through publication of recommendations and reports.

Since its establishment, the Safety Board has been concerned that certain safety problems of national significance have not been addressed as rapidly as possible, even though needed improvements were known, feasible, and timely. Therefore, the Safety Board has begun to identify a number of salient problems each year and to pursue implementation of specific safety improvements. One of these safety objectives during fiscal year 1980 was to persuade the Federal Aviation Administration to improve regulations regarding the crashworthiness of general aviation aircraft.

This Safety Report reviews past accident investigation, regulatory development, and crashworthiness research activities, and assesses the adequacy of present crashworthiness requirements and designs.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SAFETY REPORT

Adopted: December 17, 1969

THE STATUS OF GENERAL AVIATION AIRCRAFT CRASHWORTHINESS

INTRODUCTION

The use of general aviation aircraft 1/ in transportation is increasing rapidly. It has been estimated that more passengers annually travel in general aviation aircraft than in all the commercial air carriers combined. During the past decade, over 100,000 occupants of general aviation aircraft have been involved in 39,458 accidents; 17.7 percent of these accidents involved a fatality. Studies report that the chances are substantial that a general aviation aircraft will be involved in an accident during a 20-year service life; probabilities ranged from 60 to 73 percent in reports reviewed (13, 91, 97, and 133). 2/

These data, considered with the current accident and fatality rate of general aviation aircraft, raise concern about the slow pace of improvement of the crashworthiness of these aircraft. The causes and types of injuries and fatalities that occur in survivable general aviation aircraft crashes are well documented. However, National Transportation Safety Board accident investigations indicate that few changes have been made in the design of cabin interiors or restraint systems which might have eliminated or reduced these injuries. This situation contrasts sharply with the progress in improving automobile crashworthiness. For example, accident statistics show that in general aviation aircraft accidents 2 fatalities occur for every 3 serious injuries while in automobile accidents only 1 fatality occurs for each 10 serious injuries. (13, 136, 145) The high occupant survivability in automobile accidents has been attributed primarily to crashworthiness improvements required by the National Highway Traffic Safety Administration. (86, 94) The Safety Board recognizes that automobile and aircraft accident statistics are not directly comparable because of different crash loads and vehicle design objectives. However, a comparison of these statistics points up the beneficial effect of aggressive regulatory actions in improving occupant crash protection of transportation vehicles.

1/ General aviation aircraft are defined as those airplanes certificated under 14 CFR 23 and predecessor regulations, having a gross weight of 12,500 pounds or less.

2/ Numbers in parentheses refer to source publications listed by number in appendix A.

The Safety Board believes that when the crash forces transmitted to occupants through properly designed seats and restraint systems do not exceed the limits of human tolerance to abrupt decelerations, and when the cabin structure remains sufficiently intact to provide a liveable space immediately around the occupants, they should survive the accident without serious injury. (See figure 1.) The Safety Board has studied in depth the status of aircraft crashworthiness and the adequacy of Federal regulations that require occupant crash protection. 3/ This report reviews past accident investigations, regulatory developments, and crashworthiness research activities, and assesses the adequacy of current general aviation crashworthiness requirements and designs.

RESULTS OF CRASHWORTHINESS ACCIDENT INVESTIGATIONS AND ANALYSES

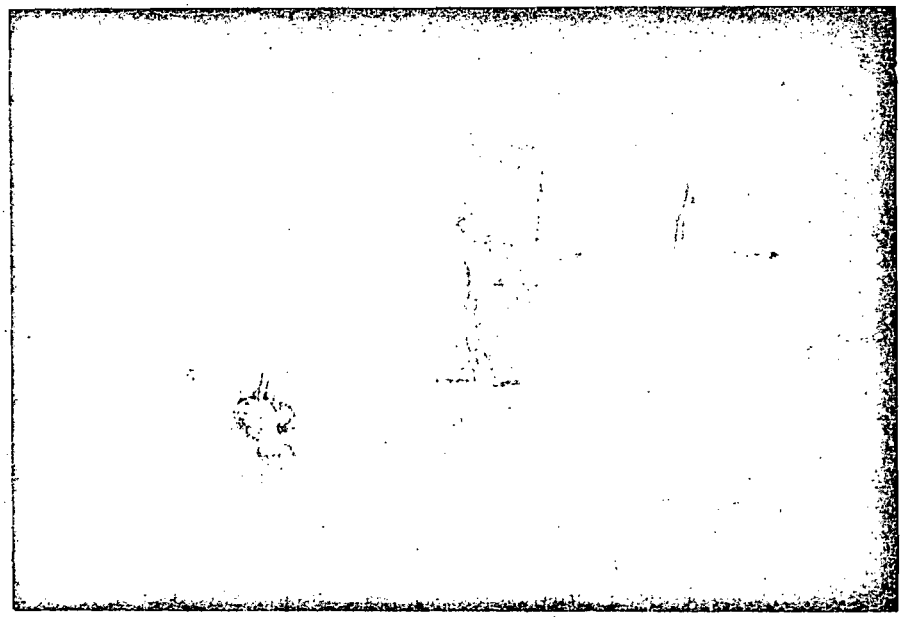
One of the earliest formal general aviation crash survivability studies based upon aircraft accident investigations was reported in a 1943 Civil Aeronautics Board (CAB) publication. (20) The CAB initiated this study "with the object [sic] of finding injury facts and determining what number of crashes are survivable." The report concluded that: (1) "the force of many accidents now fatal is well within physiological limits of survival [and] needless injuries—both serious and fatal—are caused by the unfortunate placement and design of certain objects and structures . . . ," and (2) "with a knowledge of injury causes, manufacturers and designers can modify or eliminate many hazards and provide conspicious degrees of emergency safety. . . ."

A 1944 Air Surgeon's Bulletin and a 1945 National Research Council study related the causes of injuries in light aircraft accidents. (21, 23) In 1949, an analysis of injury to 1,942 occupants of 1,442 light airplanes was conducted to evaluate the types and locations of injuries. (31) The incident pattern developed by these analyses was confirmed in a 1952 study of 800 survivors of light-airplane accidents which reported 704 injuries to the head, 641 to the lower limbs, 548 to the thorax, and 339 to the arms. (29)

A study of light aircraft accidents during an 11-year period ending in 1952 analyzed 913 accidents which involved 1,596 occupants and 15 aircraft models. (50) This study found that in the accidents that resulted in 385 of the 389 fatalities, 143 occupants died in aircraft that remained intact or were not severely distorted. Another 155 occupants died in partly collapsed cabins which retained structural integrity. Of these 389 fatalities, 298 (77 percent) died in accidents in which the cabin structure appeared crashworthy, and the study concluded that "roughly 1/3 of the 389 people killed . . . died unnecessarily."

In 1964, the CAB's Bureau of Safety noted that from January 1964 through October 20, 1964, 826 fatalities resulted from general aviation accidents. Of these fatalities, the CAB estimated that about 200 could have been prevented if shoulder harnesses had been installed and used. This estimate was based on the CAB's study of 25 accidents selected at random. Based upon its findings, the CAB made

3/ Postcrash fire problems were reported in a Safety Board Special Study, "General Aviation Accidents: Postcrash Fires and How to Prevent or Control Them" (NTSB-AAS-80-2).



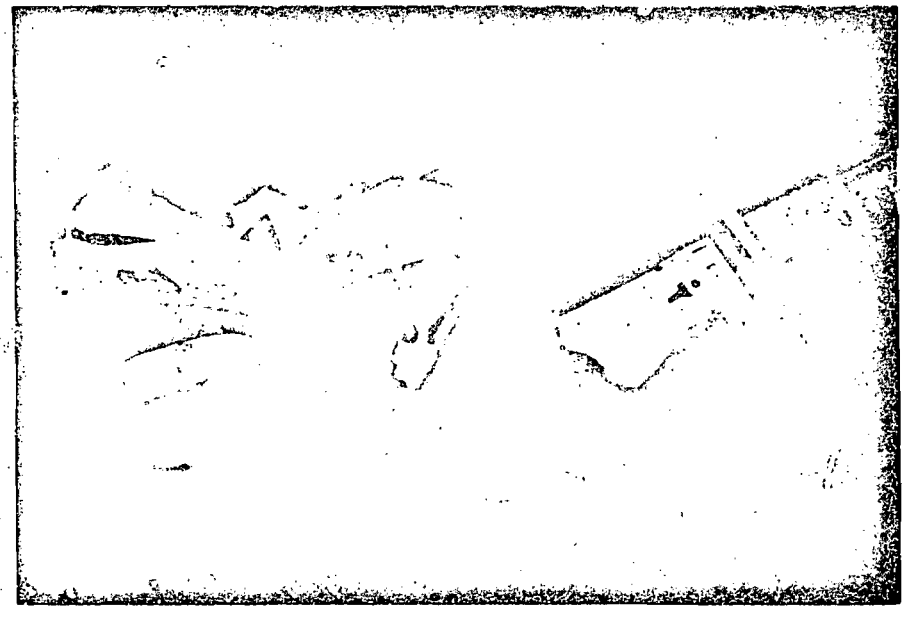


Figure 1.—Four persons were killed in this crash. The aircraft cabin remained essentially intact, and the crash should have been survivable.

three recommendations to the Federal Aviation Agency (FAA) 4/ for crashworthiness improvements (see page 17).

A 1970 Aviation Consumer Action Project report reviewed much of the history of aircraft accidents and research, regulations, and manufacturing factors involving crash survival, and included information obtained in personal interviews with aircraft manufacturers and FAA officials. (13) This study concluded, in part, that:

1. Travel by light plane is the most lethal of the major forms of transportation.

2. The light plane industry is doing very little work in the field of crash safety to correct the situation.

3. The human body, restrained by seatbelt and shoulder harnesses, can tolerate, without injury, forces sufficient to collapse today's light planes.

4. The arguments of the manufacturers against particular safety innovations on the grounds of economic infeasibility are undermined by the fact that the manufacturers have not, for the most part, taken the trouble to determine the marginal cost of added protection.

5. The light plane manufacturers have not approached crash injury protection with the normal engineering methodology which has been applied successfully to the performance aspects of the airplane.

6. The FAA sets standards which are minimum. These standards are not "the optimums, toward which the regulated should strive." [Quoted portion taken from FAA Order, "Rulemaking Policies for Safety and Air Traffic Rule," May 18, 1962].

7. It is unrealistic to expect that profit-oriented industry will strive toward optimums in an aspect of its product which has little direct effect on its profits, when only minimums are required.

Early general aviation aircraft accident investigation findings that the unrestrained or partially restrained (seatbelt only) occupant flails about within the cabin upon crash impact, striking various portions of the body against objects which penetrate or crush body structures, were confirmed in a 1953 National Advisory Committee for Aeronautics (NACA) study and in a 1971 FAA study. (40, 136) The NACA study used anthropomorphic dummies in crash tests. Impact damage to the dummies and study of motion picture film on which the tests were recorded defined the injury mechanisms. The FAA study examined general aviation accidents to evaluate the extent to which design engineers had succeeded in applying the basic packaging principles identified by DeHaven in 1944 (23), and to identify reasons for the great disparity between automobile and general aviation aircraft accident statistics. The FAA study found that the fatality rate per 100 million passenger

4/ Before 1966, when it was made a part of the U.S. Department of Transportation, the Federal Aviation Administration was the Federal Aviation Agency.

miles for automobiles was only 2.4 compared to 17.5 for general aviation aircraft. This sevenfold difference was accentuated further by the finding that only 1 fatality occurred for each 10 serious injuries in automobiles while 2 fatalities occurred for each 3 serious injuries in general aviation aircraft.

The FAA report concluded that:

> . . . in most instances the well-known principles [DeHaven's packaging principles, see page 7] have been so grossly ignored that serious and fatal injuries have occurred in anything more severe than a hard landing. . . . In fact, of all vehicles designed for human transportation, the so-called general aviation aircraft offer the least protection from, and chances of survival in, crash decelerations. . . . Minor or no injuries occurred in crashes of 1 and 2 "g" [5/] decelerations. Severe but nonfatal injuries were common in 3 to 5 "g" accidents. Fatalities and very severe injuries occurred in crash decelerations of 6 to 10 "g." At 10 "g" and above, most present general aviation aircraft disintegrate to the extent that the value of restraint equipment for crash survival is doubtful.

While the FAA report was critical of the crashworthiness of most general aviation aircraft, it acknowledged that the Beech Aircraft Corporation (Beech) Bonanza "appears to have about a 25 'g' cockpit and the Piper Aircraft Corporation (Piper) Pawnee one that can withstand impact forces up to 40 'g' . . ." The report advocated that "the manufacturers of general aviation aircraft . . . be encouraged to strengthen cockpit design of all future aircraft models." Also, the report stated that almost 100 percent of the occupants in the 70 aircraft accidents investigated were wearing seatbelts. The report concluded that passengers are aware of the need for restraint equipment and are willing to wear it in this type of transportation.

Other crashworthiness findings of the 1971 FAA study included:

1. In most cases, the seatbelts and seats themselves are inadequately attached to the cabin structure; thus, they fail or are ineffective even in moderate decelerations.

2. Even if seatbelts were ideally installed, only the pelvis would be restrained and an occupant's head, trunk, and appendages would be allowed to flail forward into structures which would be lethal even in minor-velocity body impacts.

3. The area forward of the front seat occupants is extremely unsafe for body impact because of lethal protrusions, lack of slow-return padding, sharp edges, etc.

4. The use of properly designed and installed shoulder harnesses would help prevent impact of the head and upper torso.

5/ The term "g" represents the gravitational attraction at sea level upon objects (32.2 ft/sec2).

A researcher's analysis of general aviation accidents during the 10-year period ending 1976 (94) reported that some 97,211 individuals were involved in 48,576 accidents, which resulted in an average of 1,364 fatal injuries and 696 serious injuries annually. When the historical incidence, patterns, and severity of general aviation crash injuries were compared to automobile crash injuries, over the 10-year period ending 1977, the report concluded that while no incidence of injury changes were yet evident in the majority of general aviation aircraft accidents, improvements could be seen in the automobile statistics. This finding was attributed to the occupant protection improvements required by the Federal government. The report concluded that FAA design requirements were "considerably behind the state-of-the-art," and that the majority of general aviation manufacturers had not taken strong initiatives in the past to provide occupant upper torso restraint. The report further stated that:

> It has been found that [the accident can be survivable] when cabin structures remain essentially intact without intrusion, the occupant is adequately restrained, interior-contact structures are designed to distribute load and provide energy absorption, the seating system provides adequate support and energy absorption, and the impact forces upon the occupants are within human tolerance values. . . .

Crashworthiness deficiencies found in general aviation aircraft in that accident analysis (94) included:

1. Lack of adequate upper torso restraint. Head injuries remain the most frequent injury as well as the major cause of death and serious trauma. This usually occurs when the occupant jackknifes over the seatbelt and contacts hard, sharp, unyielding, rigid structures.

2. Inability of seats to adequately attenuate vertical compressive forces. The report acknowledges that recent attention has been given to improved design of the front seats, but the rear seats do not appear to provide equivalent protection.

3. Seat support and attachment failures which can subject occupants to unfavorable positions that greatly reduce tolerance to injury.

4. Cabin interiors that contain many lethal surfaces, structures, and objects which cause death or serious trauma upon crash impact. Flailing appendages, even when upper torso restraints are worn, can contact rudders, controls, sharp edges of the control yoke, and nonyielding structures.

Safety Board investigations of 14 general aviation accidents (see appendix B) during 1979 correlate well with the above accident analysis findings. In each accident, the aircraft cabin maintained enough structural integrity for occupants to survive. However, either because shoulder harnesses were not available or were not worn when available, because seat structures failed, or because cabin interiors were not "delethalized," needless fatalities and serious injuries resulted.

CRASHWORTHINESS RESEARCH ACTIVITIES

Occupant crash protection has been of concern to aviation researchers for more than 40 years. In 1944, the National Research Council (NRC) analyzed the causes of injuries in light aircraft accidents and concluded that the "safe transportation of people in any type of vehicle must of necessity apply the practical principles which are used by every packaging engineer to protect goods in transit." (23) The principles advocated were:

1. The package should not open and spill its contents and should not collapse under reasonable or expected conditions of force and thereby expose objects inside to damage.

2. Packaging structures which shield the inner container must not be made of brittle or frail materials; they should resist force by yielding and absorbing energy applied to the outer container so as to cushion and distribute impact and thereby protect the inner container.

3. Articles contained in the package should be held and immobilized inside the outer structures by interior packaging to prevent movement and resultant damage from impact against the inside of the package itself.

4. The means for holding an object inside a shipping container must transmit forces to the strongest parts of the contained objects.

The author of the NRC report developed a series of research reports which further supported the need for improvements in general aviation aircraft crashworthiness. (24 through 33)

Since the 1944 NRC report, other researchers have provided numerous reports which show that the survivability of general aviation aircraft crashes could be greatly increased through improved occupant "packaging" techniques. (See appendix A.) It has been shown that a properly restrained occupant is capable of withstanding 20 g longitudinally and remaining nearly injury-free when the habitable area of the aircraft remains essentially intact and the impact forces are distributed over a large area of the body. Through use of additional restraint, an aircraft occupant can survive 40 g with injury. Reductions in crash impact forces transmitted to the occupant can be accomplished by use of restraining systems, energy-absorbing seats and interiors, and through the recessing of knobs, handles, levers, and other injury-producing objects.

An early research effort to improve the crashworthiness of agricultural aircraft was the 1952 demonstration of a prototype aerial applicator (crop duster) that incorporated a 50-g seat, an integral double upper torso restraint with inertial reel, a 40-g cockpit box, a storage hopper between the engine and the pilot compartment to provide an energy-absorbing structure, and an overturn structure. (32) This prototype design incorporated the basic packaging principles advocated in the 1944 NRC report and was the forerunner of modern agricultural aircraft. A study of one generation of the new agricultural aircraft for the 10-year period

ending 1973 showed that these aircraft experienced 368 accidents with only 3 percent of the occupants receiving fatal injuries. (111) In contrast for the same period, the fatality rate in all U.S. general aviation aircraft averaged 12.8 percent.

A 1953 report (40) described full-scale light-airplane crashes which simulated stall/spin accidents to determine occupant decelerations and the resulting forces on safety belts. This early research effort used anthropomorphic dummies, accelerometers, and tensiometers to measure accelerations along the longitudinal, vertical, and lateral axes for three impact speeds -- 42, 47, and 60 mph. Also, the crash impacts were recorded on motion-picture film. Tests were conducted with the front-seat dummy restrained by a seatbelt alone and with the rear-seat dummy restrained by a seatbelt/shoulder harness system or by a seatbelt alone.

Damage to dummies restrained by a seatbelt alone confirmed earlier accident study findings about the causes and types of injuries. Through study of filmed crash sequences and recorded acceleration and force measurements, researchers were able to define the movements of and the forces upon the dummies for specified restraint conditions at deceleration rates achieved during the tests. Also, data obtained from these tests provided improved understanding about the distribution of deceleration loads during crashes. The detailed descriptions reported about the movements of and damage to dummies demonstrated that it is not possible to protect front-seat occupants in moderate crashes through the use of seatbelts alone. However, the tests showed that stall/spin simulated impact speeds up to 60 mph (the maximum speed used in these tests) were survivable when occupants were restrained by a seatbelt/shoulder harness system.

The FAA has published numerous reports applicable to general aviation crashworthiness. (See appendix A.) An April 1966 report concluded that simple attenuators for reduction of head injuries in light-aircraft crashes "could be installed on present aircraft with meager weight and cost penalty and would save hundreds of lives in survivable crashes." (123) In September 1966, another report (124) stated:

1. There is a critical need to improve restraint systems in general aviation aircraft and to promote their use. This need is indicated by the significant increases in serious and fatal injuries being sustained in potentially survivable accidents.

2. One of the many directly contributing factors to these injuries is the use of inadequate or incomplete restraint equipment. It is clearly demonstrated that the current practice of using only a seatbelt to restrain vulnerable parts of the body cannot provide the necessary protection.

3. Specifically, the use of a seatbelt alone cannot provide adequate protection to a seated occupant, since the upper body components (e.g., head) are free to move during abrupt decelerations and strike surrounding structures.

This research project dynamically tested five basic general aviation aircraft models and types to evaluate the structural integrity of areas selected for restraint attachment. Each area selected was found reliable for minimum dynamic loads of 500 pounds which produced deceleration peaks in excess of 20 g with onset rates of 47 to 49 feet per second and an event duration of 0.33 second. The study concluded that for each aircraft tested, only small upholstery modifications were necessary to permit proper attachment installations for upper torso restraint belts.

A July 1971 FAA report (139) provided general information "to assist the general aviation airplane designer in developing improved structural crashworthiness designs." While little new information was presented in this report, it did provide a programmatic approach to achieving improved crashworthiness and presented improved analysis techniques. This report was followed in February 1973 by another FAA report that reaffirmed the FAA's informal, nonregulatory efforts to encourage general aviation crashworthiness improvements. (144)

In August 1972, the FAA initiated a research program for the development of a three-dimensional mathematical model of a light-aircraft seat, occupant, and restraint system. This model was developed to form the basis for a simulation computer program specifically for use in crashworthy design and analysis of light-aircraft seats and restraint systems. A user-oriented computer program, "Seat Occupant Model-Light Aircraft (SOM-LA)," was developed based upon the three-dimensional model to aid in the design and analysis of general aviation aircraft seats and restraint systems. Reports issued about this project in 1975 and 1979 (147,161) indicate that the computer program is capable of predicting, for any given set of crash conditions, the response of the seat and occupant, restraint system loads, and various injury criteria.

The February 1973 report (144) stated: "The primary technological efforts must continue to be devoted to reduce the number of crashes by improving pilot performance and airworthiness." Despite a lack of emphasis on crashworthiness design considerations, the report effectively described and documented the need for improvements in general aviation aircraft crashworthiness and provided current information to assist an aircraft design engineer in developing "his own acceptable means" for complying with FAA airworthiness standards and "as a contribution to the overall effort" toward increasing safety in small airplanes. Crashworthiness considerations suggested as important to the designer included:

1. Seat orientation—since experimental studies have shown that human tolerance is dependent on the contact area and the load direction with respect to the body.

2. Seat parameters—since the inertial loads imposed on a seat in a crash situation are generated by the effective weight of the occupant plus the weight of the seat. Also, the loads imposed upon the seat by the occupant can vary depending on whether the restraint system is anchored to the seat or to the airframe.

3. Seat design requirements due to occupant velocity relative to cabin floor velocity under impact conditions—since the maximum relative velocity can create deceleration factors of 1.2 to 2 times that of the floor deceleration.

4. Seatbelt anchors and buckles—since these are the common points of failure.

5. Occupant upper torso restraint systems—since seatbelts alone do not provide the degree of body support to prevent fatal head and upper torso injuries. (Considerable information is provided on shoulder harness and inertial reel design considerations).

6. Control column and wheel designs—since these items are in the head and torso flailing area and can cause serious injury to an occupant thrown against them.

7. Control design—since padding, recessing, and yielding designs can minimize puncture hazards.

8. Protective padding of items in the occupant flailing area—since restraint systems cannot prevent flailing of the extremities.

9. Anchoring of cabin equipment—since loose items or fixed equipment can become lethal missiles upon crash impact.

Another FAA report, published in August 1973, compared the levels of crash protection provided by seatbelt-alone, seatbelt/shoulder harness, and seatbelt/air bag occupant restraint systems for general aviation aircraft. (145) Tests showed that the seatbelt/shoulder harness and the seatbelt/air bag systems compared favorably and decreased the acceleration for the head area by a factor of 3 and for the chest area by 1 1/2 times the acceleration experienced with a seatbelt-alone occupant restraint system. The seatbelt/air bag system was found to be most effective in preventing the flailing of upper extremities. However, the potential for this system to cause a hazard through inadvertent actuation and the problem of developing a reliable crash actuator made the seatbelt/shoulder harness system most desirable.

In August 1978, the FAA issued an initial project report which evaluated the potential for reducing crash injuries through improved seat design. (157) This report pointed out that there is no standard specified in 14 CFR 23 for absorbing downward inertial forces generated during crash conditions in airplanes that do not have retractable landing gear. The report went on to conclude that to meet the minimum maneuver load factors of 14 CFR 23.337 (see page 12), the downward load factor for seats would have to be 3.8 g for normal category, 4.4 g for utility category, and 6.0 g for aerobatic category airplanes. FAA seat standards are established in 14 CFR 37, Technical Standard Order Authorization, which adopts Technical Service Order C39a (TSO-C39a), and this TSO, in turn, adopts National Aircraft Standard 809 (NAS-809). NAS Standard 809 establishes static directional

seat strength requirements for normal and utility aircraft seats as: forward, 9.0 g; sideward, 3.0 g; upward, 3.0 g; and downward, 7.0 g. However, the TSO provides that the manufacturer need not exceed the requirements of the applicable regulations; thus, the sideward design force requirement of NAS-809 is reduced by 50 percent and the downward design force requirements are eliminated.

The 1978 FAA report included the results of a survey of six small airplane manufacturers' seat data and reported the range of ultimate static seat capabilities to be:

Load Direction	Range of Test Load Findings (g)
Forward	7.9 - 12.7
Sideward	1.8 - 04.2
Downward	6.1 - 10.6
Upward	2.6 - 04.5

From these data, it was estimated that a 17-percent improvement in survivability could be realized without changing the forward design factor if 14 CFR 23 required that seat design load factors be increased to: sideward, 3.0 g; downward, 7.5 g; and upward, 5.5 g. Deficiencies in current seat criteria listed in this report were:

1. The basic minimum design strength for seats is designated in terms of a static load factor, in that the occupant is to be protected when he experiences the designated inertial forces, regardless of the acceleration level imposed on the occupant/seat/restraint system by the attaching airframe. However, current data indicate that peak airplane accelerations can be expected to produce inertial loads which exceed current seat strength requirements. When safety belts are anchored to the seats, seat reaction loads, as indicated by a May 1969 FAA/NAFEC [National Aviation Facilities Experimental Center] study (135) are significantly greater than a simple occupant weight times the airplane acceleration, and reduce the protection afforded occupants.

2. The assumption that occupant/seat/restraint systems are rigid masses is not valid and to realize a more rational level of safety, seat criteria are needed which recognize the effects of dynamic loading.

The report made a convincing argument for developing new seat standards and testing requirements. Criteria for new standards and justifications for the proposed changes were included.

Several recent research reports (149, 152 through 162) have been issued by the FAA and the National Aeronautics and Space Administration (NASA) about the findings and analysis of a joint general aviation crash test program (KRASH). This program, initiated jointly by the FAA and NASA in 1973, included a series of crash tests to obtain information on single- and twin-engine airplanes under controlled free-flight conditions and had as its objectives (1) to derive an understanding of what happens to the structure of an airplane subjected to crash loads, and (2) to learn how various impact parameters affect the magnitude and pattern of the

structural damage. The justification used for conducting the tests was to obtain essential information for predicting structural collapse and for designing new concepts for seat, occupant restraint systems, and cabin interiors. The program designers recognized that this effort was similar to the National Advisory Committee for Aeronautics crash test program conducted in the early 1950's (40), but believed that additional testing was justified to obtain data representative of current general aviation airplanes. Project KRASH developed a computerized method for analyzing general aviation aircraft under probable accident conditions. This analytical tool is intended to assist aircraft designers in the development of improved crashworthiness and presently is being used experimentally by at least one major aircraft manufacturer.

CRASHWORTHINESS REGULATIONS 6/

The Air Commerce Act of 1926 assigned to the U.S. Department of Commerce the regulatory responsibility for aviation operations. This Act made possible the first Federal airworthiness and other standards for aircraft in the United States, which became effective on December 31, 1926. These Air Commerce Regulations included the first requirement for seatbelts, and a June 1, 1928 revision contained the first seat-anchoring requirement. Later revisions of these regulations included requirements for minimum seatbelt strengths, seat and seatbelt anchor strengths, seatbelt buckle operation, and the first occupant-restraint strength requirements.

The Air Commerce Act of 1926 was superseded by the Civil Aeronautics Act of 1938 which broadened the authority for regulating aircraft safety and design standards (17) and transferred the responsibility for administering aviation safety programs to the CAB. On November 13, 1945, the CAB published as Title 14, Part 3 of the Code of Federal Regulations (14 CFR 3) its requirements for general aviation aircraft airworthiness, which included design requirements for occupant protection during minor crashes. The fuselage was required to be designed to give every reasonable probability that all occupants, when proper use was made of installed belts and harnesses, would escape serious injury under minor crash conditions even though parts of the aircraft were damaged.

The minor crashes were defined as situations in which the occupants experience the following ultimate acceleration forces in all combinations:

	Crash Forces by Aircraft Type	
Acceleration Force Category	Normal and Utility (g)	Aerobatic (g)
Upward	0 to 3.0	4.5
Forward	0 to 9.0	9.0
Sideward	0 to 1.5	1.5

6/ For a chronology of general aviation regulatory requirements affecting aircraft crashworthiness, see appendix C.

Additional crashworthiness requirements for seatbelts, seats, and anchorages were included in other sections of 14 CFR 3, but were not much different from regulations previously promulgated by the Department of Commerce.

Revisions to 14 CFR 3 in 1950 related the strength requirement for seatbelts to the forces generated by minor crashes adopted in 1945. The wording of the occupant protection requirement was modified to require the fuselage design to provide only "reasonable assurance" rather than "every reasonable probability" that occupants escape serious injury in the event of minor crashes.

In 1951, the CAB published an interpretation of its occupant protection requirements, and this interpretation became a part of its regulations. The interpretation stated that cockpit arrangements and cabin structure collapses had caused excessive injuries during crashes and that close study of crash results had shown that the human body, when properly supported, could tolerate crash forces capable of demolishing contemporary general aviation aircraft. In view of the fact that injuries and fatalities in many moderate and severe accidents were purely mechanical results of poor cockpit designs, the CAB issued suggestions to aircraft manufacturers for the elimination of projections and sharp edges, for anchoring of objects within the aircraft cabin, and for improving safety belt anchorages.

The Federal Aviation Act of 1958 established the Federal Aviation Agency and among other responsibilities, made it responsible for aviation safety. (42) The crashworthiness requirements of 14 CFR 3 were continued in effect and remained virtually unchanged until 1969 when the FAA required, for newly certificated general aviation aircraft, that each occupant be protected from head injury by installing seatbelts and shoulder harnesses, by installing seatbelts and eliminating injurious objects within the striking radius of the head, or by installing seatbelts and an energy-absorbing rest to support the arms, shoulders, head, and spine. This action had no effect upon newly manufactured, previously certificated aircraft since the requirements of 14 CFR 23 7/ were made applicable only to newly certificated aircraft. Existing aircraft were "grandfathered" and unaffected by the revision.

In 1973, the FAA issued a Notice of Proposed Rulemaking (NPRM) which proposed that all general aviation aircraft be equipped with shoulder harnesses and that occupants be required to wear these safety belts during takeoffs and landings. Also, this NPRM described additional crashworthiness improvement needs that had previously been suggested, and were supported by the FAA research and development program findings. The FAA stated, however, that information currently available was not sufficient to support rulemaking action in these additional crashworthiness areas, but that courses of action for upgrading the crashworthiness of small airplanes had been identified for possible future action.

Four and one-half years after publication of the NPRM, the FAA issued a final rule on June 9, 1977. Other than requiring shoulder harness installations for front seats (pilot and copilot seats) in all general aviation aircraft of all types

7/ CAB regulations 14 CFR 3 were renumbered by the Federal Aviation Agency in 1964 and became 14 CFR 23.

manufactured after July 18, 1978, this rulemaking action provided limited added crash protection for occupants of general aviation aircraft since the requirements to delethalize cabin interiors applied only to newly certificated general aviation aircraft—not newly manufactured aircraft—and the requirement for front-seat occupants to use available shoulder harnesses during takeoff and landing extended only to crewmembers.

DEVELOPMENT OF OCCUPANT CRASH PROTECTION

The initial emphasis in aircraft design was airworthiness; consideration of crashworthiness developed much later. Occupant restraints (seatbelts) for airplanes were introduced by the U.S. Army in 1910, and an improved restraint system that included upper torso restraint was introduced in 1917. (76, 91) Civil aviation aircraft were first required to have seatbelts in 1927. These occupant restraints were intended primarily to keep occupants of open-cockpit aircraft in their seats during aerial maneuvers rather than to provide crash protection. The forerunners of modern shoulder harnesses appeared in U.S. Army Air Corps aircraft in 1939 after 2 years of experimentation. (2) This early experimentation showed that shoulder harnesses averted injury in aircraft impacts up to 30 g while seatbelts alone did not prevent injuries at crash forces of 8 g.

During the early 1940's, the 40-g cockpit of World War II fighter planes was developed, improvements in the strength of the 3-inch standard belt webbing were made, seat and harness attachment improvements were developed, and the inertial reel for shoulder harnesses was introduced. (91)

Studies of crashworthiness in the 1940's and advancements in crash injury avoidance achieved by military aviation innovations provided the basis for development of the new generation of aerial applicator (cropduster) aircraft and the crash safety design features which began to be developed in some general aviation aircraft. For example, the Beech Bonanza incorporated a long nose which absorbed crash forces as it deformed; the reinforced wing root structure minimized the potential for the wing to tear off parts of the fuselage should the wing be impacted during a crash; and the cockpit was reinforced to provide protection for occupants. Another Beech airplane, the Twin Bonanza, incorporated an energy-absorbing nose and reinforced cabin, but also placed the engine nacelles ahead of the cabin with the cabin located above and aft of the leading edge of the wing. This aircraft's weight was designed so that most (62 percent) was below and ahead of the occupants to provide crash protection with only a minor portion of the weight (4 1/2 percent) in a position which could damage the cabin during a crash.

The installation of shoulder harnesses for occupant protection in early general aviation aircraft also was a Beech innovation. Beech publications in 1951 show that Beech installed shoulder harnesses as standard equipment in the Twin Bonanza and publicized their safety values to prospective aircraft buyers. (8,9,10,11) The outcome of this effort was reported in the FAA's March 22, 1965, letter to the CAB (see page 17): "One airplane manufacturer [Beech] did install shoulder harnesses.... They found, however, that owners did not use them and furthermore, did not even want them installed. This manufacturer subsequently

ceased to furnish them except on a special infrequent request of a particular customer."

Some crashworthiness deficiencies in current production aircraft as reported in a 1970 report (13) included:

1. Compasses mounted on the instrument panel where they would be a likely lethal target for an occupant's head.

2. Baggage stowage and tie-downs attached to backs of seats, where, if stowed during a crash, baggage inertial forces would add to the forces which must be resisted by the seat attachments.

3. Small open-ended control wheels which offer considerably less protection than earlier wheel designs for chest impacts. In fact, some control wheels had instruments mounted in the center of the control wheel hub and had protruding knobs.

4. Control panels which offered little, if any, yielding for head impacts.

5. Lack of protection at the bottoms of control panels to prevent injuries to flailing lower limbs during crash decelerations.

6. Ashtray, seatback, control column, and other interior equipment designs that flailing heads or limbs could easily strike during crash decelerations.

7. Inadequate seat and restraint designs to protect the occupant in a moderate-to-severe crash in which the cabin area could be expected to provide a survivable environment.

A 1978 report included information about the status of occupant restraints in general aviation aircraft manufactured from 1972 through 1975 and included projections for 1977 and 1978 aircraft. (94) Analysis of these data shows that for the 1972-1975 aircraft, Beech provided as standard equipment shoulder harnesses for crew seats on 10 to 15 percent of its 1972 heavy single- and twin-engine aircraft, for 100 percent of its crew seats in light single-engine aircraft after mid-1973, and for 100 percent of its passenger and crew seats for all aircraft models after mid-1975. Other than for aerial applicator models, Piper, in 1974, provided shoulder harnesses as standard equipment for crew seats only on its heavy twin-engine aircraft. The Cessna Aircraft Corporation (Cessna) did not install shoulder harnesses as standard equipment during 1973 except in its aerial applicator models. Cessna offered shoulder harnesses as optional equipment on its 1973 aircraft for crew seats, but not for passenger seats. Piper 1973-1974 heavy twin-engine models offered optional shoulder harness installations for crew seats only, but no shoulder harness installations were offered for single-engine and light twin-engine aircraft. Information about the 1977-1978 production aircraft indicated little projected change in the equipment offered for this type of protection. (See appendix D for data about other aircraft manufacturers.)

What improvements have been made in present-day aircraft? Because of the 1977 FAA rul change, all crew (front) seats on general aviation aircraft manufactured after July 18 1978, must be equipped with shoulder harnesses and crewmembers are required to wear available shoulder harnesses during takeoff and landing. However, shoulder harnesses are not required for passenger seats, and, if available, passengers are not required by regulation to wear them. Improved seat designs and standards have been developed by some general aviation aircraft manufacturers, but these seats are not required by FAA standards. In fact, required design standards for seats and occupant restraint systems in general aviation aircraft are far below those for the family automobile. For example, some automobile crashworthiness standards are: 8/

- 49 CFR 571.203 - Impact protection for the driver from the steering control system which requires collapsible steering columns to minimize chest, neck, and facial injuries to the driver as a result of impact.

- 49 CFR 571.204 - Steering control rearward displacement which specifies requirements limiting the rearward displacement of the steering control into the passenger compartment to reduce the likelihood of chest, neck, or head injury.

- 49 CFR 571.207 - Seating systems which establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact.

- 49 CFR 521.208 - Occupant crash protection which currently requires all passenger cars to have seatbelts. This standard contains provisions which will phase in passive restraints (belts, air bags or other devices which require no activation on the part of the occupant) for automobiles beginning in September 1981. These passive restraint provisions specify vehicle crashworthiness requirements in terms of forces and accelerations measured on anthropomorphic dummies in test crashes.

- 49 CFR 571.209 - Seat belt assemblies which specifies requirements for such assemblies as webbing and latches.

- 49 CFR 571.210 - Seat belt assembly anchorages which establishes requirements for seatbelt assembly anchorages to insure their proper location for effective occupant restraint and to reduce the likelihood of their failure.

Not only are the FAA technical standards outdated (the FAA's TSO-C22f and TSO-C39a which establish standards for safety belts and seats, respectively, are based on National Aircraft Standards which were last revised in 1950 and 1956, respectively (74,75)), but occupant crash protection improvements implemented by

8/ See Title 49 Transportation, Part 571 Federal Motor Safety Standards, Code of Federal Regulations for complete crashworthiness requirements for automobiles.

the FAA and incorporated into 14 CFR 23 are applicable only to newly certificated general aviation aircraft. This permits the continued manufacture of previously certificated aircraft for decades without state-of-the-art crash protection. For this reason, the crashworthiness deficiencies noted in the 1970 report (13) will continue in newly manufactured, previously certificated aircraft unless a manufacturer voluntarily makes these improvements or unless the regulations are changed.

Design advancements for delethalization, improved seats and anchorages, and effective restraint equipment are currently available to make general aviation aircraft crashes more survivable. (39,43,81,85,98,99,131,135,151)

SAFETY BOARD EFFORTS TO STIMULATE IMPROVED CRASHWORTHINESS STANDARDS

One of the earliest efforts to convince the FAA that occupants of general aviation aircraft were being injured needlessly came from the CAB's Bureau of Safety 9/ in 1964. In a November 3, 1964, letter to the FAA, the CAB recommended that:

> Shoulder harnesses for each occupant be required on all newly certified general aviation aircraft unless it can be demonstrated that the seatbelt alone will preclude the seat occupant from contacting injurious objects within the striking radius of the head.
>
> Shoulder harnesses and crash helmets for each occupant be required on all aircraft engaged on a hazardous flight such as aerial spray applications [cropdusting] or [on a] "low and slow" flight such as game or wildlife count or aerial surveys.
>
> In line with the [FAA's] desire to promote aviation safety by education, . . . issue a series of Advisory Bulletins to all pilots, stressing the desirability of utilizing safety equipment, such as shoulder harnesses and crash helmets, as a standard practice.

The FAA responded on March 22, 1965, stating:

> The difficulty [in implementing the proposal for shoulder harnesses] is that present requirements do provide adequate protection from serious injury up to specified crash loads. . . . We do not have sufficient justification . . . for revising the existing regulations.

The response also indicated that the FAA had under review rules governing agricultural operations, which was the primary thrust of the second CAB recommendation. In response to the third CAB recommendation, the FAA stated:

9/ The CAB's Bureau of Safety was the forerunner of the National Transportation Safety Board.

> The idea of promoting the use of shoulder harnesses through safety education means received the unanimous approval of all factions of the industry commenting on your questions. . . . Insofar as shoulder harnesses are concerned, we will encourage their use through Safety Education pamphlets and during Safety Education meetings.

Based upon the review of a petition filed with the FAA on February 25, 1970, by the Aviation Consumer Action Project, the Safety Board wrote to the FAA on August 28, 1970, to provide its support for needed crashworthiness improvements. The letter stated, "Our view is that the aircraft manufacturers, on the one hand, have concentrated their efforts on the airworthiness aspect of their product, and have minimized their efforts to provide realistic levels of crashworthiness." The Safety Board recognized that a considerable body of technical data had been developed, much of it by the FAA's Civil Aviation Medical Institute (CAMI), the FAA's National Aviation Facilities Experimental Center (NAFEC), and through FAA-sponsored research grants, showing that significant savings in lives and injuries can accrue through improved general aviation crashworthiness. Also, the Safety Board pointed out that the National Highway Safety Bureau, 10/ with essentially the same basic data that the FAA possessed, had forged ahead in the automotive field to provide substantial crashworthiness protection for occupants of automobiles, while the FAA regulations provided protection only for a minor crash.

The Safety Board's letter recommended that the FAA reevaluate its position regarding (1) shoulder harnesses, (2) delethalization of aircraft interiors, (3) dynamic testing of seats, (4) emergency landing inertial force standards, and (5) crash fire protection. 11/ The letter concluded that it was time for the FAA to recognize the validity of the total accident and research findings in the field of aircraft occupant crash protection, and the Safety Board requested a report on the FAA's evaluation of the Aviation Consumer Action Project petition and actions to be taken.

The FAA responded on September 3, 1970, stating that part of its many years of research efforts were translated into new rules effective September 14, 1969, for aircraft type-certified after that date. Additionally, the FAA said it was "hard at work on additional rules [sic] proposals and a notice of proposed rulemaking is underway." The FAA assured the Safety Board that its "specific recommendations will be taken into account in the preparation of our proposed rulemaking."

On October 22, 1972, the Safety Board sent a letter to the FAA Administrator to remind him that the FAA had given its assurance that FAA positions relative to general aviation crashworthiness would be reevaluated and that the five recommendations contained in the August 28, 1970, letter would be considered. The Safety Board's letter reminded the FAA of the rulemaking notice that it had reported to be under development, and requested a status report.

The November 7, 1972, reply from the FAA stated that the rulemaking proposal for general aviation crashworthiness standards was expected to be issued

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10/ Now the National Highway Traffic Safety Administration.
11/ See appendix E for Safety Board general aviation crashworthiness recommendations and responses.

before the end of the year. The rulemaking was to propose a requirement for the installation of shoulder harnesses on airplanes in service that had structural attachment provisions for harnesses, and, after a certain date, on newly manufactured airplanes. Also, there would be a requirement that future airplane compartment interiors be designed to protect occupants from injury caused by contact with interior objects. As to the other three Safety Board concerns—dynamic testing of seats, emergency landing inertial forces, and crash fire protection--the FAA stated, despite the FAA accident studies and research findings earlier referenced, that current data pointed to possible future courses of action, but were insufficient to support rulemaking action.

On January 29, 1973, the Safety Board responded to the FAA's November 1972 letter complimenting the Administrator on the decision to propose requirements for shoulder harnesses and delethalization of cabin interiors of general aviation aircraft. This letter also pointed out several inconsistencies regarding shoulder harness requirements for aircraft certificated under other FAA regulations.

On March 12, 1973, the Safety Board commented on the FAA's NPRM, "Crashworthiness for Small Airplanes," Docket No. 10162 (38 FR 2985), published on January 31, 1973, and characterized the proposal as "a significant step toward remedying a serious problem in general aviation safety," and identified two aspects of the proposal which merited additional consideration:

1. While the Safety Board agreed that the need for shoulder harnesses was significantly greater for forward-facing seats, it pointed out that rearward-facing seats needed the additional protection afforded by shoulder harnesses for crashes or emergency landings involving multidirectional inertial forces.

2. The proposed exemption for certain airplanes which did not have structural provisions for the attachment of shoulder harnesses would unnecessarily exempt a large number of airplanes which would continue in the active inventory for years to come and deny the increased protection of shoulder harnesses to their occupants. The Safety Board recommended that these airplanes be included under the requirement, but be given a longer period of time in which to make the installations.

Meanwhile, as a result of an aircraft accident investigation in which an inadequate seat attachment design allowed empty seats to separate during relatively moderate deceleration forces, the Safety Board recommended on September 26, 1975, that the FAA require dynamic testing of seats to insure more realistic protection of occupants from serious injury in minor crashes (recommendation A-75-51). The investigation revealed that the "quick disconnect" seats and attachments had been statically tested as required by 14 CFR 37 and were found to comply with the strength requirements. The FAA's response to this recommendation stated that it was currently unable to comply with the recommendation because criteria for dynamic testing would have to include input pulse shapes and response characteristics that were not available. The FAA acknowledged that its 1969 report "Dynamic Test Criteria for Aircraft Seats,"

(NA-69-5), was directed at development of such criteria, but stated it was not suitable for developing a regulation. The FAA stated necessary data were being gathered in full-scale, controlled crash tests at Langley Research Center and, when realistic criteria were established, regulatory action would be undertaken.

The response to the Safety Board's comments on the FAA's 1973 NPRM came in the form of a DOT Consumer Advisory News Release on June 24, 1977, which announced the issuance of the final rule. This release stated that the FAA rule would require the installation of shoulder harnesses for the front seats of all small airplanes manufactured after July 18, 1978, to reduce the potential for injury and death in survivable accidents. The FAA rule also required crewmembers occupying seats equipped with shoulder harnesses to wear them on takeoff and landing, and required other seats in these newly manufactured airplanes to be equipped with seatbelts and the area surrounding these seats to be delethalized (shoulder harnesses for rear seats were not required). The news release stated that this FAA action was prompted by a Safety Board recommendation and a petition submitted by the Aviation Consumer Action Project.

In response to the regulation adopted by the FAA, the Safety Board on December 8, 1977, issued recommendations Nos. A-77-70 and -71 which asked that action be taken to:

> Amend 14 CFR 23.785 to require the installation of approved shoulder harnesses at all seat locations as outlined in NPRM 73-1, and
>
> Amend 14 CFR 91.33 and 91.39 to require installation of approved shoulder harnesses on all general aviation aircraft manufactured before July 18, 1978, and after a reasonable lead time, at all seat locations as outlined in NPRM 73-1.

The FAA responded to these recommendations on February 8, 1978, stating that it was unable to justify these amendments while considering comments received to NPRM 73-1, nor could it find that these recommendations provided new information to justify another rulemaking action on the subject.

A Safety Board letter of October 25, 1978, to the FAA expressed continuing concern about the level of protection provided occupants of general aviation aircraft in severe, but survivable crashes. The letter related information about an accident in which a pilot was ejected from his restraint system when a seatbelt fitting was deformed and the retaining pin separated. It was related that a similar failure occurred in the copilot restraint system, but the pin did not separate. The pilot was seriously injured when he struck numerous cockpit surfaces and protrusions. Tests of the seatbelt fittings confirmed that they complied with the ultimate load factor requirements of the FAA's TSO-39a for seats, but further testing showed that the loads imposed upon the fittings during the crash were in excess of the requirements of 14 CFR 23.561, especially in the lateral direction. Again, the Safety Board urged the FAA to give highest priority to the initiation of rulemaking to establish realistic minimum load factor requirements and certification test criteria for occupant/seat/restraint systems. Also, the Safety

Board requested a status report on the actions and proposed actions of the FAA regarding these expressed concerns.

On November 9, 1978, a Safety Board letter to the FAA described occupant restraint system failures which had occurred in a recent aircraft accident. It was pointed out that the seatbelt fitting strengths complied with the FAA standards, but fitting failures in this survivable accident resulted in needless injuries to the occupants. The letter recognized the FAA's full-scale light-airplane crash tests and seat/occupant tests which were in progress, reiterated Safety Board recommendations Nos. CY-70-42 and A-75-51, and urged the FAA to give its highest priority to a rulemaking project for establishing realistic inertial load factor requirements and test criteria for occupant/seat/restraint systems.

On November 16, 1978, the Safety Board sent another letter to the FAA expressing its continuing concern that all passengers of general aviation aircraft "are not adequately protected by the recent rulemaking which made mandatory shoulder harnesses at front seats only." It described prior activities of the Safety Board urging this added protection and pointed out that the present delethalization requirements were not adequate since the inertial forces which designs must accommodate "are considerably less than those forces experienced in many survivable aircraft accidents." The FAA was advised that Safety Board recommendations Nos. A-77-70 and -71 were being held in an "Open-Unacceptable Action" status because the Safety Board questioned the FAA response that there was insufficient justification to impose the additional costs of shoulder harness installations on owners of older aircraft. The Safety Board pointed out that according to an FAA/CAMI report, Cessna had been providing structural "hard points" for shoulder harness installations since 1957 and that Beech had offered factory-installed shoulder harnesses in the past. The Safety Board requested the FAA to provide it with a copy of the FAA cost-effectiveness analysis referred to in its 1977 final rule on "Crashworthiness for Small Airplanes," which the FAA used to determine that shoulder harness retrofit for older airplanes was impractical. The Safety Board also requested information regarding the number of manufacturers which have engineered shoulder harness "hard points" in their aircraft. Also, the FAA was asked to respond to the following questions:

1. What data does the FAA have to indicate that deletnalization of cabin interiors will prevent the types of injuries commonly found in survivable accidents?

2. Why does the FAA consider delethalization more effective than shoulder harnesses. What data substantiate that claim?

3. What criteria exist or will be developed for the delethalization of cabins?

4. How will these criteria be applied?

5. How will the FAA insure that such data will be applied universally [among] all FAA Regions?

In a January 5, 1979, letter, the Safety Board suggested that its Chairman and the FAA Administrator meet to discuss crash survivability in air carrier and general aviation aircraft. The Administrator agreed with this suggestion and the meeting was held on February 1, 1979.

The Safety Board's November 9, 1978, letter to the FAA was answered on February 15, 1979. The Administrator reviewed the purposes of the full-scale crash tests and the man-seat model research programs in progress and advised of a third research project, "Dycast." Project "Dycast" was scheduled for completion in mid-1982 and would develop a mathematical model to simulate crashes of aircraft structures. The Safety Board also was informed that the FAA was in the process of developing a proposed rulemaking to amend TSO-C39a for seats and that this project would be completed by the end of 1979. Completion of the test programs in progress would enable the FAA to prescribe dynamic design loads in lieu of, or in addition to, the correct static design loads. The Safety Board would be kept advised of the progress of the programs described.

A second February 15, 1979, letter from the FAA responded to the Safety Board's letter of November 16, 1978. The Administrator advised that the FAA's June 16, 1977, amendments to 14 CFR 23 and 91 were the most recent actions taken relative to improving general aviation crashworthiness. The FAA said that the current rules were supported by the previous FAA findings that a shoulder harness retrofit requirement was not appropriate, and that it believed that delethalization of light-aircraft cabins would be preferable. The Administrator conceded that, since the February 1979 discussions with the Safety Board Chairman, he had determined that earlier FAA decisions regarding crashworthiness should be reconsidered. The reply stated that the Acting Associate Administrator for Aviation Standards had been directed to carry out an analysis of the issues and provide recommended options. Also, the letter stated that the questions raised in the Safety Board's letter would be included in the analysis, and that a detailed response would be provided "as soon as I am satisfied that all available information has been properly taken into account."

On April 4, 1979, Safety Board staff met with staff from the FAA Office of Aviation Safety to discuss the FAA's action regarding Safety Board recommendations Nos. A-77-70 and -71. At this meeting, the background of these recommendations was discussed, including the arguments made in published reports over the past 20 years to support the need for shoulder harnesses and the extensive work of the Highway Safety Research Institute, which includes considerable data about restraint systems which the Safety Board believes to be applicable to general aviation crashworthiness.

An April 13, 1979, memorandum from the FAA Associate Administrator for Aviation Standards concerning the status of the FAA project on general aviation crashworthiness discussed the April 4, 1979, meeting with Safety Board staff. This memorandum stated:

> Actions already underway [by the FAA] include research of past accident records, the furnishing of historical and cost analysis data to AVP-110 [an

FAA unit in the Office of Aviation Policy] for use in a projected cost analysis, and participation in planning meetings.

An FAA letter of September 24, 1979, advised the Safety Board that a regional survey of shoulder harnesses in small airplanes was being conducted, and that until completion of this study, the FAA could not make any conclusion about the cost-effectiveness of a retrofit requirement.

On December 27, 1979, the Safety Board wrote to the FAA Administrator and again requested the information first requested in its November 16, 1978, letter. The Safety Board also sought to determine the status of the FAA's project for reconsidering its opposition to requiring shoulder harnesses and other crashworthiness improvements. This letter expressed the Safety Board's desire to know what specific actions had been taken by the FAA, asked that a timetable for completion of the project be established and provided to the Safety Board, and requested that the FAA provide a copy of its previous cost-effectiveness analysis information used to support its 1977 decision not to require the retrofit of shoulder harnesses in pre-1978 general aviation aircraft.

The FAA Administrator's March 28, 1980, reply acknowledged that the regional survey of shoulder harnesses in small airplanes had been completed, that regulatory analysis in accordance with Executive Order 12044 12/ was proceeding, and that the analysis was intended to be complete no later than April 30, 1980. The Administrator also stated that the "informal" regulatory assessment made at the time of adoption of the current shoulder harness requirement had been reviewed and that the FAA analysis team was reassessing all aspects to satisfy the intent of Executive Order 12044. Since the final report was to be available within 1 month, the FAA Administrator stated that "we do not believe it would serve any useful purpose to supply the original 'rough' assessment." The Administrator stated that the information requested in the Safety Board's November 16, 1978, letter relative to delethalization also would be included in the soon-to-be-delivered final report.

Since the FAA projected date for completion of its regulatory analysis had passed and information previously requested by the Safety Board had not been received, the Safety Board wrote to the Administrator on June 3, 1980, requesting that the FAA inform it when the regulatory analysis and information requested by Safety Board letters dated November 18, 1978, and December 27, 1979, could be expected. No response to this request has been received to date.

The research and accident study reports reviewed in this report, specifically the FAA reports, have documented many crashworthiness improvements needed in general aviation aircraft to protect occupants during survivable crashes. The documented improvements are the same as, or similar to, crashworthiness improvements sought by the CAB and the Safety Board as early as 1965. No reason which justifies the FAA's failure to require these long-documented crashworthiness improvements has been communicated to the Safety Board nor does the Safety Board understand the FAA's reluctance to require improved general aviation aircraft crashworthiness.

12/ Executive Order 12044 sets forth detailed guidelines which must be met by Federal agencies when implementing new regulations.

THE CONTINUING NEED FOR CRASHWORTHINESS IMPROVEMENTS

The need for the following improvements has been well documented by research and accident investigation findings referenced in this report:

1. Safety Belt Performance—current requirements are 50 percent less than the 1950 industry standard adopted by TSO-C22f because of an exception allowed by the FAA. FAA safety belt strength and test requirements are substantially less than those required by Federal Motor Vehicle Safety Standard (FMVSS) No. 209 13/ and do not require dynamic testing to simulate crash environment conditions.

2. Upper Torso Restraints—current requirements affect only general aviation aircraft manufactured after July 18, 1978, and then only require shoulder harnesses for the front seats. FAA's research and other studies since 1944 have shown upper torso restraint to be an essential element to provide effective occupant restraint, even for minor crash forces.

3. Seat Performance—current requirements specify design for 170-pound occupants at specified minimum inertial emergency landing conditions and adopt a 1956 industry standard which was established prior to the development of most present state-of-the-art equipment and test methods. This requirement is less rigorous than the FMVSS 209 requirements for automobile seats, does not require dynamic testing to simulate crash environment conditions, and has been shown to be inadequate through FAA research, even for the minimum inertial force standards which have been established. (157)

4. Seat and Safety Belt Attachment Performance—current requirements allow tests to be conducted statically only in the direction of critical loads for small airplanes (no requirement is specified for attachments for helicopters). Research has identified the need to evaluate the combined directional loadings and to dynamically test seats.

5. Delethalization of Cabin Interiors—The 1969 amendment to 14 CFR 23.785 provides as one alternative for occupant protection the elimination of injurious objects within the striking radius of the head. The 1977 amendment required that, for newly certificated general aviation aircraft, the area surrounding each seat within striking distance of the occupant's head or torso (with safety belt fastened) be free of potentially injurious objects. However, no criteria have been established by the FAA against which one can measure and determine if an aircraft complies with the extent of delethalization intended by these requirements.

13/ This standard and other FMVSS are issued by the National Highway Traffic Safety Administration.

The Safety Board agrees with the FAA that aircraft cockpit and other cabin areas should be delethalized. However, until occupants are properly restrained with seatbelt and upper torso restraints there will not be any marked decrease in the number of persons fatally injured in survivable crashes.

6. Inertial Force Requirements for Survivable Crashes—The emergency landing criteria of 14 CFR 23.561 are insufficient to provide reasonable protection for occupants during minor crashes as contended by the FAA and are wholly inadequate to provide required protection for occupants in moderate-to-severe crashes which should be survivable. Research, including that performed by the FAA, has shown that the human body, properly restrained, is capable of withstanding 20 g longitudinally with little or no injury and can survive 40 g with injury. It should be noted that the FAA's Advisory Circular 43.13-2A recommends a 25-g design when pilots retrofit shoulder harnesses into their aircraft.

7. Shoulder Harness Retrofit—For about 35 years, the FAA has known of the great increases in survivability which could be attained by the installation and use of shoulder harnesses. Also, the FAA has advocated the installation of shoulder harnesses into older aircraft for at least 15 years but did not require their installation on new aircraft until 1978, and then only for front seats.

While the FAA advocates the retrofit of shoulder harnesses, this generally simple installation is quite a complicated process for an individual aircraft owner. First, according to FAA Advisory Circular 43.13-2A, an engineering evaluation is required which should be performed in consultation with the airframe manufacturer. The proposed changes then have to be approved by appropriate FAA regional officials and the installation inspected by the FAA. Considering the relatively few numbers of similar models and types of aircraft compared to the numerous individually owned aircraft currently without shoulder harnesses, a rational and more constructive approach for encouraging the retrofit of shoulder harnesses would be for the FAA, in coordination with aircraft manufacturers, to develop and publish for use by aircraft owners approved, detailed shoulder harness installation instructions for each model and type of aircraft not equipped with shoulder harnesses.

8. Requirements for Newly Certificated vs Newly Manufactured Aircraft--Since 14 CFR 23 requirements apply only to newly certificated aircraft, even the few crashworthiness improvements required by the FAA may not be incorporated into a significant portion of general aviation aircraft for 10 or 20 years. The crashworthiness and other essential safety requirements should be made applicable to aircraft manufactured after the effective date of the regulation in the absence of overriding difficulties of major proportions.

As demonstrated in the historical review of crashworthiness regulations, the standards for general aviation aircraft have changed little since the Civil Air Regulations were revised in 1950. This contrasts greatly with the advancements made in the state-of-the-art through extensive studies and research projects, many of which were conducted by or for the FAA. Either the FAA office responsible for developing general aviation safety standards is unaware of the crashworthiness deficiencies documented by FAA research efforts or its management has chosen to ignore this information. Regardless of the reasons the FAA has not used its research findings for establishing improved crashworthiness standards, it now is obvious that users of general aviation aircraft are not content with the present crashworthiness regulations. A recent article (1) reported that the Aircraft Owners and Pilots Association has voiced its concern that the FAA crashworthiness standards are not adequate and has initiated an evaluation of these standards to convince the FAA about the need for crashworthiness improvements to protect pilots and passengers during survivable crashes.

The FAA "Rulemaking Policy for Safety and Air Traffic Rules," Order DA2100.1, states that the Federal Aviation Act of 1958 provides for the establishment of minimum standards. This is interpreted by the FAA Order "to mean those standards adequate to meet basic requirements, giving due regard to the state-of-the-art and needs of the national system." Considering the number of fatalities and injuries annually, the high fatality-to-injury ratio, the large disparity between the state-of-the-art, as reported in numerous research reports, and the current crashworthiness requirements of 14 CFR 23, it is apparent that the FAA is not taking aggressive action to improve the crashworthiness of general aviation aircraft.

Further evidence of the FAA's lack of aggressive action to improve the crashworthiness of general aviation aircraft is its failure to accomplish the safety objective sought in Safety Board recommendation No. A-77-71 which states:

> Amend 14 CFR 91.33 and .39 to require the 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.

Since this recommendation has been classified as "Open, Unacceptable Action" for 3 years, the Safety Board on December 17, 1980, developed new recommendations that specify dates certain by which the FAA should accomplish the desired safety improvements. (See page 28.)

CONCLUSIONS

1. General aviation aircraft are unnecessarily lethal in crash situations which should be survivable.

2. The majority of serious injuries and deaths in general aviation aircraft crashes result from insufficient occupant restraint systems and inadequate crashworthiness designs of cockpit and cabin interiors.

3. The installation and compulsory use of shoulder harnesses at each general aviation aircraft occupant seat would be one of the most effective means for markedly reducing the current serious injury and fatality rates.

4. FAA and industry studies indicate that most effective crashworthiness occupant protection features can be incorporated during aircraft design with little or no increase in manufacturing costs.

5. General aviation manufacturers have not made effective use of crashworthiness research findings nor have they systematically pursued crash-injury protection design through use of human and systems-engineering principles.

6. Generally, aircraft manufacturers are not voluntarily incorporating proven, effective, and necessary crashworthiness designs into their products.

7. The FAA regulatory emphasis regarding general aviation aircraft has been on airworthiness with little concern to improving crashworthiness.

8. Numerous research projects conducted by the FAA have long identified means for improving general aviation aircraft occupant protection.

9. While the FAA encourages the implementation of identified crashworthiness improvements, it has failed to amend its regulations to require these long-needed improvements.

10. Private automobile crashworthiness features have been improved in comparison with general aviation aircraft, primarily because of government regulatory action.

11. FAA standards for seats, safety belts, and attachments have long been outmoded, and directed action need to be taken to bring them up to date.

12. The FAA's 1977 decision on economic grounds not to require shoulder harness installations for each occupant seat was not supported by any formal, recognized cost-effectiveness evaluation.

13. Crashworthiness and other essential safety improvements for aircraft should be made applicable to all general aviation aircraft manufactured after a specific date.

14. The FAA standards only provide occupant protection for some minor crash landings and are not adequate to reasonably protect occupants of general aviation aircraft during all crashes which would otherwise be survivable.

RECOMMENDATIONS

As a result of its review of general aviation aircraft crashworthiness, the National Transportation Safety Board reiterates its Recommendations Nos.

CY-70-42, Part 4, and A-77-70 made to the Federal Aviation Administration which state:

CY-70-42, Part 4:

> [Initiate] regulatory action . . . to raise the "minor crash landing" inertia forces of [14 CFR] 25.561 to a level comparable to those produced by a moderate-to-severe crash landing. Until a reasonable crash design condition is decided upon, including a specified crash acceleration pulse, it is suggested that the longitudinal inertia force be raised to 20 to 25 and the forces about other axes be similarly increased.
> (Recommendation Status: Previously closed when the FAA issued a Notice of Proposed Rulemaking whose requirements, if made final, would have accomplished the recommended action.)

A-77-70

> Amend 14 CFR 23.785 to require the installation of approved shoulder harnesses at all seat locations as outlined in NPRM 73-1.
> (Recommendation Status: Open, Unacceptable Action)

Additionally, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> Require that those general aviation aircraft manufactured to include attachment points for shoulder harnesses at occupant seats 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. (Class II, Priority Action) (A-80-125)
>
> Develop, in coordination with airframe manufacturers, detailed, approved installation instructions for installing shoulder harnesses at each seat location in current models and types of general aviation 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. (Class II, Priority Action) (A-80-126)
>
> Require that those general aviation aircraft for which FAA-approved harness installation instructions have been developed be fitted with shoulder harnesses at each seat location no later than December 31, 1985, and, in the interim, require this modification as a requisite for change in the FAA registration. (Class II, Priority Action) (A-80-127)
>
> At established intervals, extend the application of all newly established occupant protection provisions of 14 CFR 23 to all newly manufactured general aviation aircraft. (Class II, Priority Action) (A-80-128)

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." (Class II, Priority Action) (A-80-129)

Revise current standards for seat and restraint systems to incorporate needed crashworthiness improvements identified in FAA Research Project reports. (Class II, Priority Action) (A-80-130)

Establish standards for the dynamic testing of occupant protection devices required in general aviation aircraft. (Class II, Priority Action) (A-80-131)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
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/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

December 17, 1980

APPENDIXES

APPENDIX A

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APPENDIX B

SAFETY BOARD CRASHWORTHINESS INVESTIGATIONS OF 14 GENERAL AVIATION AIRCRAFT ACCIDENTS IN 1979 13/

Accident No. 1

A Cessna 172, on an instructional cross-country flight, encountered lowering ceilings. The student pilot, who occupied the left-front seat, began a 180-degree turn with the aircraft and it struck a hillside. The instructor pilot was in the right-front seat, and two passengers were in the two rear seats. The front seats were equipped with seatbelts and shoulder harnesses. The rear seats were only equipped with seatbelts. The instructor pilot was not wearing his shoulder harness and died on impact. The student pilot, who also was not wearing his shoulder harness, received serious injuries. The occupants in the two rear seats were seriously injured. The cabin remained essentially intact.

Injury	Cause of Injury
Left Front-Serious	
Head - Contusions, abrasions	Impact with instrument panel
Torso - Abrasions	
Extremities - Fractured right femur	
Right Front-Fatal	
Head - Fractured skull, laceration	Impact with instrument panel and yoke
Torso - Multiple abrasions and contusions	
Extremities - Fractured femur and both ankles	
Left Rear-Serious	Not available
Head - Contusions	
Torso - Contusions, fractured femur	
Extremities - None	
Right Rear-Serious	
Injuries unknown	

Accident No. 2

A Beech-18 aircraft experienced landing gear problems; after repeated attempts the gear would not extend. The aircraft made an emergency crash landing on a grassy strip. The cabin area remained intact. The front seats were equipped with both seatbelts and shoulder harnesses. The pilot was wearing his full restraint system; however, the occupant in the right-front seat was only wearing a seatbelt. The pilot did not sustain any injuries, but the occupant of the right-front seat received serious injury.

13/ All accidents included occurred before the FAA required pilots in front seats to wear installed shoulder harnesses during takeoffs and landings.

Injury	Cause of Injury
Left Front-None	
Right Front-Serious	
Head - Contusions, lacerations	Impact with instrument panel
Torso - Compression fracture of the spine (L1)	
Extremities - Contusions	Flexing during vertical g-loading

Accident No. 3

Witness observed a Piper PA-28 flying erratically and attempting to land on an interstate highway. The touchdown was so hard that the right main gear separated from the aircraft. The pilot, the sole occupant of the aircraft, was killed. The pilot's face hit the instrument panel. Although the front seats were equipped with seatbelts and shoulder harnesses, the pilot only wore his seatbelt. The cabin remained essentially intact although the occupiable space was reduced about 25 percent.

Injury	Cause of Injury
Left Front-Fatal	
Head - Skull fractual, right temporal	Impact with instrument panel
Torso-Compression fracture of the spine (L1)	Vertical deceleration
Extremities - Fractured right tibia	Flexing during vertical g-loading

Accident No. 4

During a go-around attempt, a Beech C-9 aircraft rolled left along the longitudinal axis and hit the ground inverted. The cockpit area was distorted about 25 percent in the area of the right-front seat. Although the aircraft interior remained relatively intact, the aircraft was destroyed by postcrash fire. All of the occupants wore seatbelts, but there were no shoulder harnesses. The occupants of the front two seats and a rear seat were thrown downward and to the front. The occupant in the right-front seat was killed.

Injury	Cause of Injury
Left Front-Serious	
Head - No information available	
Torso - No information available	
Extremities - No information available	

Injury	Cause of Injury
Right Front-Fatal	
Head - Compound fracture of the skull, lacerations to face	Impact with instrument panel
Extremities - Lacerations	
Rear Seat-Serious	
No available information	

Accident No. 5

A Beech 24R aircraft took off, climbed to about 350 feet, entered a steep left bank, and nosed into the ground. The aircraft was damaged substantially and the cabin area was reduced about 25 percent in the forward section of the aircraft. A student pilot occupied the left-front seat and the instructor occupied the right-front seat. Both seats were equipped with seatbelts and shoulder harnesses. The student pilot was wearing both seatbelt and shoulder harness. The instructor did not wear his shoulder harness. The instructor sustained fatal injuries.

Injury	Cause of Injury
Left Front-Serious	
Head - Skull fracture, lacerations	Instrument panel inward crushing
Torso - Compression fracture of the spine (L-4), abdominal contusion	
Extremities - Lacerations	
Right Front-Fatal	
Head - Compound skull fracture, lacerations and contusions	Instrument panel inward crushing
Torso - Compression fracture of the spine (L-1)	
Extremities - Fracture of both forearms	

Accident No. 6

A Beech A-36 aircraft lost an engine, and the pilot attempted a gear-up landing in a cottonfield. The two front seats were equipped with seatbelts and shoulder harnesses; however, neither occupant elected to wear the shoulder harness. During the crash, the interior of the aircraft remained intact. Both front-seat occupants were seriously injured, and the other three occupants escaped injury.

Injury	Cause of Injury
Left Front-Serious	
Head - Contusion	Decelerative forces against instrument panel
Torso - Fracture of the spine (L-1)	
Extremities - Minor abrasion	

Injury	Cause of Injury
Right Front - Serious Head - Abrasions Torso - Fracture of the spine (L-2) Extremities - Contusions	Decelerative forces against instrument panel

Accident No. 7

A Mooney M205 aircraft was on final approach when it stalled, its nose dropped, and it hit the water. The cockpit and cabin remained essentially intact. The aircraft was equipped with seatbelts, which the occupants were wearing, but no shoulder harnesses. Of the four occupants in the aircraft, three received minor injuries and one, the right-rear occupant, was seriously injured.

Injury	Cause of Injury
Left Front-Minor Head - Laceration Torso - None Extremities - None	Impact with instrument panel
Right Front-Minor Head - Contusion, lacerations Torso - None Extremities - Lacerations	Impact with instrument panel
Left Rear-Minor Head - Contusion, lacerations Torso - Contusion Extremities - None	Seatback impact
Right Rear-Serious Head - Contusion and lacerations Torso - Fractured ribs (L-9) Extremities - Contusion	Seatback impact

Accident No. 8

A PA-34-200 aircraft had just turned on final approach when it collided in-flight with another single-engine aircraft. The PA-34 sustained minor damage and was able to land successfully; however, its left wing and landing gear struck one of the navigation light structures. The aircraft came to rest nosedown at the side of the runway. Both the pilot and the occupant in the right-front seat wore seatbelts and shoulder harnesses. The interior of the aircraft remained essentially intact. The left-side window was broken during the collision and the pilot suffered lacerations to the face. No medical data were received to classify the injuries.

Accident No. 9

A Beech 18 aircraft encountered severe icing conditions and, while making a missed approach, stalled and hit trees one-quarter mile from the departure end of the runway. The aircraft was subsequently destroyed by fire. The pilot, who was wearing only a seatbelt, managed to crawl out of the cockpit to safety. There was no shoulder harness available.

Injury	Cause of Injury
Left Front-Serious	
Head - Skull fracture, numerous lacerations, contusions	Impact with instrument panel
Torso - Contusion, second-degree burns	Postcrash fire
Extremities - Contusions, third-degree burns	Postcrash fire

Accident No. 10

A Cessna 182 encountered increasingly lowering ceilings after takeoff. The pilot had begun to reverse his course when the aircraft struck trees. The aircraft, which sustained substantial damage, was not found for 36 hours. The pilot, who was wearing his shoulder harness, suffered lacerations of the face because the rear leg clamps of his seat broke from the track and there was severe buckling upward and forward. The other three occupants wore seatbelts, but they had no shoulder harnesses. The one fatality in the right-rear seat sustained internal injuries and a crushed chest.

Injury	Cause of Injury
Left Front-Serious	
Head - Laceration	Impact with instrument panel
Torso - Fracture of the spine (L-1)	
Extremities - Lacerations	
Right Front-Serious	
Head - None	
Torso - Compression fracture of the spine (L-2)	Seat buckling
Extremities - None	
Left Rear-Serious	
Head - None	
Torso - Compression fracture of the spine (L-4), internal injuries	Seat buckling
Extremities - Contusions	

Right Rear-Fatal

Head - None	
Torso - Chest crushing, internal injuries	Right cabin wall deformation
Extremities - Laceration	

Accident No. 11

An Aeronca 7BCM aircraft was flying along a hilly coastline "beachcombing" when the aircraft hit the bottom of a hill in a partially wooded area. The pilot survived and extracted himself and the emergency locator transmitter from the aircraft. However, he died shortly afterward from a ruptured thoracic aorta. The cockpit area was reduced about 25 percent. The pilot wore his seatbelt, but no shoulder harness was available.

Injury	Cause of Injury
Front-Fatal	
Head - Lacerations to face	Impact with instrument panel
Torso - Lacerations; contusion left lung; collapsed lung; fractured left rib	Possibly impact with control column
Extremities - Lacerations	

Accident No. 12

The Cessna 206 aircraft experienced an engine failure, and struck trees and crashed into the ground almost vertically. The decelerative forces were from the front to the rear of the aircraft. The pilot was not wearing his available shoulder harness, but was wearing his seatbelt. The lack of upper torso restraint allowed the pilot's upper body to contact the yoke and instrument panel. He sustained fatal injuries. The female occupant in the right-front seat wore both her shoulder harness and seatbelt and only sustained fractures of the lower extremities. The cockpit area was reduced about 25 percent.

Injury	Cause of Injury
Left Front-Fatal	
Head - Skull fracture, lacerations	Impact with instrument panel
Torso - Crushed chest	
Extremities - Lacerations, contusions	Impact with yoke
Right Front-Serious	
Head - None	
Torso - Minor contusions	
Extremities - Fractured right and left tibia	Crushing of the floor

Accident No. 13

A Beech A-36 began its takeoff roll and rotated in a nose-high angle, but never left the runway. Instead, the aircraft continued 200 feet past the end of the runway and hit a highway embankment. Neither of the two occupants was wearing his available shoulder harness. There were considerable vertical decelerative forces involved since the pilot died of a laceration of the thoracic aorta. He also impacted the yoke. The occupant in the right-front seat died from massive head and facial injuries due to impact with the instrument panel. The cabin area remained essentially intact.

Injury	Cause of Injury
Left Front-Fatal	
Head - Fractured skull, lacerations Torso - Compression fracture of the spine (L1) Extremities - Fracture of both ankles	Impact with instrument panel
Right Front-Fatal	
Head - Skull fractures, lacerations Torso - Contusions Extremities - Fractured right forearm	Impact with instrument panel

Accident No. 14

A Cessna T206 aircraft hit a mountain in a nose-high attitude, and the aircraft slid through the snow and high brush, flipped on its back, and came to rest 100 feet from the initial impact area. The injuries to the occupants were all from longitudinal impact against the control yokes and instrument panel. The cockpit occupiable area was reduced about 25 percent. The two occupants, who were seated in the front two seats, were killed. The front seats were equipped with seatbelts and shoulder harnesses; the shoulder harnesses were not in use.

Injury	Cause of Injury
Left Front-Fatal	
Head - Fracture of maxilla and mandible, lacerations and contusions Torso - Transverse fracture of the spine (T8) and laceration of the left upper pulmonary lobe; bilateral hemothorax. Extremities - None	Impact with instrument panel and control yoke
Right Front-Fatal	
Head - Facial and skull lacerations Torso - Multiple rib fractures, laceration of the left pulmonary lobe, laceration of the thoracic aorta	Impact with instrument panel and control yoke
Extremities - Fractured right and left forearms, left tibia, and fibula	Forward floor crushing, rudder, brake pedals

APPENDIX C

CHRONOLOGY OF CRASHWORTHINESS REGULATIONS

The Air Commerce Act of 1926 assigned to the U.S. Department of Commerce the regulatory responsibility for aviation operations. Through its Aeronautics Branch, the Department of Commerce developed the first Federal airworthiness and other standards for aircraft in the United States. These regulations were known as the Air Commerce Regulations, Bulletin No. 7 (ACR), and became effective on December 31, 1926. Paragraph (A)(3) of Section 15 of the ACR required "Seat belts or equivalent apparatus for pilots and passengers in [an] open cockpit [of aircraft] carrying passengers for hire." This apparently was the first requirement for seatbelts in civil aircraft and also seems to have been the first occupant-protection requirement. This regulation was revised effective June 1, 1928, with the addition to the revised ACR Section 10, paragraph (l)(c) of a requirement that "Seats or chairs in cabin airplanes shall be firmly secured in place."

Aeronautics Bulletin 7A, effective July 1, 1929, established the first restraint strength requirements. In addition to the 1928 occupant-protection requirements, the ACR regulations required that "Safety belts and their attachments shall 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. The attachment shall be such as to be capable of carrying this load through to the main structure."

An expanded ACR, effective January 1, 1931, required in paragraph (C)(3) of Chapter 3, Section 34, Supplies and Equipment:

> Safety belts or equivalent for pilot and passengers in all aircraft. Seats or chairs in cabin aircraft shall be firmly secured in place. Seatbelts and their attachments shall 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. The attachment shall be such as to be capable of carrying this load through to the main structure.

The ACR was revised and reorganized again effective January 1, 1933; however, the requirements for seats and seatbelts were not changed. Effective March 1, 1933, the airworthiness requirements were separated from the ACR into a new Aeronautics Bulletin No. 7-F, "Airworthiness Requirements for Aircraft Components and Accessories." This bulletin applied to any accessory or component classified as important if, by malfunctioning, it could endanger the safety of the aircraft or the cargo or passengers in the aircraft, or persons or property beneath the aircraft. To be approved, the items had to:

1. Satisfactorily fulfill the purpose for which they are intended.
2. Be free from undue hazard, both in themselves and in their method of operation.
3. Be constructed of suitable and dependable materials.

4. Be manufactured and installed in accordance with the air commerce regulations insofar as those regulations pertained to the particular unit.

Paragraph (A) of Section 27, Design Conditions, stated:

Safety belts for use in airplanes shall be capable of withstanding a load of 1,000 pounds applied in the same manner as a person's weight would be applied in a crash. They shall also be easily adjustable and equipped with a quick-release mechanism capable of being operated by hand under a load of 400 pounds. The quick-release mechanism shall be designed to withstand the required load of 1,000 pounds without undue distortion, so that when the load is relieved to 400 pounds the mechanism may be worked by hand.

A revision of the ACR, effective October 1, 1934, required that the design load of 1,000 pounds should be applied upward and forward at an angle of approximately 45 degrees with the floorline.

Because of the growth and increasing public interest in aviation, the limited safety authority granted by the Air Commerce Act of 1926 was broadened in the Civil Aeronautics Act of 1938. This Act conferred increased authority on the Department of Commerce for regulating aircraft safety and design standards through Civil Air Regulations, and also created an Air Safety Board to enforce air commerce and manufacturer safety standards.

On November 12, 1945, the Civil Aeronautics Board (CAB) published final regulations: 14 CFR 3, "Airplane Airworthiness—Normal Utility, Aerobatic, and Restricted Purpose Categories." Title 14 CFR 3.3811, Emergency Provisions, required that the fuselage be designed to give every reasonable probability that all occupants, if they made proper use of seatbelts or harnesses for which provisions were made in the design, would escape serious injury in the event of a minor crash, although it was accepted that parts of the airplane might be damaged. The minor crash conditions were defined as conditions in which the occupants experience the following ultimate acceleration forces in all combinations:

Acceleration Force Category	Crash Forces by Aircraft Type	
	Normal Utility (g)	Aerobatic (g)
Upward	0 to 3.0	4.5
Forward	0 to 9.0	9.0
Sideward	0 to 1.5	1.5

Also, 14 CFR 3.3811 required that the fuselage, in combination with other portions of the structure of airplanes having retractable landing gear, be designed to afford protection of the occupants in a wheels-up landing with moderate descent velocity. Additionally, airplanes other than those whose configuration rendered the possibility of turnover remote were required to have a fuselage designed in combination with other portions of the structure to protect the occupants in a complete turnover.

Title 14 CFR 3.3822 required that all seats, berths, and supporting structures be designed for a passenger weight of 170 pounds (190 pounds with parachute for the aerobatic and utility category) and for the maximum load factors corresponding to all specified flight and ground load conditions, including the emergency conditions described in 14 CFR 3.3811. The section also required that pilot seats be designed for the reaction resulting from the application of the forces to the primary flight controls as specified in 14 CFR 3.230.

Title 14 CFR 3.38221, Seat Belt or Harness Provisions, required that provisions be made at all seats and berths designed as occupiable during takeoff and landing for belts or harnesses necessary to comply with the emergency conditions of 14 CFR 3.3811.

Title 14 CFR 3.715, Safety Belts, was revised on January 6, 1950, to require that airplanes manufactured on or after January 1, 1951, be equipped with approved safety belts which provided strength corresponding to the ultimate load factors specified in 14 CFR 3.386. Also, attachments were required to be designed to comply with the ultimate load factors.

On March 8, 1950, the Civil Air Regulations again were revised, and minor changes were made to 14 CFR 3.386, Emergency Provisions. This provision stated:

> The fuselage shall be designed to give reasonable assurance that each occupant, if he makes proper use of belts or harnesses for which provisions are made in the design, will not suffer serious injury during minor crash conditions as a result of contact of any vulnerable part of his body with any penetrating or relatively solid object, although it is accepted that parts of the airplane may be damaged.

The changes in wording from the requirement that every "reasonable probability" from serious injury be assured through fuselage design to providing "reasonable assurance" reduced substantially the responsibility of airplane manufacturers. The requirements for airplanes with retractable landing gear and for protection in the event of overturn remained unchanged. However, a note was added which stated that a vertical ultimate acceleration of 3 g and a friction coefficient of 0.5 at the ground might be assumed.

On September 27, 1950, in a notice in the Federal Register (page 6500), the CAB proposed that the design strength for seats and berth attachments be increased by a factor of 1.33, i.e., each inertial force specified in paragraph 3.386 against which each occupant was to be protected during minor crashes was increased. Also, it was proposed to require that seatbelts be of an approved design.

In April 1951, the CAB published an interpretation of 14 CFR 3.386 which became 14 CFR 3.386-1, Crash Protection. This interpretation stated that cockpit arrangements and cabin structure collapse had been found to cause excessive injuries in crashes. The interpretation was based on close study of crash results which showed that when the human body was properly supported, it could tolerate crash forces that exceeded those necessary to demolish contemporary aircraft structures. The interpretation set out the following points of general significance:

1. Many survivable accidents are fatal because of insufficient design considerations.

2. The torso is rarely exposed to dangerous injury when seatbelts hold and control wheels provide support for the chest.

3. Protection from head injuries, the principal cause of crash fatalities, can be reduced by eliminating, shielding, or redesigning elements in the cabin which permit solid head blows.

In view of the fact that injuries and fatalities in many moderate and severe accidents were purely mechanical results of poor cockpit designs, the CAB included "guide rules for design" as suggestions to aircraft manufacturers. These suggestions included the elimination of projections and sharp edges; anchoring of objects such as compasses; providing flat, yielding surfaces to absorb forces; and strengthening safety belts, because many had failed without causing bruises to the occupant's hip or causing internal injuries.

On September 17, 1953, the CAB published in the Federal Register (page 5563) a supplement to 14 CFR 3.386 which established acceptable methods for applying the required loads to seats and berths in analyses or tests. While the supplement acknowledged that the actual forces consisted of many combinations of forward, sideward, downward, upward, and aft loads, the simplified test procedure permitted the manufacturer to assume that the critical loads acted separately.

The passage of the Federal Aviation Act of 1958 established the Federal Aviation Agency (FAA) and made it responsible for aviation safety. The Civil Air Regulations applicable to crashworthiness were continued unchanged for the next 6 years; however, interpretations of these regulations were frequently issued by the FAA. In the interpretations relative to restraints, the FAA pointed out that:

> The torso is rarely exposed to dangerous injury when the seatbelts hold and control wheels provide reasonable support for the chest. In personal aircraft every consideration should be given to holding the body by adequate safety belt installations, and by the support which can be provided in control wheels and instrument panels . . . . The present "1,000 pound" safety belts have failed in a high percentage of accidents without causing internal injuries or bruising of the hips. In failing, they have exposed the pilot to excessive injuries.

On September 28, 1964, the FAA issued a new 14 CFR 23 entitled, "Airworthiness Standards—Normal, Utility, and Aerobatic Category Airplanes," which replaced Part 3 of the Civil Air Regulations and essentially recodified the previous regulations. The stated purpose of this rulemaking action was to rewrite the existing regulations in one writing style throughout—not to change the substance.

The need for shoulder harness protection must have become strongly evident to the FAA since it issued in 1965 Advisory Circular (AC) 43.13-2, "Acceptable Methods, Techniques, and Practices - Aircraft Alterations." This AC has been

revised several times, the last time in June 1977. This AC included in Chapter 9, "Shoulder Harness Installations," information about different types of shoulder harness restraint systems, retrofit design considerations, and details on modifications needed for anchorage points for several airframe construction types. Also included was the fact that structural repair kits available from many manufacturers were available for establishing necessary anchorage points.

In section 146, General, the AC states that "Basic requirements of the aircraft airworthiness rules are designed to provide an aircraft structure to give each occupant a reasonable chance of escaping serious injury in a crash landing. These requirements adequately provide for conditions that can be expected to occur in various types of survivable accidents." This statement contrasts with the objective stated for shoulder harnesses (not required in the aircraft design), "to prevent incapacitating and/or fatal injuries to personnel involved in a survivable crash condition in which the aircraft structure remained reasonably intact." The AC acknowledged that the FAA had established no standards for shoulder harness materials, attachments, or acceptance tests. To date, no standards have been established.

When the Department of Transportation (DOT) was created by the U.S. Congress in 1966, the FAA was placed within the DOT under the administration of the Secretary of Transportation. The agency name was changed to the Federal Aviation Administration.

In 1967, the FAA proposed that 14 CFR 23 be further amended, and proposed (32 FR 5791, April 11, 1967) that the requirements for seats, berths, and belt attachment factors be combined into one section of the regulations which would require either (1) that effective upper torso restraints be installed, (2) that the airplane interior be designed to eliminate injurious objects within the striking radius of the head, or (3) that energy-absorbing support for the upper torso be provided. The explanation given for this action was: "Experience indicates that a significant reduction in injuries and fatalities may be obtained . . . ."

Title 14 CFR 23.785, Seats and Berths, was revised effective September 14, 1969, (34 FR 13078) to require that:

> Each occupant must be protected from head injury by: (1) A safety belt and shoulder harness that will prevent the head from contacting an injurious object; (2) A safety belt plus the elimination of any injurious object within striking radius of the head; or (3) A safety belt plus an energy-absorbing rest that will support the arms, shoulders, head, and spine.

In the discussion section of this rulemaking, the FAA commented that "the fact that shoulder harnesses were presently available as optional equipment and that they may not be used by some occupants does not negate the need for the rule change." Further, it was pointed out that the FAA had an educational program, Advisory Circular 00-21, and Report AM 66-33 to encourage shoulder harness use.

Effective August 30, 1971, a new FAA rule required that every occupant flying on a U.S.-registered civil aircraft fasten safety belts during takeoff and landing. Even though there had been a requirement for seatbelts for some general

aviation aircraft since 1926 and for all general aviation aircraft since 1931 (except during the period 1964-1969), there had never been a legal requirement to use these occupant protection items. This requirement affected some 130,000 general aviation aircraft.

In 1973, the FAA issued a Notice of Proposed Rule Making (NPRM), Docket 10162, "Crashworthiness for Small Airplanes," which proposed to require the installation of shoulder harnesses on all airplanes manufactured after 1 year from the effective date and on small civil airplanes manufactured prior to that date if they had structural provisions for the attachment of shoulder harnesses. Also, this NPRM proposed to require occupants of seats equipped with shoulder harnesses to use them during takeoff and landing. The FAA stated that it believed the proposed shoulder harnesses should reduce the probability of occupant injury in small airplanes and further that additional protection should be provided in the area surrounding each seat within striking distance of the occupant's head, torso, and flailing arms and legs. Thus, the FAA proposed a new section 14 CFR 23.785(j), that would require this area be free of sharp edges, protuberances, and hard areas. The NPRM acknowledged that additional suggestions for regulatory change had been made to increase the design "g" force levels, to require that the cockpit or cabin structure remain intact under those impact forces, to require dynamic testing of seats, and to require further means to reduce potential ignition sources associated with accidents. In response to these suggestions, the FAA stated that its research and development programs and the data and recommendations submitted did indicate possible future courses of action for upgrading the crashworthiness of small airplanes, but present information was not sufficient to support such rulemaking action.

Four and one-half years after its initial proposal, the FAA on June 9, 1977, issued a final rule based on its 1973 NPRM. Except for requiring shoulder harnesses at front seats in aircraft manufactured after July 18, 1978, the FAA rejected the proposal for shoulder harness installations at occupant seats stating that,

> based upon an evaluation of the expected benefits and other impacts on the public and private sectors, . . . the adoption of this amendment will result in a significant improvement in the chances of occupants of small airplanes covered by the amendment to survive minor crash landings and provide those occupants additional protection in more severe crashes at nominal cost. Over the next 25 years, it is estimated that approximately 1,875 lives may be saved by this amendment at an average cost of less than $5.5 million per year.

The final rule, 14 CFR 23.785, did require that newly certificated general aviation aircraft be designed to eliminate, within striking distance of an occupant's head or torso, potentially injurious objects, sharp edges, protuberances, and hard surfaces. Also, changes made in the final rule to 14 CFR 91.7 require that crewmembers, while at their station during takeoff and landing, keep available shoulder harnesses fastened. This requirement does not apply to a passenger occupying a front seat equipped with a shoulder harness.

APPENDIX D

SHOULDER HARNESS RESTRAINT SYSTEM INSTALLATION ON U.S. GENERAL AND BUSINESS AIRCRAFT AND HELICOPTERS 1972 - 1975

COMPANY	MODEL	YEAR	PERCENT	STANDARD	OPTION	CREW	PASSENGER
Beech	Heavy Singles Twins	1972	10-15		x	x	
	Light Singles	1973 ½	100	x		x	
	All Models	1975 ½	100	x		x	x
Piper	Ag Models	Pre-1972	100	x		x	
	Singles Light Twins	1972					
	Heavy Twins	1973	50		x	x	
	Heavy Twins	1974	100	x		x	
Cessna	Ag Models	Pre-1972	100	x		x	
	Twins Incl. Jet	1973	50		x	x	
	Singles	1973	5		x	x	
Gulfstream	Viking	1973	50-70		x	x	x
	Citabria Decathalon Scout (Aerobics)	1972	90	x		x	x
Mooney	All	1973	40		x	x	
Mitsubishi	MU-2	1973				x	
Rockwell	Ag Model	1974	100	x		x	
	112A (1)	1972	10, 20	x	x	x	x
	Twins	1972	10		x	x	
	Jet	Pre-1972	100	x		x	
Swearingen	Merlin Metro	Pre-1972	100	x		x	
Lockheed	Jetstar	Pre-1972	100	x		x	
Grumman	G1 G2	Pre-1972	100	x		x	
Ted Smith	All	1975	100	x		x	
Lear	All	Pre-1972	25		x	x	
Bell	206L	1974	50		x	x	

MANUFACTURER	MODEL	YEAR	PERCENT	STANDARD	OPTION	CREW	PASSENGER
Hughes	369 369	Pre-1972	75		x	x	x

(1) 1971 Aero Commander 111 and 112 had 3 interior options: "Standard" (with manually adjustable shoulder strap at the crew stations, optional armrest on the two rear seats, or optional with inertia reel and lock); "sport interior" (shoulder strap with inertia reel and lock standard at crew stations and optional on two rear seats); "super sport interior" (shoulder strap with inertia reel and lock standard on all four seats).

II. PROJECTED RESTRAINT FOR 1977-78 PRODUCTION AIRCRAFT

MANUFACTURER	MODEL	SEAT TYPE	INERTIA	FIXED	SEAT BELT ONLY	% INERTIAL REEL
Bell	205	CREW	OPT	OPT	STD	30%
		PASS	NONE	NONE	STD	
	206	CREW	OPT	STD	STD	
		PASS	OPT	--	STD	
	212	CREW	OPT	STD	STD	
		PASS	NONE	NONE	STD	
	214	CREW	OPT	STD	STD	
		PASS	NONE	NONE	STD	
	222	CREW	OPT	OPT	STD	
		PASS	NONE	NONE	STD	
Cessna	300-400 Ser	CREW	OPT	NONE	STD	50%
		PASS	NONE	NONE	STD	
	500 Ser	CREW	STD	NONE	STD	100%
		PASS	STD	NONE	STD	
Cessna	Single Engine	CREW	OPT	OPT	STD	50%
		PASS	OPT	OPT	STD	50%
Lear	24, 25, 36	CREW	STD	NONE	STD	100%
		PASS	NONE	NONE	STD	
Swearingen		CREW	STD	STD	STD	80%
		PASS	NONE	NONE	STD	
Ted Smith		CREW	STD	NONE	STD	100%
		PASS	NONE	NONE	STD	
Beech	All Models	CREW	CREW	STD	NONE	100%
		PASS	PASS	STD	NONE	
Lake		CREW	STD	NONE	STD	75%
		PASS	NONE	NONE	STD	
Ballanca	Viking	CREW	OPT	STD	STD	100%
		PASS	OPT	OPT	STD	
	Decathelon Citabria	CREW	OPT	OPT	STD	30%
		PASS	OPT	OPT	STD	
Hughes	500	CREW	OPT	OPT	STD	85%
		PASS	OPT	OPT	STD	
	300	CREW	STD	NONE	STD	100%
		PASS	STD	NONE	STD	
Rockwell		CREW	NONE	OPT	STD	0
		PASS	NONE	NONE	STD	

(1) 100% inertial crew and pass. thru Mid-1977, after that less than 50%

APPENDIX E

PREVIOUS NTSB CRASHWORTHINESS (RESTRAINT SYSTEMS) SAFETY RECOMMENDATIONS AND RESPONSES

RECOMMENDATION NUMBER: CY70-042

RECOMMENDATION SUBJECT:

1. SHOULDER HARNESSES SHOULD BE REQUIRED ON ALL GENERAL AVIATION AIRCRAFT AT THE EARLIEST PRACTICAL DATE. THE RECENT AMENDMENT 23-7 IS A STEP IN THE RIGHT DIRECTION BUT DOES NOT GO FAR ENOUGH. THE DRAFT REPORT MADE BY FAA'S DR. JOHN SWEARINGEN ON CRASH INJURY FURTHER PROVIDES CORROBORATIVE PROOF OF THE BENEFIT OF SHOULDER HARNESSES IN GENERAL AVIATION AIRCRAFT. 2. DELETHALIZATION OF AIRCRAFT INTERIORS SUITABLE ENERGY-ABSORBING PADDING BE REQUIRED ON ALL INTERIOR STRUCTURES TO PROTECT OCCUPANTS. ALL PROTUBERANCES LIKELY TO CAUSE 3. DYNAMIC TESTING OF SEATS CONSIDERABLE RESEARCH DATA ARE AVAILABLE, POINTING TO THE NEED FOR DYNAMIC TESTING OF AIRCRAFT SEATS. STATIC TESTS ALONE ARE NOT REALISTIC, AND CANNOT DIRECTLY BE RELATED TO CRASH ENVIRONMENTS. THESE CONCLUSIONS ARE VERIFIED BY THE WORK COVERED IN FAA'S AIRCRAFT DEVELOPMENT SERVICE REPORT NA-69-5, "DYNAMIC TEST CRITERIA FOR AIRCRAFT SEATS. "IT IS THEREFORE REQUESTED THAT THE FAA INITIATE REGULATORY ACTION TO IMPLEMENT THE RECOMMENDATIONS IN THIS REPORT. 4. EMERGENCY LANDING CONDITIONS REGULATORY ACTION BE INITIATED TO RAISE THE "MINOR CRASH LANDING" INERTIA FORCES OF FAR 23.561 TO A LEVEL COMPARABLE TO THOSEPRODUCED BY A MODERATE-TO-SEVERE CRASH LANDING. UNTIL A REASONABLE CRASH DESIGN CONDITION IS DECIDED UPON, INCLUDING A SPECIFIED CRASH ACCELERATION PULSE, IT IS SUGGESTED THAT THE LONGITUDINAL INERTIA FORCE BE RAISED TO 20 TO 25 AND THE FORCES ABOUT THE OTHER AXES BE SIMILARLY INCREASED. THE INERTIA FORCES SPECIFIED IN TABLE 1-1 OF THE U. S. ARMY AVIATION MATERIAL LABORATORIES TECHNICAL REPORT 67-22, "CRASH SURVIVAL DESIGN GUIDE" COULD WELL SERVE AS THE BASIS FOR A CIVIL AIRCRAFT CRASH DESIGN CONDITION. 5. CRASH FIRE PROTECTION FUEL TANKS AND FUEL SYSTEMS BE DESIGNED TO MINIMIZE THE SPILLAGE OF FUEL IN MODERATE TO SEVERE CRASHES. MATERIALS USED IN AIRCRAFT INTERIORS SHOULD NOT SUPPORT A SELF-SUSTAINED COMBUSTION, AND SHOULD NOT GIVE OFF TOXIC FUMES. FURTHER, FUEL IGNITION BE MINIMIZED BY REQUIRING THE CIRCUIT ISOLATION OF ELECTRICAL ENERGY SOURCES IN CRASHES.

RESPONSE:

9/3/70 FAA RESPONDED STATING THEY ARE PREPARING A NOTICE OF PROPOSEDRULE MAKING ON THE SUBJECT OF THIS RECOMMENDATION AND THAT THEIR STAFF WILL BE IN TOUCH WITH THE BOARD'S

TECHNICAL PERSONNEL. THEY ALSO ENCLOSED A COPY OF THEIR DISPOSITION OF PETITION RE. RALPH NADER'S CRASHWORTHINESS PETITION. 11/7/72 IN RESPONSE THE FAA INDICATED THAT AN NPRM COVERING RECOMMENDATIONS 01 AND 02 WOULD BE RELEASED BEFORE THE END OF THE YEAR. WITH REGARD TO PART 3, 4, AND 5THE FAA INDICATED THERE MAY BE NEED FOR IMPROVEMENTS IN THESE AREAS,BUT THE INFORMATION PRESENTLY AVAILABLE WAS NOT SUFFICIENT TO SUPPORT RULEMAKING ACTION.(B) SEE FEDERAL REGISTER, VOL. 42, NO.116—THURSDAY, JUNE 16, 1977, PAGE 30601 (COPY ATTACHED). (IT WAS TAKEN 7 YEARS FOR THIS RECOMMENDATION TO BE IMPLEMENTED. SAFETY BOARD'S FOLLOW-UP ACTION INCLUDED RESPONSES TO NPRM 73-1 AND FAA'S NOTICE NO. 74-5 AIRWORTHINESS REVIEW PROGRAM.) EVALUATION OF IMPLEMENTED ACTION PART 23 AND PART 91 ARE NOW AMENDED TO REQUIRE THE INSTALLATION OF SHOULDER HARNESSES FOR THE FRONT SEATS OF ALL SMALL AIRPLANES MANUFACTURED AFTER JULY 18, 1978. CREW MEMBERS OCCUPYING SEATS WITH REQUIRED SHOULDER HARNESSES MUST HAVE THEM FASTENED DURING TAKE-OFF AND LANDING. THE NEW REQUIREMENT IS NOT RETROACTIVE TO PREVIOUSLY MANUFACTURED SMALL PLANES. PART 23 IS AMENDED WITH THE FOLLOWING NEW PARAGRAPH: "THE CABIN AREA SURROUNDING EACH SEAT, INCLUDING THE STRUCTURE, INTERIOR WALLS, INSTRUMENT PANEL, CONTROL WHEEL, PEDALS, AND SEATS, WITHIN STRIKING DISTANCE OF THE OCCUPANT'S HEAD OR TORSO (WITH THE SAFETY BELT FASTENED), MUST BE FREE OF POTENTIALLY INJURIOUS OBJECTS, SHARP EDGES, PROTUBERANCES, AND HARD SURFACES. IF ENERGY ABSORBING DESIGNS OR DEVICES ARE USED TO MEET THIS REQUIREMENT THEY MUST PROTECT THE OCCUPANT FROM SERIOUS INJURY WHEN THE OCCUPANT EXPERIENCES THE ULTIMATE INERTIA FORCES PRESCRIBED IN SECTION 23.561(B)(2)."

RECOMMENDATION NUMBER: A-73-056

RECOMMENDATION SUBJECT:

ISSUE AN AIRWORTHINESS DIRECTIVE FOR ALL PIPER PA-28-140/180 AIRCRAFT, WHICH HAVE THE REAR BENCH SEAT INSTALLATION, TO REQUIRE REPLACEMENT OF THE PRESENT 1/8-INCH DIAMETER SEATBELT ATTACHMENT CABLE WITH A STRONGER CABLE, OR, ALTERNATIVELY, TO REROUTE THE PRESENT 1/8-INCH CABLE TO ELIMINATE THE STRESS CONCENTRATION WHICH MAY RESULT FROM THE CABLE CONTACT WITH THE SEAT FRAME.

RESPONSE:

8/10/73 RESPONSE FROM THE FAA TO SAY THAT THE STATIC TEST OF THE SEATBELT INSTALLATION DEMONSTRATED A STRENGTH OF 12G IN THE FORWARD DIRECTION. THE TEST CONDITIONS EXCEEDED REQUIREMENTS, SINCE THE TESTLOADS INCLUDED COMBINED LOADING WITH FORWARD, UPWARD AND SIDEWARD COMPONENTS, WHICH

RESULTED IN MORE SEVERE CONDITIONS THAN STRAIGHT LOADINGS IN EACH DESIGN DIRECTION APPLIED SEPARATELY. FAA REVIEW OF THE SEATBELT INSTALLATION SHOWED THAT THE ATTACHMENT CABLE DOES NOT COME INTO CONTACT WITH THE SEAT FRAME WITHIN THE DESIGN ENVELOPE. THE SEAT FRAME AND STRUCTURE WOULD HAVE TO FAIL AND DEFORM BEFORE CONTACT CAN BE MADE. SINCE THE REAR SEAT FRAME IN THE AREA OF THE CABLE IS A ROUND TUBING MATERIAL, IT WOULD NOT RESULT IN AN UNUSUALLY HIGH STRESS CONCENTRATION ON CONTACT. THE STRENGTH OF THE 1/8-INCH DIAMETER CABLE IS 2,000 POUNDS IN TENSION. THIS IS HIGHER THAN THE MINIMUM REQUIRED SEATBELT STRENGTH AND THE STRENGTH OF THE SEAT. REVIEW OF THE PA-28 SERVICE RECORDS SHOWED NO PREVIOUS CASE OFTHIS TYPE FAILURE SINCE TYPE CERTIFICATION IN 1960. THE ACCIDENT REPORT INDICATED THAT HIGH IMPACT LOADS WERE TRANSMITTED TO THE STRUCTURE AS A RESULT OF HITTING TREES AND THE GROUND. THE RIGHT WING WAS COMPLETELY BROKEN OFF, THE LEFT WING ALMOST SEVERED, AND MAJOR STRUCTURAL DAMAGE WAS INFLICTED. THE FAA CONCLUDED THAT THE INSTALLATION MET STRENGTH REQUIREMENTS BUT THAT LOADS IN EXCESS OF DESIGN REQUIREMENTS WERE IMPOSED. THEY THEREFORE FOUND NO BASIS FOR ISSUANCE OF AN A.D.1/13/75 - ALTHOUGH THE FAA RESPONSE INDICATED THAT NO FURTHER ACTION WOULD BE TAKEN, THEIR RESEARCH CONTINUED AND RESULTED IN FULFILLING THE INTENT OF THE RECOMMENDATION BY THE ISSUANCE OF AD-74-09-04.

RECOMMENDATION NUMBER: A-75-051

RECOMMENDATION SUBJECT:

AMEND 14 CFR 23.785(F) TO REQUIRE DYNAMIC TESTING OF SEATS TO INSUREMORE REALISTIC PROTECTION OF OCCUPANTS FROM SERIOUS INJURY IN A MINOR CRASH. (CLASS III)

RESPONSE:

FAA LTR: FAA IS UNABLE TO AMEND 14 CFR 23.785(F) TO REQUIRE DYNAMIC TESTING UNLESS REALISTIC CRITERIA ARE ESTABLISHED. NECESSARY DATA ARE NOW BEING OBTAINED BY FULL SCALE CONTROLLED CRASH TESTS BEING CONDUCTED AT LANGLEY RESEARCH CENTER. IN ADDITION, WE ARE CONDUCTING SEAT/OCCUPANT TESTS AT NAFEC AND ARE ESTABLISHING COMPUTER CAPABILITY THROUGH MATHEMATICAL MODELING AT OUR CIVIL AEROMEDICAL INSTITUTE AT OKLAHOMA CITY. WHEN REALISTIC CRITERIA ARE ESTABLISHED, REGULATORY ACTION WILL BE TAKEN. 2/15/79 - FAA LTR IN RESPONSE TO NTSB 11/9/78 LTR: IN ADDITION TO THE VARIOUS RESEARCH AND DEVELOPMENT CONTRACTS IN SUPPORT OF THE GENERAL AVIATION CRASHWORTHINESS PROGRAM, WE ARE IN THE PROCESS OF DEVELOPING A NOTICE OF PROPOSED RULEMAKING TO AMEND TSO-C39A FOR SEATS. WE EXPECT TO COMPLETE THIS PROJECT BY THE END OF 1979.

RECOMMENDATION NUMBER: A-77-070

RECOMMENDATION SUBJECT:

AMEND 14 CFR 23.785 TO REQUIRE INSTALLATION OF APPROVED SHOULD HARNESSES AT ALL SEAT LOCATIONS AS OUTLINED IN NPRM 73-1.

RESPONSE:

FAA LETTER: THIS PROPOSAL WAS CONSIDERED IN NPRM 73-1. IT WAS NOT CONSIDERED SUPPORTABLE IN THE RULEMAKING PROCESS AND THE BOARD HAS PROVIDED NO NEW INFORMATION TO JUSTIFY FURTHER RULEMAKING ACTION. AMENDMENT NO.'S 23-19 AND 91.109 SET FORTH IN DETAIL THE REASONING FOR THE WITHDRAWAL OR ADOPTION OF PROPOSALS IN NPRM 73-1. 2/15/79 - FAA LTR: BASED ON THE INFORMATION AVAILABLE TO THE FAA AT THE TIME OF THEIR DECISIONS ON THOSE AMENDMENTS, THE AGENCY DETERMINED THAT A SHOULDER HARNESS RETROFIT REQUIREMENT WAS NOT APPROPRIATE. FURTHER, IT WAS ALSO BELIEVED THAT DELETHALIZATION OF LIGHT AIRCRAFT CABINS WOULD BE PREFERABLE TO A REQUIREMENT THAT ALL SEATS BE EQUIPPED WITH SHOULDER HARNESSES. HOWEVER, FAA HAS COME TO THE CONCLUSION THAT THEIR EARLIER DECISIONS REGARDING THESE ISSUES SHOULD BE RECONSIDERED. AN ANALYSIS OF THESE ISSUES WILL BE CARRIED OUT AND OPTIONS WILL BE CONSIDERED. 3/28/80 - FAA LTR: SURVEY OF SHOULDER HARNESSES IN SMALL AIRPLANES HAS BEEN COMPLETED. PROCEEDING WITH REGULATORY ANALYSIS IN ACCORDANCE WITH EXECUTIVE ORDER 12044, COMPLETION DATA NOT LATER THAN 4/30/80. IN PROCESS OF UPDATING "TECHNICAL REPORT NO. FS-70-5922-120A, A SUMMARY OF CRASHWORTHINESS INFORMATION FOR SMALL AIRPLANES." ON COMPLETION OF ABOVE, THE FAA WILL DETERMINE THE PROPER COURSE OF ACTION TO PURSUE AND WILL PROVIDE A DETAIL RESPONSE.

RECOMMENDATION NUMBER: A-77-071

RECOMMENDATION SUBJECT:

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 RESONABLE LEAD TIME, AND AT ALL SEAT LOCATIONS AS OUTLINED IN NPRM 73-1.

RESPONSE:

FAA LETTER: THIS WAS CONSIDERED DURING THE EVALUATION OF RESPONSES TO NPRM 73-1 AND FOUND UNSUPPORTABLE. THEY FIND INSUFFICIENT JUSTIFICATION TO PROCEED WITH ANOTHER RULEMAKING PROCESS AT THIS TIME.

2/15/79 - FAA LTR: BASED ON THE INFORMATION AVAILABLE TO THE FAA AT THE TIME OF THEIR DECISIONS ON THOSE AMENDMENTS, THE AGENCY DETERMINED THAT A SHOULDER HARNESS RETROFIT REQUIREMENT WAS NOT APPROPRIATE. FURTHER, IT WAS ALSO BELIEVED THAT DELETHALIZATION OF LIGHT AIRCRAFT CABINS WOULD BE PREFERABLE TO A REQUIREMENT THAT ALL SEATS BE EQUIPPED WITH SHOULDER HARNESSES. HOWEVER, FAA HAS COME TO THE CONCLUSION THAT THEIR EARLIER DECISIONS REGARDING THESE ISSUES SHOULD BE RECONSIDERED. AN ANALYSIS OF THESE ISSUES WILL BE CARRIED OUT AND OPTIONS WILL BE CONSIDERED. 3/28/80 - FAA LTR: SURVEY OF SHOULDER HARNESSES IN SMALL AIRPLANES HAS BEEN COMPLETED. PROCEEDING WITH REGULATORY ANALYSIS IN ACCORDANCE WITH EXECUTIVE ORDER 12044, COMPLETION DATA NOT LATER THAN 4/30/80. IN PROCESS OF UPDATING "TECHNICAL REPORT NO. FS-70-5922-120A, A SUMMARY OF CRASHWORTHINESS INFORMATION FOR SMALL AIRPLANES." ON COMPLETION OF ABOVE, THE FAA WILL DETERMINE THE PROPER COURSE OF ACTION TO PURSUE AND WILL PROVIDE A DETAIL RESPONSE.