U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

UNITED STATES ARMY AVIATION CRASH INJURY RESEARCH

Final Report

U. S. ARMY TRECOM Contract DA 44-177-TC-802

16 September 1961 to 15 December 1962

TRECOM Technical Report 63-23

prepared by:

AVIATION CRASH INJURY RESEARCH
PHOENIX, ARIZONA
A DIVISION OF
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NEW YORK, NEW YORK

FSF

HEADQUARTERS
U. S. ARMY TRANSPORTÁTION RESEARCH COMMAND
Fort Eustis, Virginia

This report was prepared by Aviation Crash Injury Research, a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-TC-802. Work reported herein was performed during the period 16 September 1961 - 15 December 1962.

During the contract year, thirteen separate work items were pursued by the contractor. These are briefly discussed on an individual basis. Where a project resulted in the publication of a technical report, a resumé of the conclusions and recommendations contained therein is presented. All such conclusions and recommendations are concurred in by this Command.

Aviation crash injury research is a continuing program. Since the U. S. Army Transportation Research Command assumed cognizance of this task in 1959, data of the type discussed in this report have been accumulated through accident investigations, aircraft evaluations, statistical analyses, and experimental crash tests. These data have been used to substantiate the recommendations made for changes in military specifications and aircraft design criteria. Many changes have already been made; others will be made as the data are validated.

FOR THE COMMANDER:

KENNETH B. ABEL
Captain, TC
Adjutant

APPROVED BY:

WILLIAM J. NOLAN
USATRECOM Project Engineer

TRECOM Technical Report 63-23
December 1962

UNITED STATES ARMY AVIATION

CRASH INJURY RESEARCH

FINAL REPORT

under

U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
Contract DA 44-177-TC-802
Task 1AO24701A12101
(Formerly Task 9R95-20-001-01)

16 September 1961 to 15 December 1962

AvCIR 62-29

Prepared by
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for
U. S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

ACKNOWLEDGEMENTS

The Flight Safety Foundation is greatly appreciative of and wishes to acknowledge the voluntary contributions of members of its Technical Supervision Committee, particularly those by I. Irving Pinkel, in connection with the overall experimental research program.

Dr. Lee Gregg, Professor of Psychology, Carnegie Institute of Technology, was extremely helpful in guiding the statistical and psychological approach to aircraft crash injury analysis and in his assistance in supervision and monitoring the expanded program undertaken during this contract period.

Extensive assistance was rendered by the Office of the Surgeon General, Department of the Army, through the assignment of Lloyd E. Spencer, Major, MSC, to the project.

U. S. Army TRECOM also contributed greatly by the detailing of a flight surgeon, Daniel J. Schneider, Captain, MC, and the later assignment of James Schamadan, Captain, MC, as his replacement, to this activity. The efforts of these full-time professional medical specialists have greatly enhanced the overall research effort of this organization.

The close cooperation rendered by the United States Army Board for Aviation Accident Research in all fields of endeavor undertaken is greatly appreciated.

The knowledgeable guidance rendered by John P. Stapp, Colonel, USAF, in the field of human tolerance has greatly assisted all phases of our endeavor, especially the experimental research program.

The close cooperation rendered by the various State agencies in the support of our aircraft accident data accumulation effort is gratefully acknowledged. Without the support of the countless field investigators involved, this program would not have reached the successful proportions it did.

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ILLUSTRATIONS

ILLUSTRATIONS (Cont'd.)

SUMMARY

During this year of the program of Army Aviation Flight Safety, added emphasis was given to full-scale remote control crash testing of aircraft and to the development and testing of crash and postcrash fire inerting and suppression systems. Intensive activities were carried on in statistical analysis. Work continued in the training of crash injury investigators and in the field investigation of Army aircraft accidents. Definite accomplishments can be reported in all work items. The basic contract was amended during the third quarter of the contract year to increase the scope of work under the basic contract to provide for the acquisition of a second remote control system for the droning of rotary-wing aircraft. The contract was further amended to extend the completion date to 15 December 1962.

PART I

1. Because of the character of aircraft accident experience during this period, only four military accidents were investigated which would fall into the normal framework of crash injury investigation.

   These were:

   U. S. Army L-19A Aircraft Accident, Holloman Air Force Base, New Mexico - 26 October 1961; Technical Report No. TREC 62-9.

   U. S. National Guard H-13E Helicopter Accident, Amityville, New York - 5 January 1962; TCREC Technical Report No. 62-64.

   U. S. Army L-19E Aircraft Accident, Fort Carson, Colorado - 22 January 1962; AvCIR Technical Report No. 62-2.

   U. S. Army HU-1A Iroquois Helicopter Accident, Fort Carson, Colorado - 7 May 1962; TCREC Technical Report No. 62-87.

   In the civilian field, one accident was investigated which was of special significance to the Army since nap-of-the-earth-type Army operations are very similar to the cropduster operation. This accident, which occurred at Phoenix, Arizona, 18 October 1961, involved a Snow S-2B Aerial Applicator, TCREC Technical Report No. 62-43.

These investigations all resulted in reports which were published during this period.

2. Tasks related to the collection, analysis, and dissemination of data pertaining to crash safety design criteria studies were completed and reported upon, namely:

   "Strength Analysis of Carriage Attachment Fitting on Crew Seats, HU-1 Aircraft and Recommendations for Improvement", TCREC Technical Report 62-84, October 1962;

   "Modifications to the Passenger Seat Belt Tiedown Attachments in the U. S. Army HU-1 Series Bell Iroquois Helicopter", TCREC Technical Report 62-45; and

   Design for Safety Memos.

3. Accident investigations and full-scale droned testing of aircraft have brought to light several design details contained in military specifications concerning troop seats, litters, and crew seats which have special significance to crash injury and which could be improved by redesign or modification.

   During the period, a report recommending extensive modifications of the existing troop seat specifications was forwarded for review and approval. This report was published as "Military Troop Seat Design Criteria", TCREC Technical Report 62-79, November 1962. Extensive effort was also expended in the detailed review of specifications pertaining to the crew seat. As a result of this study, a report titled "Crew Seat Design Criteria for Army Aircraft" is contemplated in the near future. The evaluation of the litter specification had been held in abeyance pending the results of the full-scale droned helicopter crash which was conducted on 12 September 1962. The data obtained from this test will form a basis for a report* designating the required modification or revision of the litter specification.

4. Two major tests were conducted during this reporting period in the current series of helicopter crash tests. Both of these tests involved remotely controlled H-21A helicopters. The first of these tests (T-6), employing a simple and extremely limited remote control system, was conducted on 29 July 1962. Installed in the aircraft, in which a postcrash fire was anticipated, was a 30-bottle ambient air sampling system (designed and fabricated by AvCIR), five ambient air temperature thermocouples, three calorimeters, and a left and right aircraft engine exhaust manifold temperature pickup. Three accelerometers were also installed to measure the vertical, lateral, and longitudinal accelerations to which the airframe would be exposed.

   The other major experiment (T-7) in this series of H-21A helicopter crash tests was conducted on 12 September 1962. One objective of the test was to determine the manner in which forces are developed in the structure of an aircraft during survivable crash conditions; to trace these forces through the aircraft structure and through the components, such as seats, litters, and restraint systems; and to determine how these forces affect the occupants during the crash. The other major objective was to dynamically test, under actual crash conditions with a postcrash fire, a postcrash fire inerting system designed and fabricated by AvCIR for the purpose of reducing or eliminating the incidence of postcrash fire in aircraft accidents.

5. A study was conducted under subcontract with Vought Aeronautics, a Division of Chance Vought Corporation, to determine the feasibility of a dynamic testing device with the capability of reproducing accelerations and crash forces experienced in aircraft accidents in three planes (vertical, longitudinal, and lateral) simultaneously with independent control of the accelerations and pulse shapes in each plane.

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* Reference: TRECOM Technical Report 63-3, AvCIR 62-23.

The study was completed and a draft report was submitted in February 1962.

6. A report was compiled, entitled "Helmet Design Criteria, Based on the U. S. Army APH-5 Helmet Evaluation", TCREC 62-57, April 1962, which presents, in addition to a complete evaluation of the currently employed crash helmet, the APH-5, a conceptual design of an improved head protective device incorporating desirable features of a crash helmet.

7. During the reporting period, two drafts of statistical studies were prepared, namely:

   "Mechanisms of Injury in Modern Lightplane Crashes: A Statistical Summary of Causative Factors"; and "Judgement of Volume from Photographs of Complex, Irregular Shapes."

   Various other tasks were generated from the aforementioned drafts as follows: Structural Analysis of Light Aircraft, Development of Damage Rating Scale, Evaluation of Impact Severity Measures, and Reliability of Damage Ratings by Direct and Photographic Methods.

8. Some of the symposia significant to the work effort under this contract which were attended are as follows:

   International Congress of Aviation and Cosmonautical Medicine, Paris, France, 26-30 September 1961;

   Impact Acceleration Stress Symposium, Brooks Air Force Base, San Antonio, Texas, 26-30 November 1961; and

   Aviation Crash Injury Research Symposium, Arlington, Virginia, December 1961.

9. During the contract period, five training courses of 2 weeks' duration were held, in which 39 military students were trained. Of these, 20 were flight surgeons and aviation medical officers and 19 were aviation officers.

10. Other tasks related to crash injury developed during the contract period were:

"Dynamic Test of an Experimental Troop Seat", TCREC Technical Report 62-48, June 1962;

"Breakaway Fuel Cell Concept", TREC Technical Report 62-37, May 1962; and

"Handbook for Aircraft Accident Investigators", April 1962.

11. During this period, an additional work item was initiated which specified that "The Contractor shall search, gather, catalogue, and evaluate applicable information and data on impact acceleration." Thus, Project SIAT (Synthesis of Impact Acceleration Technology for aviation crash injury prevention) was initiated under the auspices of the U. S. Army Transportation Research Command. Approximately nine hundred documents, unique to this study, were catalogued and are available in a library at the AvCIR facility in Phoenix, Arizona. Approximately three hundred additional references of apparent applicability were also identified and are being obtained, where possible, at the time of this report's preparation. A bibliography is currently being published.

12. In order to properly simulate an actual crash, it is necessary to have all components, i. e., the engine, rotors, transmissions, etc., operable so that actual crash loads and kinematics can be recorded. Therefore, the study of the feasibility of an aircraft droning system device was completed and a specification was prepared. The specification for the droning device included the control of an H-21, in flight, into a controlled crash at a predetermined speed, rate of descent, attitude, and angle of impact. Upon evaluation of proposals received, the Kaman Aircraft Corporation was awarded a subcontract for the design and construction of a remote control system; and this unit was successfully utilized in Crash Test No. 7.

PART II

Studies designed to examine the feasibility and practicability of improving the attachment of seat belt and shoulder harness inertia reels for crew and passengers in selected Army aircraft were completed during this period.

These were:

Personnel Restraint Systems Study - Basic Concepts;

Personnel Restraint Systems Study - AC-1 DeHavilland Caribou;

Personnel Restraint Systems Study - HC-1B, Vertol Chinook; and

Personnel Restraint Systems Study - HU-1A and HU-1B Bell Iroquois.

WORK ITEM 1

FIELD INVESTIGATION OF ACCIDENTS

"The Contractor shall conduct crash injury investigations of selected military and civilian aircraft accidents which, in the judgment of the Contractor, have significant crash safety or crash survival aspects. The Contracting Officer may also designate specific aircraft accidents to be investigated subject to availability of Contractor personnel to perform such work."

Postcrash investigation of aircraft accidents provides valuable information on engineering and medical factors directly related to survivability and, in turn, provides support for improvements in crash safety design.

Military and civilian aircraft accidents, screened for significant crash safety or crash survival aspects, are fully investigated by personnel of this organization, and reports are completed.

Four military accidents and one civilian accident of this nature were selected for investigation, and subsequent reports were made during this period.

These were:

1. U. S. Army L-19A Aircraft Accident, Holloman Air Force Base, New Mexico - 26 October 1961;
2. S-2B Snow Aerial-Applicator Accident, Phoenix, Arizona - 18 October 1961;
3. U. S. National Guard H-13E Helicopter Accident, Amityville, New York - 5 January 1962;
4. U. S. Army L-19E Aircraft Accident, Fort Carson, Colorado - 22 January 1962; and
5. U. S. Army HU-1A Iroquois Helicopter Accident, Fort Carson, Colorado - 7 May 1962.

U. S. ARMY L-19A AIRCRAFT ACCIDENT, HOLLOMAN AIR FORCE BASE, NEW MEXICO - 26 OCTOBER 1961 - TREC Technical Report 62-9, February 1962

This accident occurred during performance of simulated bombing attacks on an Army bivouac near Holloman Air Force Base, New Mexico.

The pilot had completed several bombing runs on the camp and was in the process of making a run on a mess tent with the plane in a steep right turn. During this run, the right wing of the aircraft contacted the structure of the mess tent, 13 feet above the ground. After collision with the tent, the aircraft crashed out of control. After lengthy skidding and gyrations, the aircraft came to a stop and burned (Figure 1).

The investigation revealed that the pilot was seriously injured during impact and was then severely burned by the fire which developed at the end of the crash sequence. The observer, in the rear seat, was also injured when he released his lap belt and was ejected from the aircraft during the crash sequence.

As a result of this investigation, it was recommended that:

1. The latching mechanism of the pilot's seat be improved;

2. Consideration be given to the development of crash-fire inerting systems for Army aircraft;

3. Further efforts be devoted to the improvement of the APH-5 retention system; and

4. Radio compartments underneath the rear seat be relocated or padded with energy absorbing material.

S-2B SNOW AERIAL-APPLICATOR ACCIDENT, PHOENIX, ARIZONA - 18 OCTOBER 1961 - TCREC Technical Report 62-43, May 1962

This civilian aircraft accident was of particular interest to the U. S. Army, as nap-of-the-earth-type Army operations are very similar to the cropduster operation. This accident occurred while the aircraft was engaged in applying insecticide to a cotton field near Phoenix, Arizona.

1

Figure 1. Kinematics of
Holloman Air

Figure 1. Kinematics of the Crash Sequence of the L-19A, Holloman Air Force Base, New Mexico.

At the completion of an application run and at approximately 200 feet altitude, the pilot experienced an abnormal vibration in the aircraft which increased in severity until r. p. m. control and airspeed were lost and a stall occurred.

The aircraft crashed in a near-vertical position, left wing first, progressively collapsing the nose up to the forward main wing spar. Rebounding to an upright position, the aircraft spun counterclockwise nearly a half-turn, where it came to rest (Figure 2).

Investigation revealed that the crash protection features incorporated into the aircraft were instrumental in crash force attenuation to the cockpit section and damage reduction to the cockpit environment. The moderate injuries sustained by the pilot were directly related to improper use of the shoulder harness. It was further revealed that the location of the shoulder harness is of special significance relative to occupant retention.

As a result of this investigation, it was recommended that:

1. The shoulder harness anchorage be located immediately above the seat back and attached to the roll-bar structure;

2. Inertia reels be incorporated in the restraint system employed in this aircraft; and

3. Consideration be given to the value and utilization of crash protection design, as illustrated in this report, in future Army fixed-wing aircraft which will be utilized in nap-of-the-earth operations.

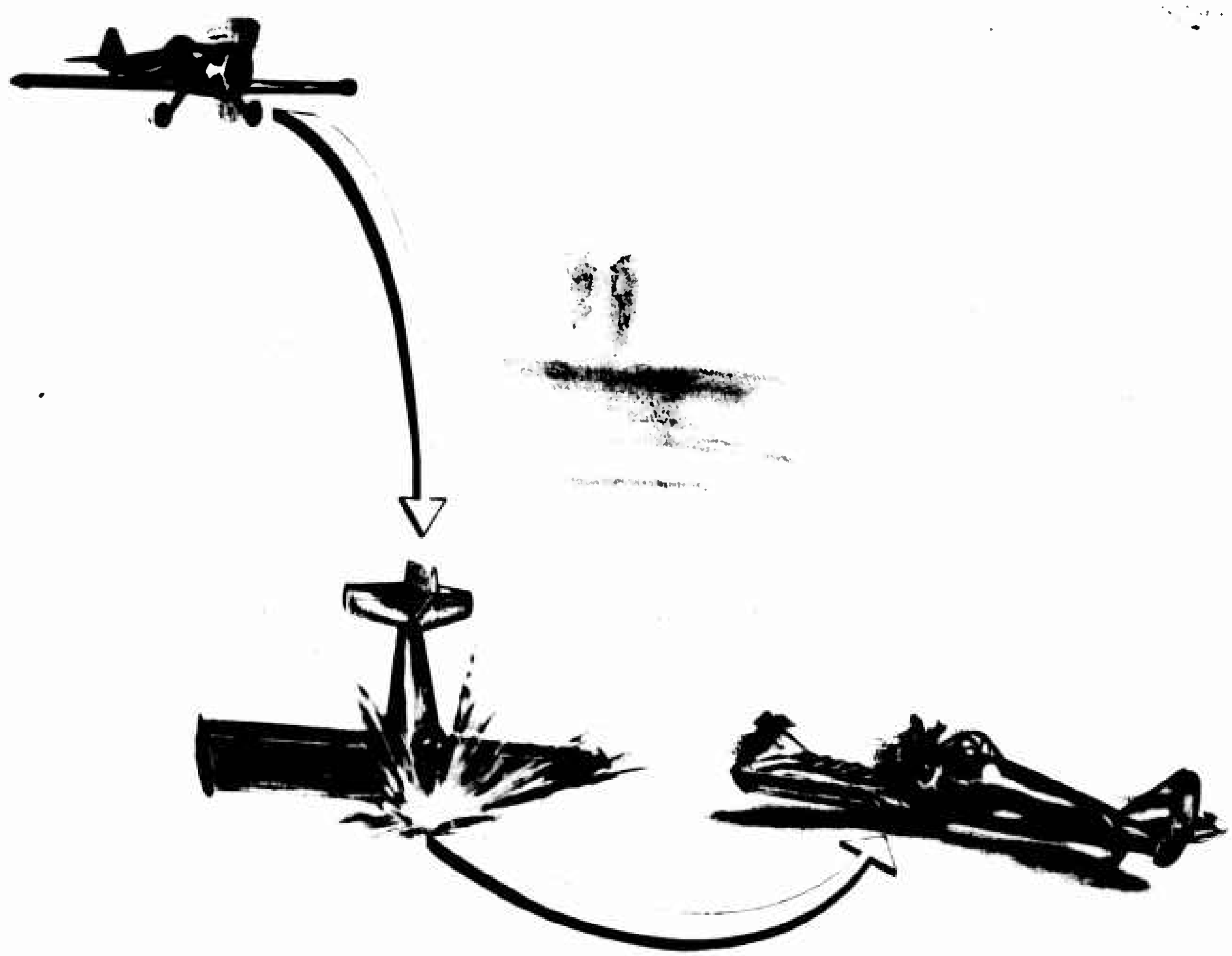

Figure 2. Kinematics of the Snow S-2B Accident, Phoenix, Arizona.

U. S. ARMY NATIONAL GUARD H-13E HELICOPTER ACCIDENT, AMITYVILLE, NEW YORK - 5 JANUARY 1962 - TCREC Technical Report 62-64, August 1962

This accident occurred while the helicopter was on a test flight following routine maintenance. Because of the location of the airport, the flight path required flight over a residential district of Lindenhurst, New York.

Shortly after a normal take-off, engine failure was experienced at about 300 feet altitude. The pilot immediately initiated autorotation, selecting a paved street within a residential district as the forced landing site. During autorotation, an unsuccessful attempt was made to fly over two utility wires obstructing the flight path. In this near-vertical descent, the wires were struck and severed, and the aircraft impacted on the street below (Figure 3). The passenger released his restraint system, evacuated the aircraft, and assisted the pilot in evacuation.

The investigation revealed that the pilot sustained a compression fracture of the vertebra, while the passenger was uninjured.

As a result of this investigation, it was recommended that:

1. The seat cushion of the H-13 series helicopter be fabricated of energy absorbing material (yield strength of approximately 12 pounds per square inch) to prevent magnification of forces and to reduce transmission of forces;

2. Unyielding components or accessories not be positioned directly beneath occupants' seat pans in design of future helicopters; and

3. A study be undertaken to determine the effects of flight control positioning and/or apprehension in causing pilots to assume a forward flexed position during anticipated crash maneuvers.

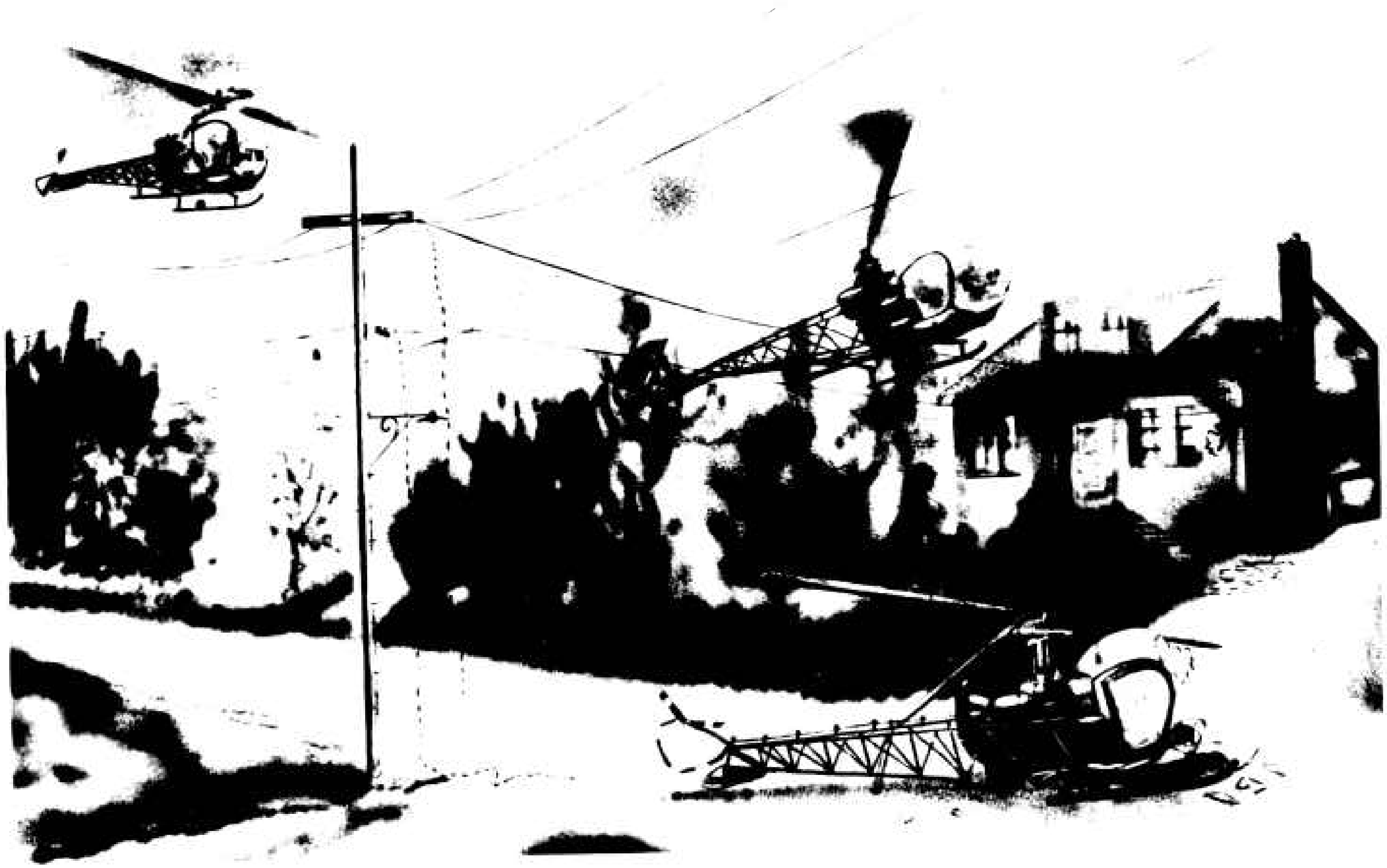

Figure 3. Crash Sequence of the H-13E Accident, Amityville, New York.

U. S. ARMY L-19E AIRCRAFT ACCIDENT, FORT CARSON, COLORADO - 22 JANUARY 1962 - Memorandum Report, AvCIR 62-2, February 1962

The aircraft involved in this accident was engaged in a simulated low-level bombing attack on Army troops and vehicles near Butts Army Airfield on the Fort Carson military reservation.

The pilot had completed several runs when he inadvertently struck the ground in a level attitude. The aircraft then bounced back into the air and struck again, 36 feet distant, tearing the left landing gear and wing strut free and then sliding with a slight roll to the left, on the fuselage, for 300 feet. At this point, an embankment was struck by the right landing gear and the right wing dropped and was crumpled under the fuselage; the fuselage then continued to slide for approximately 600 feet (Figure 4).

Investigation revealed extensive damage to the entire aircraft and inward collapse of the occupiable area. The pilot sustained compression fractures of the vertebrae and lacerations of the face. The passenger received only a minor head laceration.

It is believed that the attachment of the restraint system to primary structure prevented more serious injuries to the occupants than could be expected in accidents with damage incurred of this magnitude.

As this accident investigation resulted in only a memorandum report, no recommendations were made that were not adequately covered by reports of previous accidents involving the L-19 aircraft.

U. S. ARMY HU-1A IROQUOIS HELICOPTER ACCIDENT, FORT CARSON, COLORADO - 7 MAY 1962 - TCREC Technical Report 62-87, November 1962

This accident occurred while the aircraft was engaged in a service mission within the Fort Carson military reservation. Aboard the aircraft were the pilot and five passengers.

Prior to the crash, the pilot made an attempt to fly out of an apparent high rate of sink. Realizing that the attempt would be unsuccessful, the pilot executed a full flare and committed the aircraft to a crash landing. Initial impact occurred on the tail skid, followed by the tail boom, which failed just forward of the tail pylon. The main fuselage impacted on the right skid, the rotor blades cutting into the tail section; the aircraft then rebounded into the air. On the second impact, it struck the ground slightly, rolled to the left and the flailing blades completely severed the tail boom; again the aircraft became slightly airborne, whence it turned to the left and struck the ground a third time on its right side. At this point, the remaining fuselage rolled over one and one-half times, and came to rest inverted. During the roll, various components were torn free and dispersed throughout the area (Figure 5).

Five of the six occupants received varying degrees of injury ranging from minor to severe, and one passenger became a fatality.

The investigation revealed that the predominant cause of injury was failure of all roof support members. The investigation also revealed a continuing trend in the failures of the carriage attachment fittings in the crew seats.

As a result of the crash injury investigation, it was concluded that appropriate changes to the basic helicopter structure and seat structure are required to provide acceptable crashworthiness standards.

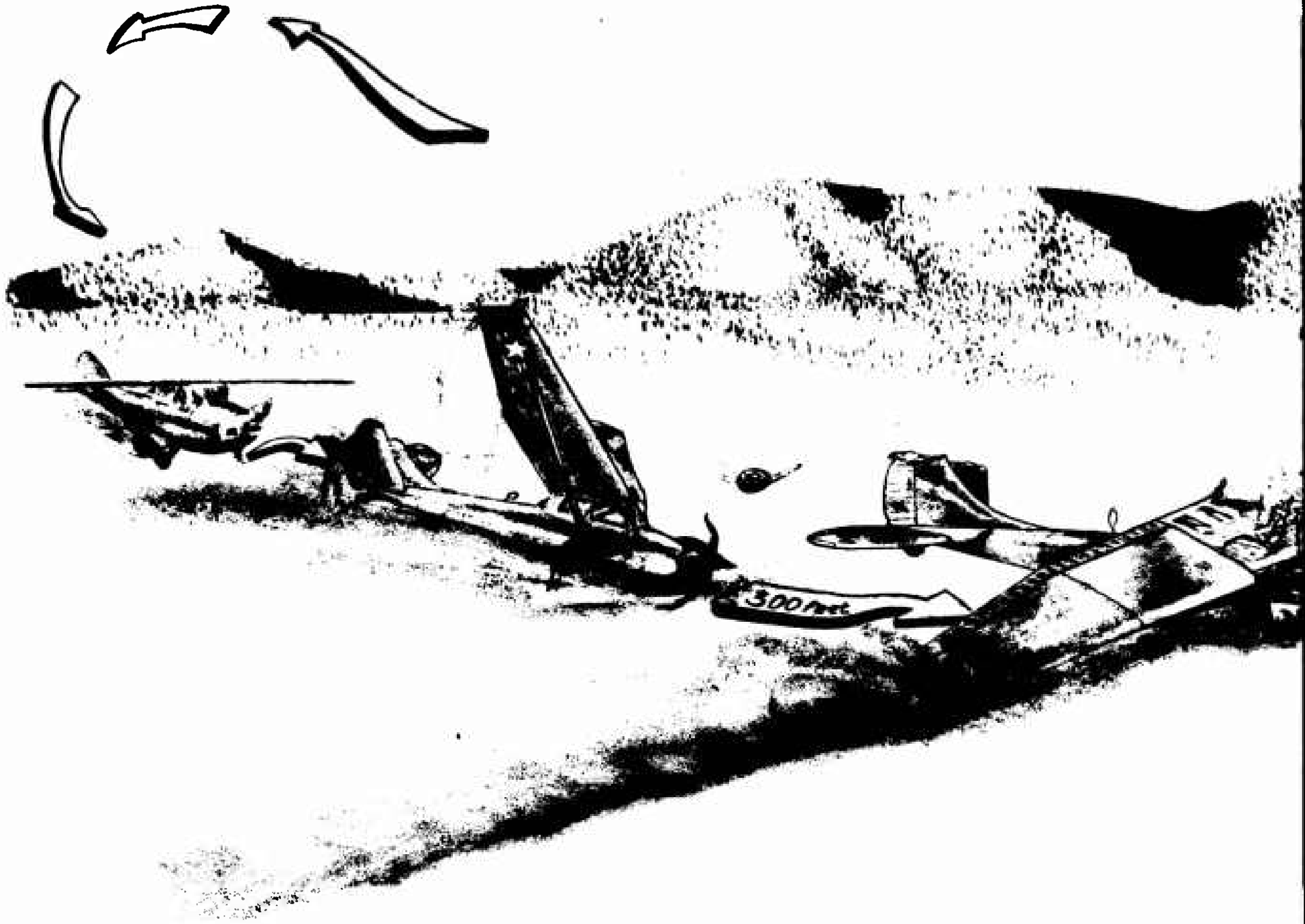

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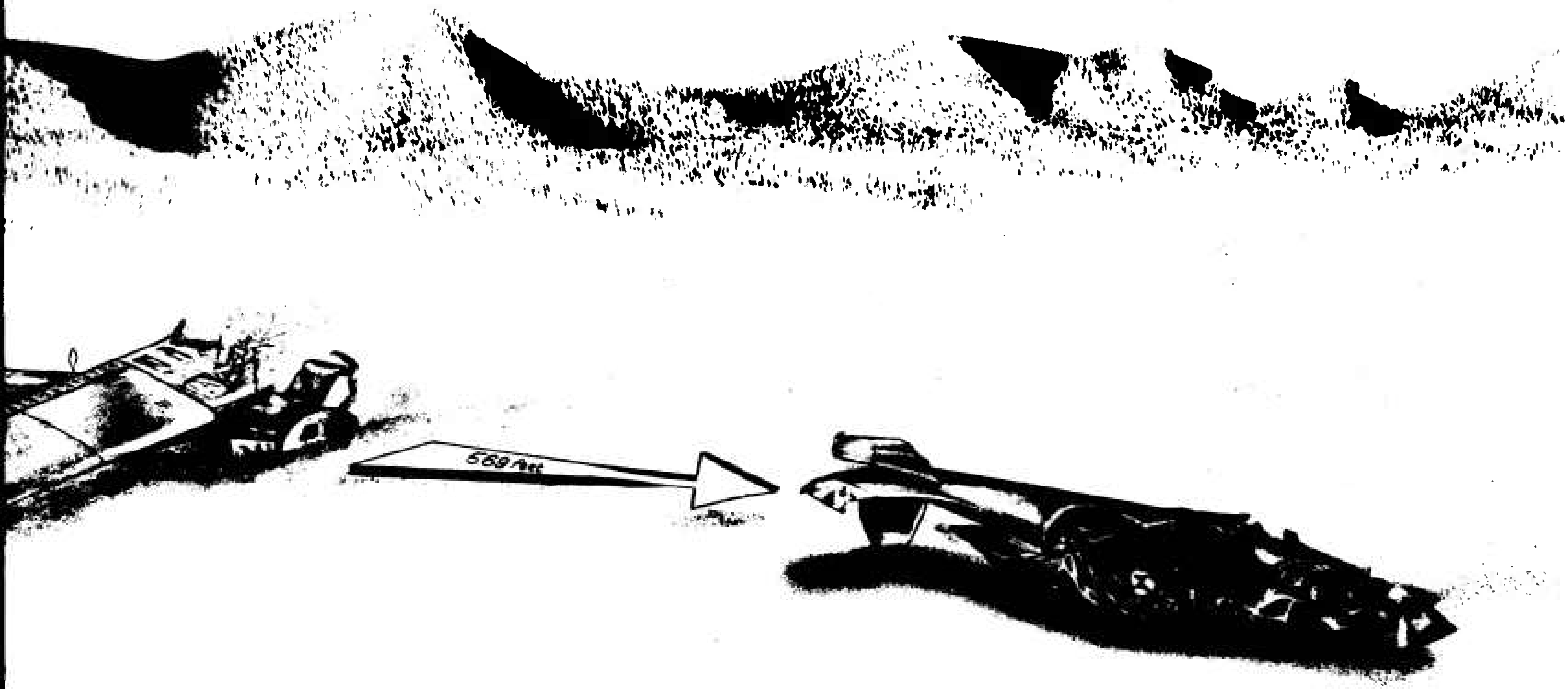
Figure 4. Kinematics of the L-19E Accident, E



L-19E Accident, Fort Carson, Colorado.

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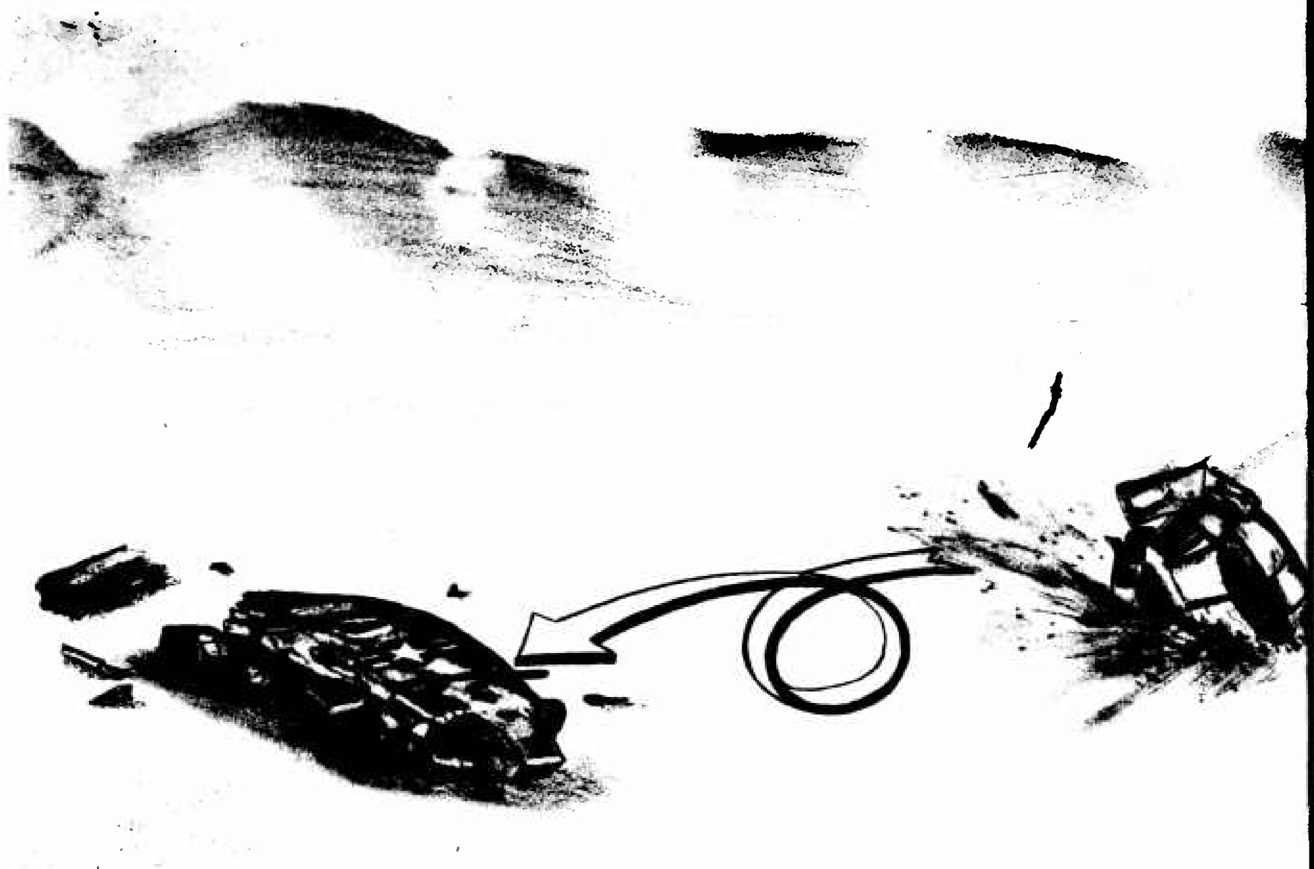

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Figure 5. Crash Sequence of th

Figure 5. Crash Sequence of the HU-1A Accident, Fort Carson, Colorado.

2

WORK ITEM 2

CRASH SAFETY DESIGN CRITERIA

"The Contractor shall collect, analyze and disseminate data pertaining to crash safety design criteria."

AvCIR continues to collect, collate, and analyze crash survival data, placing emphasis on impact accelerations and human tolerance. Data relative to the dynamic response of rotary-wing aircraft and their components, generated in the full-scale helicopter crash tests conducted during 1961 and 1962 (item 4), are being studied and compared with existing data for their effect on, and for possible inclusion as, specific recommendations in a proposed Army handbook of instructions for aircraft design engineers, specification developers, research groups, and other interested agencies.

Some of the accomplishments completed under Work Item 2 are as follows:

> Strength Analysis of Carriage Attachment Fitting on Crew Seats, HU-1 Aircraft, and Recommendations for Improvement, TCREC Technical Report 62-84, October 1962.
>
> Modifications to the Passenger Seat Belt Tiedown Attachments in the U. S. Army HU-1 Series Bell Iroquois Helicopter, TCREC Technical Report 62-45, May 1962.
>
> Design for Safety Memos.

STRENGTH ANALYSIS OF CARRIAGE ATTACHMENT FITTING ON CREW SEATS, HU-1 AIRCRAFT AND RECOMMENDATIONS FOR IMPROVEMENT, TCREC Technical Report 62-84, October 1962.

The crew seat of the HU-1A aircraft has failed frequently in survivable-type accidents, with the primary failure occurring in the carriage attachment fitting (part number 204-070-742-1). The most recent accident investigated by this agency occurred at Fort Carson, Colorado, 7 May 1962 (reference Item 1, TCREC Technical Report 62-87). Analysis disclosed that occupant inertia load of the order of 11G could have caused these failures.

A simple field modification was presented which would reduce stresses in the fitting by a factor of approximately two. No new parts needed to be manufactured; two AN bolts and one NAS spacer were the only additional parts required.

On the basis of accident evidence and a detailed stress analysis of the existing attachment fitting, it was concluded that the fitting is excessively stressed due to the moment fixity of its connection to the carriage channel. Consequently, it presents a weak link in the tiedown chain (seat belt, seat belt anchorage, shoulder harness and anchorage, seat structure, seat anchorages, and floor). Based upon the disclosures of the analysis, it was recommended that the proposed field modification (Figure 6) be incorporated on all HU-1A and HU-1B aircraft.

MODIFICATIONS TO THE PASSENGER SEAT-BELT TIEDOWN ATTACHMENTS IN THE U. S. ARMY HU-1 SERIES BELL IROQUOIS HELICOPTER, TCREC Technical Report 62-45, May 1962

Analysis of several HU-1 helicopter accidents disclosed a definite weakness in the occupant tiedown system. This deficiency has contributed, either directly or indirectly, to the injury of personnel involved in these accidents.

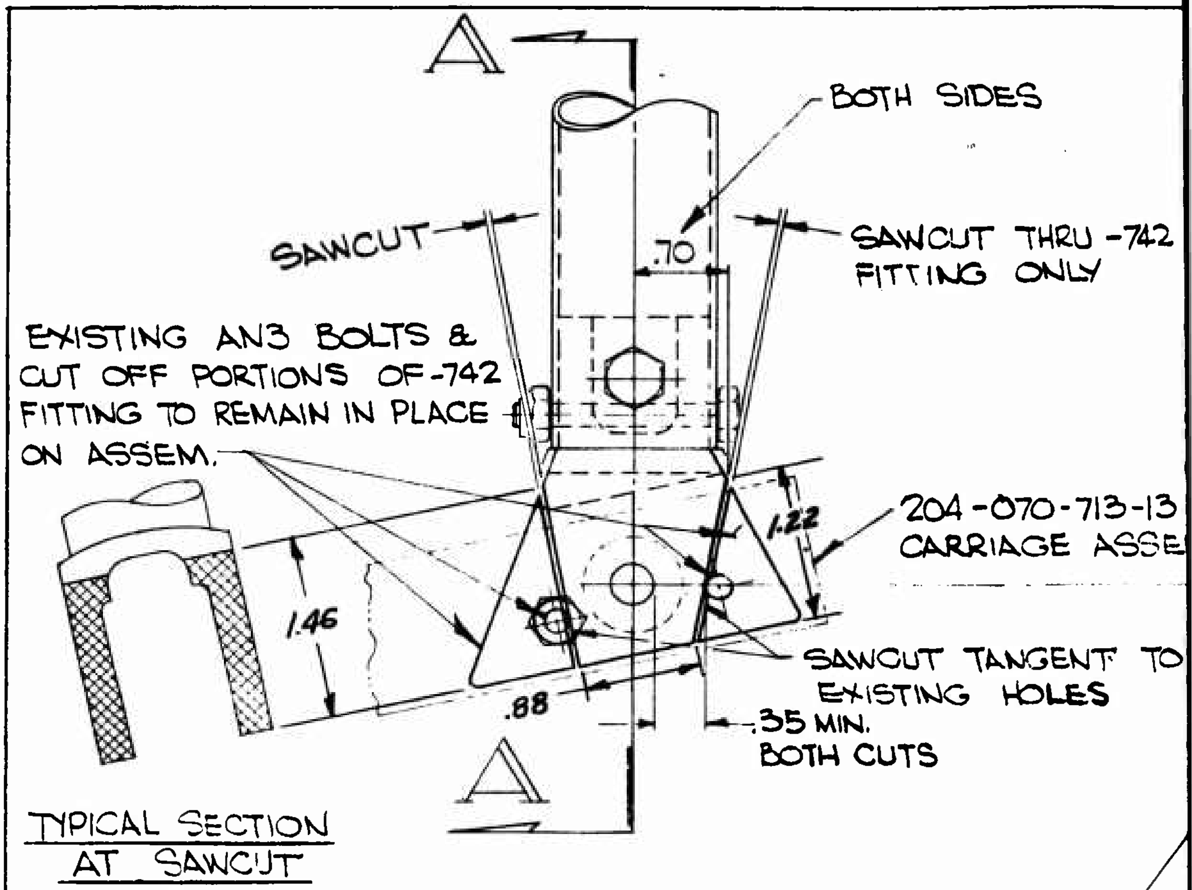
This report proposed both an interim fix and a permanent solution to the problem of troop seat safety belt anchorage failures in the HU-1 series aircraft. A quick "off the shelf" interim fix to make the existing tiedown system four times more effective and a permanent fix that would ensure that the strength of the tiedown was equal to the seat belt strength was proposed.

A complete list of equipment required, cost of retrofit, man-hours for installation, detailed installation drawings, and step-by-step retrofit instructions for use of maintenance personnel were included in the report.

Figure 7 depicts the interim fixes recommended in the report.

DESIGN FOR SAFETY MEMOS

The dissemination of data pertaining to crash safety design has been initiated in the form of single-page "design for safety memos."



7. REASSEMBLE IDENTICAL TO EXISTING ARRANGEMENT
6. THE CUT OFF PORTIONS OF 204-070-742 TO REMAIN IN PLACE ON REASSEMBLY !
5. DRILL OUT EXISTING ROLLER TO .47 DIA.
4. DRILL NEW 3/16 DIA HOLE THRU TUBE AND FITTING
3. SAWCUT FITTING AS SHOWN
2. REPLACE EXISTING SPACER WITH NAS43-5-53
1. REMOVE FITTING, 1.25" STEEL TUBE, AND CARRIAGE CHANNEL FROM SEAT…

MODIFICATION PROCEDURE:

1

Figure 6

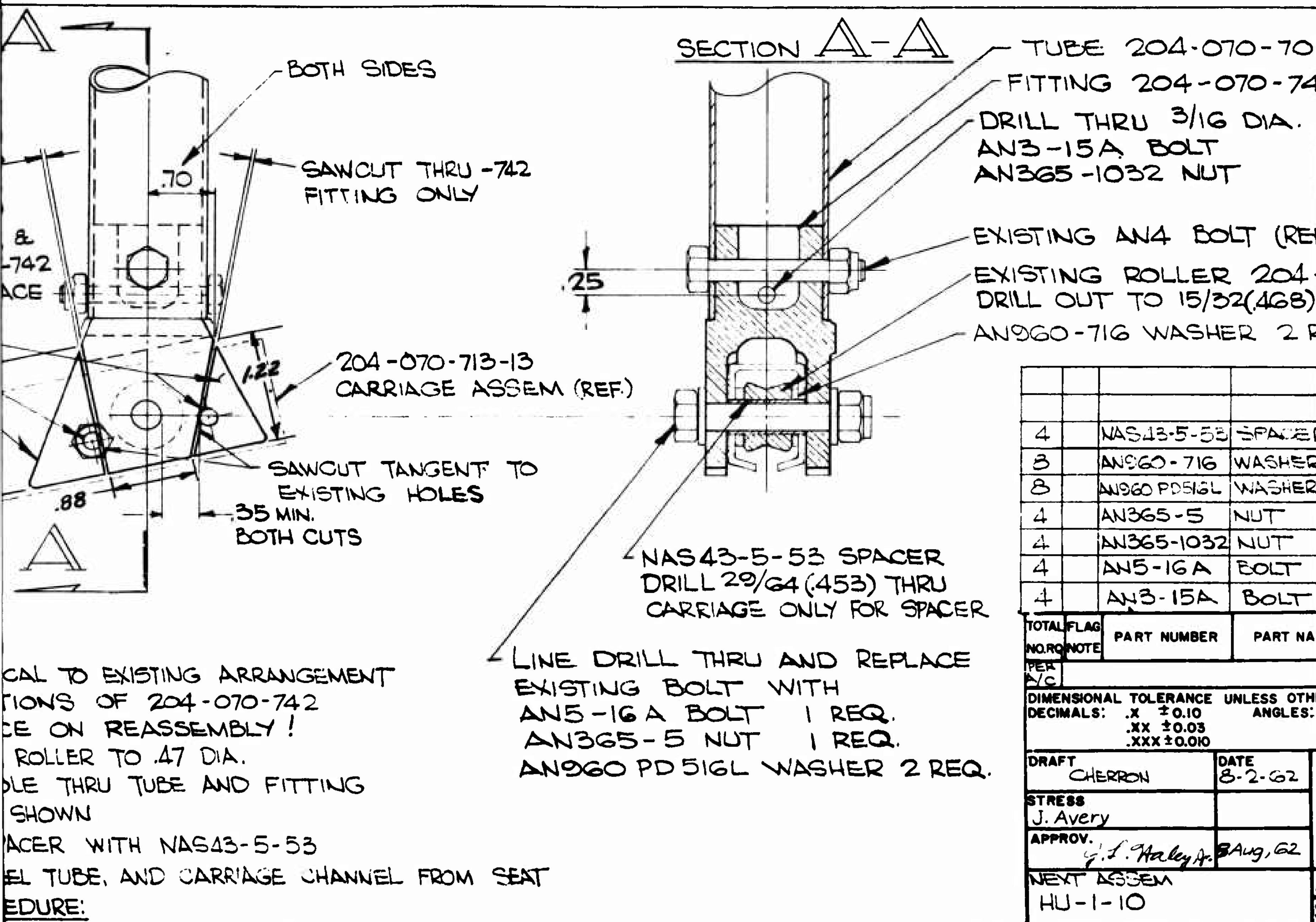
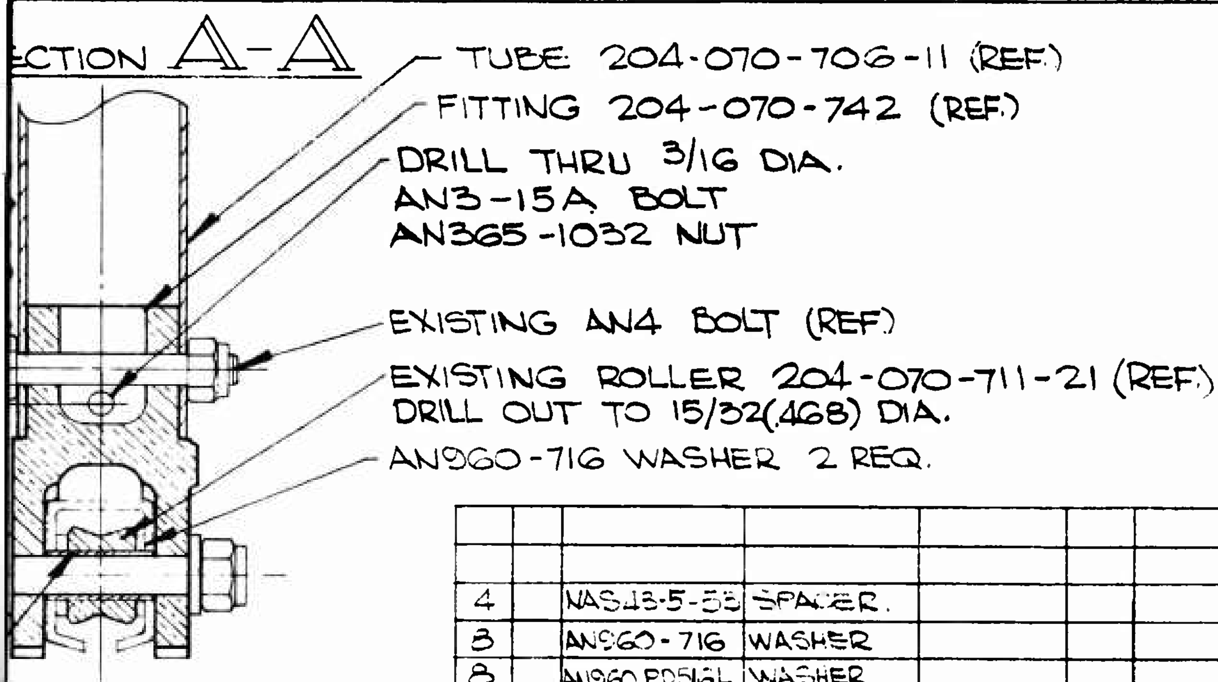


Figure 6. Modification Aft Carriage Attachment, Crew Seat.

N AFT CARRIAGE ATTACHMENT, CREW SEAT



43-5-53 SPACER
L 29/64 (.453) THRU
IAGE ONLY FOR SPACER

THRU AND REPLACE
LT WITH
OLT 1 REQ.
NUT 1 REQ.
IGL WASHER 2 REQ.

TOTAL NO. RQ PER A/C	FLAG NOTE	PART NUMBER	PART NAME	MATERIAL	STOCK	GOVT SPEC.	DIA.	THK	WIDTH	LGTH	FINAL TEMPER	UNIT WT.
4		NAS43-5-53	SPACER.									
8		AN960-716	WASHER									
8		AN960 PD516L	WASHER									
4		AN365-5	NUT									
4		AN365-1032	NUT									
4		AN5-16A	BOLT									
4		AN3-15A	BOLT									

LIST OF MATERIALS

DIMENSIONAL TOLERANCE UNLESS OTHERWISE SPECIFIED:
DECIMALS: .X ±0.10 ANGLES: ±1 DEGREE
.XX ±0.03
.XXX ±0.010

DRAFT CHERRON	DATE 8-2-62	MODIFICATION AFT CARRIAGE ATTACHMENT, CREW SEAT	AVIATION CRASH INJURY RESEARCH A DIVISION OF FLIGHT SAFETY FOUNDATION PHOENIX, ARIZ.
STRESS J. Avery			
APPROV. G. L. Haley Jr.	8 Aug. 62		
NEXT ASSEM HU-1-10		AIRCRAFT: HU-1 SCALE: FULL SIZE	HU-1-12

3

Aft Carriage Attachment, Crew Seat.

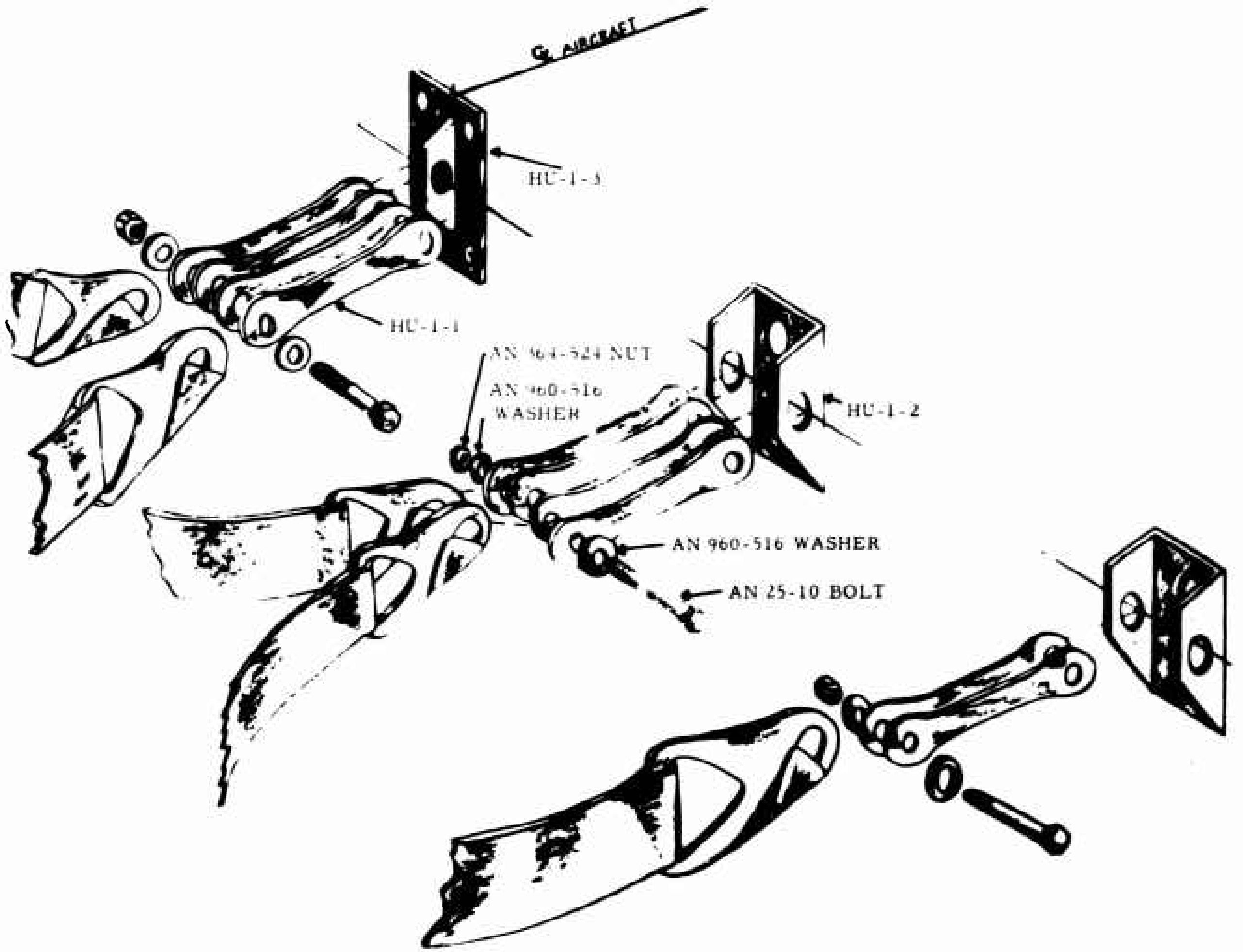


Figure 7. Interim Fix of the Seat Belt Tiedown in the HU-1 Aircraft.

Each memo covers a specific deficiency found in an investigation or analysis of an aircraft accident. This deficiency is illustrated and briefly described for the benefit of aircraft designers. Deficiencies which exist in both military and civilian aircraft are emphasized in these memos.

Three single-page "design for safety memos" have been completed and have received extensive distribution during this period. Approximately 4,000 copies of these memos were mailed to all interested agencies in the aviation field. Response to these design memos has been very favorable, and they will continue to be published and distributed on a periodic basis.

These memos are 62-1 through 62-3, shown on the following pages.

OCCUPANT RESTRAINT

Improper Harness Tiedown Contributed to Fatal Injury

DESIGN FOR SAFETY
AvCIR MEMO

The SITUATION

A light personal plane stalled out during a turn and struck the ground at an estimated speed of 60 mph and a 30 degree angle of impact. The pilot suffered a depressed skull fracture (fatal) when his head struck environmental structure. The cockpit area remained relatively intact and the impact conditions can, therefore, be considered survivable.

The HAZARD

Seat belt and shoulder harness were anchored to the pilot's seat. Consequently, all inertia loads resulting from the crash deceleration were transmitted to the seat-floor anchorages. The two aft legs failed and the seat hinged forward, allowing the pilot to come into forcible contact with structure ahead.

CORRECTIVE ACTION

To reduce the stress on the seat, RESTRAINT SYSTEMS SHOULD BE ANCHORED TO BASIC AIRCRAFT STRUCTURE. If this is not practicable, the seat structure itself and its anchorages should be designed to withstand the ultimate dynamic loads compatible with survivable impact conditions.

AVIATION CRASH INJURY RESEARCH A DIVISION OF FLIGHT SAFETY FOUNDATION, INC.
2871 SKY HARBOR BLVD. PHOENIX, ARIZONA

FSF

AvCIR DFSM NO. 62-1

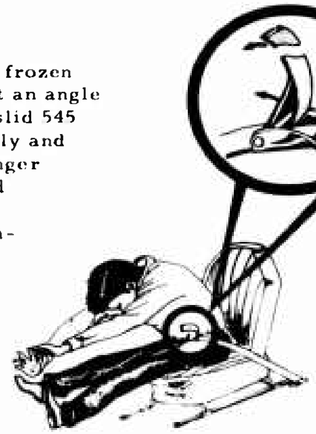
Figure 8. AvCIR Design for Safety Memo No. 62-1.

OCCUPANT RESTRAINT

Inadvertent Release of Seat Belt Buckle

DESIGN FOR AvCIR MEMO SAFETY

The SITUATION



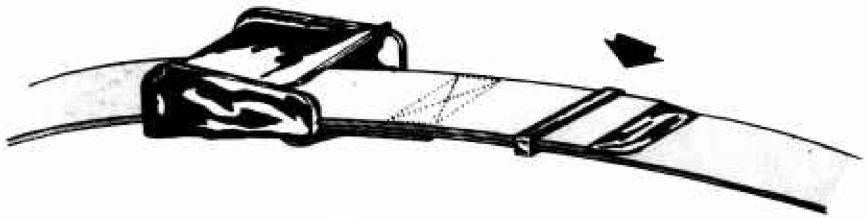
A light aircraft crashed on a snow-covered, frozen lake at a speed of approximately 110 mph, at an angle of approximately 15 degrees. The aircraft slid 545 feet. The pilot's seat belt functioned properly and he survived with minor injuries. His passenger was thrown clear of the aircraft and suffered fatal head injuries. There were no gross failures of the passenger's seat belt and cam-type buckle. Several serration marks in the belt webbing were indicative, however, of intermittent slippage of the buckle. It is assumed that this progression of hold and slip resulted eventually in complete loss of restraint for the passenger.

The HAZARD

It has been shown, experimentally, that inertia loads acting on the "free end" of the seat belt webbing may contribute to buckle slippage by lifting the lip of the buckle. Depending on the nature and the sequence of the crash pulses, this slippage may be complete or partial. In the latter case, part of the webbing may pass through the buckle before it finally locks, thereby imparting heavy jolt loads on the occupant, as well as the entire restraint system.

CORRECTIVE ACTION

One suggested method to avoid inadvertent buckle release due to inertia loads, acting on the unused portion of the webbing, is the incorporation of a belt loop through which the "surplus" webbing of the seat belt can be inserted and held down. The design of the loop should preclude interference with the normal release of the belt.



AVIATION CRASH INJURY RESEARCH A DIVISION OF **FLIGHT SAFETY FOUNDATION, INC.**
2871 SKY HARBOR BLVD. PHOENIX, ARIZONA

AvCIR DFSM NO. 62-2

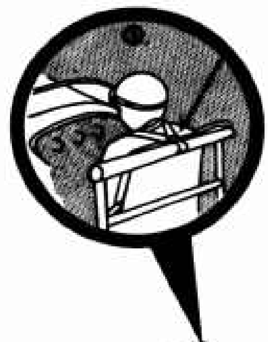
Figure 9. AvCIR Design for Safety Memo No. 62-2.

OCCUPANT RESTRAINT

DESIGN FOR SAFETY — AvCIR MEMO

The SITUATION

A late-model agricultural aircraft, incorporating several crash safety features, struck the ground in a vertical dive after propeller failure at about 200 feet above the ground. The aircraft was completely destroyed, except for the centrally located cockpit and the empennage. The pilot, protected by a seat belt, shoulder harness and helmet, suffered a broken jaw and broken ribs.

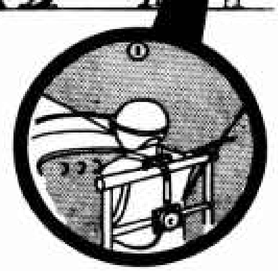


The HAZARD

The shoulder harness was anchored to basic structure, but did not incorporate a spring-loaded reel (Detail 1). In order to have sufficient freedom of movement while utilizing the harness, the pilot was in the habit of wearing the shoulder straps under his arms. Consequently, his head struck the top of the instrument panel during the severe longitudinal deceleration, while the pressure of the shoulder straps caused fractures of his lower ribs. (See figure.)

CORRECTIVE ACTION

The crash resistance of well-designed aircraft structure can be fully utilized only in conjunction with an adequately stressed and used restraint system (seat, seat belt and shoulder harness). To insure proper use of the shoulder harness, without interference with the pilot's movements in the cockpit, it is necessary, in most aircraft, to anchor the shoulder harness via a spring-loaded reel (Detail 2). By making this reel impact-sensitive, in addition to manual-locking provisions, the pilot's upper torso and head protection will be optimal under all crash conditions.



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AvCIR DFSM NO. 62-3

Figure 10. AvCIR Design for Safety Memo No. 62-3.

REVIEW OF TECHNICAL CHARACTERISTICS AND MILITARY SPECIFICATIONS

"When requested by the Contracting Officer, the Contractor shall review and comment on military and technical characteristics and model specifications for Army aircraft components or related equipment. The Contractor shall also evaluate current Army aircraft, mock-ups, and prepared designs for Army aircraft as designated by the Contracting Officer."

Accident investigations and full-scale dynamic testing of aircraft have brought to light several design details contained in specifications concerning troop seats, litters, and crew seats which have special significance to crash injury and which could be improved by redesign or modification.

The military specifications reviewed in connection with this problem include:

1. MIL-S-27174 (USAF) 8 April 1960 - "Seat, Troop, Variable Seating Width";

2. MIL-S-5804B (ASG) 24 September 1957 - "Seat, Troop, Wall-Style, Cargo Aircraft";

3. MIL-A-8865, relating to litter installations;

4. MIL-A-8867, relating to crew seats; and

5. Other specifications relating to seat belt and shoulder harness installations. (See Work Item 2, Crash Safety Design Criteria, and Restraint Systems Study.)

A detailed study and evaluation were made on the aforementioned military specifications pertaining to the troop seats. The purpose of this study was to evaluate certain criteria set forth in the applicable troop seat specifications relative to providing adequate occupant protection during survivable crash force decelerations. A report recommending extensive modification of the existing specifications was entitled "Military Troop Seat Design Criteria."

MILITARY TROOP SEAT DESIGN CRITERIA - NOVEMBER 1962 - TCREC Technical Report 62-79

Strength requirements set forth in military specifications governing the design and fabrication of troop seats currently utilized in Army aircraft were analyzed. The analysis was made in light of accident experience with this seat, human tolerance as presently known, and accelerations and forces which mav be anticipated in accidents involving Army aircraft.

The analysis revealed that the strength requirements were considerably lower than what can be tolerated by the occupants of the seats; they were also lower than the accelerations or forces that are associated with Army aircraft accidents, substantiating the conclusion that these seats fail under relatively minor accident conditions, as experienced by the Army.

This report is very significant in the crash injury prevention field, and recommendations contained therein have been extracted in part and are as follows:

> "Recommendations: The following recommendations are presented in light of the foregoing discussions, with particular consideration being given to the experimentally obtained human tolerance data and to the experimentally obtained acceleration environment for light and medium weight rotary-wing aircraft and C-46 and C-119 cargo transports. They should be considered subject to modification upon the presentation of new data, but are now believed to be the best compromises possible in view of existing evidence."
>
> "It is recommended that the appropriate military specifications applicable to troop seats for rotary-wing aircraft be modified to reflect the following requirements:"
>
> "1. Longitudinal and Lateral Design-Loads: The seat, its support system and the occupant restraint system should in combination be capable of maintaining 25G for 0.20 second and 45G for 0.1 second in the pelvic region of a suitable dummy having a weight and mass distribution of that of the heaviest occupant expected."
>
> "2. Vertical (Headward) Design Loads: The seat, its support system and the occupant restraint system

should in combination be capable of continuously maintaining 25G ±5G in the pelvic region of the dummy described in Paragraph 1, while deforming through at least 12 inches of vertical travel with respect to the airframe and, where possible, up to 15 inches or more of vertical travel. This is an energy absorption requirement and the mechanism in which the energy is absorbed is unimportant. Through appropriate design this can conceivably be done by use of: (a) mechanical devices, (b) crushable materials, or (c) in the seat structure itself. Whatever the method, the acceleration as a function of displacement should be constant at 25G within the specified 5G tolerance in order that the most effective use be made of the limited space between the seat pan and floor. In addition, the seat, its support system, and the occupant restraint system should in combination be capable of sustaining 25G for 0.10 second without gross failure."

"3. Manner of Loading: The 'seat system' should be capable of satisfying requirements 1 and 2 both simultaneously and separately without loss of restraint of the occupant during or after impact and in such manner as to maintain alignment of the occupant torso in a normal sitting position. Further, the system, in event of failure due to loads in excess of the design values, should present no projections or cutting edges."

"4. Restraint System: The restraint system should include a lap belt and shoulder harness. Additional body support in the form of thigh and chest straps should be considered where consistent with operational requirements of the aircraft and personnel aboard."

"5. Application to Fixed-Wing Aircraft: A considerable amount of impact acceleration data presently exists as a result of the experimental work done by NACA. The experiments conducted, however, were generally directed toward the crash-fire problem and were of such nature that they generally gave relatively low vertical decelerations as compared with known human tolerance to headward pulses. Modifications of either the impact conditions or type of airframe structure would very probably change the end results."

"Military troop transports presently in use and those planned for the future are of the V/STOL types, required to operate on short, unimproved runways. In addition, military troop transports generally do not have large cargo compartments between the floor structure and bottom of the fuselage. It can, therefore, be assumed that the operating procedures required, coupled with the lack of energy absorption structure beneath the floor of the aircraft, will result in accidents in which high vertical accelerations will be imposed upon the occupants of these military transport aircraft. It is, therefore, probable that the requirements set forth in Paragraphs 1 through 4, specifically including Paragraph 2, apply both to fixed- and rotary-wing aircraft. It is thus recommended that, for the present, no distinction with regard to crashworthiness be made in the specifications for troop seats for these two types of aircraft."

Extensive effort has been expended in the detailed review of specifications pertaining to design criteria for crew seats. Research has been conducted on the basis of a detailed examination of the provisions of the current military specifications (MIL-A-8867), with emphasis placed on the analysis of the requirements for load-carrying capabilities of these seats. Results of the foregoing study have been incorporated with the accident experience associated with these seats, human tolerance to rapidly applied accelerations, and forces which can be anticipated in actual accidents. Initial indications are that recommendations will be made to modify the requirements of these specifications to incorporate greater load-carrying capabilities. As a result of this study, a report entitled "Crew Seat Design Criteria for Army Aircraft" is contemplated in the very near future.

LITTER SPECIFICATION

The evaluation of the litter specification (MIL-A-8865) had been held in abeyance pending the results of the full-scale droned helicopter crash which was conducted on 12 September 1962. The aircraft used for this test was an obsolete H-21A helicopter, which was crashed from actual flight, simulating a typical aircraft accident.

One objective of this test was to determine the manner in which forces are developed in the structure of an aircraft during a survivable crash; to trace these forces through the aircraft structure, through the components, to the litters, seats, and restraint systems; and to determine how and why these forces affect the occupants during the crash.

Aboard the aircraft during the crash was a stack of litters (two) used by the military services for transporting wounded or sick personnel by air. Fully instrumented anthropomorphic dummies occupied the litters. Electronic data was obtained, including acceleration, force, and various other measurements from the aircraft structure, litters, restraint systems, and from the pelvic regions of the dummies. High-speed photography was also utilized.

During the impact sequence, the forward litter strap attachment-fitting ripped out of the overhead structural member. At the same time all four of the sidewall litter attachment brackets ripped off the structural members resulting in both litters, with the "patients" becoming projectiles, crashing to the floor, one atop the other.

The data obtained from this test will form a basis for a report designating the required modification or revision of the litter specification. Figure 11 depicts the time sequence and kinematics of the litter installation during the crash.

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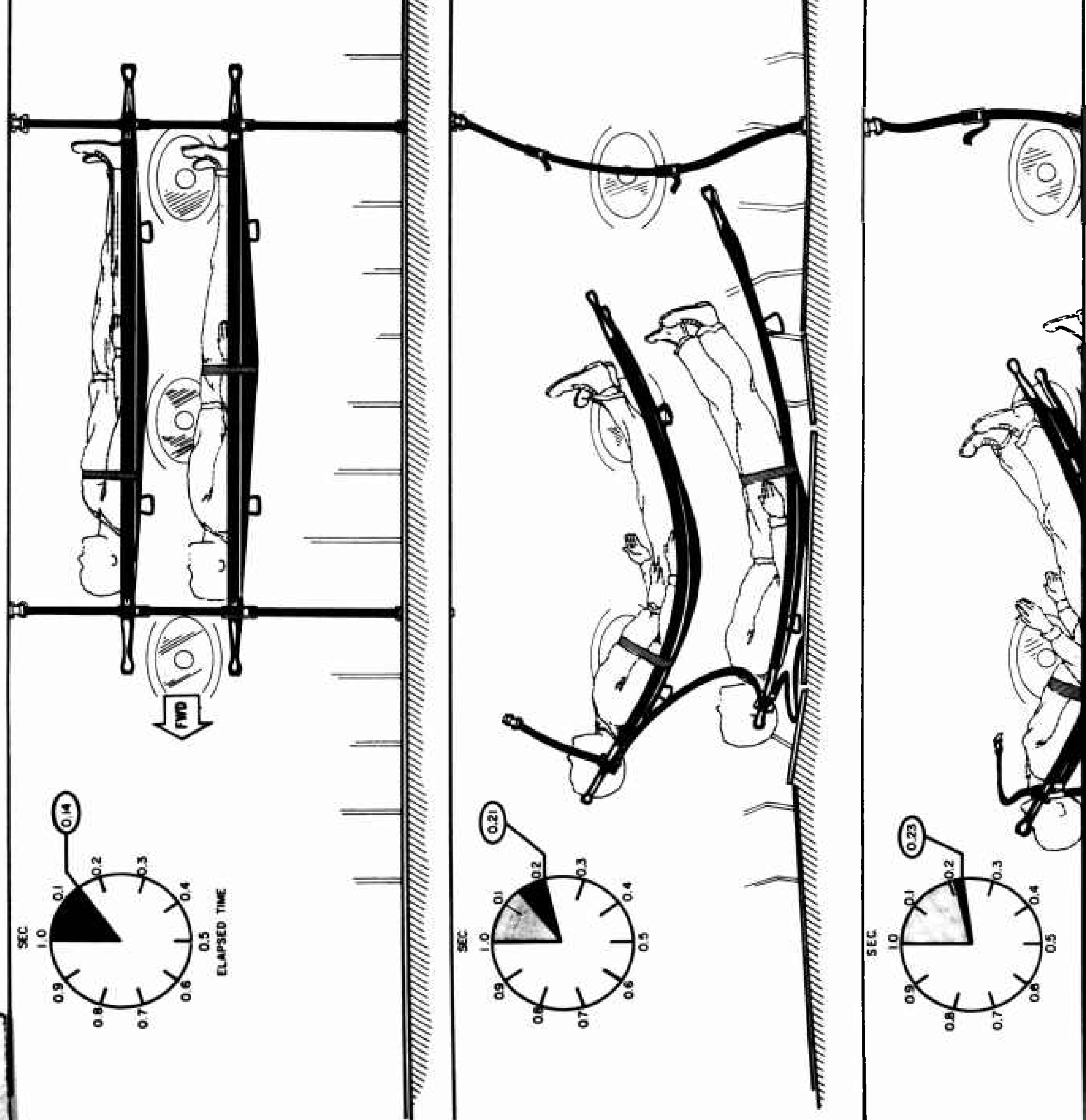
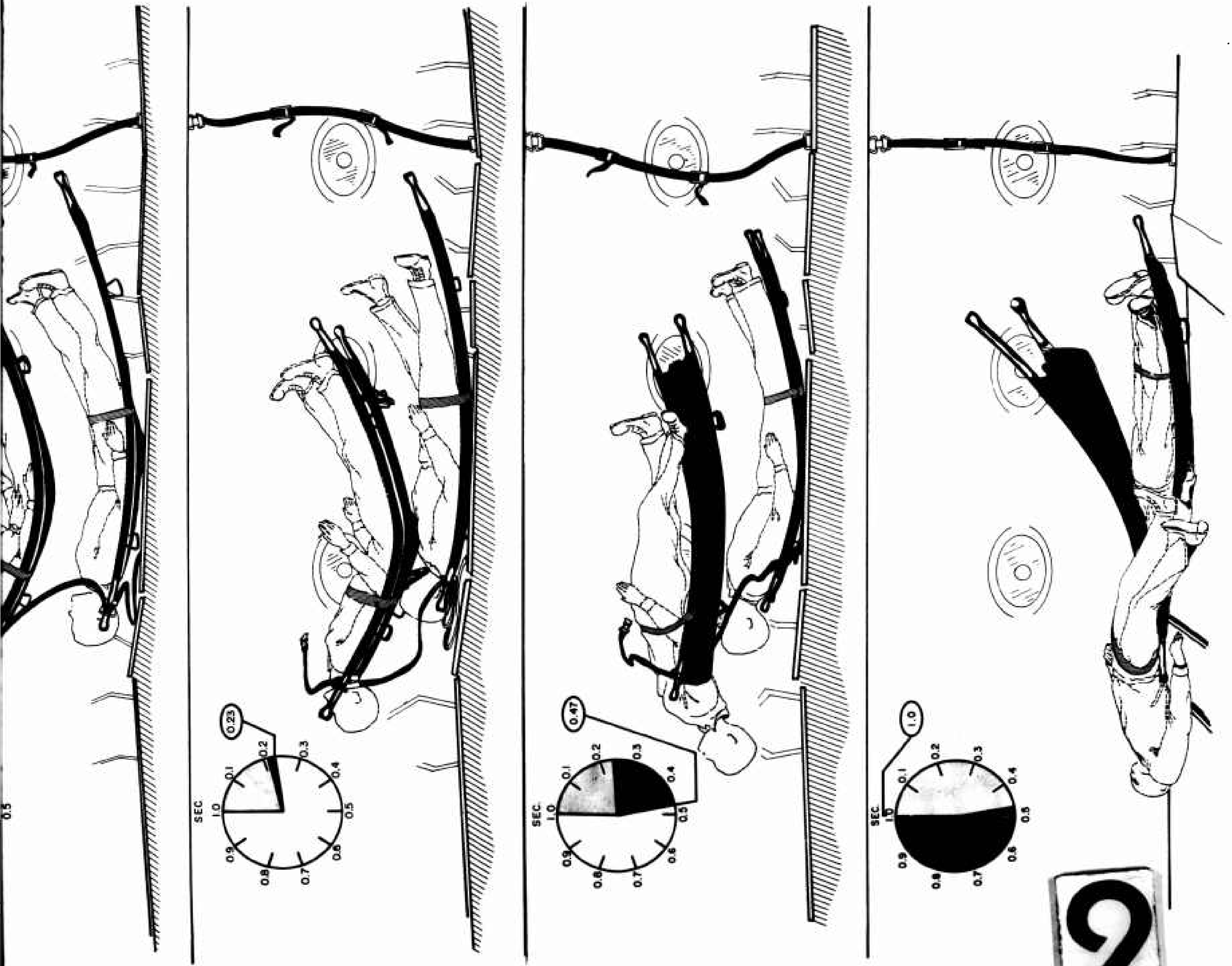


Figure 11. Time Sequence and Kinemati



…re 11. Time Sequence and Kinematics of Litter Failures.

CRASH TESTING OF FULL-SCALE AIRCRAFT AND DYNAMIC TESTING OF COMPONENTS

"The Contractor shall conduct an Experimental Research Program for the crash testing of selected full-scale aircraft and the dynamic testing of components and related equipment. In performing this work the Contractor shall study both crash injury and postcrash fire problems and shall include the design, construction, installation and testing of experimental systems for preventing, inerting, and suppressing crash and postcrash fire for at least one model of Army helicopter to be supplied by the Contracting Officer."

Analysis and study of the 160 channels of useful electronic data obtained during the crash tests conducted during fiscal year 1961 and the correlation of this information with the high-speed film coverage of these tests continue. The initial information gathered from these sources indicates that the series of tests or experiments are successful, and that repeatable information can be obtained with the techniques employed in the tests. In fact, there will be an almost continuous comparative analysis of these data as data from new tests become available and as continuous efforts to develop practical and logical design criteria are made.

The data have also been used extensively in the evaluation of the troop and crew seat specifications (Work Item 3), and provide the basis for recommended revisions of current specifications. Summaries of the data obtained from the crash tests have also been provided to TRECOM, USN, and other agencies for their use in the development of Army aircraft related equipment.

Two major tests were conducted during this reporting period in the current series of helicopter crash tests. Both of these tests involved remotely controlled H-21A helicopters.

CRASH TEST NO. 6

The first of these tests (Test No. 6) was conducted at the Deer Valley Airport test area on 29 July 1962, employing a simple and extremely limited remote control system for flight control of the aircraft. Installed in the aircraft, in which a postcrash fire was anticipated, was a 30-bottle ambient air sampling system, designed and fabricated by AvCIR (Figure 12), five ambient air temperature thermocouples, three calorimeters, and a left and right aircraft engine exhaust manifold temperature pickup. Three accelerometers were also installed to measure the vertical, lateral, and longitudinal accelerations to which the airframe would be exposed. Six ground-mounted high-speed and normal-speed cameras were installed at various locations in the test area to record the actual crash on film. To preclude the possible loss of high-cost photographic equipment, only one camera was installed aboard the aircraft. A quick removal system was employed to preclude its loss in a postcrash fire. The objective of this test was an accurate determination of the atmospheric environment to which aircraft occupants are exposed immediately following an aircraft crash involving postcrash fire. Figures 13 and 14 depict pre- and postcrash views of Test No. 6.

Although it did not perform entirely as anticipated in its droned flight, the aircraft was crashed from flight and a postcrash fire occurred. A considerable amount of useable data was obtained in this experiment, including 30 samples of atmosphere taken from three locations within the aircraft at 30-second intervals, as well as a full spectrum of temperature variances. Several reports are being prepared covering all aspects of this experiment as the data are analyzed.

CRASH TEST NO. 7

Test No. 7 in this series of H-21A helicopter crash tests was conducted on 12 September 1962. One objective of the test was to determine the manner in which forces are developed in the structure of an aircraft during survivable crash conditions and to trace these forces through the aircraft structure and the components, such as seats, litters, and restraint systems, to determine how the forces affect the occupants during the crash.

The other major objective was to dynamically test under actual crash conditions a postcrash-fire inerting system designed and fabricated by AvCIR for the purpose of reducing or eliminating the incidence of postcrash fire in aircraft accidents. This system consisted of five subsystems as follows:

1. Exhaust water spray system.
2. CO_2 induction system.
3. Oil and fuel flow shut-off system.
4. Electrical de-energizing system.
5. Inerting system actuating mechanism.

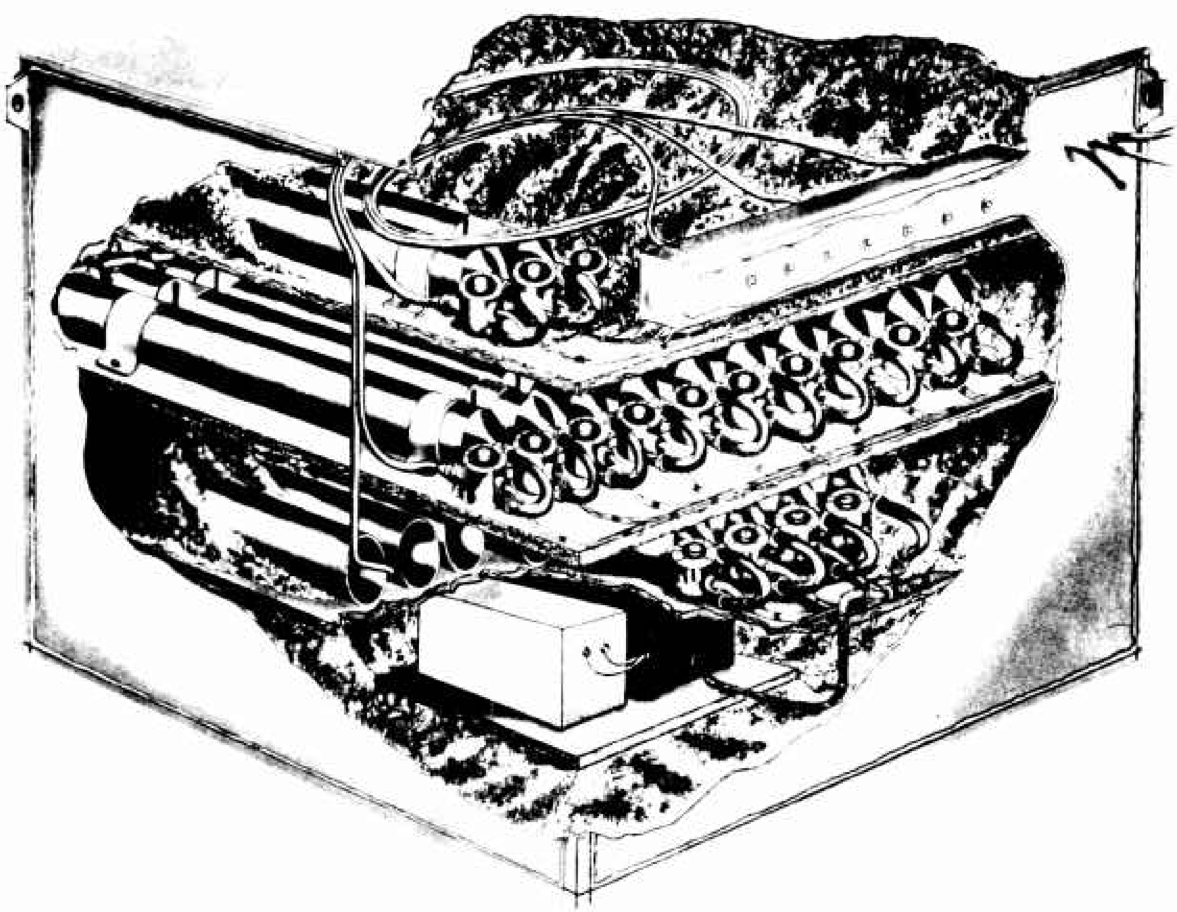


Figure 12. 30-Bottle Ambient Air Sampling System.

Figure 13. Precrash View of Test No. 6.

Figure 14. Postcrash View of Test No. 6.

The aircraft was controlled during this flight through a radio-link remote control system, developed for this purpose under a subcontract with the Kaman Aircraft Corporation (Work Item 12). This drone control system provided three-directional stabilization for flight maneuvers through collective pitch control, forward cyclic control, lateral cyclic control, antitorque pedal control, and throttle control. A directional gyro and a gyro horizon were also mounted at the helicopter center of gravity. The gyros provided altitude and directional control signals to the servo control actuators.

A radio receiver decoder was installed for the purpose of converting the radio link control signals from the flight control transmitter on the ground into signals suitable for use in the computer actuator control system. The ground control station consisted of an F. M. transmitter to provide the radio transmission link for the system.

The actual flight profile recorded by a Fairchild Flight Analyzer Camera is presented as Figure 15.

On the morning of 9 September 1962, the crash flight was attempted, but was aborted in flight because of failure to develop full engine power. The helicopter was successfully landed by remote control, with no damage to any components, which, in itself, proved the adaptability of this system. Following this aborted flight, the decision was made to reschedule the flight for 12 September 1962.

On the morning of 12 September 1962, at 0815, a very successful flight was made with all flight systems functioning perfectly. The aircraft reached a height of 57 feet and a forward speed of 33 miles per hour, crashing at an angle of 39.5 degrees with the ground, with a vertical rate of descent of 2,400 feet per minute, or 40 feet per second.

The conditions at impact were very near the exact conditions desired, and produced a severe but survivable "accident". The helicopter was slightly nose-low on impact with the ground. Upon impact, the nose gear failed, driving up into the belly of the cabin fuselage just aft of the cockpit, forcing a section of the cabin floor upward a distance of almost a foot. An instant after nose gear failure, both left and right main gears failed at the attachment points resulting in the struts ripping into both sides of the fuselage and rupturing the main fuel cell. Red dye-colored water in the main fuel cell sprayed the aircraft and surrounding area. Some gasoline lying on the water in the main fuel cell from previous tests, along with gasoline vapors,

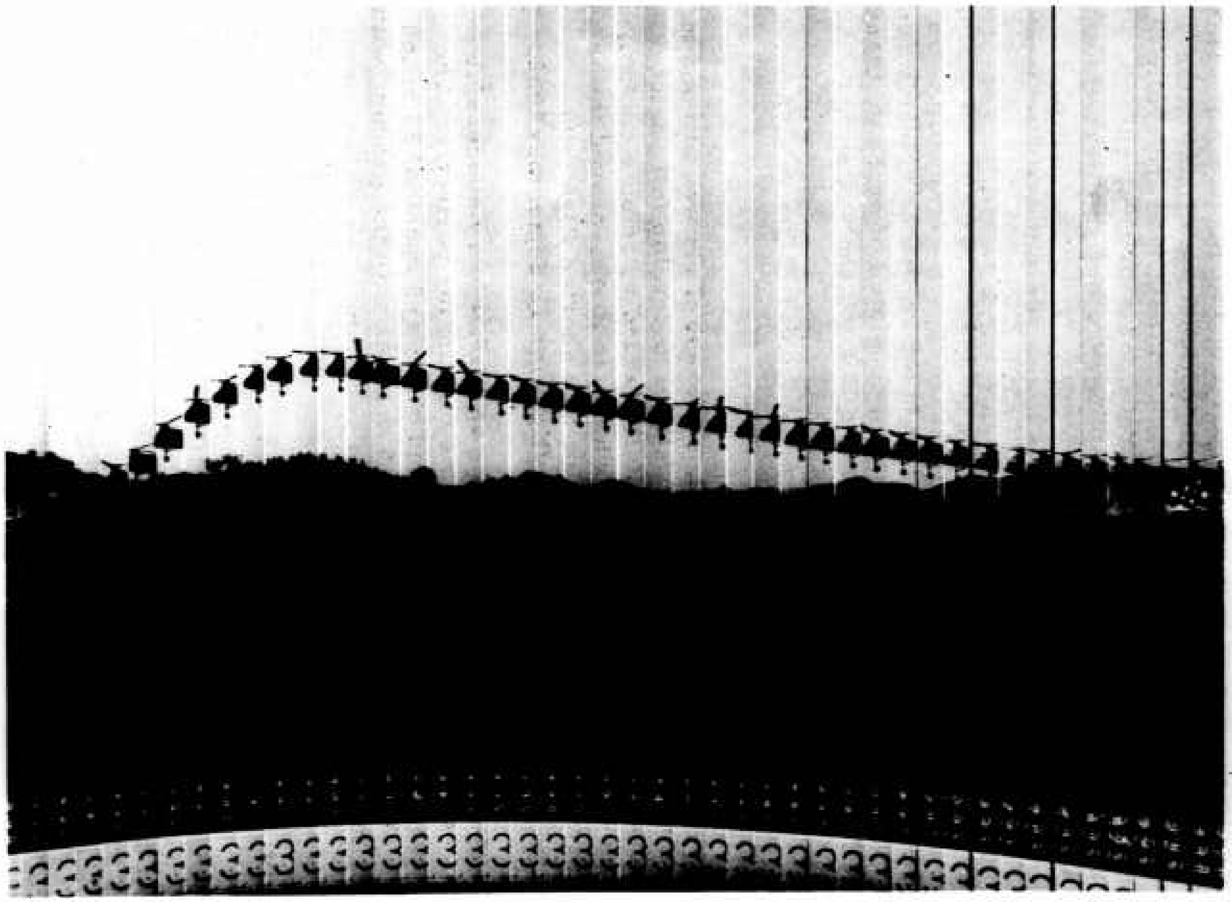


Figure 15. Photograph of the Fairchild Flight Analyzer Film. The flight is shown from shortly after take-off to crash impact. There is approximately 11 feet of aircraft travel between exposures.

ignited and burned for approximately 2 minutes. Very little damage was done by the fire before it died down and was subsequently extinguished. Exact cause of the fire is not known at this time; however, preliminary examination of the high-speed film has led us to assume that abraded sparks from the main gear attach points caused the ignition. All elements of the crash fire inerting system functioned except the electrical cutoff system. It is also possible that failure of this part of the system may have resulted in sparks which could have ignited the fire.

Installed aboard the aircraft on this experiment were two experimental energy absorption troop seats, a commercial helicopter passenger seat, and a standard rack of H-21A litters. These seats and litters were all occupied by anthropomorphic dummies. A dummy also was placed in the standard H-21 pilot seat, and one was seated on a block of paper honeycomb with a back support of the same material.

A total of 54 channels of electronic data were recorded on ground-mounted oscillographs through a trailing umbilical cable. These included acceleration, force, strain, and other measurements from instrumentation located throughout the aircraft and in the dummy passengers.

Seven high-speed 16mm cameras, mounted at strategic locations within the aircraft, were automatically triggered just prior to impact, recording all action within the aircraft on color film at speeds of up to 500 frames per second. Ten cameras, both standard and high-speed types, photographed the aircraft from several ground positions during the crash.

A schematic diagram of the aircraft and the various installations made for this test is shown in Figure 16.

Only a preliminary examination of both the electronic and photographic data has been made at this date; however, the crash test appears to meet all pretest expectations and to be the best and most complete of all tests performed to date. A series of reports covering all phases of these tests are being prepared. Figures 17 through 27 depict precrash, actual crash, and postcrash views of this test.

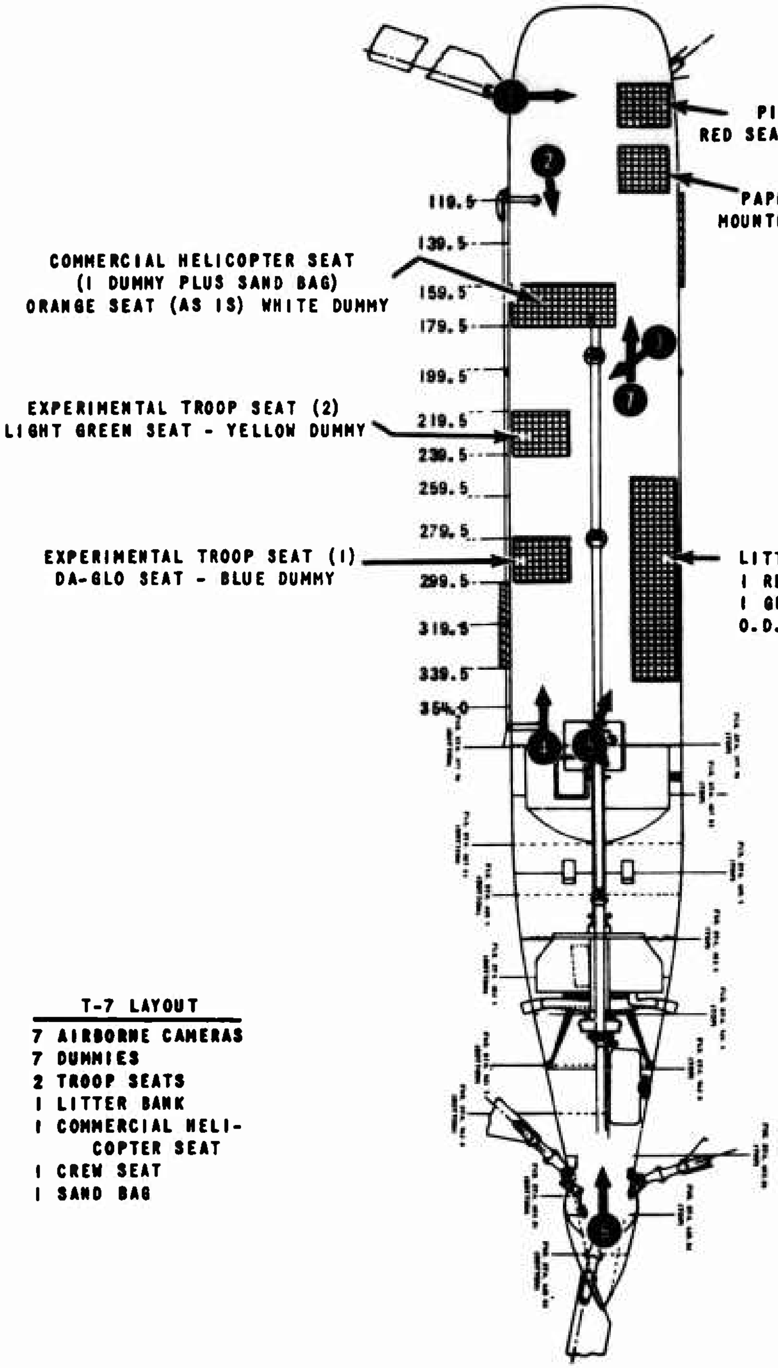


Figure 16. Schematic Diagram of Aircraft and Various Installations.

Figure 17. Helicopter Just Prior to Crash Flight.

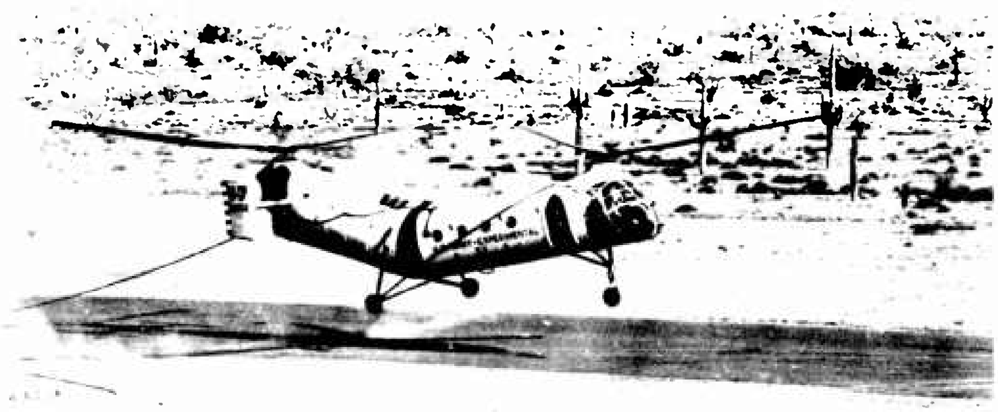


Figure 18. Crash Test Vehicle Just After Lift-Off. Note trailing umbilical cable through which all data were recorded during actual crash sequence.

Figure 19. Crash Test Vehicle During Flight Under Complete Remote Control.

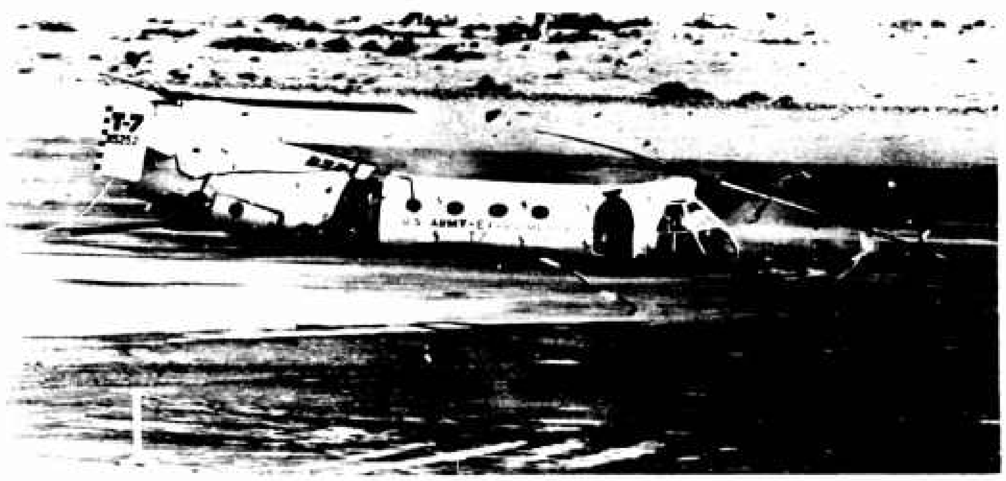


Figure 20. Aircraft Just After Impact.
The nose gear and both main gears have completely failed. Note the wrinkles in the fuselage skin in the dark band just ahead of the main landing gear.

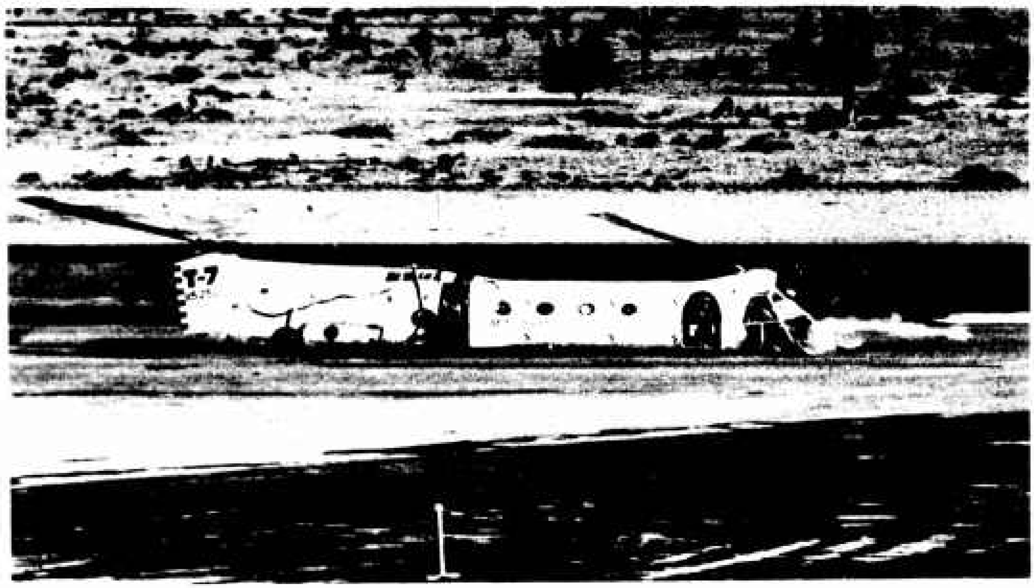


Figure 21. Entire Bottom Surface of Fuselage Is in Contact With the Ground.

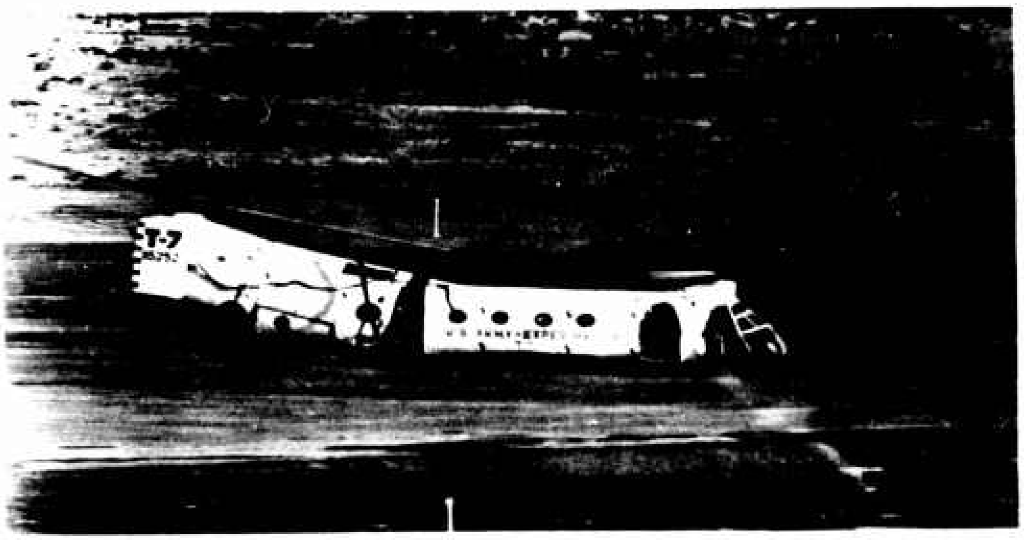


Figure 22. Aircraft Turning and Tail Moving Upward Again to Its Normal Position.

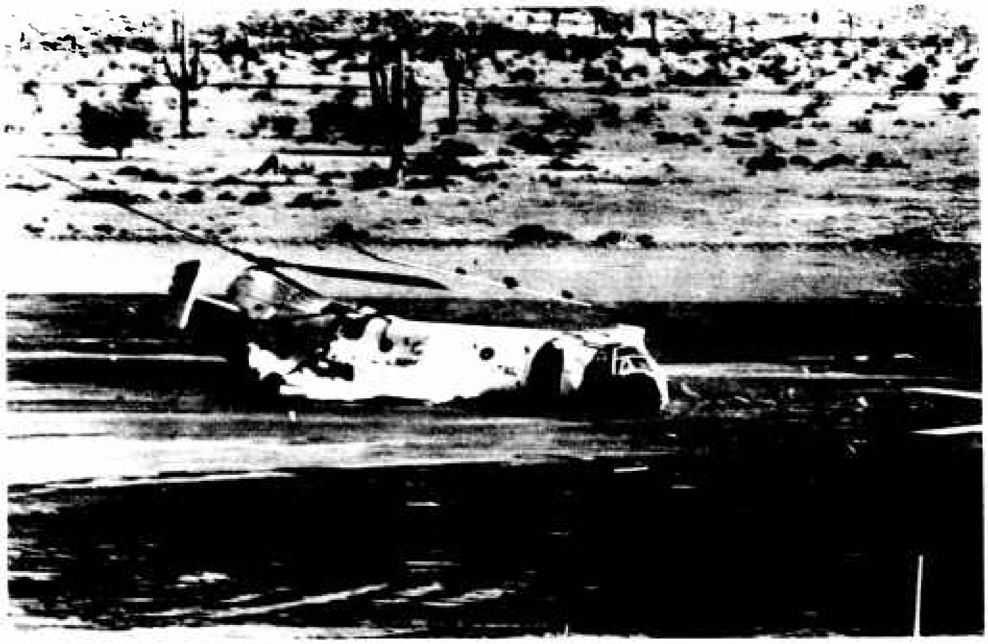


Figure 23. Photograph Taken Shortly After the Flash Fire Began.
(The aircraft now beginning to rotate clockwise.)

Figure 24. Tail Section and Its Relationship to the
Forward Portion of the Fuselage.

Figure 25. Aircraft at Rest.

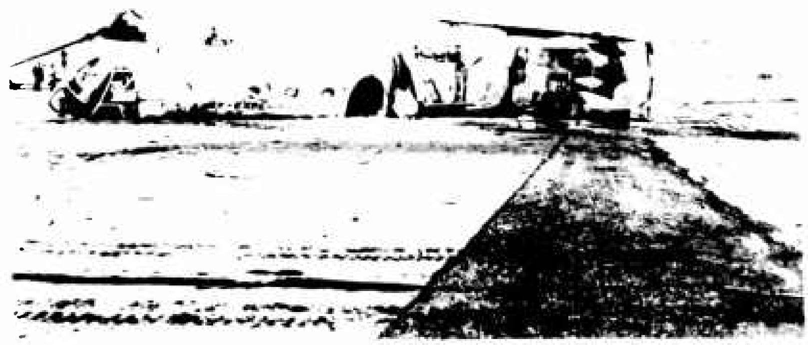


Figure 26. Final Resting Position of Aircraft, Left Side.

Figure 27. Right Side of Aircraft.

SPECIAL EQUIPMENT FOR DYNAMIC CRASH TESTS

"The Contractor shall conduct a study covering the design of special equipment for performing dynamic crash tests of aircraft and components with the study to include estimates of costs for construction and for operation of such equipment."

The purpose of this work item was to conduct a feasibility study of a dynamic testing device with the capability of reproducing accelerations and crash forces experienced in aircraft accidents in three directions (vertical, longitudinal and lateral) simultaneously with independent control of the accelerations and pulse shapes in each plane.

This study was made under subcontract with Vought Aeronautics of Dallas, Texas. The study was completed and a draft report was submitted by Vought Aeronautics on 26 February 1962. The study concluded that one of the concepts studied, "Transporting Carts with Grounded Catapults", provided the greatest potential for fulfilling the requirements outlined in the original study specification. The study also recommended that this arrangement be the subject of additional study and detailed design to optimize the impact program velocity envelope and to arrive at the best relationship between device size and specimen size.

The results of the study were reviewed by TRECOM, Mr. Pinkel of NASA, FAA representatives, and FSF personnel. It was concluded that the system finally recommended by Vought was not practicable and that a further conceptual study should be made. As of this date, one unsolicited proposal has been received and is being reviewed.

CRASH SAFETY EQUIPMENT AND PROCEDURES

"The Contractor shall study crash safety and crash survival equipment, methods and procedures and integrate this study into the Experimental Research Program insofar as possible."

Head trauma is an exceedingly common occurrence in aircraft accidents. Because of the seriousness of this problem, it is of paramount importance that all possible steps be taken to protect aircraft occupants against this type of injury.

Accordingly, a report was compiled which presented a complete evaluation of the currently employed crash helmet, the APH-5, and offered a conceptual design of an improved head protective device incorporating those features considered desirable in a crash helmet. *

This report provided a discussion of:

1. The problem and significance of head injury in aircraft accidents;

2. The pathology of head injuries;

3. The requirements of protective devices of the head against traumatic injury;

4. The characteristics of the presently employed Army helmet, the APH-5;

5. Injury patterns as they occur in Army accidents relative to specific deficiencies of the APH-5 helmet; and

6. Recommendations and concepts for resolution of the deficiencies manifest in the APH-5.

In this report, the APH-5 is used as a basis for study in the development of concepts for recommendations by which its deficiencies can be utilized in organizing thought for design of an ultimate head protective device (HPD). Figure 28 illustrates concepts of resolution of

*Helmet Design Criteria, Based on the U. S. Army APH-5 Helmet Evaluation - TCREC 62-57, April 1962.

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Figure 28. Illustration of C

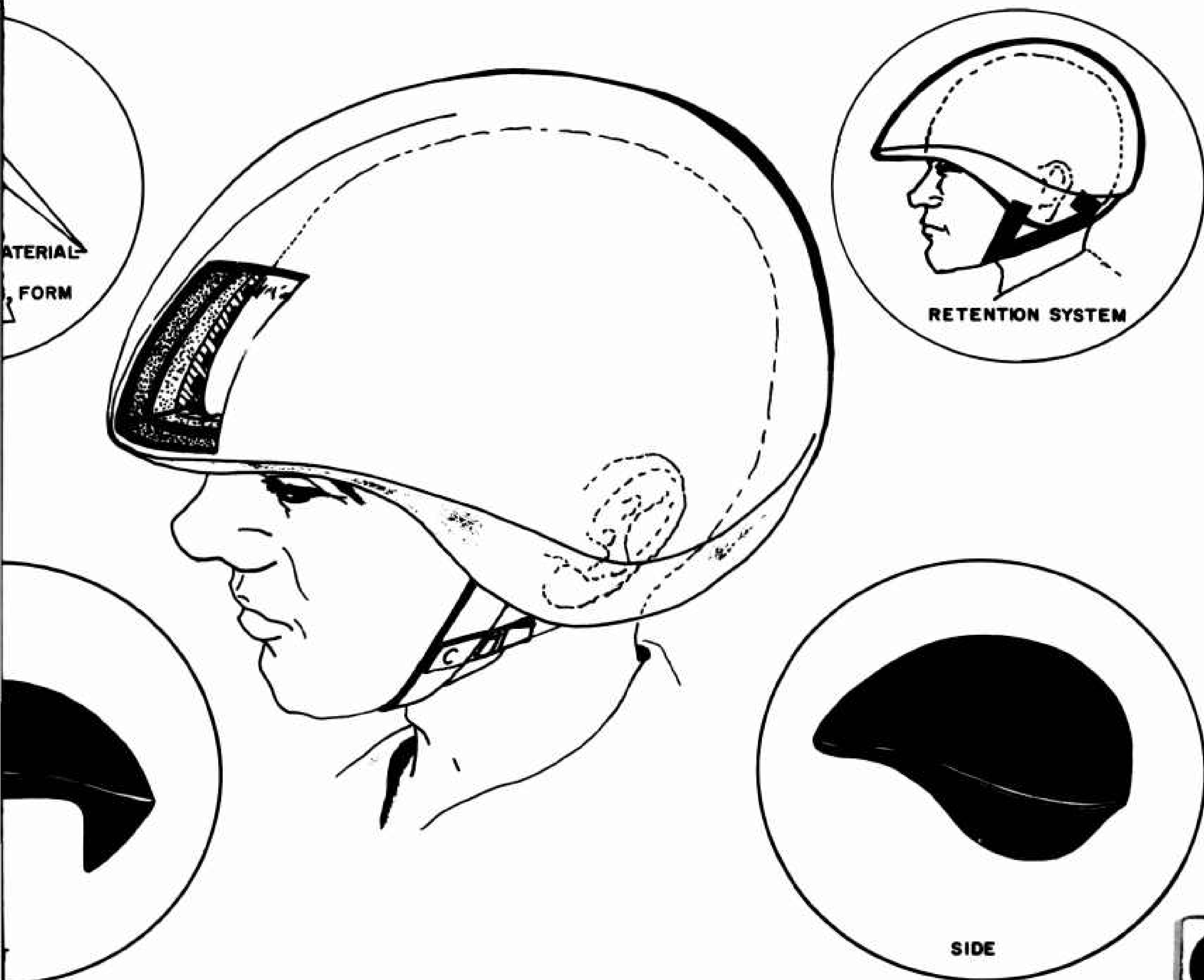

Figure 28. Illustration of Concepts of Resolution.

some prominent problems encountered in the APH-5. They include:

1. <u>The Shell</u>

   A parabolical sequence build-up is recommended in lieu of the sphere presently used.

2. <u>Stress Concentration</u>

   Screws, knobs, and specialized metal objects on the surface of the HPD serve as injury producers. Therefore, it is recommended that the helmet surface be kept clean and that all components be integrated into the unit structure.

3. <u>The Liner</u>

   The liner of any HPD must be of sufficient thickness to provide adequate absorption of energy so as to attenuate externally applied forces to survivable (internal) limits. It is shown that the concept of paraboloid sector configuration not only increases the geometric material strength of the shell, but also positions the energy absorbing liner material to where it is most critically needed.

4. <u>The Inner Liner</u>

   A pliable material must be used in the inner liner that is soft enough to be comfortable, but minimally elastic.

5. <u>Retention</u>

   A concept of a retention system is recommended whereby the helmet is secured by circumferential anchorage to the base of the head, applying retention to the chin and accipital-nuchal protuberances primarily, but facilitating these by tying them together.

6. <u>Avionics</u>

   A miniaturized auditory configuration is recommended; it should preferably be situated within the external auditory canal of the ear and incorporate a throat microphone, which would permit this system to be completely separate from the helmet.

7. Comfort

Fit should be on an individual basis and the inner liner should be molded to the anthropometric architecture of the individual wearer's head.

Weight is important during prolonged wearing of a helmet to avoid tiring of the wearer's neck, to make maneuvering of the head easy, and to avoid excess loading of the spinal column during vertical decelerations. Location of the center of gravity of the helmet in relation to that of the head is of importance to avoid a feeling of top-heaviness.

Closeness of fit and low heat transfer through the liner produce a stagnant environment and prevent dissipation of heat through evaporation or by conduction and radiation. Ventilation holes and the use of forced air are possible methods to prevent this condition. A very promising concept for cooling of the liner, however, would be the use of thermoelectric heat transfer devices, which, when minaturized, can be embedded in the surface of the liner.

Study continues in this field to add to extensive experience gained in the past and to stay abreast of new developments which may be presented in allied fields.

STATISTICAL AND CLINICAL ANALYSIS OF ACCIDENT DATA

"The Contractor shall collect aircraft accident data from Military, Federal and State Aviation Agencies, whether military or civilian type aircraft are involved. The Contractor shall conduct statistical and clinical analyses of the data so collected. In performing the work, the Contractor shall orient investigative and medical personnel in techniques of investigation, analysis and reporting through field contacts and appropriate instruction manuals."

Substantial support for conclusions and recommendations with respect to crash safety design is developed through statistical and clinical analysis of mass aircraft accident data, both engineering and medical. These data are obtained from routine reporting of accidents by military and civilian agencies. Detailed reports on special AvCIR accident and medical forms are received from offices of the Federal Aviation Agency, Civil Aeronautics Board, state aviation agencies, state police groups, and the U. S. Army. During the period, a total of 98 accident cases were received. This is a marked increase in the total number of cases received and is a direct result of personal contact made with numerous state agencies involved in aircraft accident investigations. This contact was made by personnel of AvCIR as a result of a survey conducted earlier when it was determined that various state agencies throughout the United States conduct investigations of aircraft accidents occurring within their state boundaries.

The survey indicated that there were 31 states which had a governmental agency authorized to investigate aircraft accidents. Personal contact was made with 27 of these agencies by Dr. Alfred C. Barnes to solicit their cooperation, assistance, and participation in our aircraft data collection system and in the use of AvCIR reporting forms for this purpose. Twenty of these state agencies agreed to participate in this effort. Cases in increasing numbers are now being received.

MECHANISMS OF INJURY IN MODERN LIGHTPLANE CRASHES: A STATISTICAL SUMMARY OF CAUSATIVE FACTORS, TCREC Technical Report 62-83, November 1962

This study was undertaken to evaluate the interrelationship between primary impact variables, seat and belt tiedown effectiveness, and injuries sustained by occupants of 342 lightplanes involved in spin-stall crashes or collisions with the ground while in flight. The data were obtained during the period 1953-1960 and are to be contrasted with data previously reported for the period 1942-1952 (when light aircraft were primarily of fabric-skin covering).

Contrary to the earlier findings,* seat failure now occurs more frequently than belt failure. The curve of belt failure plotted as a function of impact velocity does not accelerate as rapidly as that from the earlier data, whereas the seat-failure curves from the two sets of data are comparable. Since injuries are found to be more severe when seats fail than when belts fail, there is a suggestion that seat tiedown improvements may not have kept pace with improvements in seat belt manufacture and installation. Overall, however, when tiedown is considered to be effective, injuries are less severe for the more recent data, thereby suggesting that better overall protection is afforded today's pilots. Occupants wearing shoulder harnesses were least severely injured, although some still received facial and skull fractures. Since structural collapse was generally not extensive for these data, flailing of the body against injury-producing structures within the occupant's environment is seen to be a significant source of injuries. Injury severity was found to increase little as a function of impact velocity, but did increase rapidly as a function of angle of impact.

It was concluded that:

1. The most critical determinant of injury and death in modern lightplane crashes is flailing of the body against injury-producing structures within the occupant's environment.

2. Injury severity in modern lightplane crashes is largely a function of severity of head injury.

3. When the tiedown chain remains intact, severity of injury is decreased even at high angles of impact and at impact velocities exceeding 90 miles per hour. Its value is further enhanced when the shoulder harness is used.

* Reference: TREC Technical Report 61-96; AvCIR 61-4.

4. In general, better overall protection is afforded today's pilots, as witnessed by the fact that injuries are less severe for the recent data despite an average increase in velocities estimated at impact. This may be a reflection of aircraft design practices in addition to the increased rate at which overall tiedown is effective.

5. There is still room for improvement in the design, manufacture, and installation of components of the tiedown chain. It appears that seat tiedown improvements have not kept pace with improvements along other lines. There is a suggestion from the data that seats fail most often under conditions where vertical crash forces predominate.

It was recommended that:

1. Inasmuch as injury severity is so strongly related to severity of head injury, violent contact between the head and aircraft structures must be prevented. This can be done through use of the shoulder harness, of the crash helmet, and of crash-safe design principles within the cockpit.

2. Greater attention should be given to seat design and installation, especially with regard to incorporation of energy-absorption principles.

3. Hazards of the high-angle crash typical of the spin-stall crash need greater attention, together with further incorporation of crash safety design principles in aircraft structures.

4. A much better understanding of crash-injury dynamics may be realized if studies such as the present one were based upon larger numbers of cases known to be a random sample from the population of all accidents. The goal should be to obtain all accident injury cases. This would certainly facilitate the conduct of studies to determine the relation to injury severity of such factors as seated position, control wheel or landing gear characteristics, high wing versus low wing, single versus twin engine, etc.

STRUCTURAL ANALYSIS OF AIRCRAFT

This study deals with the structural analysis of aircraft as a means to predict their reactions to crash loads and resultant damage patterns. The study is being done first on aircraft of the tube and fabric type construction. The information or system generated will then be applied to aircraft employing the more complicated semi-monocoque-type construction. Detailed analysis of the tube and fabric aircraft continues, and several structural analysis systems are being considered in this study to arrive at the most adaptable method to employ, as a basis of calculations, to obtain aircraft structural reactions to crash loading conditions.

JUDGMENT OF VOLUME FROM PHOTOGRAPHS OF COMPLEX, IRREGULAR SHAPES

Accident investigation procedures involve estimates or judgments of damage to the aircraft. One aspect of these postcrash observations of particular relevance to crash injury studies is the reduction in volume of the occupiable area. It has been proposed that a panel of analysts, working from photographs, could provide more accurate and reliable estimates of such characteristics than would a single field investigator working under uncontrolled conditions. The present study examines the feasibility of making judgments of volume reduction, a three-dimensional problem, from two-dimensional representatives of objects and attempts to identify the perceptual factors that might influence such judgments.

Hypotheses regarding the role in such a task of such factors as number and angular disparity of photography, the stimulus complexity (i.e., damage characteristics) of the object, the geometric properties of the intact object, and changes in memory for visual forms were submitted to empirical analysis in a laboratory study in which 279 college students judged from photographs the volume reduction of damaged metal containers. The independent variables included number of photographs - two, three, or four - and angular disparity - low, moderate, high. Photographs of 40 damaged containers, 10 for each of 4 different types of objects - cylinder, cylindroid, rectangular-base box, and square-base box - were assembled into notebooks to correspond to the 9 cells of the experimental design in order to test subjects in groups. Subjects made their judgment of volume reduction to the nearest 5 percent on a rating scale.

Comparison of the constant errors in judgment revealed accuracy to vary significantly as a function of angular disparity and the stimulus characteristics of the individual objects. Analyses performed on the average errors demonstrated accuracy of judgment to vary as a complex function of the number of photographs, angular disparity, type of object, and degree of damage. In general, three photographs provided the most accurate judgment. Judgments of volume reduction of low-damage stimuli were generally more accurate from groups of photographs having low angular disparity, while those of high-damage generally were better at higher angular disparities. Two dimensions along which three-dimensional shapes might be scaled were identified: the volume reduction of "square" objects was judged more accurately than that of "round" objects, while those objects with symmetrical bases were judged more accurately than those with unsymmetrical bases. The generalization was offered that more complex shapes contain greater information and, thus, more and different views are requisite to provide valid transmission of this information to the observer. Individual observers were found to be reasonably consistent from one type of object to another in over- or underestimating volume reduction. An average correlational index of .71 was obtained. The estimate of single-observer reliability for volume reduction judgments was .64.

Additional research is indicated in order to determine the role played in judgments of volume reduction of additional variables falling within the areas of stimulus attributes, viewing conditions, and observer characteristics.

It was concluded that:

1. Accuracy of observers' judgments of volume reduction varies as a direct function of the amount of information provided by photographs and as an inverse function of the complexity of the stimulus object. Three photographs generally provided the most accurate judgment. Volume reduction judgments of low-complexity (i.e., low-damage) shapes were generally made more accurately from groups of photographs having low angular disparity, while those of high complexity were made better at high disparity.

2. Observers' judgments of volume reduction vary with the type of geometric shape rated. Objects with square edges were judged more accurately, overall, than were those with round edges. Objects with symmetrical bases were

judged more accurately than were those with unsymmetrical bases.

3. Judgments of volume reduction, under the conditions of the present experiment, yielded a reliability estimate of about .64. If a panel of analysts were to make independent ratings of volume reduction, the number of raters required, so that the average ratings would have a reliability of about .95, would be 11. Clearly, a panel of this size is too large for economical processing of routine accident cases. We might expect that training and further refinements in the rating procedures would substantially improve the ratings.

DEVELOPMENT OF DAMAGE RATING SCALE

The immediate objective of this work is the completion of multiple regression analyses of the damage ratings for a group of 215 accident cases received from 1952-1961. The analyses are being carried out at Carnegie Institute of Technology, and their purpose is to improve the predictive efficiency of the damage ratings included in the current AvCIR report form. The criterion variable to be predicted is Degree of Injury. It is expected that this study will provide a basis for revising the report form so that more useable damage information can be obtained from the field investigator.

EVALUATION OF IMPACT SEVERITY MEASURES

Similar to the above study is another which is concerned with the use of data pertaining to impact conditions in the prediction of degree of injury. Multiple regression analyses are being performed on the same group of 215 accident cases. It is hoped that this work will provide a basis for revising the report form so that more useable impact information can be obtained. This study is being carried out at Carnegie Institute of Technology.

RELIABILITY OF DAMAGE JUDGMENTS UNDER THREE CONDITIONS OF INSTRUCTION

This investigation was concerned with the reliability of judgments of damage of complex, irregular shapes. Hypotheses were developed regarding the role of such variables as instructions, object configuration, and angle of view. These hypotheses were subjected to test in a laboratory study in which 145 college students made assessments of "damage" from photographs of collapsed metal containers. Ten photographs, of varying degrees of "damage", of each of four container types were used. These container types differed according to base configuration - circular, elliptical, square, and rectangular.

Three sets of instructions were used. Subjects were required to order the photographs and assign values according to the "amount of damage", "surface complexity", or "amount of volume reduction." Five different angles of view were used, ranging from 0 degree (perpendicular to the horizontal axis of the object) to 90 degrees (in line with the horizontal axis). The data are presently undergoing analysis, and a report is expected in the very near future.

RELIABILITY OF DAMAGE RATINGS BY DIRECT AND PHOTOGRAPHIC METHODS

The purpose of this experiment is to estimate the reliabilities of damage estimates of various aircraft structures under conditions of direct and photographic observation of the damaged aircraft. The small panel of trained investigators will alternate in assessing damage by on-the-scene investigation and through viewing photographs of the damaged components. Approximately half of the data has been collected. The ultimate goal is to obtain information concerning the cues involved in the process of rating damage to aircraft components.

RELIABILITY OF DAMAGE RATINGS AS A FUNCTION OF TRAINING AND EXPERIENCE

It is supposed that variability in damage ratings stems from inadequate knowledge of the original, intact object that serves as the standard against which the damaged object is compared. Further, it is known that agreement among raters is enhanced by instruction or experience in making judgments according to prescribed criteria. Subjects of varying aviation training and experience will rate damage from photographs of progressively damaged aircraft components. The ultimate objective is to obtain knowledge needed to improve both our accident report form and our methods of training investigators.

WORK ITEM 8

LIAISON WITH GROUPS AND AGENCIES

"The Contractor shall maintain liaison with groups and agencies concerned with aircraft Crash Injury, Crash Survival and Crash Worthiness programs. The Contractor shall participate in conferences, meetings, forums, symposia and seminars related to the objectives of the contract program."

During the reporting period, members of this organization participated in various conferences, meetings, symposia, and seminars related to the Aviation Crash Injury field. The exchange of information at these meetings was found to be of real value to the overall objectives of this research program. Some of the pertinent meetings or symposia attended by members of AvCIR are summarized below.

International Congress of Aviation and Cosmonautical Medicine, Paris, France, September 26-30, 1961:

The Congress was under the sponsorship of the French Air Force and Departments of Education, National Health and Transportation. Numerous presentations in regard to head protection of occupants in aircraft were presented by participants from 14 countries.

A presentation, entitled "Limits of Seat-Belt Protection During Crash Decelerations", was made by Mr. Gerard M. Bruggink at this meeting. In this presentation, three cases were reviewed in which aircraft occupants, restrained only by seat belts, received serious or fatal decelerative injuries. This presentation indicated some of the trauma which may be expected when the tolerable and injurious limits of seat belt protection are exceeded. The inherent limitation in seat-belt protection in aircraft accidents was recognized, and a suggested realistic compromise between the ideal and the practicable dynamic strength of such a system in relation to occupant environment and strength of aircraft structure was presented.

Impact Acceleration Stress Symposium, Brooks Air Force Base, San Antonio, Texas, November 26-30, 1961:

The purpose of this symposium was to bring together personnel from organizations in this country and foreign countries for the purpose of summarizing the work going on world-wide in the "impact acceleration stress" field. Mr. Merwyn A. Kraft, Research Coordinator, Flight Safety Foundation, formally presented an explanation of the work being carried on by FSF. Dr. James W. Turnbow of AvCIR made a presentation on the results of a study being made by FSF and Vought Aeronautics to determine the feasibility of constructing a three-axis crash-simulator. Mr. Victor E. Rothe of AvCIR was a member of a special committee which remained in session after the meeting to summarize proceedings and to develop conclusions and recommendations for a report to be published.

Aviation Crash Injury Research Symposium, Arlington, Virginia, December 1961:

The purpose of this symposium was to bring together high-level officials of the Department of Defense as well as Federal and Civil agencies that have an interest in Aviation Crash Injury. Mr. Merwyn A. Kraft of the FSF and Dr. James W. Turnbow of AvCIR assisted Mr. Francis P. McCourt of TRECOM in describing the work being done by FSF for the U. S. Army and other Governmental agencies, such as U. S. Navy, USAF, CAB, FAA, and U. S. Public Health Service.

Captain Daniel J. Schneider, MC, and Captain Lloyd E. Spencer, MSC, representatives of AvCIR, visited Holloman Air Force Base, New Mexico, to meet with Major Ellis R. Taylor, Chief of the Biodynamics Branch, and Colonel John P. Stapp of the USAF School of Aviation Medicine.

The subjects discussed at this conference were:

1. The cytopathologic physiology of human or animal tissues under abrupt deceleration conditions;

2. The relationship of the studies in deceleration physiology that are presently in process at Holloman as they relate to our research at AvCIR;

3. The evaluation of restraint systems as they might be affected in retrofit of current Army aviation; and

4. Observation of sled runs in the study that is being carried on in nervous system responsitivity to deceleration.

The information obtained during this trip is being used in developing long-range plans for possible medical research in connection with our crash test program and in the restraint systems study.

Captain Daniel J. Schneider participated in a conference at Fort Rucker, Alabama, which was called for the purpose of evaluating the currently employed U. S. Army crash helmet. The purpose of the conference was twofold: first, to evaluate considerations that could be given to retrofit of the current APH-5 helmet during the next year; second, to consider the establishment of a working group for development of a new crash helmet for Army aviation personnel. Captain Schneider was made a member of the working group established during this conference.

During the contract period, numerous other presentations were made by members of the AvCIR staff to personnel at the following organizations, meetings, and conferences:

FAA District Office, Chicago, Illinois
American Medical Association
U. S. Army Transportation Materiel Command
State Aviation Agencies
Davis-Monthan Air Force Base
FSF Seventh Annual Business Aircraft Safety Seminar
American Helicopter Society
Signal Corps Safety Directors' Conference, Fort Huachuca, Arizona
Aviation and Missile Safety Division of the University of Southern California
Sixth U. S. Army Aviation Safety Conference

TRAINING IN CRASH INJURY INVESTIGATION

"The Contractor shall provide five (5) training courses, each of two (2) weeks duration, in crash injury investigation at its Aircraft Accident Investigation School for the training of forty (40) military students to be designated by the Government. The Government shall designate eight (8) students for attendance at each of the five (5) courses to be conducted hereunder."

The U. S. Army recognizes the urgent need to develop a group of key military personnel with specialized skills for the scientific investigation of aircraft accidents as they affect injury and survival. Only from this can come the more complete and accurate information required by analysts and designers in the determination of causes of injury and, subsequently, in the development of improved designs or procedures.

During the contract period, five training courses of 2 weeks' duration each were held in which 39 military students were trained. Of these, 20 were flight surgeons and aviation medical officers and 19 were aviation officers.

The curriculum of this course is designed to provide personnel with the knowledge necessary to investigate and analyze aircraft accidents relative to (1) finding specific causes of minor, serious, and fatal injuries sustained in fixed-wing, rotary-wing, and transport aircraft crashes; (2) determining reasons for survival and nonsurvival; (3) evaluating the effect of crash safety design, both structural and environmental; (4) evaluating the overall crashworthiness of aircraft in relation to impact severity; (5) recommending new engineering design criteria to prevent serious or fatal injuries from occurring in future survivable-type accidents. The value of this program is evidenced by the much higher quality of crash injury reports received by AvCIR from Army field agencies when accident investigations have been handled by those with this training background.

Of the total of 60 hours comprising the course, one-half of the time is devoted to the investigation phase, including 8 hours of field investigation at simulated accident sites and 4 hours of crashworthiness evaluation and analysis of actual aircraft.

The following table summarizes military attendance:

Dates	Aviation	Medical
9 Oct. - 20 Oct. 1961	2	5
4 Dec. - 15 Dec. 1961	2	6
15 Jan. - 26 Jan. 1962	6	2
5 Feb. - 16 Feb. 1962	2	6
5 Mar. - 16 Mar. 1962	7	1
	19	20

All instruction in this course is handled by the AvCIR staff; however, this customarily is supplemented by specialized, technical presentations by one or two guest lecturers at each course. The following guest lecturers contributed greatly to the success of these courses during this period:

Emil Spezia, Aviation Psychologist, Human Factors Section, USABAAR, Fort Rucker, Alabama.

Dr. Anchard Zeller, Chief, Human Factors Branch, Directorate of Flight and Missile Safety Research, Norton AFB, California.

Jack Carroll, Air Safety Investigator, Bureau of Safety, Civil Aeronautics Board, Washington, D. C.

Captain Cecil Grimes, Human Factors Section, USABAAR, Fort Rucker, Alabama.

I. Irving Pinkel, Chief, Fluid System Components Division, Lewis Research Center, NASA, Cleveland, Ohio.

Colonel John P. Stapp, USAF, MC, Assistant for Aerospace Medicine, Advanced Studies Group, Hq. USAF Aerospace Medical Center, Brooks AFB, Texas.

Captain Anthony Bezreh, MC, Human Factors Section, USABAAR, Fort Rucker, Alabama.

Bernard C. Doyle, Senior Technical Analysis Specialist, Engineering Division, Bureau of Safety, Civil Aeronautics Board, Washington, D. C.

Charles O. Miller, Chief of Systems Reliability, Chance-Vought Corporation, Dallas, Texas.

Major Ellis R. Taylor, Chief of the Biodynamics Branch, Holloman AFB, New Mexico.

RELATED TASKS

"The Contractor shall perform other specified related tasks assigned by the Contracting Officer, or as recommended by the Contractor and approved by the Contracting Officer within limits of available manpower, facilities and funds."

DYNAMIC TEST OF AN EXPERIMENTAL TROOP SEAT, TCREC Technical Report 62-48, June 1962

A seat similar to the one used for the full-scale crash drop test conducted by AvCIR on 9 August 1961 (Figure 29) was tested at Wright-Patterson Air Force Base, Ohio, during the period 13 through 23 December 1961, utilizing a vertical deceleration drop tower. Three test programs were conducted. The first series of tests were conducted to determine the deformation rate for the energy absorbers used in the seat. This deformation rate was then used to compute drop heights for the initial seat drops. Twelve drops of single energy absorber and various weight combinations were conducted during this series. The second series of tests consisted of five drops of the seat itself, with the energy absorbing devices incorporated in the seat mechanism. The third series of tests consisted of six drops of the seat at increasing 5G increments, without the energy absorbers installed, until ultimate failure of the seat occurred.

On the basis of the tests conducted, it is concluded that the shape of the acceleration pulse can be changed from a high G triangular shape to a low G trapezoidal shape and that forces imposed upon the seat can be reduced by approximately one-half through use of the energy absorbing features incorporated in the experimental troop seat.

As a result of these tests, it was recommended that:

1. The concept of the Hardman Mark III energy absorbing system be utilized in the design of all troop seats which are to be used in Army aircraft.

2. A new troop seat which incorporates the concepts of the Hardman Mark III energy absorbers be designed.

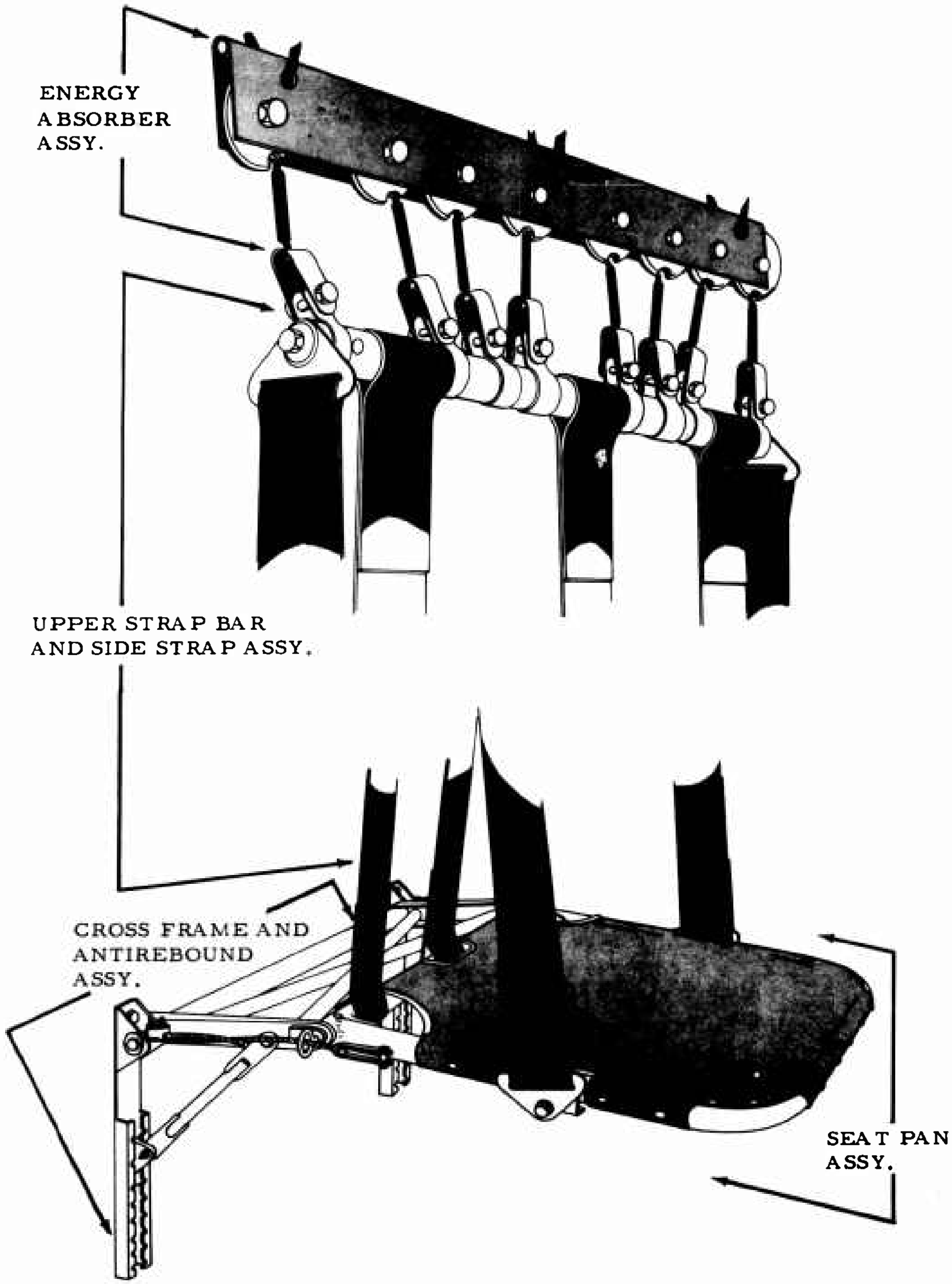

Figure 29. Seat Sketch Showing Assemblies.

3. All future testing of seats include dynamic as well as static conditions.

4. The concept of attaching the seat to structure other than the floor be considered in future seat designs.

BREAKAWAY FUEL CELL CONCEPT, TREC Technical Report 62-37, May 1962

In June 1961, AvCIR conducted a crash test utilizing an H-13G helicopter. An experimental breakaway fuel cell system, developed by the U. S. Army Board for Aviation Accident Research, was incorporated in this test.

Although the breakaway fuel cell system did not function entirely as anticipated during the dynamic crash test, analysis of the test results indicates that the concept of the system is sound and that the possibility of application of this concept exists.

The report recommended that:

1. The concept of breakaway fuel cells as developed by the United States Army Board for Aviation Accident Research be further developed and tested during future crash tests.

2. A study be made to determine the feasibility of breakaway fuel system installation on existing and future models of Army fixed- and rotary-wing aircraft (Figure 30).

3. Additional dynamic testing of the breakaway fuel cell system utilizing various methods of tank construction and tank suspension systems on both fixed-wing and rotary-wing aircraft be conducted. A simple drop test device can be utilized for this purpose.

HANDBOOK FOR AIRCRAFT ACCIDENT INVESTIGATORS

This handbook has been prepared as a guide for aircraft accident investigators who are now participating, through their agencies' programs, in the research program of AvCIR in an effort to find better ways of defining and describing accidents and increasing the accuracy of judgments made by investigators.

Figure 30. Concept of Operations of the Breakaway Fuel Tanks.

Crash injury research attempts to correlate basic relationships between causes of injury and the injuries that are the consequences of these causes in a crash. A large part of this effort depends on proper instructions in ways of describing and measuring the circumstances surrounding the crash so that conclusions can be translated into engineering design principles.

Two very important reasons are presented to justify a thorough and accurate accident investigation report. The first is that typical accident patterns or configurations can be identified. Such information tells us what kind of tests we should set up for the more highly controlled experimental crash testing program. Our progress will be greater if we understand the factors contributing to injury in frequently occurring accident configurations because the efforts will be expanded in the places where they will do the most good. The second reason is that, with such information, we can keep track of changes in injury that come about from changes in design. We can evaluate attempts to improve crashworthiness, tiedowns, occupant environment, and energy absorption, and to eliminate postcrash hazards. Related to this second reason is the identification of problem areas. By following the crash safety trends over periods of time, new problems may be discovered.

The handbook offers instructions in how the accident report forms are to be filled out, at the same time giving the basic reasons why certain information is requested. Special instructions are given for correct procedure in taking photographs of crashes for visual recording, a very important aspect of the final analysis. Sample AvCIR investigation report forms and a "sighting diagram" with instructions are included to aid in reporting accident data. Medical report forms and the AvCIR Degree of Injury Scale are presented with instructions as general information.

WORK ITEM 11

SYNTHESIS OF IMPACT ACCELERATION TECHNOLOGY (SIAT)

On 8 December 1961, the U. S. Army Chief of Transportation and the Cornell-Guggenheim Aviation Safety Center cosponsored an Aviation Crash Injury Symposium, bringing together high-level officials of the Department of Defense and Federal and Civil agencies having an interest or responsibility in this field. Resulting from this conference was the formation of an Aviation Crash Injury Steering Committee, whose mission was to "review programs and studies, make recommendations as to what research should be conducted and where, in order to accomplish the aims of the Symposium most effectively."

A subsequent meeting on 18 May 1962 finalized a specific course of action by the committee, the first phase of which was to be a review of data from all known information sources to date relative to the impact acceleration aspects of crash injury prevention, with emphasis on the crash loads aspects of the problem. It was also suggested that some method be devised to facilitate simplified retrieval of the collected information for the benefit of subsequent investigators.

In June 1962, a supplemental agreement to the contract was initiated which stated the following: "The Contractor shall search, gather, catalogue, and evaluate applicable information and data on impact acceleration preparatory to evolving ranges of acceleration time pulses, including acceleration magnitudes, plus shapes and durations, for fixed-wing and rotary-wing aircraft for crew, passengers, and equipment within the crew and passenger compartments."

Thus, Project SIAT, Synthesis of Impact Acceleration Technology, for aviation crash injury prevention, was initiated with the dual purpose of assisting the Steering Committee and to provide the basis for increasingly efficient direction of crash injury research and implementation of corrective action as deemed necessary for U. S. Army aviation vehicles.

In the interest of adhering to a reasonable schedule for this effort, the scope of the project was established firmly to preclude an ever-present tendency to divert the investigators' interests to other aspects of the problem. Therefore, it was decided immediately to limit the literature and information search to the following five areas:

HAZARD EXPOSURE - How many lives are at stake (passengers, pilots, crew members) in injury-producing accidents of nonejection-seat aircraft?

CRASH LOADS - What pulse patterns are imposed on the aircraft and personnel during a crash, from the standpoint of acceleration.

HUMAN TOLERANCE - How well can people tolerate these crash impact loads?

DESIGN FOR IMPACT ACCELERATION - To what extent can aircraft structure and interior equipment incorporate crash safety design characteristics, and what are their anticipated degrees of effectiveness?

TEST AND ANALYSIS METHODOLOGY - What are the optimum techniques for analyzing or testing problem areas in crash injury research?

Approximately nine hundred documents unique to this study were catalogued and are available in a library at the AvCIR facilities in Phoenix. Approximately three hundred additional references of apparent applicability were also identified and are being obtained, where possible, at the time of this report's preparation. An information retrieval system was devised to facilitate future crash injury research using these data. A bibliography is currently being prepared on these documents.

The primary effort during this study was devoted to collecting the data. However, the scores of personal contacts made throughout the industry and the reading of documents themselves provided a general insight into the Nation's technology in impact acceleration crash injury research.

REMOTE CONTROL SYSTEMS

In order to properly simulate an actual crash, it is necessary to have all components, i.e., the engine, rotors, transmissions, etc., operable so that actual crash loads and kinematics can be recorded. Therefore, the study of the feasibility of an aircraft droning system device was completed and a specification was prepared. The specification for the droning device included the control of an H-21, in flight, into a controlled crash at a predetermined speed, rate of descent, attitude, and angle of impact. Upon evaluation of several proposals received, the Kaman Aircraft Corporation was awarded a subcontract for the design and construction of this control system.

The method selected for the performance of this test utilized a radio-link drone control system to control the helicopter through a predetermined flight profile. The profile of an actual flight as recorded by a Fairchild Flight Analyzer Camera is presented as Figure 15 in Work Item 4.

The helicopter flight controls on the left side of the cockpit were modified to accommodate the drone control system. Five Sperry SP-3 computer actuators were installed and connected to the collective pitch control, the forward and aft cyclic control, the lateral cyclic control, the antitorque pedals, and the throttle control. A directional gyro and gyro horizon were also mounted at the helicopter's center of gravity. The gyros provided altitude and directional control signals to the servo control actuators.

A standard engine tachometer, which provides a signal to the pilot engine speed indicator, was also used in this system. Additional wiring was provided to supply the tachometer output signal to the throttle computer actuator.

A control junction box was installed to function as an interconnection location between the computer actuator and the control signal inputs. It also included test switches, power equipment, and signal conditioning circuiting for the system.

A switch panel was installed on the top of the right collective pitch control stick. These switches were used by the pilot during test flights of the control system and during the final system checkout and setup prior to the droned flight.

A Babcock Electronics Corporation BCR-50 radio receiver decoder was installed on the radio rack directly behind the copilot's seat. The receiver-decoder converted the radio link signals from the transmitter on the ground into signals suitable for use in the computer actuator control system.

The ground control station consisted of an F. M. transmitter operating at a carrier frequency of 406. 4 Mc and was used to provide the radio transmission link for the system.

RESTRAINT SYSTEMS STUDY

Studies of feasibility and practicability of improving the attachment of seat belts and shoulder harness inertia reels for crew and passengers in selected Army aircraft were completed during this period for the Transportation Materiel Command. The first report, "Basic Concepts", provides the overall considerations and background for the three reports concerning the AC-1, HC-1, and the HU-1A and 1B aircraft. Detailed studies of crew and passenger restraint systems to be modified and complete sets of blueprints for accomplishing these modifications were made on the three aircraft noted above. The reports covering these studies are listed as follows:

PERSONNEL RESTRAINT SYSTEMS STUDY - BASIC CONCEPTS

This report covered the basic concepts, which are applicable to all U. S. Army aircraft, that are pertinent to a personnel restraint systems study. Man's tolerance to decelerative loads was reviewed and related to the existing restraint harnesses currently being used in Army aircraft. The magnitude of decelerative loads to which airframes of various aircraft have been dynamically tested, while still maintaining a livable volume in the cabin, was also reviewed; it was noted that man's tolerances to impact loading are, in general, higher than airframe limits.

Several practical harness configurations were discussed, the load distribution between the various components of the harness were explored, and design strength values were recommended. A restraint harness configuration for side-facing personnel was also discussed. The dynamic strength of restraint systems was discussed and related to the static strength of these systems.

From this study it was concluded that:

1. Forward-facing personnel, restrained by lap belt and shoulder straps only, tend to "submarine" under the lap belt during deceleration; the "submarining" can cause serious injuries. The addition of a lap belt tiedown (a vertical attachment to prevent upward movement of the lap belt) will reduce the "submarining" and improve the

restraint provided by the existing lap belt and shoulder straps.

2. The optimum width of a lap belt is considered to be 2.5-3.0 inches for all aircraft passengers; this width insures minimum webbing pressure consistent with comfort.

3. The standard double-strap shoulder harness should be increased in width from the existing 1.72 inches to a width of 2.0 inches. This width insures minimum webbing pressure consistent with comfort. The increased shoulder strap width will hopefully reduce the physiological effects of deceleration.

4. The optimum angle of the lap belt, measured in respect to the seat cushion, is 45-55 degrees.

5. Side-facing personnel need upper torso restraint to insure that decelerative forces are applied perpendicular to the spine; however, the addition of shoulder straps for personnel seated on existing understrength troop seats is not considered worthwhile, because failure of these seats will nullify the benefits of the shoulder straps.

6. The side-facing restraint harness, with the diagonal strap and arm band, illustrated in this report, offers several advantages over the standard, double-shoulder strap, forward-facing harness.

7. Shoulder straps for forward-facing and side-facing personnel should pass over the shoulders at an angle between zero and 30 degrees with respect to a horizontal plane.

8. The type G-1, 1800-pound shoulder harness (dwg. AF50D3770) is understrength and permits excessive elongation.

9. Harness components should be designed to withstand the following loads for a minimum of 0.1 second:

Shoulder Straps	-	4000 lb
Lap Belt	-	6000 lb
Inverted "V" Strap	-	3000 lb
Belt Tiedown Strap	-	2500 lb

10. Existing lap belts and shoulder straps in Army aircraft are described by ten military specifications and fifteen (USAF and Navy) drawings; it would seem logical to select one specification or drawing to govern all belt and shoulder strap procurement in future designs.

11. Inertia reels should be dynamically tested to determine their resistance to rapid extension rates as expected in actual crashes, and the automatic inertia locking adjustment should be changed from 2-3G to 2.5-3.5G to insure against inadvertant actuation.

12. The entire "tiedown chain", which includes the lap belt, the shoulder harness, the seat, the floor, and all related anchorages, should be compatible with the restraint harness design. In order to make the various components of the "tiedown chain" equal to the known human tolerance limits, and to the apparent crash limits of aircraft structures, the following strength values should be considered for use by restraint system designers:

    Transverse direction (perpendicular to the spine) -
        45G for 0.10 second, and
        25G for 0.20 second

    Vertical direction (headward) - 25G* for
        0.10 second

* The 25G limit in the vertical direction is based upon the human limits as noted in this report; minor injuries are expected in the neighborhood of this value, but the injuries should not be serious enough to prevent an escape from the aircraft. Since the vertical (headward) decelerations in survivable aircraft accidents, particularly with VTOL aircraft, will often exceed this value, some method of energy absorption should be provided in seat designs in order that decelerative loads do not exceed 25G.

13. The failure strength of restraint system designs which utilize ductile materials can be considerably higher where "limit analysis" and ultimate design concepts are used in preference to traditional elastic stress analysis, in which plastic deformation is avoided. Limit analysis and ultimate design are dependent upon plastic deformations.

14. The use of ductile materials in the "tiedown chain" is desirable in that plastic deformations tend to dampen short-duration peak loads such as actually experienced in accidents.

PERSONNEL RESTRAINT SYSTEMS STUDY - AC-1 DeHAVILLAND CARIBOU

This report presented detailed suggestions for the improvement of the personnel restraint system in the U. S. Army AC-1 aircraft. The recommendations pertained primarily to strengthening existing restraint system components rather than to a basic change of the system. The modifications presented indicate an increased strength of the crew seats from 20-25G to 35-40G, and of the troop lap belt anchorages from 12-15G to 22-28G.

It is interesting to note that the above strength increases can be achieved with a weight reduction of 1 pound per aircraft at a cost of approximately two hundred dollars per aircraft.

This report included the following information:

1. Engineering - Strength analysis of proposed modifications.

2. Parts Procurement - Detailed engineering drawings with a bill of materials from which retrofit kits can be procured.

3. Parts Manufacture - Drawings necessary for the manufacture of retrofit kits.

4. Retrofit Kit Installation - Sufficient drawings for installation of the retrofit kits by Army personnel in the field.

5. Administrative - A cost and weight summary of proposed modifications along with the expected strength increase.

This study led to the following conclusions:

1. The restraint system in the AC-1 is designed in accordance with, and in many instances exceeds, the requirements of the applicable military specifications; however, it is still less than one-half of the desired strength in accordance with crash load data and human tolerance data.

2. The restraint harness in the cockpit is designed for approximately a 40G loading; however, the addition of a lap belt tiedown as shown in this report will improve the effectiveness of this harness in preventing pelvic region injuries resulting from the upward movement of the lap belt during longitudinal decelerations.

3. Attaching the lap belts and shoulder harness of the crew seats to basic structure does not appear to be the most practical method for strengthening the restraint system.

4. If the cockpit crew seats and supporting structure are reinforced, as indicated in this report, the crew's restraint system is calculated to sustain a 35G longitudinal load combined with a 17G lateral load.

5. The lap belts for the troops are designed for a 25G load, but the lap belt attachment to fuselage structure is designed for only half this amount.

6. If the troop lap belt attachments to fuselage structure are reinforced, as indicated in this report, the belts are calculated to sustain 25G loads in all directions.

7. The addition of shoulder straps for troops is not practical unless the troop seats are redesigned and modified to withstand higher crash loads in accordance with known limits.

PERSONNEL RESTRAINT SYSTEMS STUDY - HC-1B, VERTOL CHINOOK

This report presented detailed recommendations for the improvement of the personnel restraint system in the U. S. Army HC-1B aircraft. The recommendations pertained primarily to strengthening the existing restraint system components. The modifications proposed indicated the following strength improvements: (1) Cockpit - The crew's restraint system is increased from an 8-12G value to a 25-30G value; (2) Troop Compartment - The troops' lap belt attachments are increased from a 10-15G value to a 22-28G value.

The above strength increases can be achieved with a weight increase of 7 pounds per aircraft and at a cost of approximately three hundred dollars per aircraft.

This report included the following information:

1. Engineering - Strength analysis of proposed modifications.

2. Parts Procurement - Detailed engineering drawings with a bill of materials from which retrofit kits can be procured.

3. Parts Manufacture - Drawings necessary for the manufacture of retrofit kits.

4. Retrofit Kit Installation - Sufficient drawings for installation of the retrofit kits by Army personnel in the field.

5. Administrative - A cost and weight summary of proposed modifications.

This analysis of the HC-1B personnel restraint system revealed that:

1. The personnel restraint system in the HC-1B is designed in accordance with, and in many instances exceeds, the requirements of the applicable military specifications; however, it is still only about one-fourth of the desired strength in accordance with crash load data and human tolerance data.

2. The shoulder straps, inertia reel, and lap belts in the cockpit are designed for a 40G loading; however, human tolerance experiments indicate that this harness allows the lower torso to "submarine" under the belt during high longitudinal decelerations. The "submarining" can cause abdominal and spinal injuries.

3. Attaching the lap belts of the crew seats to basic structure does not appear to be the most practical method for strengthening the restraint system for the pilot and copilot; however, if the cockpit crew seats and supporting structure are reinforced, as indicated in this report, the crew's restraint system is calculated to sustain a 27G longitudinal load combined with a 13.5G lateral load.

4. The troop commander's or crew chief's seat should be equipped with a shoulder harness and lap belt tiedown strap. If a shoulder harness and lap belt tiedown combination are added to the lap belt, the troop commander's restraint harness is considerably improved.

5. The troop commander's seat appears inadequate to sustain vertical loads in a survivable crash because of the manner in which it is attached to the aircraft structure.

6. The lap belts for the troops are designed for a 25G load, but the lap belt attachments to fuselage structure are designed for only half this amount.

7. If the troop lap belt attachments to fuselage structure are reinforced, as indicated in this report, the belts are calculated to sustain 25G loads in all directions.

8. The addition of shoulder straps for troops is not practical unless the troop seats are redesigned and modified to withstand higher crash loads in accordance with known human limits.

9. The resistance of the crew seats to vertical loads would be improved if an energy-absorbing type seat cushion is used. The use of this cushion would also reduce the spinal column loads of the seat occupant.

PERSONNEL RESTRAINT SYSTEMS STUDY - HU-1A and HU-1B BELL IROQUOIS

This report presented detailed recommendations for the improvement of the personnel restraint system in the U. S. Army HU-1A and HU-1B aircraft. The recommendations pertained primarily to strengthening the existing restraint system components. The modifications proposed indicate the following strength improvements: (1) Cockpit - The crew's restraint system is increased from a 10-12G value to a 20-25G value; (2) Troop Compartment - The troops' lap belt attachments are increased from a 12-15G value to a 22-25G value.

The above strength increases can be achieved with a weight increase of 7 pounds per aircraft and a cost of approximately seventy dollars per aircraft.

This report included the following information:

1. Engineering - Strength analysis of proposed modifications.

2. Parts Procurement - Detailed engineering drawings with a bill of materials from which retrofit kits can be procured.

3. Parts Manufacture - Drawings necessary for the manufacture of retrofit kits.

4. Retrofit Kit Installation - Sufficient drawings for installation of the retrofit kits by Army personnel in the field.

5. Administrative - A cost and weight summary of proposed modifications.

This analysis of the HU-1A and HU-1B personnel restraint system revealed that:

1. The personnel restraint system is designed in accordance with, and in many instances exceeds, the requirements of the applicable military specifications; however, it is still only about one-fourth of the desired strength in accordance with crash load data and human tolerance data.

2. The shoulder straps, inertia reel, and lap belts in the cockpit are designed for a 30G loading; however, human tolerance experiments indicate that this harness allows the lower torso to "submarine" under the belt during high longitudinal decelerations. The "submarining" can cause abdominal and spinal injuries.

3. Attaching the lap belts of the crew seats to basic structure does not appear to be the most practical method for strengthening the restraint system for the pilot and copilot; however, if the cockpit crew seats and supporting structure are reinforced and the shoulder harness is attached to the cargo floor, as indicated in this report, the crew's restraint system is calculated to sustain a 20.6G longitudinal load combined with a 10.3G lateral load.

4. The lap belts for the troops are designed for a 25G load, but the lap belt attachments to fuselage structure are designed for only half this amount.

5. If the troop lap belt attachments to fuselage structure are reinforced as indicated in this report, the belts are calculated to sustain a 25G load.

6. The addition of shoulder straps for troops is not practical unless the troop seats are redesigned and modified to withstand higher crash loads in accordance with known human limits.

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6. Crash Safety Equipment and Procedures.
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