PHOTOGRAPH THIS SHEET

LEVEL

INVENTORY 1

AD-A207 579

DTIC ACCESSION NUMBER

DOT/FAA/AM-89/3

DOCUMENT IDENTIFICATION

FEB 1989

This document has been approved for public release and sale; its distribution is unlimited.

DISTRIBUTION STATEMENT

ACCESSION FOR	
NTIS GRA&I	☒
DTIC TAB	☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION /	
AVAILABILITY CODES	
DIST	AVAIL AND/OR SPECIAL
A-1	

DISTRIBUTION STAMP

DTIC ELECTE MAY 10 1989 S E D

DATE ACCESSIONED

DATE RETURNED

89 5 10 039

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC

DTIC FORM 70A MAR 86

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

DOT/FAA/AM-89/3

Office of Aviation Medicine
Washington, D.C. 20591

Injuries to Seat Occupants of Light Airplanes

Eugene J. Colangelo, M.D.
Julie C. Russell, M.P.H.

Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, Oklahoma 73125

FEBRUARY 1989

Technical Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA-AM-89-3		

4. Title and Subtitle	5. Report Date
INJURIES TO SEAT OCCUPANTS OF LIGHT AIRPLANES	February 1989
	6. Performing Organization Code: AAM-610
7. Author(s): Eugene J. Colangelo, M.D. and Julie C. Russell, M.P.H.	8. Performing Organization Report No.
9. Performing Organization Name and Address: FAA Civil Aeromedical Institute, P.O. Box 25082, Oklahoma City, OK 73125	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Office of Aviation Medicine, Federal Aviation Administration, 800 Independence Ave., SW, Washington, D.C. 20591	13. Type of Report and Period Covered: TECHNICAL REPORT
	14. Sponsoring Agency Code

15. Supplementary Notes

This work was performed under task AM-B-88-TOX-57

16. Abstract

A series of 55 light-airplane accidents was examined in an effort to demonstrate the role of seats in the genesis of injury in seat occupants. Good engineering design of airplane seats is an important related issue which is not treated in this study. Case selection attempted to include only those events in which significant but not extreme accelerations occurred. Ten of the fifty-five cases involved joint failure of seats and restraint systems. The majority of the observations were provided by aviation medical examiners who were typically very highly motivated practitioners of medicine with special interests and accomplishments in aviation. The other cases were reported by FAA accident investigators.

No reliable marker of energy level was found in the data collected to control the finding that large accelerations tend to injure people and damage seats as well as most other structures regardless of the other interrelationships that might be involved.

The existence of seat damage does little, by itself, to define the seat's role in injury causation. Interpretation of injuries established by clinical and autopsy observations suggests that the large majority of injuries are caused by mechanisms which can proceed independently of seat failure. Restraint systems likely play the more important role.

17. Key Words	18. Distribution Statement
Aircraft accident; airplane seat failure; impact injury; injury mechanism; impact acceleration; airplane occupant impactors.	Document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	26	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgement

The authors wish to acknowledge the efforts of the late Dr. William Kirkham in initiating this project. The Aviation Medical Examiners (AMEs) who participated in the on-site investigations and supplied data for the study are also gratefully acknowledged.

INJURIES TO SEAT OCCUPANTS OF LIGHT AIRPLANES

INTRODUCTION

There is continuing concern for the well-being of occupants of light airplanes that are involved in accidents. Engineering technology provides for design changes in airframes that may significantly reduce or even prevent injuries to persons involved in such accidents (24,27,32). Many of these changes can be incorporated without adversely affecting the efficiency of the vehicle and without incurring unreasonable costs. Definition of the specific mediators of injury and their relative importance is necessary so that the most rewarding improvements in airplane design can be implemented. The airplane seat, because of its proximity to the occupant, is expected to mediate injury as well as attenuate injury, and may be an integral part of the restraint system. For this reason it is important to define the role of the seat with respect to injuries sustained by its occupant (3,29). To this end a selected series of light-airplane accidents was studied in an effort to better understand the relationship of light-airplane seats to the injuries sustained by their occupants.

BACKGROUND

Two complementary lines of research contribute to the understanding of this problem. Laboratory experiments conducted under controlled conditions establish limits of structural tolerance of seats as they are exposed to forces applied through such mechanisms as test track accelerators. Anthropomorphic dummies, electronic instrumentation and high speed photography can be used to define much of the mechanics involved under these conditions (4). A common limitation in such approaches is the uncertainty that the parameters selected for the experiment truly reflect the circumstances operative in an airplane accident. The other research approach depends on observations derived from actual airplane accidents which are representative but correspondingly limited by the absence of needed measurements of energy transfers and accelerations (18,21,22).

Recent publications (19) have described airline seats as a significant cause of injury to passengers because the seats may become detached from their moorings during an accident sequence. It has been suggested that seats should perform better if they were aft facing so that forces were applied through the seat back over the largest available area of contact with the occupant (6).

However, the rearward-facing seat has found limited application in general aviation. Sideward facing seats introduced characteristic problems. Aircraft design engineers have demonstrated the potentially beneficial influence that aircraft seats can introduce into those events characterized by prominent vertical accelerations applied approximately parallel to the occupant's spinal column, Gz (6,24,32,33). Seats can provide needed additional stopping distance and can help change the rate at which energy is released to the seat occupant and help reduce potentially damaging energy transfers to noninjurious levels (12). It is not clear which of these diverse experiences with vehicular seats are similar to seat performance in actual light airplane accidents and how much influence seat design has on injury occurrence and severity.

Research into automobile accident experience indicates that the seat typically had little to do with determining occupant survival (16). The accelerations commonly applied, -Gx, tend to separate the victim from his seat through the action of inertial forces which cause the occupant to travel toward the front of the vehicle (9,10). The seat in such events, characterized predominantly by -Gx accelerations, may allow the rear seat passenger to strike the seat back ahead if he is carried forward by inertial forces. In certain instances, seat displacement in auto accidents can cause submarining and subsequent internal and spinal injuries to front seat occupants.

Such observations, especially in light of Swearingen's (31) comparison of the light airplane experience to the motor car with potentially similar velocities, leads one to appreciate the importance of determining the characteristics of light-airplane accidents. Furthermore, the nature of airplane accidents can be influenced by operational and structural factors which may be changing over the years as light airplanes gain more speed and sophistication, operate in more adverse weather conditions and challenge the proficiencies of the pilots involved to a greater extent.

Some delineation of the typical forces intrinsic to the common light airplane accidents would provide a basis for determining injury mechanism and the seat's role in those events. The General Aviation Safety Panel, GASP, postulated certain parameters that it considered representative of the light airplane accident, for purposes of conducting sled tests on various general aviation airplane seats (4,9). A downward vertical velocity that was sufficiently great to cause a resultant force vector at impact to approximate 60 degrees below the plane of the floor was chosen by the panel.

In a recent series of reports, The National Transportation Safety Board (NTSB) defined relationships between the opportunity for survival in light-airplane accidents and the impact angle or airspeed of the airplane at its major impact point (20,21,22). These reports suggest that survivable experiences tend to occur when the impact angles are small and the vertical accelerations do not predominate. An envelope of survivability was estimated to be 45 knots at 90 degrees of impact angle, 60 knots at 45 degrees, and 75 knots at 0 degrees.

The detailed analysis of injury sustained in light-airplane impacts would also contribute to an understanding of the mechanisms involved. While many similar injuries can be inflicted in a variety of ways, there are certain characteristic findings which suggest likely mechanisms of injury. For example, compression fractures of vertebral bodies in the low thoracic and lumbar spine typically occur as a consequence of forces acting approximately parallel to the long axis of the spine (28). Forces acting perpendicularly to the spine are more likely to produce a translational displacement of vertebrae. These forces can also produce rotation and extension of the spine. Similarly, a typical finding in light-airplane accidents involves blunt trauma applied to the head affecting the face predominantly and typically resulting from striking the head against a control wheel, instrument panel, console or other cockpit structure (18,31). These face and head injuries suggest mechanisms that proceed independently of seat performance unless the back of a forward seat serves as a contact point for a rear passenger.

The seat may contribute to head injury in at least two ways. When the seat is a critical link in the restraint system which fails because of a deficiency in the seat or when the seat deforms and allows the body to move out of position for correct application of restraint, head injury may result. Methods of injury analysis are limited by the lack of detailed observations from the common light airplane accident that would elucidate the mechanism of injury and the impact points of the cockpit environs (2). This is true even in the cases in which autopsy examinations are conducted. Coordination between the field investigators and the pathologist performing the examination is frequently limited and not timely enough to ensure that these issues are regularly treated. Additionally, many fatally injured occupants of light airplane accidents are not autopsied. Even less information is available on occupants who are seriously injured but not killed.

In this study we examined injury experience and impact findings in actual accidents involving light airplanes. Relationships between injury pathogenesis and seat causation are described.

METHODS

Fifty-five light airplane accidents were selected for this study. The accidents occurred between April 1981 and April 1986. The maximum certificated gross weights for these airplanes were 12,500 pounds or less. The terms "aircraft accident", "fatal injury," and "serious injury" were used as defined by the NTSB (23).

Although it would have been ideal to analyze the entire population or a true random sampling of light airplane accidents as part of this study, practical limitations did not permit this. The proportions of makes and models of aircraft represented in this series correspond to those of the general aviation fleet (8). The sample was composed of accidents in which the energies were sufficient to truly test seat performance and cause injury. The very low energy incidents, such as a flat tire developing early in the take-off roll or the low velocity ground loop in which no significant damage occurred were excluded. At the other end of the spectrum, the kind of accident in which the damage is extremely severe and much of the evidence is destroyed by impact, fire or other environmental misfortune was also excluded. The terms "survivable" and "non-survivable" have been applied to delineate the polarization in this concept (11,20,27,32). The case selection criteria included the following:

1) Must be an accident according to NTSB definition (22)
    a) plane must have sustained substantial damage

    or

    b) at least one occupant experienced severe or fatal injury.
2) Must be a light airplane (12,500 pounds or less)
3) Wreckage not destroyed by fire so that seat and restraint evidence available.
4) Must be a survivable accident
    a) deceleration forces do not exceed human tolerance.
    b) some portion of the passenger cabin remains substantially intact.

The observations of the available evidence at the accident site were made by aviation medical examiners (AMEs), National Transportation Safety Board or Federal Aviation Administration (FAA) investigators while post-mortem studies were usually conducted by county or state medical examiners or pathologists.

Several cases were investigated by crash injury investigators from the Civil Aeromedical Institute (CAMI). The relevant information derived from these efforts was submitted to FAA regional flight surgeons who reviewed the documents, commented and interpreted them as they saw fit and forwarded them to the Civil Aeromedical Institute, CAMI, for collation and analysis.

To facilitate the acquisition of the appropriate evidence and to introduce a degree of uniformity into the data acquisition process, CAMI developed a form (FAA form 8025-3) on which critical observations were recorded and data automatically processed. This form called for estimates of the attitude of the airplane at impact, damage to occupiable and non-occupiable portions of the airframe, diagrams of the directions the occupants were thrown at impact, force directions and damage affecting the seats, restraint system characteristics, the injuries inflicted on the occupants and the causes of injury. (see Appendix A) There were two questions inviting narrative comments regarding injury pathogenesis and crashworthiness.

Sources of information collected for analysis included:

1. The National Transportation Safety Board report of the accident (NTSB Form # 6120.4)
2. The Report of Medical Findings in Aircraft Accidents, FAA form 8025-2
3. The Special Study Form, FAA form 8025-3
4. Photographs of the accident site and the injuries sustained
5. Autopsy protocols
6. Comments and interpretations by the regional flight surgeon.

Many observers did not respond to all questions and there is some suggestion that the questions were not always interpreted in the same way. The occasional responses that included mutually exclusive descriptions were either corrected or deleted. All of the desired information was available only in rare instances. However, since the FAA form 8025-3 included a synthesis of the critical information that would ordinarily be distributed through all the sources described above, a case was accepted into this series if the FAA form 8025-3 was available and case selection criteria were met.

In order to assess seat failure it was necessary to define consistent criteria which could be applied to the whole series, since individual observers were not provided uniform standards by which to establish failure. Frequently, no assessment of the significance of a given seat damage was provided.

For purposes of this study, based on a consideration of the relevant literature, the authors defined the presence of one or more of the following conditions as seat failure (1,4,5,6,7,11,15,25,27,30,32,33).

1. The seat detached from its attachment points in such a way that it rendered the restraint system inoperative or ineffective. Typically this condition developed when the lap belt was attached to the seat.

2. The seat detached from its attachment points allowing for displacement of the seat from its original position. Instances of minor deformations, cracks, and failures in one or more attachment points that did not result in movement of the seat from its original position were excluded from the seat failure population.

3. The seat acted as an impactor causing injury to an airplane occupant. The typical example of this kind of failure was the circumstance in which the rear seat passenger moved forward striking a part of the back of the seat ahead.

4. The seat failed to protect its occupant from impactors intruding into the volume of space designed for the occupant.

Each case was reviewed at CAMI with the goal being to extract observations regarding force directions and magnitude, nature of the injuries and causal relationships.

RESULTS

All the desirable information suggested above was not submitted in every case. Autopsy protocols were often missing on fatal cases. Many observers did not respond to all questions and there is some suggestion that the questions were not always interpreted in the same way. Table I describes the kinds of documentation that were submitted.

TABLE I

INFORMATION SUBMITTED FOR 55 ACCIDENTS

NUMBER OF CASES WITH 8025-3	55
NUMBER OF CASES WITH PHOTOGRAPHS	36
NUMBER OF CASES WITH AUTOPSY PROTOCOLS	11
NUMBER OF CASES WITH 8025-2, REPORT OF MEDICAL FINDINGS IN AIRCRAFT ACCIDENTS	15
NTSB REPORT OF AIRCRAFT ACCIDENT	23

Most of the observations were made by aviation medical examiners (Fig. 1). In the fields of interest, there were no significant differences among responses from the several groups of observers. Regional flight surgeons rarely reversed or amended the essential observations.

Figure 1 describes the sources of observers as follows: Aviation medical examiners (AMEs) investigated 62% of the accidents, representatives of a Flight Standards District Office (FSDO) or a General Aviation District Office (GADO) investigated 27% of the accidents, and investigators dispatched from the Civil Aeromedical Institute (CAMI) investigated 11% of the accidents. NTSB accident reports were obtained when available and used to supplement data submitted on FAA-form 8025-3.

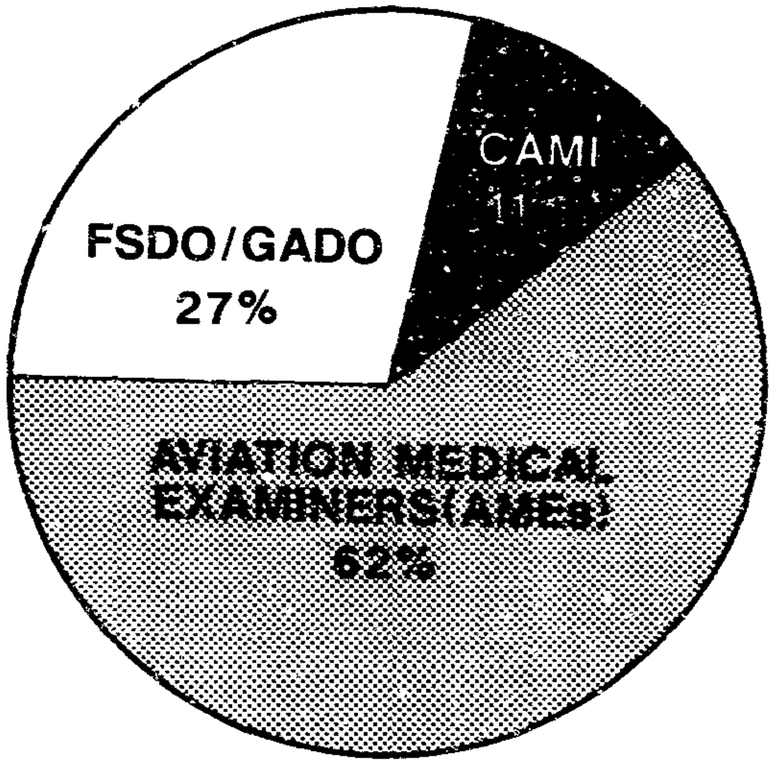


FIGURE 1 - SOURCES OF OBSERVERS

Figure 2 describes seat failure modes with seat detachment being the most common, occurring in nearly 3/4 of seat failures. Partial detachments without major seat dislocation occurred frequently and are included in this group. Out of 133 occupied seats, 52 were classified as failed. Figure 2 illustrates the proportions of failed seats falling into four broad categories of seat failure. The categories are defined as follows:

A. Seat detached and caused restraint system failure - 10 (19%)
B. Seat detached only - 28 (54%)
C. Back of seat as impactor - 11 (21%)
D. Seat failed to protect occupant from intrusion by other objects - 3 (6%)

Seat failure events are counted in one category only, the category describing the most noteworthy failure.

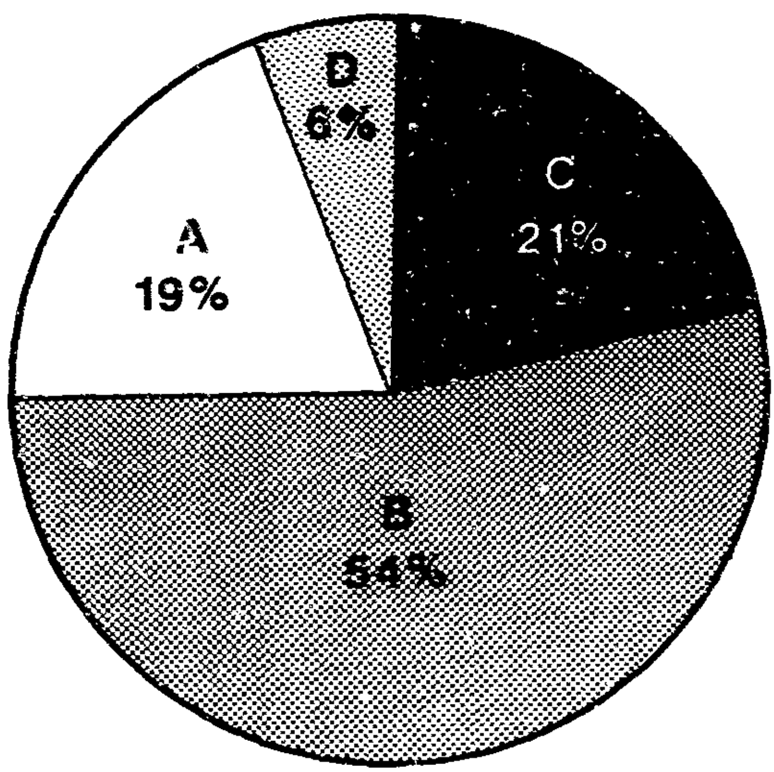


FIGURE 2 - SEAT FAILURE MODE (52 SEAT FAILURES)

Investigators were asked to estimate the directions of the forces that caused seat occupants to move during the accident sequence. They drew arrows representing the movements of seat occupants with respect to the primary axes of the airplane. While there was no attempt to impose a unit of measure for these forces, the lengths of the arrows were proportional to the estimated relative magnitudes interpreted by the investigator. The angular relationships and the temporal sequence of the forces represented by these arrows were also determined by the field investigators. Quantitative measurements of deceleration magnitudes, slope of the terrain, and the attitude of the airplane at each impact point were generally not available.

Figure 3 presents the outlines on which investigators inserted arrows to represent the seat occupants' motions during the accident sequence.

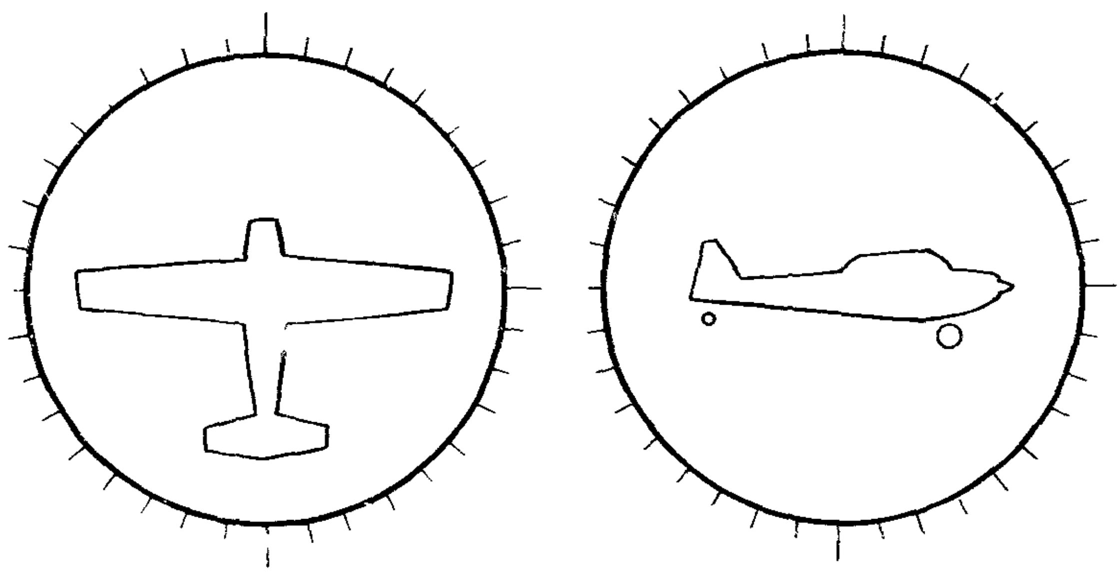


FIGURE 3 - Drawings Submitted by Investigators

In ten of the cases, our contributors responded with arrows *drawn to depict the forces as suggested above. Each of these* arrows was resolved into a horizontal and vertical component which could be added vectorially to approximate a mean vector for that event. Additionally, some sense of the relative role of vertical forces compared to longitudinal forces was implied. *Transverse forces producing yaw were not reported as being* predominant and were not similarly analyzed for relative magnitude and direction. Some components of transverse force were probably reflected in the depictions of movement in the plane containing the longitudinal and vertical axes of the *aircraft.*

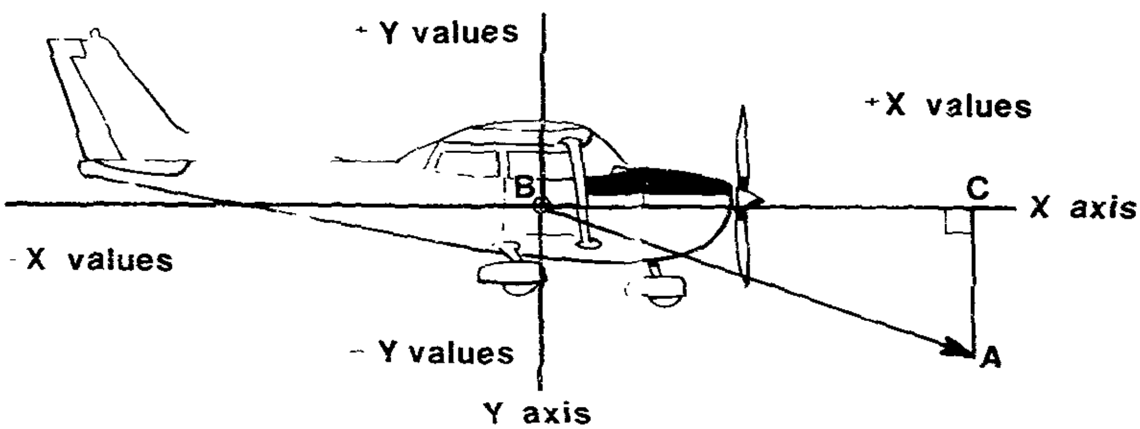


FIGURE 4. FORCE VECTOR DIAGRAM ON CARTESIAN COORDINATES

Figure 4 is a drawing of an airplane superimposed on a Cartesian coordinate system having an x axis parallel to the horizontal and a vertical y axis perpendicular to the horizontal. The x axis is parallel to the longitudinal axis of the airplane while the y axis is parallel to its vertical axis. The arrow drawn in by the observer to represent the direction that inertial forces moved the seat occupant can be inserted as line AB in Figure 4. As in any other conversion from polar to rectangular quantities, the vector AB can be represented by equivalent values of x and y or equivalent vectors BC and CA. The reader is reminded that the use of "x" and "y" in this context should not be confused with the common use of these letters to describe acceleration directions applied to aircraft occupants.

These observations and the corresponding sense for the relative influences of horizontal and vertical forces can be presented as in Table II. Based on the assumption that the horizontal component, which was always the larger one, could be assigned a value of one arbitrary unit, the relative influence of vertical forces could be expressed in relation to that unit. The arrows depicting the forces acting on seat occupants are presented as polar quantities in the right half of Table II while the left half presents the corresponding rectangular equivalents. Analysis revealed that the ratio of averaged vertical forces to averaged horizontal forces was 0.28/1.00.

TABLE II

FORCE VECTORS

HORIZONTAL/VERTICAL X axis	Y axis	RELATIVE LENGTH & ANGLE OF RESULTANT VECTOR	
1.0	0	1.0	0 degrees
1.0	-.2	1.0	-11
1.0	-.44	1.1	-24
1.0	-.46	1.1	-25
1.0	-.5	1.1	-27
1.0	-.26	1.0	-15
1.0	0	1.0	0
1.0	-.6	1.2	-31
1.0	-.17	1.0	-10
1.0	0	1.0	0
1.0	-.16	1.0	-9
1.0	-.6	1.2	-31
1.0	-.33	1.1	-18
1.0	-.42	1.1	-23
1.0	0	1.0	0
1.0	-.26	1.0	-15
1.0	-.3	1.0	-17
1.0	-.28	1.0	-16
1.0	-.71	1.2	-35
1.0	0	1.0	0

Each drawing submitted on 20 accidents was analyzed. The remaining 35 cases contained insufficient information. Results shown in Table II indicate that the magnitude of the combined vertical forces is about one third of the magnitude of the combined horizontal forces. The mean angle of the resultant force vectors is estimated to be 15 degrees below the horizontal axis.

TABLE III
RESULTANT FORCE DIRECTION AND CONSEQUENCES

RESULTANT VECTOR	SEAT & OCCUPANT OUTCOME	
<15 DEGREES	11 ACCIDENTS	(26 OCCUPANTS)
	12% SEAT FAILURE	(3/26 SEATS)
	58% SERIOUS/FATAL INJURY	(15/26 OCCUPANTS)
>15 DEGREES	9 ACCIDENTS	(18 OCCUPANTS)
	17% SEAT FAILURE	(3/18 SEATS)
	83% SERIOUS FATAL INJURY	(15/18 OCCUPANTS)

As the terminal flight path became steeper or more nearly vertical, there was a tendency for greater seat damage and injury to be inflicted. This relationship is represented in Table III. Neither the proportion of seat failures nor the proportion of serious/fatal injuries are significantly different statistically at low impact angles vs. high impact angles. Using the chi squared test, p=.63 and .07 respectively. This is likely due to the small sample size, sample selection and imprecise measurements. These results parallel those of the NTSB reports which define opportunity for survival as a function of impact angle and airspeed.

The frequency of seat failure among persons with serious or fatal injury was considered. Out of a group of 96 occupants who were seriously or fatally injured, 46 were in seats which failed. The binomial test yields a p value of 0.69. This p value indicates that there is no statistically significant difference in the observed proportion of seriously/fatally injured persons in failed seats from those in seats that did not fail (26).

Without controlling for energy level, it is not appropriate to infer a causal relationship between seat failure and injury severity. Energy level is related to both seat failure and injury severity so that any apparent association is likely due to the energy level exerted on both the seat and the occupant. It is not proof of a causal association between seat failure and injury severity.

Stratification is one method to control biasing factors such as energy level (17). Data collected in this study was not adequate to reliably stratify most accidents into high and low energy categories. Impact angle was estimated for a few of the accidents, but information on stopping distance and estimated speed were not available. If this information were available, the relationship between seat failure and injury severity could be examined for the two subgroups, high and low energy accidents. It is hypothesized that, if an adequate sample were available, there would be no association between seat failure and injury severity in low energy accidents. Humans sustain injury at much lower energy levels than are needed to damage a seat and common forces tend to separate man and seat. At higher energy levels both the seat and its occupant are likely to be damaged.

TABLE IV
INVESTIGATORS' DETERMINATION OF SEAT ROLE IN INJURY CAUSATION

RESPONSE	FREQUENCY	PERCENT
SEAT ADDED TO INJURY	9	10
SEAT LESSENED INJURY	7	8
SEAT MADE NO DIFFERENCE TO OCCUPANTS INJURY	70	82

One field on the FAA form 8025-3 asked the investigator to determine if the seat failure had added to the occupant's injury, ameliorated injury, or didn't make any difference. For 35% of the occupants this field was blank. Of the remaining cases 10% reported the seat added to the occupants injury, 8% indicated that the seat distorted and cushioned the impact, 82% reported the seat did not make any difference in the occupant's injury.

The accidents in which the seat was interpreted to have influenced the injury are summarized as follows:

Case 1: A Mitsubishi MU-2 crashed while the pilot attempted an emergency landing during a thunderstorm near Scottsdale, Arizona. Six of the occupants of this plane suffered increased injury severity due to seat failure.
The pilot's seat detached from the floor and the pilot was ejected from the plane. A female passenger, in an aft-facing seat on the right side of the plane, sustained an injury which almost amputated 2/3 of her thigh. In this case the seat failed to protect the occupant from an object which protruded through the cabin wall. Two other passengers also seated in aft facing seats were killed when hit by flying objects. The seat failed to protect these occupants from unrestrained cargo when the cargo net attachments failed. Two other passengers in forward facing seats were hit by flying objects and their seats also detached from the floor as heavy cargo moved forward at impact.

Case 2: A Cessna 172 crashed during takeoff seriously injuring all four occupants. Two young men seated in the back suffered severe facial fractures when the seat legs detached from the floor and both lap belts failed, allowing both back seat passengers to impact the back of the front seats.

Case 3: A Bellanca Citabria crashed while practicing aerobatics. One of the back seat legs separated causing the five point harness to fail. The pilot sustained fatal skull fractures when his head impacted the instrument panel and windscreen.

Case 4. The pilot of a Cessna 182 attempted to make an emergency landing in a muddy field. The plane struck a slightly elevated gravel road, detached the nose gear and slid 80-100 feet in a 30 to 40 degree nose down attitude. The pilot's seat partially detached and the copilot's seat completely detached. The AME investigator reported that the seats effectively attenuated energy to protect the occupants. Both occupants were seriously injured with facial fractures.

Case 5. The engine of a Cessna 172 failed during an approach to the airport and an emergency landing in a field was attempted. All four seats detached during the crash. The AME reported the seats did attenuate energy and helped protect the occupants from more serious injury.

Case 6. The engine of a Beech Sundowner failed during a touch and go landing. The pilot attempted to make a right turn back to the airport, stalled and decelerated through several trees. The pilot's seat remained attached to the floor, but the legs of the seat deformed to cushion the impact.

Table V is a tabulation of injuries reported on FAA form 8025-3 in order to determine their relative frequencies by anatomic body region. The percentage of the population exposed to the accident experience who sustained injury to each of the major body areas listed in the table are presented. Seven percent of occupants, although exposed to crash forces, were not injured. Thirty six percent of occupants were fatally injured, thirty six percent seriously injured and twenty one percent sustained minor injury.

TABLE V DISTRIBUTION OF ALL INJURIES REPORTED ON FAA FORM 8025-3

INJURY BY BODY REGION	OBSERVED FREQUENCY	FREQUENCY PERCENT
ALL HEAD INJURY	90	68 (90/133)
SEVERE HEAD INJURY	33	25 (33/133)
CHEST INJURY	52	39 (52/133)
ABDOMINAL INJURY	38	29 (38/133)
PELVIC INJURY	9	7 (9/133)
SPINAL INJURY	29	22 (29/133)
LOWER EXREMITIES	39	29 (39/133)
UPPER EXTREMITIES	30	23 (30/133)

This table presents the number and percent of the 133 total occupants exposed to injury producing forces to each body region.

A tabulation of the occurrence of injury to each anatomic region as a percentage of all observed injury is presented in Table VI. Tabulation of autopsy data regarding injury revealed what one would expect, that the most obvious and compelling injuries were consistently noted. Those more subtle injuries, such as injury to the spine, were not reported as often as in living patients. Injuries to the head and chest accounted for a large portion of the injuries in both autopsy and clinical injury reported in this series (13,14). These injuries are unlikely to be mediated by the seat, except in cases in which the seat caused failure of the restraint system.

TABLE VI
PER CENT OF INJURY BY ANATOMIC REGION OF BODY
(Derived from 11 autopsies)

REGION	FREQUENCY	PERCENT
UPPER EXTREMITIES	9	8
LOWER EXTREMITIES	16	14
HEAD	30	27
THORAX/ ABDOMEN	51	46
SPINE/PELVIS	6	5
TOTAL	112	100

Table VII represents the distribution of impactors for the 78 occupants who had a response for this question (58% of the total population). Seventeen occupants struck no objects and the impactor was unknown for 38 occupants. There were 147 impactors reported for this group. The intrument panel and the yoke were most often reported as impactors which would indicate a predominantly forward motion of the occupant.

TABLE VII
DISTRIBUTION OF INJURY PRODUCING IMPACTORS

IMPACTOR	FREQUENCY	PERCENT
YOKE	31	21
INSTRUMENT PANEL	36	24
STRUCK BACK OF SEAT	12	8
STRUCK BY FLYING OBJECT	11	7
MADE IMPACT WITH FLOOR	4	3
MADE IMPACT WITH RUDDER PEDALS	11	7
MADE IMPACT WITH WINDSCREEN/WINDOW	10	7
STRUCK COCKPIT/CABIN STRUCTURAL MEMBERS	24	16
STRUCK OTHER OBJECTS	8	5

DISCUSSION

The data available for analysis in this study is characterized by the usual limitations attendant to airplane accidents that are investigated under various conditions of opportunity and with varying degrees of thoroughness and completeness. Many of the observations are merely best estimates rather than precise measurements. While certain limitations may have been introduced by the variety of observers, there was the opportunity for individual bias to be limited by the many independent inputs. We believe the main trends are credible even though it may not be realistic to interpret all numerical data points with the precision and confidence expected in laboratory conditions.

The idealized data base would logically consist of the complete accident report along with photographs, the FAA form 8025-2 which includes the regional flight surgeon's review, a complete autopsy examination with pathogenetic explanations of all injuries and the FAA form 8025-3 designed for this study to elicit critical relevant observations. This ideal was seldom realized. Table I presents the sources of material submitted in this series. Because all cases admitted to this series were accompanied by FAA form 8025-3 which sampled critical areas from all the other sources, essential data points were more consistently available than Table I might suggest. The majority of the observations were provided by aviation medical examiners who were typically very highly motivated practitioners of medicine with special interests and accomplishments in aviation. The remainder of the cases were reported by FAA accident investigators.

Under the best of circumstances, medical evidence derived from accident investigation is difficult to obtain for a number of reasons. When an accident occurs, it is a common practice to remove the occupants from the wreckage and to seek medical attention for survivors. When a trained Aviation Medical Examiner is available in the area, it is often several hours to a few days before he arrives at the accident site. Once the occupants have been removed and the aircraft stored in a hangar, it is extremely difficult to reconstruct relationships between airframe structures and specific injuries. Often restraints have been cut to remove occupants and seats sometimes are removed entirely from the wreckage by rescue personnel. When an Aviation Medical Examiner is not assigned to an accident, the medical data collected is often scant and generally not suitable for research regarding crash injuries.

One might suppose that any damage to the seat, however trivial, would be noteworthy and capable of contributing to significant injury of its occupant. However, the mechanics of some seat deformation and external damage clearly provide for the attenuation of applied energy and thereby reduce injury. Individual cases report seat damage which is not clearly related to any injury. The appropriate criteria for seat failure becomes correspondingly more complicated.

The authors established the seat failure criteria described earlier and depicted in Fig. 2 based on the evidence in this series and the relevant literature (14). In the majority of seat failures, the seats became detached from their moorings allowing for dislocation with respect to their normal positions in the aircraft. The seats that detached or failed in such a way that they allowed the restraint system to become ineffective were considered a separate category. This was done in recognition of the importance that appropriate restraint could assume in such circumstances. In the typical case from this grouping, injury was sustained by the occupant as he separated from the seat and impacted other forward cockpit structures.

Changes in restraint attachment points and other modifications of the restraint system are likely to be more direct and effective points of intervention than efforts in seat modification.

Similarly, it is difficult to determine if the cases in which a rear seat occupant struck the rear of a forward seat represent seat failure as tabulated in Fig. 2, or whether rear seat restraints and appropriate spacing between seats are the proximate problems. We believe that it will be more fruitful to consider the restraint system as a separate but closely related problem which is best solved by interventions that directly address restraint system elements rather than the seat. That approach implies that anchor points for belts should be determined in a context that provides for the most secure performance of the restraint system without favoring the seat as an attachment point over any other appropriate structure.

It is unlikely that seat failure would be related to severe or fatal injury by simple, direct mechanisms that allow for observation of seat damage as a reliable marker of seat-induced injury. Comparisons between seriously and fatally injured occupants of failed and intact seats suggest that such a simple relationship does not exist in this series. There were approximately equal numbers of failed and intact seats occupied by persons seriously or fatally injured. Seat failure alone is not a reliable marker of seat-induced injury.

The likely mechanism explaining this disparate relationship involves the occupant in "survivable" accidents selected by this series experiencing inertial forces which tended to separate him from the seat resulting in not loading the seat and in preventing contact with the seat. It would thereby tend to lose its opportunity to serve as an impactor. In such circumstances, the seat would appear to be successful merely by remaining attached to the airframe without having to sustain the added forces introduced by the occupant's mass. If the population in this series were weighted toward those occurrences in which there were predominantly vertical loads applied to the seat and its occupant, the results may have been different. The available data would indicate that the seats' influence on injury severity is relatively small. It is likely that the injuries caused by factors other than the seats would overshadow findings of seat induced injury.

The related issue of high versus low energy impact was subject to examination by using the vectors described as being less than 15 degrees to identify low energy events in comparison to those cases in which the resultant vectors exceeded 15 degrees. NTSB findings in (20,21,22) suggest that this technique can assist in identifying the high energy impacts. Table III presents this tabulation to show the expected increase in injury with high angle events. A corresponding increase in seat failure suggests that injury and seat failure may both be dependent on another variable, very probably the magnitude of the energy transfer and the associated large accelerations. The question of causal relationships between seats and occupants' injuries is directly addressed by responses presented in Table IV. In 10% of the cases the seat was considered to have added to the injury; in 8% the seat attenuated or diminished the injury while in 82% the seat appeared to play no role in inflicting the observed injuries. This finding agrees with Cannon's (2) study which points out the difficulty of establishing a causal relationship between a particular structural failure and coincident injury.

An analysis of the injuries sustained by seat occupants was attempted in an effort to examine whether or not the nature of the injuries might help define the role of the airplane seat in causing or attenuating those injuries. Unfortunately, in the vast majority of the injuries reported, the precise pathogenetic mechanism for the injury was never established. Consequently, injuries to the spine and pelvis described by the existing data from this series could have developed from a variety of mechanisms that could not be differentiated.

The likely mechanism explaining this disparate relationship involves the occupant in "survivable" accidents selected by this series experiencing inertial forces which tended to separate him from the seat resulting in not loading the seat and in preventing contact with the seat. It would thereby tend to lose its opportunity to serve as an impactor. In such circumstances, the seat would appear to be successful merely by remaining attached to the airframe without having to sustain the added forces introduced by the occupant's mass. If the population in this series were weighted toward those occurrences in which there were predominantly vertical loads applied to the seat and its occupant, the results may have been different. The available data would indicate that the seats' influence on injury severity is relatively small. It is likely that the injuries caused by factors other than the seats would overshadow findings of seat induced injury.

The related issue of high versus low energy impact was subject to examination by using the vectors described as being less than 15 degrees to identify low energy events in comparison to those cases in which the resultant vectors exceeded 15 degrees. NTSB findings in (20,21,22) suggest that this technique can assist in identifying the high energy impacts. Table III presents this tabulation to show the expected increase in injury with high angle events. A corresponding increase in seat failure suggests that injury and seat failure may both be dependent on another variable, very probably the magnitude of the energy transfer and the associated large accelerations. The question of causal relationships between seats and occupants' injuries is directly addressed by responses presented in Table IV. In 10% of the cases the seat was considered to have added to the injury; in 8% the seat attenuated or diminished the injury while in 82% the seat appeared to play no role in inflicting the observed injuries. This finding agrees with Cannon's (2) study which points out the difficulty of establishing a causal relationship between a particular structural failure and coincident injury.

An analysis of the injuries sustained by seat occupants was attempted in an effort to examine whether or not the nature of the injuries might help define the role of the airplane seat in causing or attenuating those injuries. Unfortunately, in the vast majority of the injuries reported, the precise pathogenetic mechanism for the injury was never established. Consequently, injuries to the spine and pelvis described by the existing data from this series could have developed from a variety of mechanisms that could not be differentiated.

Translational forces applied to the spine in the X axis could have caused spinal injury as plausibly as Z axis forces tending to compress the spine from mechanisms likely to have been mediated through the seat. The evidence, then, is equivocal with respect to defining the injury population clearly caused by seat actions. However, it is possible to identify the general distribution of injuries in this series. Table VI presents the frequency of injury affecting the general anatomic regions of the body. Obviously, many occupants sustained multiple injuries. Each reported injury was tabulated so that the total number far exceeds the number of occupants at risk. Perhaps the most significant observation related to this information is that head injury predominates. The critical vital functions exposed by head injury and the vulnerability or propensity toward lethal outcomes make head injury even more important than the numbers themselves might suggest.

Table VI presents the injuries described through autopsy examination. These differ from the previous findings partly because of the routine procedures applied at autopsy which favor finding some diseases rather than others. Backache and ligamentous sources of pain would be identified in the clinical patient and not in the deceased patient. However, head injury still persists as numerically important being second only to the combined torso injuries. Spinal injury was not prominent in the autopsy data.

Injury causing structures in the airplane are tabulated in Table VII. The noteworthy observations are that the control wheel and instrument panel were identified more frequently than other structures. The seat was identified as the impactor only 8% of the time. As was suggested earlier, the proximate cause of injury in these events depends on restraint effectiveness, space allocation and other elements.

SUMMARY

This series of light airplane accidents was examined in an effort to demonstrate the role of seats in the genesis of injury in seat occupants. Case selection attempted to include only those events in which significant accelerations challenged the seats' effectiveness without imposing unrealistic, extreme demands on the seats and their occupants. No reliable marker of energy level was found in the data collected to control the energy level as a confounding variable to allow clarification of the finding that large accelerations tend to injure people and damage seats as well as most other structures regardless of the other inter-relationships that might be involved.

The existence of seat damage does little, by itself, to define the seat's role in injury causation. Interpretation of injuries established by clinical and autopsy observation suggests that the large majority of injuries are caused by mechanisms which can proceed independently of seat failure. Restraint systems likely play the more important role.

CONCLUSIONS

1. Head trauma represents a major manifestation of life-threatening injuries observed in this series. These injuries usually resulted from impacts with objects other than the seats.

2. The seat occupants in this series experienced inertial forces estimated to be oriented approximately 15 degrees below the longitudinal axis of the airplane.

3. Seat damage per se is not a reliable indicator of injury sustained. The function of the seat may be subtle and indirect so that injury may result from mechanisms in which the seat's contribution is not apparent.

4. The seat's influence on injury severity is relatively small. It is likely that injuries caused by factors other than the seat overshadow findings of seat induced injury.

5. Even though the seat was implicated as a cause of injury in only a small minority of the cases, optimum crashworthiness suggests that seats be considered as a part of the energy-attenuating systems to be designed into the airframes.

6. The presence and use of upper torso restraints can improve the injury experience by reducing the likelihood of head injury.

REFERENCES

1. Brinkley JW, Raddin JH, Biodynamics: Transitory Acceleration. In: Fundamentals of Aerospace Medicine Roy DeHart Ed. Lea & Febiger, Philadelphia. 1985 p. 184-186, 199.

2. Cannon MR, Final Program Report for the Controlled Impact Demonstration Seat Experiments and Development, Test Results, and Cost Benefit Study. Simula 1985.

3. Chandler RF, Human Injury Criteria Relative to Civil Aircraft Seat and Restraint Systems, Aerospace Technology Conference and Exposition, Long Beach, Calif Oct 14-17, 1985.

4. Chandler RF, Data for the Development of Criteria for General Aviation Seat and Restraint System Performance. General Aviation Aircraft Meeting and Exposition, Wichita, KS, April 16-19, 1985.

5. Coltman JW, Design and Test Criteria for Increased Energy Absorbing Seat Effectiveness. Simula, 1983 FAA-AM-83-3.

6. Desjardins SP, Simula Inc., Aircraft Crash Survival Design Guide; (Volume IV) Structural Crashworthiness USARTL-TR-79-22 (A-E); 1980; Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia 23604.

7. FAA Advisory Circular AC-No.21-22; Injury Criteria for Human Exposure to Impact. 6/20/85

8. FAA Statistical Handbook of Aviation- Calender Year 1983. US Dept. of Transportation, FAA p. 170.

9. General Aviation Safety Panel (GASP) Proposal for Enhanced Crash Tolerance for Small (FAR Part 23) General Aviation Aircraft with Fewer than 10 Passenger Seats. Federal Register 1-31-83 CE-83-1 #23494.

10. Gikas PW, Forensic Aspects of the Highway Crash Pathology Annual 1983: 18 pp 147-163.

11. Greer DL, Breeden JS, Heid TL, Crashworthy Design Principles, General Dynamics/Convair Contract # FA-WA-4583 Sept 1984. FAA-ADS-24.

12. Haddon W, Baker SP, Injury Control, In D.Clark and B McMahon, Eds. Preventive and Community Medicine. Boston, Mass. Little Brown and Co., pp. 109-140. 1981.

13. Kihlberg JK, Multiplicity of Injury in Automobile Accidents. In: Gurdjian ES, Injury and Crash Protection pp. 5-26. 1970

14. Laananen DH, Simula Inc., Aircraft Crash Survival Design Guide; (Volume II) Aircraft Crash Environment and Human Tolerance USARTL-TR-79-22 (A-E); 1980; Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia 23604.

15. Laananen DH, Simula Inc., Aircraft Crash Survival Design Guide; (Volume III) Aircraft Structural Crashworthiness USARTL-TR-79-22 (A-E); 1980; Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia 23604.

16. Laananen DH, et al Simula Inc. Computer Simulation of an Aircraft Seat and Occupant in a Crash Environment. March 1983 (SOMLA)

17. McKinlay, S.M. The design and analysis of observational study. A review. Journal of the American Statistical Association 70. 503-523.

18. McMeekin RR, Aircraft Accident Investigation In DeHart R Ed., Fundamentals of Aerospace Medicine Lea & Febiger, Philadelphia. 1985 p. 796.

19. Nolan, D. Airline Safety:The Shocking Truth. Discover, Oct. 1986.

20. NTSB General Aviation Crashworthiness Project Phase 1, 1985

21. NTSB General Aviation Crashworthiness Project - Impact Severity and Potential Injury Prevention in General Aviation Accidents Phase 2 NTSB/SR-85/01

22. NTSB General Aviation Crashworthiness Project Phase 3 Acceleration Loads and Velocity Changes of Survivable General Aviation Accidents. NTSB/SR-85/02.

23. NTSB Regulation, Part 830.1 and 830.2, Subpart A, Code of Federal Regulations

24. Pennybaker AL, Ross JW, Wilson GW, A Summary of Crashworthiness Information for Small Airplanes. FAA-TR-592-120A FE 1973.

25. Robertson LS, Estimates of Motor Vehicle Seat Belt Effectiveness and Use: Implication for Occupant Crash Protection. American Journal of Public Health Sept, 1976, Vol 66 #9 pp 859-864.

26. Siegal S, Non-Parametric Statistics, McGraw-Hill Book Company, New York, NY 1956.

27. Snyder R, Crashworthiness Investigation of General Aviation Accidents, Society of Automotive Engineers Business Aircraft Meeting, Wichita, KS April 8-11, 1975 SAE #750537.

28. Snyder RG, A Case of Survival of Extreme Vertical Impact in the Seated Position. FAA-AM-6219.

29. Snyder RG, Occupant Impact Injury Tolerances for Aircraft Crashworthiness Design. Society of Automotive Engineers, National Business Aircraft Meeting, Wichita, KS Mar. 24-26, 1971 #710406.

30. Snyder RG, Occupant Restraint Systems of Automotive Aircraft, and Manned Space Vehicles. In Gurdjian ES Ed. Impact Injury and Crash Protection. Chas. E. Thomas Pub. 1970. p. 497.

31. Swearingen JJ, General Aviation Structures Directly Responsible for Trauma in Crash Deceleration. FAA-AM-71-3.

32. Turnbow JW, Haley JL, A Review of Crashworthy Seat Design Principles. SAE Air Transport and Space Meeting, New York, NY. April 27-30, 1964.

33. Underhill B, McCullough B, An Energy Absorbing Seat Design for Light Aircraft , Piper Aircraft Corporation. National Business Aircraft Meeting, Wichita, Kansas. Mar 15-17, 1972 #720322.

APPENDIX A

FAA Form 8025-3 (1-81)

SEAT AND RESTRAINT CRASHWORTHINESS DATA

Accident Identification

DATE:	LOCATION:	
AIRCRAFT MAKE & MODEL:		N-NUMBER:

1. Indicate attitude of aircraft at its time of maximum impact.

NOSE

90°	75°	60°	45°	30°	15°	FLAT	
☐	☐	☐	☐	☐	☐	☐	Other ________

ROLL

60°	40°	20°	FLAT	20°	40°	60°	
☐ L	☐ L	☐ L	☐	R ☐	R ☐	R ☐	Other ________

YAW (Lateral Impact Forces)

30°	20°	10°	0°	10°	20°	30°	
☐ L	☐ L	☐ L	☐	R ☐	R ☐	R ☐	Other ________

Additional comments on phase of flight, aircraft speed, attitude or peculiarities of impact that reveal forces acting on aircraft and occupants. Sketch if indicated.

2. Estimate the survivability of impact. (Check one)

☐ Survivable ☐ Partly survivable ☐ Survival by chance ☐ Non-survivable

3. Damage to OCCUPIABLE area. Record by entering check in appropriate place.

Cabin Structure	Forward	Top	Bottom	Right	Left	Aft
Intact						
Distorted						
Bent/Partly Collapsed						
Collapsed/ Buckled						
Torn free/ Disintegrated						

Use the following criteria:

Intact – No apparent damage.

Distorted – Damage is confined to slight bending, wrinkling or twisting, however, the structure retains its size and shape.

Bent/Partially Collapsed – Members are bent, twisted or deformed so that the structure, as a whole, has changed in general shape and decreased in volume.

Collapsed/Buckled – The structure retains little of its original shape or volume.

Torn Free/Disintegrated – The structure is torn away, mangled, or broken into fragments.

4. Record NON-OCCUPIABLE area damage. Record by entering check in appropriate place.

Aircraft Structure	Nose	Tail	R/Wing	L/Wing
Intact				
Distorted/ Wrinkled				
Bent/Partly Collapsed				
Buckled/ Crumpled				
Broken/ Collapsed				
Torn free/ Disintegrated				

Use the following criteria:

Intact – No apparent damage

Distorted/Wrinkled – Damage is confined to slight bending, wrinkling or twisting; however the structure retains its size and shape.

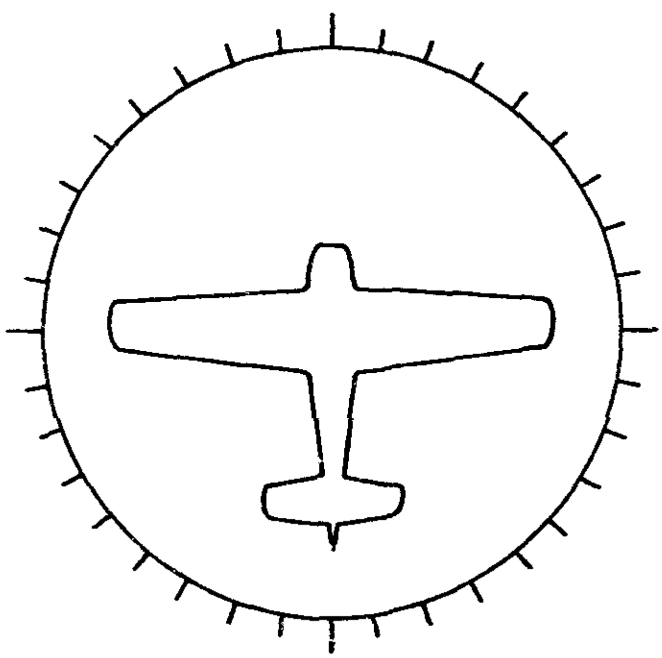
Bent/Partly Collapsed – Members are bent, twisted or deformed so that the structure as a whole has changed in general shape and decreased in volume.

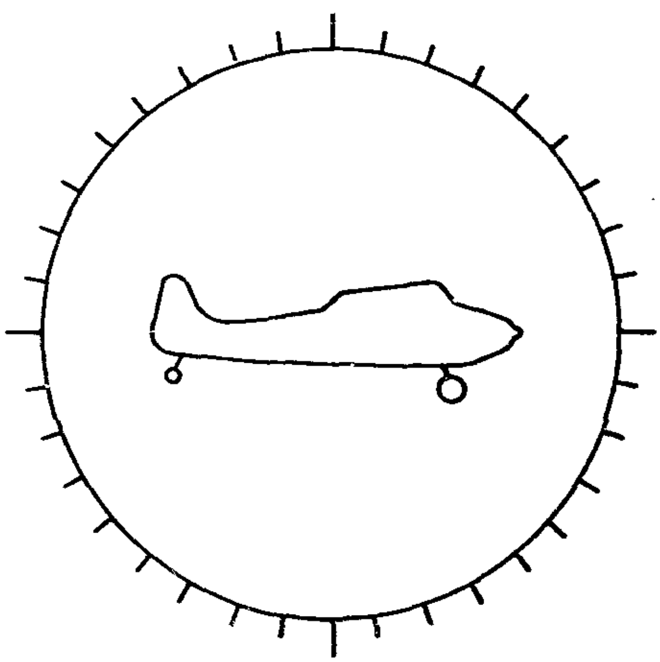
Buckled/Crumpled – Structures are grossly bent or warped; show crushing or large creases and wrinkles.

Broken/Collapsed – Structures are broken, broken down, caved in or folded together.

Torn Free/Disintegrated – Major parts are separated, structural form is lost, structures are strewn about or broken into smaller parts.

5. On the following diagrams draw an arrow or arrows to record the direction or directions occupants were thrown (in relation to the aircraft) at the time of impact/impacts. Use the length of arrow to designate the relative force and numbers 1, 2, 3, etc., on arrows to indicate the sequence.



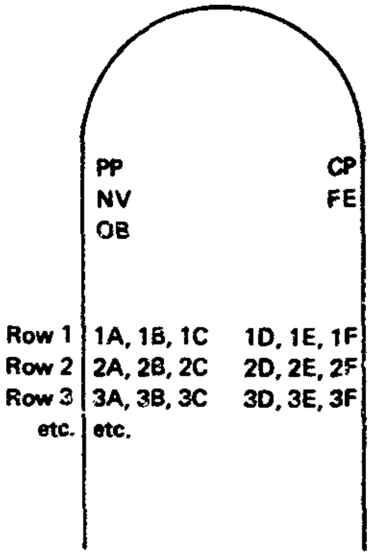


6. Cabin Seating

Code seat locations in accident aircraft at bottom of page using alpha/numeric codes as shown in examples below.

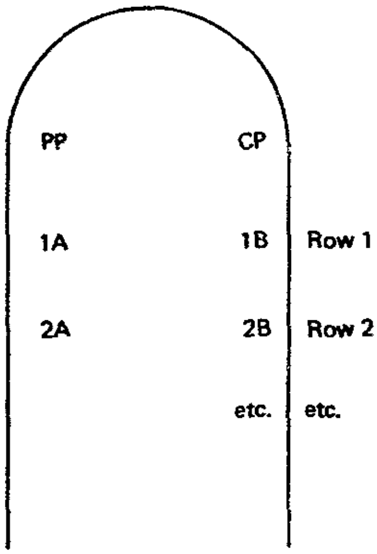
EXAMPLES

Large Aircraft
Nose of Aircraft

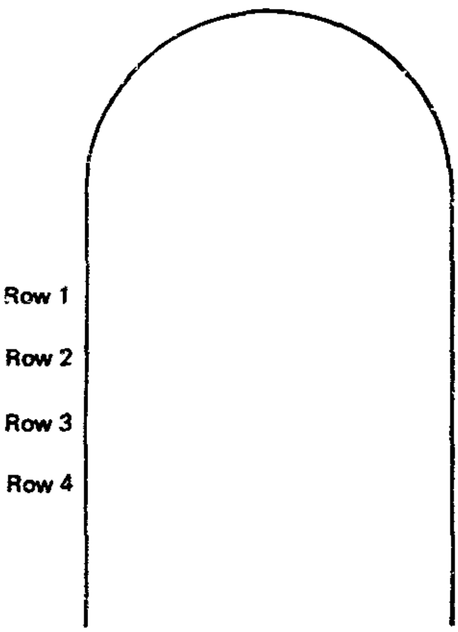


PP – Pilot
CP – Copilot
NV – Navigator
FE – Flight Engineer
OB – Observer
1A – Row 1, Seat A
2B – Row 2, Seat B
3C – Row 3, Seat C

Small Aircraft
Nose of Aircraft



Accident Aircraft
Nose of Aircraft



Please record all seats and use these seating designations in completing the table in Question #7 & #8.

Comments:

7. Seat Findings.

Complete this table Enter findings using codes given below. Record findings for each seat whether or not it was occupied.

Seat Position a	Occupied b	Facing c	Direction of Horiz. Forces d	Vertical Forces e	Floor f	Seat-to track Floor Attach. g	Seat legs/ Pedestal h	Seat back i	Pan/frame j

Codes for seat and restraint system findings.

a Seat Position. record position as designated in number 6, cabin seating

b. Occupied: YES NO

c. Facing.

- A forward
- B aft
- C - swivel
- D - Fixed complete side facing
- E - bench side facing
- F - other (write in)

d Directions of horizontal (forward-aft lateral) forces acting on each seat.

- A - left
- B - left and forward
- C - forward
- D - right and forward
- E - right
- F - right and aft
- G - aft
- H - left and aft

e Vertical forces:

Downward
- A - minor
- B - moderate
- C - severe

Upward
- D - minor
- E - moderate
- F - severe

f. Floor:

- A. No distortion or buckling under seat
- B. Minor distortion or bucking under seat - enough to cause only minor strain of seat track and/or attachment
- C. Moderate distortion or buckling under seat - sufficient to cause moderate strain but not fail seat tracks and/or attachments.
- D. Severe distortion or buckling under seats - enough to fail seat tracks and/or attachment.
- Z - Unknown

g. Seat-to-track/floor attachment

- A - seat remained attached to track/floor
- B - seat partially detached from track/floor
- C - seat completely separated from track/floor
- D - not applicable Z - unknown

h Seat legs and/or pedestal:

- A - no seat deformation
- B - minor bending or deformation of seat leg and/or pedestal
- C - severe deformation or bending but seat legs and/or pedestal not broken
- D - legs and/or pedestal broken but not separated
- E - legs and/or pedestal broken in several places and badly separated
- F - not applicable Z - unknown

i. Seat back.

- A - seat back damage minor or none
- B - back broken but not separated
- C - back broken and separated from seat pan
- D - not applicable Z - unknown

j. Pan/frame damage:

- A - minor - slight bending or deformation
- B - moderate - pan/frame bent or warped but not broken
- C - severe or separated - bent and warped with fracture of structural members
- D - not applicable Z - unknown

8. Lapbelt and Upper Torso Restraint Findings.

Complete this table. Enter findings using codes given below. Identify each restraint system by seat position.

	LAP BELT				UPPER TORSO RESTRAINT					INERTIA REEL	
		Attachment					Attachment				
Seat Position a	Used b	Inboard c	Outboard d	Function e	Type f	Used g	Aft h	Forward i	Function j	Installed k	Function l

Codes for restraint findings:

a. Seat position: record position as designated in cabin seating.

LAPBELTS

b. Used: Yes — No – installed, not used — N – not installed — Z – don't know

LAPBELT ATTACHMENT POINTS

c. Inboard attachment (right in single or tandem seated aircraft)
- A – On seat
- B – On floor
- C – on wall, bulkhead or console
- D – via cable to frame
- Z – unknown

d. Outboard attachment
- A – on seat
- B – on floor
- C – on wall, bulkhead or console
- D – via cable to frame
- Z – unknown

e. Function
- A – held with no problem
- B – complete failure at right attachment
- C – complete failure at left attachment
- D – complete failure both attachments
- E – failure of hardware other than attachment (explain)
- F – partial failure of webbing
- G – complete failure of webbing
- Z – unknown

UPPER TORSO RESTRAINT (UTR)

f. Type: D – double — S – single — O – none

g. Used: Yes — No – installed but not used — N – not installed — Z – unknown

h. Aft Attachment
- A – to seat only
- B – to wall or overhead
- C – to floor
- D – to frame via cables
- Z – unknown

i. Forward Attachment
- A – lapbelt
- B – seat
- C – floor
- D – console
- E – wall
- Z – unknown

j. Function
- A – held with no problem
- B – complete failure at aft attachment
- C – complete failure at forward attachment
- D – complete failure both attachments
- E – failure of hardware other than attachment
- F – partial failure of webbing
- G – complete failure of webbing
- H – does not pertain
- Z – unknown

(Use narrative comments for clarity)

INERTIA REELS

k. Installed. Yes — No

l. Function
- A – held with no problem
- B – failed to latch
- C – partially latched but held
- D – partially latched, but did not hold
- E – failure of reel housing
- F – indication of functional problem in reel before accident
- Z – unknown

(Explain with narrative comments to clarify any finding)

9. Injuries and Injury Causes.

Complete this table. Enter findings using codes on following page Enter multiple codes as they apply.

Name	Age	Sex	Seat Position a	Ht/Wt Occupant b	Severity of Injury c	Head Skull and Brain d	Face e	Arms f	Chest g	Abdomen h	Pelvis i	Legs j	Spine Spinal Cord k	CAUSES OF INJURIES: Shoulder Restraint l	Lap Belt m	Seat n	Cockpit/Cabin Structure o
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	

Codes for injuries and injury causes:

Record name, and sex as available.

a. Seat Position – Record position as designated in number 6, Cabin Seating
   Z – unknown

b. Height and Weight – record for each occupant (such as 6'0" 165 lbs)

c. Severity of Injury
   F – fatal
   R – serious with more than 10% residual disability expected.
   S – serious
   M – minor
   N – none
   Z – unknown

d. Head, Skull and Brain
   A – blunt trauma with multiple fractures of skull – or partial decapitation
   B – blunt trauma with lesser degree of skull fracture than A
   C – blunt trauma with small skull fracture
   D – penetrating trauma with fracture of skull
   E – penetrating trauma without fractures
   F – abrasions and lacerations – severe
   G – abrasions and lacerations – minor to moderate
   H – brain laceration with fractures
   I – brain laceration without fractures
   J – severe brain contusion and/or bleeding
   K – mild to moderate brain contusion and/or bleeding
   X – no significant abnormalities
   Z – unknown

e. Face
   A – blunt trauma with serious fractures, maxilla and/or other facial bones
   B – blunt trauma with moderately serious fractures, such as mandible, maxilla and/or other bones
   C – blunt trauma with minor fractures, mandible, nose, teeth
   D – penetrating trauma with fractures
   E – penetrating trauma with permanent eye injury
   F – penetrating trauma without fractures
   G – abrasions and lacerations severe
   H – abrasions and lacerations minor to moderate
   X – no significant abnormalities
   Z – unknown

f. Arms (Designate L for left; R for right; U for unknown side)
   A – traumatic amputation below shoulder
   B – traumatic amputation below elbow
   C – compound/comminuted fractures upper arm
   D – compound/comminuted fractures lower arm
   E – fracture/fractures upper arm
   F – fracture/fractures lower arm
   G – fractures wrist
   H – fractures fingers
   I – fractures thumb
   J – dislocated shoulder
   K – dislocated elbow
   L – dislocated wrist
   X – no significant abnormalities
   Z – unknown

g. Chest
   A – blunt trauma with crushing or opening of chest cavity, heart and lungs
   B – blunt trauma with fractures of sternum and/or ribs – not lethal in itself
   C – blunt trauma, minor without fractures
   D – penetrating wound in chest, 2 or more inches in diameter
   E – penetrating wound in chest, less than 2 inches in diameter
   F – traumatic rupture of heart
   G – tearing or rupture of aorta
   H – contusion of heart – non-lethal
   I – contusion of lungs – non-lethal
   J – no significant finding
   K – closed pneumothorax
   L – bleeding into pleural cavities
   X – no significant abnormalities
   Z – unknown

h. Abdomen
   A – abdominal cavity widely opened
   B – abdominal wall has penetrating injury
   C – contusion of abdomen with wall intact
   D – internal bleeding severe
   E – internal bleeding moderate
   F – internal bleeding slight
   G – contusion with rupture of internal organs
   H – contusion with abdominal symptoms
   I – contusions and abrasions without internal symptoms
   X – no significant abnormalities
   Z – unknown

i. Pelvis
   A – multiple fractures
   B – simple fracture
   C – contusions without fractures
   D – rupture of bladder
   E – lacerations and/or abrasions
   X – no significant abnormalities
   Z – unknown

j. Legs (Designate L for left; R for right; U for unknown side)
   A – traumatic amputation below hip
   B – traumatic amputation below knee
   C – compound/comminuted fractures upper leg
   D – compound/comminuted fractures lower leg
   E – simple fracture upper leg
   F – simple fracture lower leg
   G – fracture or dislocation at ankle
   H – fractures in bones of feet
   I – contusions and abrasions without fractures
   J – sprain, strain with discomfort
   K – dislocation hip
   L – dislocation knee
   X – no significant abnormalities
   Z – unknown

k. Spine and Spinal Cord
   A – transection of the spine
   B – fracture/fractures neck without cord damage
   C – fracture/fractures neck with cord damage
   D – fracture/fractures thoracic spine without cord damage
   E – fracture/fractures thoracic spine with cord damage
   F – fracture/fractures lumbar spine without cord damage
   G – fracture/fractures lumbar spine with cord damage
   H – compression fracture/fractures cervical vertebrae, no cord damage
   I – compression fracture/fractures thoracic vertebrae, no cord damage
   J – compression fracture/fractures lumbar vertebrae, no cord damage
   K – cervical strain
   L – thoracic strain
   M – low back strain
   X – no significant abnormalities
   Z – unknown

CAUSE OF INJURIES

l. Shoulder restraint
   A – caused contusions and fractures of chest
   B – caused abrasions and contusion of chest
   C – left abrasions and marks on chest without injury
   D – caused no injury
   E – installed but not used
   F – not installed
   Z – unknown

m. Lap belt
   A – apparently compressed abdomen causing internal injuries
   B – apparently rode high and compressed abdomen without serious injuries
   C – left abrasion and contusion on pelvis, abdomen
   D – caused no injuries
   E – installed but not used
   Z – unknown

n. Seat
   A – failed badly, added to injuries
   B – failed badly, did not add to injury
   C – partially broke, adding to injury
   D – partially broke, not adding to injury
   E – distorted and cushioned impact
   F – caused no injury
   Z – unknown

o. Cockpit/Cabin Structure

   During impact occupant:

   A – struck yoke
   B – struck instrument panel
   C – struck back of seat
   D – struck partition or divider
   E – was struck by flying object
   F – made impact with floor
   G – made impact with rudder pedals
   H – made impact with windscreen or window
   I – struck cockpit – cabin structural members – posts, etc.
   J – struck other objects, specify ____________
   K – struck no objects
   Z – unknown

10. Make comments regarding specifics of injuries, causes of injuries and especially role of seats and/or restraints in causing or preventing injuries.

11. Comment on any other crashworthiness (injury causing) findings in this accident. Illustrate any findings with sketches.

12. Record the manufacturer of seats and/or restraint systems that may have malfunctioned or failed.

13. Information collected by:

Name ____________________

Address ____________________

____

____

Phone ____________________