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16. Abstract

This report reviews 47 survivable or partly survivable accidents investigated since 1973 by personnel from the Civil Aeromedical Institute. The accidents were reviewed for a number of features of crashworthiness and, in particular, for injuries to occupants in relation to the severity of the impact and the performance of cabin and restraint systems. Opinions were rendered by trained crash injury investigators as to the role or expected role in seats and upper torso restraints in adding to or lessening the injuries.

The data support the general concepts that nonoccupiable portions of the aircraft receive greater physical damage than occupiable areas. The greatest damage to the occupiable area is to the forward portion of cockpit/cabin and the occupants have a greater chance of survival if the cockpit/cabin remains reasonably intact. Occupants seated forward in the cockpit/cabin receive greater injuries than those seated more rearward. Further, the findings suggest that seat placement or seat failure to one degree or another intensified injuries (as compared to more optimum crashworthy seats) to occupants in at least 30 percent of the accidents reviewed. Upper torso restraints, in the few instances used, were beneficial, and had they been used by all occupants, would have significantly reduced the injuries.

The report discusses the relation of the occupant to the seat and restraint system and the apparent benefit to be derived from a well-designed impact attenuating seat and, in particular, use of an upper torso restraint.

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CRASHWORTHINESS STUDIES: CABIN, SEAT, RESTRAINT, AND INJURY FINDINGS IN SELECTED GENERAL AVIATION ACCIDENTS

I. INTRODUCTION.

The prime goal of aviation safety is to prevent injuries, loss of life, and loss of property. Of course, this is best done by keeping accidents from happening; the greatest efforts rightfully should be and are directed toward prevention.

However, accidents do happen and, based on past experience, they do occur with a certain predictability. Indeed, data gathered by the National Transportation Safety Board for a recent 6-year period (1973 through 1978) record a yearly average of 3,911 "small fixed-wing aircraft" (under 12,500 lb) in accidents. Of these, 663 (or 16.7 percent) resulted in one or more occupants being killed, with 1,303 being killed, as an average, or, statistically, two persons per fatal accident. In addition, there was untold injury, pain, suffering, and permanent disability in persons who survived the 663 (yearly average) fatal accidents or who were occupants in the 3,248 (yearly average) aircraft in nonfatal accidents.

Studies have shown that the human can withstand rather large impacts if the forces are properly distributed to the body. Such tolerances to decelerative forces have been amply demonstrated by a number of controlled studies using human subjects (1) and by findings in vehicular and other accidents. The tolerances, (withstanding decelerative forces without incurring permanent debilitation) are derived from evaluating impacts in relation to dynamic considerations such as rate of onset and duration of decelerative force acting upon the body. Besides varying with the rate of onset and duration, human tolerances are variable with other factors such as height, weight, and age of the individual; the type of restraint used; the application of the restraint to the body; etc. The crashworthiness load requirements applicable to seats and restraint systems specified in the Federal Aviation Regulations (2) are based on ultimate aircraft airworthiness load requirements met under static loading conditions. Although human tolerances to short duration dynamic loading appear to exceed several-fold the static loads applicable to seats and restraint systems, dynamic and static loading are not directly comparable. Specification of meaningful impact attenuating standards for seats and restraints will require definition of the dynamic components of crashes.

One of the greatest challenges to aviation safety in the coming years will be to make aircraft more crashworthy, i.e., to build and equip aircraft so that when a crash occurs the aircraft itself provides greater opportunity (within practical limitations) for reduced injury to occupants. Many of the developments in crashworthiness research are aimed at better cushioning of occupants against the decelerative forces of the crash. The most fruitful and practical means of doing this is by applying previously advocated packaging principles (3), and especially by improving seats and restraint systems (4).

It is also helpful to analyze accidents to estimate the severity of the crash, noting the integrity of the structure, analyzing the performance of the restraint systems, and reviewing injuries received by occupants. Findings in accidents can be confirmed under controlled conditions in the laboratory.

For over a decade an ongoing biomedical and crash injury field investigation research program has been conducted at the FAA Civil Aeromedical Institute (CAMI). In this program, accidents were investigated to reveal any of a wide range of human factors such as: previous illnesses in the crew; medications or drugs taken by the crew; fatigue; physical stresses; psychological stresses; types of injuries received; causes of impact injuries; emergency egress from aircraft; smoke and fire as related to survivability; other environmental conditions such as water, ice, and snow, as related to postcrash survival; and a number of other biomedical factors that may have contributed to the crash or related to occupant injury or survival. Findings as related to survival of the impact have been a prominent feature of these investigations. Although each investigation was not undertaken specifically to investigate crashworthiness, certain such aspects came forth in many investigations. These included features such as the deformation of aircraft cockpit and cabin structures; the state of integrity and probable function of seats and restraint systems; probable impact of occupants against aircraft structures and the correlation of injuries with the direction and severity of impacts. The function and adequacy of seats and restraints have been of particular concern (5) because modifications of these systems, to give greater protection to occupants, often can be made at less expense to manufacturers or aircraft owners, than modification of the airframe. Indeed, some specific changes made by manufacturers, as a result of these investigative activities (6), have improved the crashworthiness of the respective aircraft and have saved lives.

For this report, we have surveyed a number of general aviation accidents for an overall assessment of findings, particularly as they relate to the function of the restraint system--seats, lapbelts, and shoulder harnesses. Elements ofthese data have been used in other reports (6).

II. METHODS.

For this analysis we reviewed the reports of all general aviation accidents investigated by CAMI personnel from 1973 to and including most of 1979. Accidents investigated from CAMI prior to 1973 were previously reviewed (4). The current group of accidents was reviewed for a number of features of crashworthiness and, in particular, for the injuries to the occupants in relation to apparent severity of the impact and the adequacy of the function of the cabin and restraint systems. All aerial application aircraft accidents, accidents in which all occupants were killed, or where fire or water precluded a reasonable evaluation, were eliminated from the series. In all, 47 of a greater number of accidents were deemed worthy of more intensive review and tabulation, in that there was meaningful information in the accident reports or investigators were familiar enough with the particulars of the accidents to provide details. Trained crash injury investigators, who had personally investigated a number of these accidents or participated in the program at the time the accidents were investigated, reviewed all records and extracted data. In addition, these investigators, based on the information at hand, were asked to make judgments as to whether seats, lapbelts, upper torso restraints, or cabin structures were involved in producing or intensifying injuries in occupants. From these data a number of tables were derived in an attempt to answer certain questions pertaining to crashworthiness.

III. RESULTS.

The findings in the 47 accidents are shown in Table I (appended). Accompanying the table is the legend to codes used for representing the findings.

These 47 accidents involved 138 persons (including 2 lap-held children). There were 47 pilots, 40 occupants of the copilot seat, and 49 additional passengers (in seats other than the pilot and copilot seats). It was estimated that the major impact force was forward in 40 accidents, forward and left in 3, and forward and right in 1, both forward and vertical in 2 and only vertical in 1.

One aircraft crashed inverted and another cartwheeled. The remainder crashed on a straight or turning (coded as forward-turning) heading. Forty-two accidents were judged to be survivable and the remaining five only partially survivable.

Survival of an aircraft accident depends to a great extent on providing a crash-resistant container for the occupants; that is, an occupiable area that will withstand crash forces without crushing, collapsing, or disintegrating. The accidents were judged on the basis of overall damage indices for nonoccupiable and occupiable areas. This crash severity index has been used at CAMI for a number of years. It is inadequate to describe fully what an investigator may observe but serves as a means of estimating damage so that accidents generally may be compared. Such a comparison is shown in Table II.

Damage, as assessed by this method, confirms what one would expect, that the nonoccupiable structures of wings, tail, and engine, sustain greater destructive damage than the more capsulized cabin. Indeed, the crumpling and breaking away of these exterior structures, to some extent, cushions the fuselage against the forces of the impact.

TABLE II. Damage Indices (See Table I)

Damage Index	Nonoccupiable (# of Accidents)	Occupiable (# of accidents)
Minor	None	8
Moderate	13	15
Moderately Severe.	10	13
Severe	13	7
Extremely Severe	5	1
Extreme	5	3
Unclassified	1	

Damage to:	# of Accidents
Nonoccupiable Area > Occupiable Area	30
Nonoccupiable Area = Occupiable Area	14
Nonoccupiable Area < Occupiable Area	2

The results of a comparison between the damage to the cockpit area and the remainder of the cabin in 29 of the accidents (where such comparison was meaningful) are presented in Table III. Damage to the cockpit area was tabulated to be significantly greater in 13 of the accidents and equal in the remaining 16. In no instance was damage to the remainder of the cabin greater than to the cockpit area. In many individual accidents the differences in fore and aft damage in the occupiable areas were extreme.

TABLE III. Cockpit/Cabin Integrity in Accidents

	Cockpit (# of accidents)	Remainder of Cabin (# of accidents)
Intact	9	16
Distorted	5	6
Partly Collapsed	12	6
Collapsed	2	1
Burned	0	0
Disintegrated	1	0

Structural Damage to:	# of Accidents
Cockpit > Remainder of Cabin	13
Cockpit = Remainder of Cabin	16
Cockpit < Remainder of Cabin	0

Who receives the worst injuries when both pilot and copilot positions are occupied? To explore this, the severity of injuries to the occupants of the pilot position (left front) and occupants of the copilot position (right front) was recorded. Of the 39 accidents, in which both positions were occupied, injuries to occupants of the pilot and copilot positions were greater in the pilot position in 10, greater in the copilot position in 10, and equal in the remaining 19. Of course, injuries are probably a function of which side of the aircraft impacts first. There were six fatalities at the pilot position and seven at the copilot position. These data suggest there is no difference between these two positions in regard to the severity of injuries received.

Is one likely to receive more serious injury when occupying the cockpit (pilot or copilot position) or a position behind the cockpit? Table IV presents data on 23 accidents in which there were occupants in passenger seats as well as the cockpit. The most serious injury of an occupant in passenger rows other than the first is included for completeness. The injuries listed represent only the worst injury an occupant or occupants received in their position in the aircraft. There were three accidents that involved a fatality in the cockpit. Of these three accidents, the most severe injury to other occupants in the aircraft was a "serious" injury. There were 16 accidents in which the most severe injury in the cockpit position was "serious," yet, in three of these, there was at least one fatality in the first row of passenger seats. There were four accidents in which injury to an occupant in the cockpit was minor/none; occupants in the first passenger row received "serious" in one accident and minor or no injuries in the other three accidents. In two accidents, the most severe injuries were in the second row of passenger seats. With some notable exceptions, such as case #27 in which occupants of the pilot and copilot seats survived but both occupants behind them received fatal injuries, these data tend to confirm the accumulated observational experiences of general aviation crash-injury investigators that persons in the pilot and copilot positions are subjected to greater impact forces and thus receive more severe injuries than occupants in rearward positions in the aircraft. There appears to be a cabin damage gradient in the occupiable areas, greater forward and diminishing rearward, and similarly there appears to be an occupant injury gradient, greater forward and diminishing rearward. The two are obviously correlated.

TABLE IV. Comparison of Injuries in Cockpit Area With Those Received in Other Locations in Aircraft*

Cockpit		Passenger First Row			Passenger Second Row			Passenger Third Row		
(Pilot-Copilot Positions)		FAT	SER	MINOR NONE	FAT	SER	MINOR NONE	FAT	SER	MINOR NONE
Fatal	3		2	1			1			
Serious	16	3	6	7		1	2			1
Minor/None	4		1	3		2				
Total	23	3	9	11		3	3			1

*Figures represent numbers of accidents (not number of persons) and worst injury for position. Does not include unrestrained children.

Since the seat is an integral part of the aircraft occupant protection system, how did the seats function in these accidents and did seat failures or loss of adequate seat support add to the severity of the injuries received in the accidents analyzed?

Aircraft were found to have varying degrees of failures of the seats. Failures, to a great extent, varied with the design, installation, and position in the aircraft. For example, seats were found to fail at the attachment by sliding forward on the seat track, and to partially or completely detach from the track. Legs or seat pedestals were found to break, or break and the broken parts separate. For the most part, bending of legs and pedestals was considered beneficial to occupant protection. There were some failures of seat pans and seat backs. The data covered 136 seats. Of these, seat-to-track/floor attachments failed in 48, legs/pedestals failed in 25, and backs in 6. The distribution of these failures is represented by the data in Table V.

TABLE V. Incidence of Seat Failures

Seating Position	Attachments			Legs/Pedestals			Back		
	Failures	Total #	%	Failures	Total #	%	Failures	Total #	%
Pilot	19	44	43	10	46	21	2	44	5
Copilot	16	39	41	9	38	24	4	39	10
1A	4	16	25	2	16	13	0	15	
1B	6	17	35	2	17	12	0	16	
2A	2	6	33	1	6	17	1	6	17
2B	1	6	17	1	6	17	1	6	17
3A	0	1		0	1		0	1	
3B	0	1		0	1		0	1	

Here again one can see a gradient of failure from forward to aft. From these data and the general experience of investigators, the greatest failures are in the pilot and copilot seats with the seat to track/floor attachments failing in approximately 40 percent of the accidents. In 20-25 percent of the accidents there was some breaking of the seat leg or pedestal. Other seats appeared to fare better but still there were enough failures to warrant concern.

For improved crashworthiness, seats should provide support for the occupants and attenuate both forward and vertical impact forces. Abrupt failure such as sliding forward, separating from the attachment to the floor of the aircraft, or breaking of the undersupport (legs/pedestals) allows occupants to impact against the floor, instrument panels, and other occupants or structures so that the decelerative forces are greater and injuries are incurred. Similarly, in some respects, a seat that is rigid and unyielding may intensify injuries. There are no FAA requirements for seats to attenuate decelerative forces. The accidents were reviewed with the question in mind that, from practical considerations, did the seats contribute to the severity of the injuries? Such data are tabulated in Table VI.

TABLE VI. Contribution of Seats to Severity of Injury

Seat Position	Seat Contributed To Severity	Seat Did Not Contribute To Injury	Undetermined
Pilot	16	26	5
Copilot	11	26	3
Passengers	14	34	1
Total	41	86	9
Percent	30	63	7

In 30 percent of the accidents, malfunction of a seat component (some factor in the seat), fracture of legs, separation from the seat-track, etc., contributed to injuries of occupants over and above what would have been expected from impact forces. In some accidents it was obvious that a factor in the seat design was a contributor to injuries.

Almost all seats were forward-facing but there were, in these aircraft, six aft-facing and three fixed side-facing seats that were occupied. Two occupants of side-facing seats received only minor injuries, (Case #25). In another (Case #37), the only occupant to receive greater than minor injuries was in a side-facing seat. This occupant had serious abdominal injuries related to seatbelt compression of internal organs.

The tubular frame of one of two aft-facing seats in Case #21 broke, allowing the occupant to come forward and strike the pilot from behind, adding to the pilot's injuries, as he was more forcefully driven into the instrument panel. Only minor injuries were incurred in two aft-facing seats in Cases #25 and #37. Injuries occurred to occupants of aft-facing seats in Case #47, but both seats were loosened by severe cabin and floor damage and occupants in their seats were thrown out of the aircraft.

The standard method of restraining occupants in an aircraft is by means of a lapbelt. In only two accidents were there well-documented lapbelt failures. In one (Case #10), the lapbelt attachment to the floor of the aircraft failed, allowing the pilot to be hurled out of the cabin and receive fatal injuries. In Case #11, a severe impact, both lapbelts failed and the occupants were thrown free of the aircraft. Both occupants survived.

An upper torso restraint (UTR) (or other adequate head protection in accidents) has been mandated in some aircraft by the Federal Aviation Regulations (8,9). In accidents reviewed, 57 occupants had the availability of a UTR. Of these, seven were used and held. For six occupants the use and function of a UTR was unknown. The remainder (44) did not use the available UTR.

Based on their familiarity with the accident or their experience as crash-injury investigators, the reviewers correlated the injuries in each accident with the apparent dynamic scenario of the crash. For each occupant of each aircraft they then estimated whether or not, in their opinion, a UTR would have been of value in reducing injuries in this selected series of accidents. These estimates along with the occupiable area severity damage are shown in Table VII.

Among these accidents there are rare examples in which a UTR was used and greatly aided in survivability of the occupant. Unfortunately, most of the occupants of the aircraft did not have the advantage of having a UTR available and, for the most part, those who had them available did not use them. Among pilots, an estimated 43 would have benefited from a UTR, versus 4 who would not have benefited. Among copilots 36 would have benefited as compared with 4 who would not have benefited. Similarly, among passengers, 42 would have benefited as compared with 11 who would not have benefited. It is apparent from these selected accidents and these estimates, that UTR's would have reduced the severity of injuries to aircraft occupants in all positions. These findings and experienced opinions are consistent with other field investigative findings, laboratory dynamic studies, and FAA requirement that general aviation aircraft manufactured after July 18, 1978 have UTR's installed for each front seat.

Injuries to aircraft occupants by seat position are shown in Table VIII. There were 17 fatalities, mostly in the pilot and copilot positions. Those injuries classified as serious with 10 percent or more residual disability, such as the loss of an eye, an extremity, or the impaired ability to work, all occurred in persons in pilot and copilot positions.

The known types of serious injuries received are shown in Table IX. Pilots and copilots received roughly a third of their injuries to the head and face, a third to the chest and a third to the spine. Spinal injuries appeared to predominate in passengers although about one-fourth of injuries were to the head and face. A further look at spinal injuries comes from Table X in which known spinal injuries and compression fractures of vertebrae are tabulated. These figures show that the majority of serious spinal injuries in aircraft accident victims is compression fractures.

IV. DISCUSSION.

The data in this retrospective study, like much accident data, were not collected under a protocol that forced investigators to document specific findings such as attachments of all seats or precise review of hospital records on each occupant for exact details of injuries. Even so, the data recorded, findings familiar to the investigator, and the photographs allow a reasonably good overall evaluation of each accident.

TABLE VII. Estimates of Value of Upper Torso Restraints to Occupants

	Occupiable Area Damage Index						
Number of:	Minimum	Moderate	Severe	Moderately Severe	Extremely Severe	Extreme	Total
Accidents	8	15	12	7	1	4	47
Persons	23	41	31	22	4	15	136
Pilots would have been helped	7	13	12	6	1	4	43
Pilots would not have been helped	1		1	1		1	4
Copilots would have been helped	6	10	10	6	1	3	36
Copilots would not have been helped	1		1	1		1	4
Passengers would have been helped	8	16	8	5		5	42
Passengers would not have been helped		1		4		2	7

TABLE VIII. Injuries to Aircraft Occupants

Seat Position	Fatal	Serious With Residual	Serious	Minor	No Significant Abnormalities/ NONE	Unknown
Pilots	6	4	24	12	0	1
Copilots	7	2	20	9	2	0
1A	1		8	5	2	1
1B	3		6	6	3	
2A			3	2	1	
2B			3	2	1	
2C				1	1	
3B						
Totals	17	6	64	37	10	2
Percent	12.5	4.4	47.0	27.2	7.4	1.5

TABLE IX. Distribution of Major Injuries

Position	Total # Tabulated	Head and Face #	Head and Face %	Chest #	Chest %	Abdomen #	Abdomen %	Spine #	Spine %
Pilot	37	11	30	12	32	1	--	13	35
Copilot	37	11	30	10	27	3	8	13	42
Passengers	26	6	23	6	23	1	--	13	46

TABLE X. Spinal Injuries

	Spinal Injuries #	Compression Fractures #	Compression Fractures %
Pilot	13	9	69
Copilot	13	5	38
Passengers	13	10	77

The accidents reviewed here confirm what is apparent to aircraft accident investigators, that:

1. The nonoccupiable portions of the aircraft receive greater physical damage than the occupiable areas.

2. If occupants are to survive the accident, the cockpit/cabin should remain reasonably intact and not collapse upon the occupants.

3. The greatest damage to the occupiable area is to the forward portion of the cockpit/cabin.

4. Impact forces on the aircraft, for the most part, cause greater injuries to occupants seated in the forward position of the cockpit/cabin than those seated more rearward.

What is not always apparent to general aviation accident investigators is that, in specific accidents, injuries and even overall survivability of the impact may be related to a lack of incorporation of crashworthiness features of the aircraft. Investigators intent on determining the cause of the accident may overlook the fact that occupants may have survived the accident had some feature not been present, had a seat not failed, or had a shoulder restraint been used. Also, they may not take cognizance of the fact that a properly restrained occupant in some crashes may withstand impact forces that would severely damage the integrity of the aircraft. Each of the accidents reviewed was survivable or partly survivable from the standpoint of what a well-restrained occupant can withstand.

A basic principle of occupant survivability is that the container (the cockpit/cabin) remain intact and not crush in upon the occupants. Experience reveals that in most accidents the forward portion of the aircraft, the landing gear and the underside receive the brunt of the impact forces. Generally, crushing is from forward to aft in such a way that the pilot and copilot are subjected to more longitudinal force than occupants seated behind them. There appears to be no difference of injury potential between the pilot and the copilot positions. Passengers have the advantages of more bending, crushing, and deformation of aircraft structures forward of them so that they are spared the full impact forces experienced in the pilot and copilot positions. This is brought out even in this limited data.

To withstand impact forces, occupants should be adequately restrained. The seat is an integral part of any restraint system and the optimum design should cushion the occupant against forces, particularly forward and vertical forces, which are greatest in almost all accidents. Ideally, a seat should initially resist impact forces and then bend and deform in a controlled and progressive manner so as to attenuate and keep forces below a level that would cause serious injuries to the occupant. A rigid nonyielding or hard seat can lead to high peak loads on the occupant causing serious injuries. A frangible seat, one in which the attachments or seat parts break during impact, can lead to high peak impact forces on the occupants during secondary impacts with aircraft floors, panels or other structures. Seat placement (over main spar, near the floor or on or near other nonyielding structures) or seat failures of one degree or another were judged to have intensified the injuries of occupants in at least 30 percent of the accidents reviewed. Common findings were: failure of latching pins to restrain seats from traveling forward on seat tracks; detachment from seat tracks, usually by breaking of either the track or the track-attachment mechanism; and fracture of seat legs and pedestals. These and other findings (6) in which seats and seating placement appeared to be a factor raise the question of the crashworthiness suitability of seats in general aviation aircraft. In view of current FAA regulations prescribing minimum seat strength based on static testing (2), the data and observations in this report, along with other accident data, indicate that an area for improvement in occupant survivability is in providing seats that attenuate impact force to levels that can be tolerated. Additional documentation of seats as related to injuries in general aviation accidents is the subject of an ongoing accident investigation protocol in the FAA.

Except for lap-held infants and children, lapbelts were used by all occupants of the aircraft reviewed. Only a few lapbelt failures were noted and these primarily were due to failure at the attachment rather than the webbing. These findings support the general impression that if the aircraft impact is in any way survivable, the belt webbing rarely fails unless it is severely weathered and frayed, as seen in some aerial application aircraft, or it is configured so that the force of impact causes the fitting to cut the fabric. The weakest portion of the lapbelt system appears to be its attachments to the floor or aircraft structures.

Aircraft occupants use the lapbelt restraint but, for the most part, do not use the UTR. The value of restraining the upper torso cannot be overemphasized. For example, a seated passenger is restrained by a lapbelt and his/her upper torso may weigh as much as 120 lb. In an accident, the lapbelt holds the pelvis and acts as a fulcrum about which the upper torso rotates under the force of deceleration. If the deceleration is low, 2 G's, the upper torso will have an apparent weight of 240 lb, so that the occupant can barely resist the forward thrust. At 10 G's, well within the survivability envelope, the apparent weight of the upper torso will be 1,200 lb and it will swing forward with great velocity, possibly hitting the head on the instrument panel and the chest against the control wheel. Based on the velocity of the upper torso and head and the stopping distance, a force of several hundred G's may be exerted on the skull or chest. This rationale is supported by the finding that about 70 percent of general aviation accident fatalities have fractures of the skull (7). Crushing of the chest is common. These observations were made before UTR's were mandatory in aircraft.

Thus, for years it has been known that UTR's would be lifesaving to aircraft occupants in accidents. The double shoulder harness worn by aerial application pilots has saved hundreds of lives. Unfortunately there are few findings of other general aviation aircraft occupants wearing a UTR at time of impact. Of the 57 occupants of aircraft in this report who had a UTR available, only 7 used them and the UTR appeared to have lessened injuries. An outstanding example of the value of a UTR is Case #33 where the occupant in the copilot seat, an FAA employee, was estimated to have survived only because he had on the single shoulder harness.

Estimates based on accident investigation experience, as reflected in Table VII, show that of the 136 persons evaluated in the 47 accidents, 121 persons would have benefited by a UTR; the remainder would not have benefited.

The FAA has taken steps which should lead to improved occupant protection in survivable aircraft accidents. The Federal Aviation Regulations (FAR) have been changed so that since July 18, 1977, all new type-certificated airplanes must be equipped with UTR's in the front seats. For a pilot to operate a small civil airplane manufactured after July 18, 1978, the airplane must have, for each front seat, a shoulder harness designed to protect the occupant from serious head injury when the occupant experiences the ultimate inertia forces specified in other parts of the FAR (9). In addition, the FAR mandate that UTR's be worn on all takeoffs and landings by each required flight crewmember of a civil airplane, if the airplane is equipped with a shoulder harness and if the shoulder harness does not interfere with performance of duties (10). There is no provision that, in new type-certificated or newly manufactured aircraft, other seating positions (except for additional crew positions) be equipped with a means of restraining the upper torso. Neither is there provision that aircraft manufactured before the stated date be retrofitted with UTR's in any position. Crash injury experiences in other vehicles, decelerative testing under laboratory conditions, general aviation accident experience, and the experience and data in this report, all indicate that general aviation aircraft occupants under condition of impact, would benefit from wearing a UTR. The FAA's requirement of a UTR in certain airplanes and other crashworthiness improvements such as removal of sharp objects, installation of padding, etc., should reduce injuries and improve survivability.

The figures in Table IX indicate that in roughly a third of the occupants, severe injuries are to the head and face, a third to the chest, and a third to the spine. For the most part, in accidents where the cockpit/cabin retains its integrity and is not crushed upon its occupants, the severe head and face injuries probably result from the unrestrained torso traveling forward against aircraft structures. For the pilot and copilot positions this is most frequently the instrument panel or structural members. For other occupants, head and face injuries, usually less severe than for pilot and copilot positions, are received as they flex forward into the seats in front of them or move laterally into aircraft structures. Chest injuries in the pilot and copilot position frequently result from impact with the control wheel or by forward flexure onto one's own legs. Seats that travel forward, or that partially or fully detach, add to head and chest injuries. Crushed chests are less frequent in passenger positions, but can result from flexing forward and striking one's own knees. Both types of injuries would appear to be lessened by restraining the upper torso.

Spinal injuries are usually attributed to severe downloading. Overly rigid seats, seats that break and let the occupant "bottom out" on the floor, or seats that are positioned over solid structures or other unyielding structures, add to the severity of spinal injuries. Compression fractures of lower thoracic or lumbar vertebrae were conspicuous in the accidents reviewed.

This type of injury probably results from downloading on the spine or forward flexion over the lapbelt. The seat and restraint as an integrated system is apparent when one considers how a UTR may work. Restraint of forward motion and maintenance of the body in an upright position by the UTR in many instances will increase downloading on the spine--and on the seat. Increased loading on the spine should intensify injuries. It is thus apparent that the seat should be designed to attenuate this increased downloading so as to lessen injuries. The value of a seat that can attenuate these and other forces on the occupants cannot be overemphasized. The specifics of spinal injuries and seat failures should be given special emphasis in aircraft accident investigations as UTR's become more widely used. The overall and specific functioning of UTR's in general aviation accidents is the subject of an accident investigation protocol within the FAA.

The data from the 47 accidents in this report suggest that, although variable with the specific airplane, the greatest crash protection for the occupants of general aviation aircraft can be offered by providing each with a UTR (with strong attachments) and a well-anchored impact attenuating seat. This can only be accomplished though at a significant cost for newly manufactured airplanes and a major cost as a retrofit item.

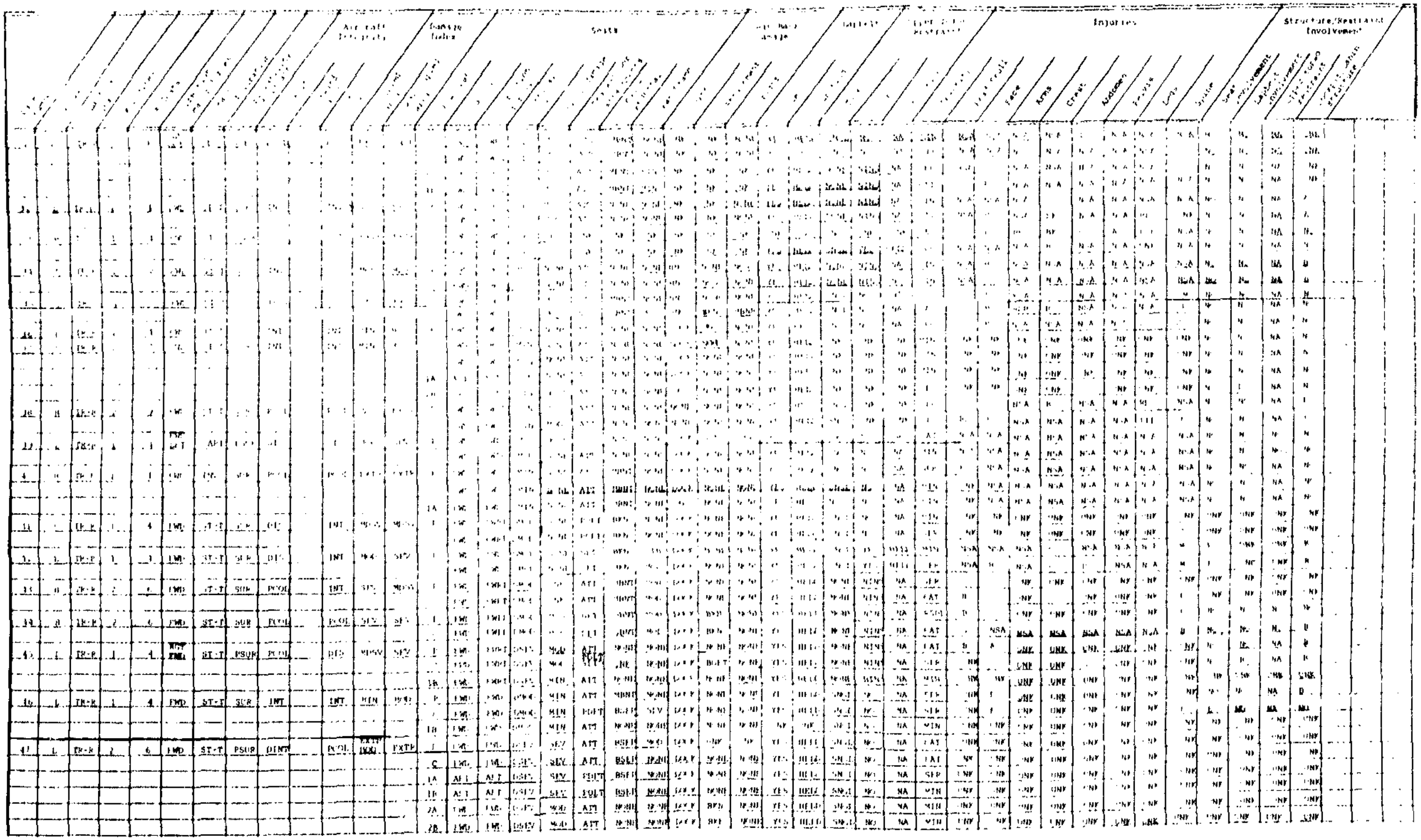
TABLE 1. Crashworthiness Findings in 47 General Aviation Accidents

								Aircraft Integrity			Damage Index		Seats									Seat Back Damage		Lapbelt			Upper Torso Restraint			Injuries								Structure/Restraint Involvement						
Case number	Wings	Landing gear	# Engines	# Seats	Direction major forces	Crash configuration	Survivability of impact	Cockpit	Forward cabin	Aft cabin	Occupied area	Unoccupied area	Row seat	Facing	Direction forces	Vertical forces	Floor damage	Track-floor attachments	Legs - pedestal	Pan/frame	Joint	Attachment	Upright	Use	Function	Type	Use	Function	Severity	Head/Skull	Face	Arms	Chest	Abdomen	Pelvis	Legs	Spine	Seat involvement	Lapbelt involvement	Upper torso restraint	Cockpit/Cabin structure			
1	L	TR-R	1	4	FWD VERT	ST-T	SUR	COL		INT	MOD	MOD	P	FWD	[illegible]	DMOD	NONE	ATT	MBNT BEN	NONE	LOCK	NONE	HBNB	YES	HELD	SNGL	NO	NA	MIN	G	NONE	NONE	NONE	NONE	NONE	NONE	K	A	NO	NA	J			
2	L	TR-F	1	2	VERT	ST-T	SUR	INT		INT	MOD	MOD	[illegible]	FWD	FWD	DMOD	NONE	PDET	NA	SEV	HNGD	NONE	HBNB	YES	HELD	NONE	NINS	NA	FAT	K	NSA	NSA	B	NSA	NSA	NSA	G	D	NO	NA	BF			
														FWD	FWD	DMOD	NONE	ATT	NA	SEV	HNGD	NONE	HBNB	YES	HELD	NONE	NINS	NA	SER	NSA	B	LG	NONE	NONE	NONE	NONE	UNK	D	NO	NA	BF			
[illegible]	[illegible]	TR-R	1	4	FWD VERT	ST-T	SUR	INT		INT	MOD	MDSV	P	FWD	FWD RGT	DMOD	NONE	ATT	BSEP	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	NSA	C,H	UG	UNK	UNK	UNK	UG	UNK	E	NO	NA	BG			
														FWD	FWD RGT	DMOD	NONE	ATT	BSEP	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	B,F	NSA	NSA	NSA	NSA	NSA	LD KH	NSA	E	NO	NA	BG			
													1B	FWD	FWD RGT	DMOD	NONE	ATT	NONE	NONE	FXD	NA	NONE	YES	HELD	NONE	NINS	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	C			
4	H	TR-R	1	4	FWD	ST-T	SUR	DIS		[illegible]	MDSV	[illegible]	P	FWD	FWD	DMIN	NONE	ATT	SLID	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	MIN	NSA	C	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	B			
[illegible]	H	TR-R	1	4	FWD	ST-T	SUR	PCOL		[illegible]	[illegible]	[illegible]	P	FWD	FWD	DMIN	SEV	DET	NONE	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	NSA	NSA	NSA	NSA	NSA	NSA	LD	NSA	NO	NO	NA	F			
													[illegible]	FWD	FWD	DMIN	SEV	ATT	NONE	NONE	LOCK	NONE	MBNT	YES	HELD	SNGL	NO	NA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													1A	FWD	FWD	DMIN	NONE	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													1B	FWD	FWD	DMIN	NONE	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
[illegible]	L	TR-R	1	6	FWD	ST-T	SUR	[illegible]		[illegible]	SEV	[illegible]	[illegible]	FWD	FWD	DMIN	NONE	PDET	MBNT	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	K	H	RF	NSA	NSA	NSA	NSA	NSA	C	NO	NA	B			
														FWD	FWD	DMIN	NONE	ATT	NONE	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	NSA	C	LF	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	B			
													[illegible]	FWD	FWD	DMOD	NONE	DET	MBNT	NONE	[illegible]	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	K	H	NSA	NSA	NSA	NSA	NSA	NSA	C	NO	NA	C			
[illegible]	L	TR-R	1	[illegible]	FWD	ST-T	SUR	INT			MIN	[illegible]	[illegible]	FWD	FWD	DMOD	NONE	PDET	NA	[illegible]	HNGD	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	E	E	NO	NA	F			
													P	FWD	FWD	DMOD	NONE	PDET	NA	[illegible]	HNGD	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	E	E	NO	NA	F			
[illegible]	L	TR-R	1	[illegible]	FWD	ST-T	SUR	INT			MDSV	[illegible]		FWD	FWRT	DMOD	NK	NK	NA	[illegible]	[illegible]	NONE	NONE	YES	HELD	SNGL	YES	HELD	SER	G	NONE	NONE	B	NONE	NONE	NONE	NONE	NO	NO	UNK	UNK			
[illegible]	[illegible]	TR-R	1	1	FWD	ST-T	SUR	INT		INT	MOD	MDSV	P	FWD	FWLF	DMOD	NONE	DET	BNT	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	MIN	NSA	NSA	NSA	NSA	H	NSA	NSA	NSA	C	A	NA	NO			
[illegible]	L	TR-R	1	6	FWD	ST-T	SUR	PCOL		INT	[illegible]	[illegible]	P	FWD	FWD	DMIN	MIN	ATT	BKN	NONE	HNGD	NONE	HBNB	YES	FLR	NONE	NINS	NA	FAT	J	B	LC	[illegible]	NSA	NSA	I	NSA	B	FLR	NA	I			
														FWD	FWD	DMIN	MIN	ATT	NONE	NONE	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	MIN	NSA	H	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													2A	FWD	FWD	DMIN	MIN	ATT	MBNT	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	G	NSA	LH	NSA	NSA	NSA	J	NSA	NO	NO	NA	NO			
[illegible]	L	TR-R	1	4	FWD	ST-T	SUR	PCOL		INT	MDSV	SEV	P	FWD	FWLF	DMOD	MIN	DET	SBNT	NONE	LOCK	MBNT	NONE	YES	FLR	SNGL	NO	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	NO	FLR	NA	UNK			
														FWD	FWLF	DMOD	MIN	DET	SBNT	NONE	LOCK	NONE	NONE	YES	CUTB	SNGL	NO	NA	RSOL	UNK	A	UNK	B	UNK	B	LND	UNK	NO	FLR	NA	H			
[illegible]	H	TR-R	1	6	FWD	ST-T	SUR	DIS		INT	MOD	MDSV	P	FWD	FWLF	DSEV	SEV	PDET	BSEP	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	NSA	H	NSA	NSA	NSA	NSA	NSA	DF	E	NO	NA	FI			
													C	FWD	FWLF	DSEV	SEV	PDET	BSEP	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	NSA	C,G	NSA	NSA	NSA	NSA	NSA	F	E	NO	NA	FI			
													1A	FWD	FWLF	DMOD	MOD	DET	SBNT	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	J	NSA	E	NO	NA	I			
													1B	FWD	FWLF	DMOD	MOD	DET	SBNT	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NINS	NA	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													2A	FWD	FWLF	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													2B	FWD	FWLF	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
													2C	FWD	FWLF	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO			
11	L	TR-F	1	2	FWD	ST-T	SUR	PCOL		--	MDSV	SEV	P	FWD	FWLF	MIN	NONE	ATT	NA	NONE	HNGD	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	K	H	NSA	B	I	NSA	I	NSA	NO	NO	NA	BJ			
													C	FWD	FWLF	MIN	NONE	ATT	NA	NONE	HNGD	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	J	H	RH	J	I	A	I	NSA	NO	NO	NA	BJ			
14	H	TR-F	1	4	FWD	ST-T	SUR	PCOL		DIS	MDSV	MDSV	P	FWD	FWD	DMOD	MOD	PDET	BSEP	NONE	LOCK	BKN	MBNT	YES	HELD	SNGL	NO	NA	SER	K	H	NSA	B	NSA	NSA	NSA	NSA	C	NO	NA	B			
													C	FWD	FWD	DMOD	MOD	PDET	MBNT	UNK	UNK	UNK	UNK	YES	HELD	SNGL	NO	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	RI	NSA	NO	NO	NA	NO			
													C 1a	FWD	FWD														SER	KE	H	H	NSA	NSA	NSA	I	NSA	NO	NO	NA	UNK			
													1A	FWD	FWD	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	K	A	RM	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	C			
													1B	FWD	FWD	DMOD	MIN	DET	MBNT	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	FAT	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	E	NO	NA	UNK			
15	L	TR-F	1	6	FWD	ST-T	SUR	PCOL		DIS	SEV	SEV	P	FWD	RAFT	DMOD	SEV	DET	SBNT	SEV	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	J	E	NO	NA	F			
													C	FWD	RAFT	DMOD	SEV	DET	SBNT	SEV	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	H	UNK	UNK	UNK	UNK	UNK	H	E	NO	NA	F			
													1A	FWD	FWD	DMOD	MIN	PDET	MBNT	NONE	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	J	E	NO	NA	F			
													1B	FWD	FWD	DMOD	MIN	DET	MBNT	NONE	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	I	E	NO	NA	F			
													2A	FWD	FWD	DMOD	MIN	DET	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	J	E	NO	NA	F			
													2B	FWD	FWD	DMOD	MIN	DET	BSEP	NONE	FXD	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	UNK	C	UNK	UNK	UNK	UNK	LF	J	E	NO	NA	CY			
16	H	TR-R	1	6	FWD	ST-T	SUR	INT		INT	MOD	MOD	P	FWD	FWD	DMOD	MIN	PDET	MBNT	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	MIN	NSA	H	NSA	C	NSA	NSA	NSA	H	NO	NO	NA	NO			
													C	FWD	FWD	DMOD	MIN	NONE	NONE	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	MIN	NSA	H	NSA	NSA	NSA	NSA	LI	NSA	NO	NO	NA	NO			
													1A	FWD	FWD	DMOD	MIN	PDET	BKN	MIN	LOCK	NONE	NONE	YES	HELD	NONE	NO	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	H	NO	NO	NA	NO			
													1B	FWD	FWD	DMOD	MIN	DET	BKN	MIN	LOCK	NONE	NONE	YES	HELD	NONE	NO	NA	SER	NSA	NSA	NSA	NSA	NSA	NSA	NSA	I	NO	NO	NA	NO			

TABLE I. (Continued)

								Aircraft Integrity			Damage Index		Seats								Seat Back Damage			Lapbelt			Upper Torso Restraint			Injuries								Structure/Restraint Involvement			
Case number	Wings	Landing gear	# Engines	# Seats	Direction major forces	Crash configuration	Survivability of impact	Cockpit	Forward cabin	Aft cabin	Occupied area	Nonoccupied area	Row/Seat	Facing	Direction forces	Vertical forces	Floor damage	Track-Floor attachments	Legs - pedestal	Pan/Frame	Joint	Attachment	Upright	Use	Function	Type	Use	Function	Severity	Head/Skull	Face	Arms	Chest	Abdomen	Pelvis	Legs	Sp.no	Seat involvement	Lapbelt involvement	Upper torso restraint	Cockpit/Cabin structure
17	H	TR-I	1	1	FWD	ST-T	SUR	CUL		DIS	SEV	MDSV	P	FWD	FWRT	DMOD	MOD	ATT	NONE	NONE	HNGD	NONE	NONE	UNK	UNK	UNK	UNK	UNK	SER	RJ	UNK	UNK	UNK	UNK	UNK	UNK	UNK	NO	NO	NA	B
													C	FWD	FWRT	DMOD	SEV	PDET	SBNT	NONE	HNGD	NONE	NONE	UNK	UNK	UNK	UNK	UNK	SER	K	A	RF	C	NSA	NSA	LG	NSA	NO	NO	NA	B
													1B	FWD	FWRT	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	UNK	UNK	UNK	UNK	UNK	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
19	H	TR-I	1	4	FWD	ST-T	SUR	PCOL		DIS	MDSV	SEV	P	FWD	FWRT	DMOD	MOD	DET	NONE	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	NA	UNK
													C	FWD	FWRT	DMOD	MOD	DET	BKN	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	NSA	NSA	NSA	C	NSA	NSA	LR RJ	M	NO	NO	NA	F
													C lap																SER	K	H	LE	NSA	NSA	NSA	RE	NSA	NO	NO	NA	B
													1A	FWD	FWRT	DMOD	MIN	ATT	NONE	NONE	UNK	NONE	NONE	YES	HELD	NONE	NA	NA	SER	NSA	NSA	NSA	NSA	NSA	CN	RG	M	NC	NO	NA	F
													1B	FWD	FWRT	DMOD	MIN	ATT	NONE	NONE	UNK	NONE	NONE	YES	HELD	NONE	NA	NA	SER	NSA	NSA	NSA	B	NSA	NSA	NSA	IJ	NO	NO	NA	C
11	H	TW-I	1	6	FWD	ST-T	SUR	INT		INT	MOD	MOD	P	FWD	FWD	DMOD	MOD	ATT	NONE	NONE	HNGD	NONE	NONE	YES	HELD	SNGL	YES	HELD	SER	NSA	NSA	NSA	NSA	NSA	NSA	NSA	J	NO	NO	NO	NO
													C	FWD	FWD	DMOD	MOD	ATT	NONE	NONE	HNGD	NONE	NONE	YES	HELD	SNGL	YES	HELD	SER	NSA	NSA	NSA	NSA	NSA	NSA	NSA	I	NO	NO	NO	NO
													1A	FWD	FWD	DMOD	MIN	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	SNGL	YES	HELD	SER	NSA	NSA	NSA	C	NSA	NSA	NSA	J	NO	NO	NO	NO
[illegible]	L	TR-I	1	2	FWD	ST-T	SUR	INT		--	MIN	MDSV	P	FWD	FWLF	DMOD	NONE	ATT	NA	MIN	HNGD	NONE	NONE	YES	HELD	UNK	UNK	UNK	SER		NSA	NSA	NSA	NSA	NSA	NSA	J	NO	NO	UNK	NO
													C	FWD	FWLF	DMOD	NONE	ATT	NA	MIN	HNGD	NONE	NONE	YES	HELD	UNK	UNK	UNK	SER	G	NSA	NSA	NSA	NSA	NSA	NSA	J	NO	NO	UNK	NO
21	L	TR-I	[illegible]	6	FWD	ST-T	SUR	INT		INT	MOD	MOD	P	FWD	FWD	DMOD	MIN	ATT	NONE	NONE	LOCK	NONE	NONE	UNK	UNK	UNK	UNK	UNK	MIN	NSA	H	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NO	B
													C	FWD	FWD	DMOD	MIN	ATT	NONE	NONE	LOCK	BKN	NONE	UNK	UNK	NONE	NA	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	M	NO	NO	NO	NO
													1A	AFT	AFT	DMOD	MIN	ATT	NONE	MOD	FXD	BDET	UNK	UNK	UNK	NONE	NA	NA	UNK	UNK	UNK	UNK	UNK	H	UNK	UNK	UNK	NO	NO	NO	NO
													1B	AFT	AFT	DMOD	MIN	ATT	NONE	MIN	FXD	NONE	NONE	UNK	UNK	NONE	NA	NA	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NO	NO
													2A	FWD	FWD	DMOD	MIN	PDET	NONE	MIN	UNK	NONE	NONE	UNK	UNK	NONE	NA	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	IJ	NO	NO	NO	NO
													2B	FWD	FWD	DMOD	MIN	ATT	NONE	MIN	UNK	NONE	NONE	UNK	UNK	NONE	NA	NA	SER	UNK	UNK	UNK	C	UNK	UNK	UG	UNK	NO	NO	NO	NO
[illegible]	L	TR-I	1	2	FWD	ST-T	SUR	INT			MIN	MOD	P	FWD	FWD	DMOD	NONE	ATT	NA	NONE	HNGD	NONE	NONE	YES	HELD	UNK	UNK	UNK	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	J	NO	NO	NA	NO
													C	FWD	[illegible]	DMOD	NONE	ATT	NA	NONE	HNGD	NONE	NONE	YES	HELD	[illegible]	UNK	UNK	SER	E	UNK	UNK	UNK	UNK	UNK	UNK	J	NO	NO	NA	NO
	H	TR-I	1	4	FWD	ST-T	SUR	INT		INT	MIN	MOD	3	FWD		DMIN	NONE	PDET	DSEP	NONE	LOCK	NONE	NONE	YES	HELD	[illegible]	UNK	UNK	MIN	NSA	B	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	B
													[illegible]	FWD	FWD	DMIN	NONE	PDET	DSEP	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	UNK	UNK	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
													1A	FWD	FWD	DMIN	NONE	ATT	NONE	[illegible]	FXD	NONE	NONE	YES	HELD	NONE	UNK	UNK	NONE	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
[illegible]	[illegible]	TR-I	1	[illegible]	FWD	ST-T	SUR	INT		--	MOD	MOD	P	FWD	FWRT	DMOD	NONE	ATT	NA	MOD	HNGD	NONE	NONE	YES	HELD	UNK	UNK	UNK	SER	G	H	M	NSA	NSA	AD	NSA	J	NO	NO	NO	NO
[illegible]	L	TR-I	2	[illegible]	FWD	ST-T	SUR	INT		INT	MIN	MOD	P	FWD	FWD	DMOD	MIN	ATT	BSEP	NONE	FXD	NONE	NONE	YES	HELD	NONE	NA	NA	RSDL	D	E	UNK	UNK	UNK	UNK	UNK	J	C	NO	NA	B
													C	FWD	FWD	DMOD	MIN	ATT	BSEP	NONE	FXD	NONE	NONE	YES	HELD	NONE	NA	NA	RSDL	NSA	NSA	NSA	NSA	NSA	NSA	LR C	C	C	NO	NA	NO
													1A	AFT	AFT	DMOD	NONE	ATT	NONE	NONE	UNK	NONE	NONE	YES	HELD	NONE	NA	NA	MIN	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	NO	NO	NA	NO
													2A	FWD	FWD	DMOD	NONE	ATT	BKN	[illegible]	UNK	NONE	NONE	YES	HELD	NONE	NA	NA	MIN	NSA	H	UM	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
													2B	F(SD)	SGT	DMOD	NONE	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NA	NA	MIN	F	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
													1B	F(SD)	RGT	DMOD	NONE	ATT	NONE	NONE	FXD	NONE	NONE	YES	HELD	NONE	NA	NA	MIN	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	PO	NO	NA	NO
[illegible]	H	TR-I	1	1	FWD	ST-T	SUR	PCOL		INT	MDSV	EXSV	P	FWD	FWD	DMOD	SEV	UNK	MBNT	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NA	NA	SER	NSA	NSA	RF	NSA	NSA	NSA	NSA	NSA	UNK	UNK	NA	BA
													[illegible]	FWD	FWD	DMOD	MOD	PDET	MBNT	NONE	LOCK	NONE	NONE	YES	HELD	NONE	NA	NA	FAT	NSA	NSA	NSA	AF	CG	UNK	UNK	UNK	NO	NO	NA	A
													1B	FWD	FWD	DMOD	NONE	ATT	NONE	NONE	UNK	NONE	NONE	N	NA	NONE	NA	NA	SER	NSA	C	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	C
[illegible]	[illegible]	TR-I	[illegible]	[illegible]	FWD	ST-T	[illegible]	PCOL		INT	MOD	MDSV	P	FWD	FWD	[illegible]	[illegible]	SLID	SBNT	MIN	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	B	C	RM	B	NSA	C	NSA	NSA	A	NO	NA	B
													[illegible]	FWD	FWD	DSEV	MOD	DET	SBNT	MIN	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	SER	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	A	UNK	NA	UNK
													1A	FWD	FWD	DSEV	[illegible]	ATT	NONE	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	FAT	UNK	UNK	UNK	A	UNK	UNK	UNK	C	NO	NO	NA	CF
													1B	FWD	FWD	DSEV	MOD	ATT	MBNT	NONE	LOCK	NONE	NONE	YES	HELD	SNGL	NO	NA	FAT	UNK	UNK	UNK	A	UNK	UNK	UNK	UNK	NO	NO	NA	CF
[illegible]	[illegible]	TR-I	1	4	FWD	ST-T	SUR	DIS		INT	MOD	SEV	P	FWD	FWRT	DMOD	NONE	DET	BSEP	[illegible]	LOCK	MBNT	NONE	YES	HELD	[illegible]	NO	NA	RSDL	J	A	NSA	NSA	NSA	NSA	I	J	E	NO	NA	B
													1A	FWD	FWRT	DMOD	NONE	UNK	NF	NF	UNK	NF	NK	YES	HELD	SNGL	NO	NA	SER	E	NSA	NSA	NSA	NSA	NSA	NSA	J	NO	NO	NA	NO
													1B	FWD	FWRT	DMOD	NONE	NF	NF	UNK	UNK	NF	UNK	YES	HELD	NONE	NINS	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NO	NO	NA	NO
[illegible]		TR-I	1	1	FWD	ST-T	SUR	PCOL		PCOL	EXSV	EXSV	P	FWD	FWRT	DMOD	MOD	DET	MBNT	NONE	NF	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	[illegible]	A	NSA	NSA	NSA	NSA	D	NSA	YES	NO	NA	YES
													[illegible]	FWD	FWRT	DMOD	MOD	ATT	NONE	NONE	NF	NONE	NONE	YES	HELD	NONE	NINS	NA	MIN	NSA	NSA	NSA	NSA	NSA	NSA	NSA	NSA	YES	NO	NO	YES
													1A	FWD	FWRT	[illegible]	MOD	ATT	NONE	NONE	NF	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	F	H	NSA	H	NSA	C	E	F	YES	YES	NA	YES
													1B	FWD	FWRT	DMOD	MOD	ATT	NONE	NONE	NF	NONE	NONE	YES	HELD	NONE	NINS	NA	SER	NSA	NSA	IJ	D	NSA	[illegible]	NSA	I	YES	YES	NA	YES
[illegible]	[illegible]	TR-I	[illegible]	[illegible]	FWD AFT	ST-T	[illegible]	PCOL			MDSV	SEV	P	FWD	FWLF	DMOD	MOD	MBNT	NA	MOD	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	RSDL	NSA	B	LRM	NSA	H	D	LBD LK	I	UNK	UNK	UNK	UNK
													C	FWD	FWLF	DMOD	MOD	MBNT	NA	MOD	HNGD	NONE	NONE	YES	HELD	NONE	NINS	NA	FAT	AJ	A	LRM	NSA	NSA	NSA	RL I	NF	UNK	UNK	UNK	B

TABLE I. (Continued)



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CODING FOR CRASHWORTHINESS DATA

I. CASE #

II. WINGS

L - Low
H - High

III. LANDING GEAR

TC - tricycle
TW - tailwheel
F - fixed
R - retractable

IV. ENGINES

1, 2, 3, etc.

V. # SEATS

1, 2, 3, etc.

VI. DIRECTION OF MAJOR FORCES

FWD - forward
AFT - rearward
LFT - left
RGT - right
VERT - vertical
***** or combination of the above

VII. CRASH CONFIGURATION

CART - cartwheeled
INV - inverted
ST-T - straight or turning upright

VIII. SURVIVABILITY OF IMPACT

SUR - survivable
PSUR - partly survivable
CSUR - survivable by chance
NSUR - nonsurvivable

IX. COCKPIT/CABIN INTEGRITY

a. Cockpit
b. Forward Cabin
c. Aft Cabin
d. Occupied Area
e. Non-Occupied Area

INT - intact
DIS - distorted
PCOL - partly collapsed
COL - collapsed
BUR - burned
DINT - disintegrated

X. DAMAGE INDEX (See below)

XI. SEATS

a. Row/Seat:

P - pilot
C - copilot

Row -- 1 A B C etc.
Row -- 2 A B C etc.
Row -- 3 A B C etc.

XI. SEATS (Con't)

b. Facing:

FWD - forward
AFT - aft
SWVL - swivel
FXSD - fixed side facing
BSID - bench side facing

c. Direction of Forward-Lateral-Aft For[illegible]

FWD - forward
FWRT - forward and right
RGT - right
RAFT - right and aft
AFT - aft
LAFT - left and aft
LFT - left
FWLF - forward and left

d. Vertical Forces

DMIN - downward-minor
DMOD - downward-moderate
DSEV - downward-severe
UMIN - upward-minor
UMOD - upward-moderate
USEV - upward-severe

e. [illegible]

NONE - no distortion [illegible]
MIN - minor [illegible]
[illegible]
[illegible]
MOD - moderate distortion [illegible]
[illegible] moderate [illegible]
[illegible] seat [illegible] and/or attachments
SEV - severe distortion or buckling [illegible]
seats [illegible]
and/or attachment
NA - not applicable
UNK - unknown

f. Seat-To-Track/Floor Attachment

ATT - seat remained attached [illegible]
SLID - seat remained attached but slid
PDET - seat partially detached [illegible]
DET - seat completely detached from [illegible]
NA - not applicable
UNK - unknown

g. Seat Legs and/or Pedestal Damage

NONE - No seat deformation
MBNT - minor bending or deformation of seat leg and/or pedestal
SBNT - severe bending or deformation but seat legs and/or pedestals not broken
BKN - legs and/or pedestals broken but not separated
BSEP - legs and/or pedestal broken in several places and separated
NA - not applicable
UNK - unknown

XI. SEATS (Con't)

h. Pan/Frame:

NONE - no deformation or damage
MIN - minor
MOD - moderate
SEV - severe or separated
NA - not applicable
UNK - unknown

XII. SEAT BACK DAMAGE

a. Joint--(type of attachment of back to pan)

FXD - fixed, rigid, not moveable
UNLK - hinged, moveable but not lockable
LOCK - hinged and lockable
NA - not applicable
UNK - unknown
(other in writing)

b. Attachment
Damage of seat back attachment to seat pan:

NONE - no damage
MBNT - minor bending at attachment
SBNT - severe bending at attachment
BKN - broken but not detached
NA - not applicable
UNK - unknown

c. Upright Damage to seatback upright (other than attachment to pan)

NONE - no damage
MBNF - minor bending forward (toward pan)
MBNB - minor bending backward (back from pan)
SBNF - severely bent forward (toward pan)
SBNB - severely bent backward (back from pan)
BKN - frame broken but not separated
BSEP - frame broken and separated
NA - not applicable
UNK - unknown

XIII. LAP BELTS

a. Use:

YES - used
NINS - not installed
NO - installed not used
UNK - unknown

b. Function:

HELD - held with no problem
RFLR - complete failure at right attachment
LFLR - complete failure at left attachment
CFLR - complete failure both attachments
OFLR - failure of hardware other than attachment

CODING FOR CRASHWORTHINESS DATA

I. CASE #

II. WINGS

L - Low
H - High

III. LANDING GEAR

TT - tricycle
TW - tailwheel
F - fixed
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1, 2, 3, etc.

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NSUR - nonsurvivable

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d. Occupied Area
e. Non-Occupied Area

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COL - collapsed
BUR - burned
DINT - disintegrated

X. DAMAGE INDEX (See below)

XI. SEATS

a. Row/Seat:

P - pilot
C - copilot

Row -- 1 A B C etc.
Row -- 2 A B C etc.
Row -- 3 A B C etc.

XI. SEATS (Con't)

b. Facing:

FWD - forward
AFT - aft
SWVL - swivel
FXSD - fixed side facing
BSID - bench side facing

c. Direction of Forward-Lateral-Aft Forces

FWD - forward
FWRT - forward and right
RGT - right
RAFT - right and aft
AFT - aft
LAFT - left and aft
LFT - left
FWLF - forward and left

d. Vertical Forces

DMIN - downward-minor
DMOD - downward-moderate
DSEV - downward-severe
UMIN - upward-minor
UMOD - upward-moderate
USEV - upward-severe

e. [illegible]

NONE - [illegible]
MIN - minor [illegible]
[illegible]
[illegible]
MOD - moderate [illegible]
[illegible] moderate [illegible]
[illegible] seat [illegible] and/or [illegible]
SEV - severe [illegible] buckled [illegible]
seats, [illegible] seat [illegible]
and/or [illegible]
NA - not applicable
UNK - unknown

f. Seat-To-Track/Floor Attachment

ATT - seat remained attached to [illegible]
SLID - seat remained attached but [illegible]
PDET - seat partially detached [illegible]
DET - seat completely detached from [illegible]
NA - not applicable
UNK - unknown

g. Seat Legs and/or Pedestal Damage

NONE - No seat deformation
MBNT - minor bending or deformation of seat leg and/or pedestal
SBNT - severe bending or deformation but seat legs and/or pedestals not broken
BKN - legs and/or pedestals broken but not separated
BSEP - legs and/or pedestal broken in several places and separated
NA - not applicable
UNK - unknown

XI. SEATS (Con't)

h. Pan/Frame:

NONE - no deformation or damage
MIN - minor
MOD - moderate
SEV - severe or separated
NA - not applicable
UNK - unknown

XII. SEAT BACK DAMAGE

a. Joint--(type of attachment of back to pan)

FXD - fixed, rigid, not moveable
HNL - hinged, moveable but not lockable
HLCK - hinged and lockable
NA - not applicable
UNK - unknown (other in writing)

b. Attachment
Damage of seat back attachment to seat pan:

NONE - no damage
MBNT - minor bending at attachment
SBNT - severe bending at attachment
BKN - broken but not detached
NA - not applicable
UNK - unknown

c. Upright — Damage to seatback upright (other than attachment to pan)

NONE - no damage
MBNF - minor bending forward (toward pan)
MBNB - minor bending backward (back from pan)
SBNF - severely bent forward (toward pan)
SBNB - severely bent backward (back from pan)
BKN - frame broken but not separated
BSEP - frame broken and separated
NA - not applicable
UNK - unknown

XIII. LAP BELTS

a. Use:

YES - used
NINS - not installed
NO - installed not used
UNK - unknown

b. Function:

HELD - held with no problem
RFLR - complete failure at right attachment
LFLR - complete failure at left attachment
CFLR - complete failure both attachments
OFLR - failure of hardware other than attachment

CODING (Continued)

XIII **LAP BELTS** (Con't)

PWEB - partial failure of webbing
CWEB - complete failure of webbing
UNK - unknown
(other in writing)

XIV. **UPPER TORSO RESTRAINT (UTR) - (SHOULDER HARNESS)**

a **Type**

DOBL - double
SNGL - single
NONE - none
UNK - unknown

b **Use**

YES - used
NINS - not installed
NO - installed but not used
UNK - unknown

c **Function**

HELD - held with no problem
AFLR - complete failure at aft attachment
FFLR - complete failure at forward attachment
BFLR - complete failure of both attachments
OFLR - failure of hardware other than attachments
PWEB - partial failure of webbing
CWEB - complete failure of webbing
NA - does not pertain
UNK - unknown
(other write in)

XV. **CODES FOR INJURIES AND INJURY CAUSES**

a **Severity of Injury**

FATL - fatal
MSDL - serious with more than 10% residual disability expected
SER - serious
MIN - minor
NONE - none
UNK - unknown

b. **Head, Skull and Brain**

A - blunt trauma with multiple fractures 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
NSA - no significant abnormalities
UNK - unknown

CODES (Con't)

c **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
NSA - no significant abnormalities
UNK - unknown

d **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
X - dislocated wrist
M - contusions, abrasions or lacerations
NSA - no significant abnormalities
UNK - unknown

e **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 - closed pneumothorax
K - bleeding into pleural cavities
NSA - no significant abnormalities
UNK - unknown

f **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

CODES (Con't)

f **Abdomen** (Con't)

F - internal bleeding slight
G - contusion with rupture of internal organs
H - contusion with abdominal symptoms
I - contusion and abrasions without internal symptoms
NSA - no significant abnormalities
UNK - unknown

g **Pelvis**

A - multiple fractures
B - simple fractures
C - contusions without fractures
D - rupture of bladder
E - lacerations and/or abrasions
NSA - no significant abnormalities
UNK - unknown

h **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
X - dislocation knee
NSA - no significant abnormalities
UNK - unknown

i. **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
NSA - no significant abnormalities
UNK - unknown

CODING (Continued)

XVI. CAUSES OF INJURIES

a. Seat Involvement

NO - caused no injury
A - distorted and cushioned impact
B - partially broke, not adding to injury
C - partially broke, adding to injury
D - failed badly, did not add to injury
E - failed badly, added to injuries
NA - does not apply
UNK - unknown

b. Lapbelt Involvement

NO - caused no injury
A - left abrasions and contusions on pelvis, abdomen
B - apparently rode high and compressed abdomen
C - without serious injury
D - apparently rode high and compressed abdomen with internal injuries
NA - does not apply
UNK - unknown
FLR - failure

c. Upper Torso Restraint (shoulder harness)

NO - caused no injury
A - left abrasions and marks on chest without injury
B - abrasions and contusion of chest
C - contusion and fracture of chest
NA - does not apply
UNK - unknown

d. Cockpit/Cabin Structure Involvement

NO - caused no injury
A - struck yoke
B - struck instrument panel
C - struck back of seat
D - struck partition or divider
E - struck by flying object
F - impact with floor
G - impact with rudder pedals
H - impact with windscreen or windows
I - struck cockpit/cabin structural member, post, etc.
J - struck overhead

X. DAMAGE INDEX

DAMAGE SEVERITY ***** STRUCTURE OF OCCUPIABLE AREA

DAMAGE SEVERITY	F/W	TOP	BTM	RGT	LFT		GRADE		SCORE
Intact							½		
Distorted							1		
Bent/Partially Collapsed							3		
Collapsed/Buckled							6		
Torn-Free Disintegrated							7		
							TOTAL		

SCORE	DEGREE OF DAMAGE	
0-2½	Minor	MIN
3-7	Moderate	MOD
7½-13	Moderately Severe	MDSV
13½17	Severe	SEV
17½21	Extremely Severe	EXSV
21½36	Extreme	EXTR
	Unable to Classify	UCLA

DAMAGE SEVERITY **** NON OCCUPIABLE AREA

DAMAGE SEVERITY	NOSE	TAIL	R/WG	L/WG			GRADE		SCORE
Intact							1		
Distorted/Wrinkled							2		
Bent/Partially Collapsed							3		
Buckled/ Crumpled							4		
Broken/ Collapsed							5		
Torn-Free Disintegrated							6		
							TOTAL		

SCORE	DEGREE OF DAMAGE	
0-4	Minor	MIN
5-8	Moderate	MOD
9-12	Moderately Severe	MDSV
13-16	Severe	SEV
17-20	Extremely Severe	EXSV
21-24	Extreme	EXTR
	Unable to Classify	UCLA

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