REPORT TO NASA COMMITTEE ON
AIRCRAFT OPERATING PROBLEMS
RELATIVE TO AVIATION SAFETY ENGINEERING
AND RESEARCH ACTIVITIES

AvSER Report No. 63-11

Prepared by
Aviation Safety Engineering and Research
2871 Sky Harbor Blvd., Phoenix, Arizona
A Division of Flight Safety Foundation, Inc.
1 September 1963
SUMMARY OF AvSER PROGRAM

The following reports highlight some of the work accomplished by the Aviation Safety Engineering and Research Division of the Flight Safety Foundation since the last report to the NASA Committee on Aircraft Operating Problems on 22 May 1963. The information presented is in summary form. Additional details may be provided upon request or the reports themselves may be obtained from AvSER.

AvCIR Report 61-18, Judgement 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 photographs, 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, or high). Photographs of 48 damaged containers, 10 for each of four different types of objects - cylinder, cylindroid, rectangular-base box, and square-base box - were assembled into notebooks to correspond to the nine 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
The estimate of single-observer reliability for post-injury judgments was 84%.

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


This report presents findings in a crash injury investigation of a U. S. Army HU-1A Bell Helicopter which crashed on 7 May 1962 at 0906 hours. The crash occurred while the helicopter was conducting a service mission on the Fort Carson military reservation.

A total of six persons were aboard the helicopter at the time of the crash, including one crew member and five passengers. Five of the occupants received varying degrees of injury, ranging from minor to severe, and one was a fatality.

A crash injury investigation of the accident was conducted by Aviation Crash Injury Research (AvCIR) under the provisions of U. S. Army Transportation Research Command contract DA 44-177-TC-602.

The investigation revealed that the predominant cause of injury was the failure of all roof support members. A continuing trend in the failures of the carriage attachment fittings in the crew seats was also noted; although not contributing to the injuries experienced in this accident, such failures are extremely dangerous because they directly affect the restraint of the occupant.
As a result of the crash injury investigation, it was concluded that:

1. The vertical roof support members in the HU-1A will not support the overhead structure under roll-over conditions, or under moderate impact conditions.

2. The cast magnesium, aft-seat carriage attachment (Part No. 204-070-742), of the pilot and copilot seats failed under the moderate impact loads experienced in this accident.

3. The anchoring of the passengers' seat belts to the aft-seat support members, approximately 4.5 inches higher than the installed safety belt attachment fittings, permitted the restrained occupants to "submarine" under their seat belts, exposing them to unnecessary internal and/or spinal injury.

4. The pilot's helmet (APH-5) failed because of stress concentration caused by the sharp edges of the visor keeper.

Based upon the foregoing conclusions, it was recommended that:

1. Consideration be given to the installation of a suitable roll-over structure in all HU-1A aircraft to prevent the roof structure from collapsing into the occupied area of the aircraft.

2. The aft-crew-seat carriage attachments be modified in the field to increase their strength.

3. The passenger compartment seat belts be attached to the firewall so that the belt crosses the iliac crest at 45 degrees.
4. The design of the structural stress concentration points and
features are designed to provide progressive deformation of the
structure when shell failure occurs in localized areas.

A. CUR Report No. 01-17, U. S. Army H-23B Helicopter Accident, U. S.
Army Transportation Aeronautical Maintenance Center, Naval Air Station,
Corpus Christi, Texas, September 1962.

This report presents findings of the crash injury investigation of a Hiller
H-23B helicopter which experienced immediate loss of rotor RPM after an
unexplained rapid vertical rise. The helicopter descended vertically from
an estimated height of 40 feet apparently uncontrolled and made contact with
a concrete ramp apron in a level attitude.

The pilot and passenger both sustained significant decelerative injuries in
the form of angular compression fractures of lumbar vertebrae.

The injury mechanism appears to involve two factors: (1) the vertical force
transmitted from structures beneath the occupants' "seat pans" was magni-
ified, and (2) the absence of any type of upper torso restraint (shoulder harness)
contributed to poor body positioning at impact.

From examination of the helicopter and occupants, it was concluded that:

1. Crash force loads experienced by the occupants approached the
   upper limit of human tolerance for the type of restraint utilized
   in this helicopter.

2. The landing gear of the H-23B absorbed a large amount of crash
   force loads, thus precluding more severe injury to the occupants.
3. The seat cushions in the H-23B provide very little capability for absorbing such forces.

4. The seat cushions utilized in the H-23B are constructed of a material that allows the occupant to "bottom out", without attenuation of crash forces.

5. Use of a proper shoulder harness installation would have prevented both occupants from being thrown forward against nonyielding structure and would have contributed to better body positioning at impact.

Based upon the foregoing conclusions, it was recommended that:

1. The H-23B be retrofitted with a shoulder harness incorporating an omnidirectional inertia reel.

2. A survey of seat cushions utilized in all present reconnaissance helicopters be made in order to determine their energy-absorbing capabilities.

3. A retrofit seat cushion be designed incorporating an energy absorption platform and a cushioning material for comfort.

4. Future design projects for all helicopters include specifications for a seat installation with adequate energy-absorption capabilities or characteristics.


This report presents a glossary of terminology used in injury analysis together with lists of common medical prefixes and suffixes for the benefit
of non-medic personnel involved in accident investigation.

These basic aids designed to supplement a concise atlas of human anatomy. Properly employed, these aids will assist not only in the interpretation of autopsy data, physician and hospital reports, etc., but will provide a means for achieving professional accuracy and detail in reporting and correspondence.


Strength requirements set forth in military specifications governing the design and fabrication of nonejection-type crew 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 may be anticipated in accidents involving Army aircraft.

The analysis revealed that the strength requirements quoted in current military specifications are considerably lower than (1) those which would be dictated by the upper limit of accelerations which can be tolerated by the occupants of the seats and (2) the accelerations and forces that are associated with Army aircraft accidents. This substantiates the observation by the Army that these seats fail under relatively moderate accident conditions, thus subjecting the occupant to further hazards, especially in increased contact injuries.

On the basis of the detailed examination of current specifications, human tolerance, and impact acceleration data, it is recommended that the crew seat specifications be revised and that dynamic load factors of 25G for 0.20 second plus 45G for 0.10 second, measured in the pelvic region of a suitable
anthropomorphic dummy, be adapted for crew seat design in the longitudinal and lateral directions, and 25G for 0.20 second for the vertical direction.

In addition, an energy absorption capability must be incorporated into the seat system to reduce the vertical accelerations, which will frequently exceed 25G, to a tolerable level.

Based upon the information contained in this report, it is concluded that:

1. Crew seats built to specification MIL-S-5822 fail under relatively moderate impact conditions, exposing the occupants to unnecessary injury or death.

2. The most significant deficiencies in the above-cited specification are the design load factors. They are incompatible with known human tolerance to abrupt accelerations and with impact acceleration levels which may be expected in potentially survivable aircraft accidents.

3. Revision of the specification, with particular emphasis on increasing the design load factors as recommended in this report, will reduce the incidence of seat failures and will provide protection for the occupants commensurate with human tolerance to acceleration and consistent with the strength and energy-absorbing characteristics of modern Army aircraft.

Based upon the foregoing conclusions, it is recommended that:

1. Applicable military crew seat and related specifications be revised to provide increased occupant protection in potentially survivable crashes.
2. All revisions of the applicable specifications be based upon the following design load factors:

a. **Longitudinal and Lateral Design Loads**: The seat, its support system, and the occupant restraint system should, individually and in combination, be capable of maintaining 25G for 0.20 second and 45G for 0.10 second in the pelvic region of a suitable anthropomorphic dummy having a weight and mass distribution of that of the heaviest occupant expected. Progressive plastic deformation of the seat and restraint system is permissible provided (1) complete failure and (2) subsequent injurious situations do not occur.

b. **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 (a) above, 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.

**AvCIR Report No. 62-23, Dynamic Test of an Aircraft Litter Installation.**

This report presents an analysis of the crashworthiness characteristics of a standard litter/patient restraint system as installed in a helicopter which was subjected to a dynamic crash test.

On 12 September 1962, Aviation Crash Injury Research conducted a dynamic crash test of an H-21 helicopter. Several personnel restraint systems were
A high-speed camera was positioned in the helicopter to record the action of the litter installation during the crash sequence.

Although the crash was considered to be survivable, the litter/patient restraint system failed completely. The details of the failures are discussed; and it is concluded that the military specifications covering litter/patient restraint systems are not realistic and, therefore, litter/patient restraint systems produced in accordance with these specifications do not provide adequate protection for the occupant under moderately severe, but potentially survivable, crash conditions.

Based on the information contained in this report, it is concluded that military specifications pertaining to litter/patient restraint systems do not require sufficient strength to provide protection for the occupants in certain potentially survivable accidents.

Based on the foregoing conclusion, it is recommended that:

1. A thorough investigation be initiated to develop realistic design criteria for litter/patient restraint systems.

2. Additional testing of litter/patient restraint systems consist of tests of the entire assembly as contrasted with the testing of single components.
This report presents an analysis of the crashworthiness characteristics of a commercial helicopter passenger seat as installed in a helicopter which was subjected to a full-scale dynamic crash test.

On 12 September 1962, Aviation Crash Injury Research conducted a dynamic crash test of an H-21 helicopter under contract to the U. S. Army Transportation Research Command. Included among several personnel restraint systems tested in this experiment was a prototype passenger seat built for a commercial helicopter. The two-passenger forward-facing seat was occupied on the aisle side by an anthropomorphic dummy and on the wall side by sandbags designed to simulate a second passenger.

The dummy was instrumented by accelerometers installed in the pelvic area. These accelerometers were arranged to permit recording of the impact decelerations in the longitudinal, lateral, and vertical directions. A tensiometer in the dummy's seat belt recorded seat belt force. A high-speed camera recorded the action of the seat and occupant during the entire crash sequence.

The seat maintained its structural integrity to the extent that a properly belted occupant would have been retained both in the seat and in the original location in the cabin. However, large displacements of the arms, legs, and
In contact to the seat, implying severe
motion to the dummy. However, it is probable that severe
motion would have occurred had such seats been present.

Based on the data presented in this report, it is concluded that:

1. This commercial passenger seat probably incorporates sufficient
   strength to provide retention in potentially survivable crashes of
   the type described in this report.

2. In this test, the floor immediately forward of the test seat
   buckled in such a way as to provide some longitudinal support
   for the seat. Only further tests or actual experience with the
   seat in accident situations will allow evaluation of the seat with
   respect to ability of the seat to withstand longitudinal accelerations
   when unsupported.

3. Flailing of the extremities of the dummy occupant occurred to
   an extent suggesting that injurious contact with other seat structures
   would have occurred had such seats been present.

4. The aisle leg of the seat is quite rigid and may constitute a hazard
   to the occupant under high vertical decelerations due to its inability
   to deform or to absorb energy.

5. The decelerations experienced in this potentially survivable crash
   would probably have caused failure of the wall attachment tube if
Based on the foregoing conclusions, it is recommended that:

1. The folding leg of the commercial passenger seat be redesigned to incorporate energy absorption capability to reduce peak vertical accelerations.

2. The attachment of the seat to the wall of service aircraft be capable of developing the full potential of the seat. The standard troop seat attachments in the H-21 are inadequate from this standpoint.

3. Additional restraints in the form of shoulder harnesses be installed.

4. Provision be made for reducing injury through contact of the lower extremities with the rear main beam of the seat in all installations involving tandem seating.


This report presents detailed recommendations for the improvement of the personnel restraint system in the U. S. Army HC-1B aircraft. The recommendations pertain 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 an 8-12G value to a 25-30G value, (2) Troop Compartment - The troop's lap belt attachments are increased from a 10-15G value to a
This report includes 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.
5. Administrative - A cost and weight summary of proposed modifications.


This report presents detailed recommendations for the improvement of the personnel restraint system in the U. S. Army HU-1A and HU-1B aircraft. The recommendations pertain 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 troop's lap belt attachments are increased from a 12-15G value to a 22-25G value.
This report includes 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.
5. Administrative - A cost and weight summary of proposed modifications.


This was a paper prepared for presentation at the Flight Safety Foundation International Air Safety Seminar held in Williamsburg, Virginia, during December 1962 by Dr. Lee Gregg.

The purpose of the paper was to present new techniques in assessing damage from aircraft accident investigations in an effort to improve ways of determining the time sequence of physical events which occur during and immediately following a crash.

Discussed are the use of concepts borrowed from the fields of psychology, mathematics, and systems engineering as they are being applied to this area.
AvCIR Report No. 62-30, Discussion of the Postcrash Fire Problem.

This was a paper prepared for presentation at the Flight Safety Foundation International Air Safety Seminar, December 1962, at Williamsburg, Virginia.

The purpose of the paper was to present possible solutions in solving the postcrash fire problem. Four possible solutions discussed were:

1. **Fire Inerting Systems** - AvCIR's experience in this field - a conclusion that acceptable fire inerting systems are feasible and would reduce the incidence of fire by a significant percentage.

2. **Containment** - Application by installation of crash-resistant fuel tank bladders.

3. **Breakaway Tanks** - AvCIR's experience in this field - a conclusion that the concept is sound and its use on certain aircraft would reduce the occurrence of fires.

4. **Solidification of Fuel** - A relatively new concept - experimental work need for determination of feasibility and practicality.

AvCIR Report No. 63-1, An Operational Test of a Fire Inerting System for Helicopters.

This report describes the theory, development, and test of a fire inerting system for helicopters. The feasibility of constructing a light weight system
It is concluded that:

1. A fire inerting system for helicopters should be in operation within 0.20 second or less after first impact.

2. A "time to operate" of 0.20 second can be attained in an operational fire inerting system.

3. A fire inerting system can be installed in a 10,000-pound aircraft with as little as 80 pounds increase in overall weight including coolant.

It is recommended that:

1. Continuance of this study should be made with the turbine engine since the primary source of power in many present day and most future production helicopters is the turbine engine.

2. An operational electrical de-energizing system be developed. This system must provide for safety while in normal flight, yet should be simple and afford maximum protection to the aircraft occupants in an emergency situation.

3. A simple but reliable operational fire-inerting-system triggering device or initiator be developed.
4. Methods of eliminating abraded sparks which have sufficient intensity to provide ignition be sought and immediately employed in all new aircraft designs.

5. The feasibility of using a flame retarding hydraulic fluid be investigated.

6. Techniques that will improve fuel containment be investigated both theoretically and experimentally.

7. The feasibility of utilizing special surfacing to increase the surface ignition temperature in operational systems be evaluated. For example, when metals are surfaced with certain compounds, e.g. platinum, their temperature must be raised an additional 300 to 700 degrees F. to provide ignition.

8. A study of the nature of fuel spillage patterns in helicopter accidents, and their effect upon ignition source and ignition delay, be made to provide a better understanding of the helicopter postcrash fire problem.

9. Control linkage tubes located in zones of the aircraft subject to in-flight fires should be constructed of steel or material possessing good strength at elevated temperatures.
This report presents an evaluation of the crashworthiness characteristics of two experimental troop seats as indicated from test data obtained from dynamic crash tests. The seats were installed and dynamically tested along with other equipment in full scale crashes of CH-21 helicopters. The first seat was tested on 12 September 1962 and the second on 19 April 1963. The tests were conducted by Aviation Safety Engineering and Research (AvSER) under contract to the U. S. Army Transportation Research Command.

The seats represented two steps in the development of a troop seat using a strut type of energy attenuation. The seats were single passenger, side-facing, bucket seats. For the test, anthropomorphic dummies were placed in the seats and restrained by lap belts and single diagonal chest straps. Accelerometers were mounted in the pelvic cavity of the dummies and arranged to permit recording of the impact decelerations. Tensiometers were mounted on the seat belts to record the belt forces. High speed cameras positioned in the helicopters recorded the reactions of the dummies and experimental seats during the crash sequences.

The seats were divided into two basic functional units. First, a seat base incorporating an energy-absorbing strut to provide the vertical support and second, an occupant enclosure which, in addition to the lap belt and chest strap, was designed to provide the occupant with restraint in the lateral and longitudinal directions.
The tests series demonstrated the effectiveness of strut type energy-absorption as a method of attenuating crash forces.

Based on the data presented in this report, it was concluded that:

1. Peak decelerations can be successfully reduced by use of an energy-absorbing support strut, even under conditions of severe floor crushing.

2. Proper attention must be given to attaching troop seats to aircraft basic structure by methods compatible in strength to the strength of the seat.

3. There is a definite tendency for the occupant to submarine when the energy-absorbing strut begins to depress.

Based on the foregoing conclusions, it was recommended that:

1. Steps be taken to begin procurement and installation of a seat based on this energy-absorbing strut concept in operational Army helicopters.

2. A more positive method of maintaining the seat pan parallel to the floor be devised.

3. A more positive restraint system such as a crotch strap be utilized to keep the occupant from submarining.
This report presents a compilation of observations of airframe deformation which occurred during a full-scale drone crash of an H-21A helicopter.

The information contained in this report, though general in nature, is intended to convey an understanding of the type and severity of damage which can be expected to occur following an unsuccessful autorotation attempt in an H-21A helicopter.

The report contains verbal descriptions of the crash sequence and the airframe deformations which resulted, as well as photographs of typical component damage.

Based on the data presented in this report, it is concluded that:

1. Although severe, this crash was potentially survivable from the standpoint of impact, since the occupiable areas of the aircraft remained reasonably intact.

2. When H-21 aircraft are involved in accidents with circumstances similar to those encountered in this test, rupture of the main fuel cell is highly probable, even in accidents much less severe than this test. This means that an extreme fire hazard exists in H-21 accidents of this nature.

3. On the basis of tests conducted to date, the upper fuselage structure offers certain specific advantages over the lower fuselage structure for support of equipment and/or occupants in accidents which involve a high vertical component of acceleration, relative to the aircraft axes.
This report describes the search and collation of currently available acceleration literature and related information of interest in aviation crash injury prevention. Approximately nine hundred documents unique to this study were catalogued and are available in a library at the AvSER 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. Major categories in which information relative to impact acceleration has been collected are as follows: hazard exposure, crash loads, human tolerance, design, and test/analysis methodology.

The primary effort during this study was devoted to collecting the data. However, the scores of personal contacts made throughout the industry during the program and the study of the documents themselves provided a general insight into the nation's technology in impact acceleration related to crash injury research. A summary of these findings was presented to the Aviation Crash Injury Steering Committee on 13 November 1962 and led to several courses of action relative to crash injury prevention.

It is concluded that:

1. The SIAT program provides a much needed inventory of knowledge of the impact acceleration phase of crash injury prevention. It provides not only a technical information center
Crash injury prevention work remains a significant requirement although there are countless volumes of material available in the impact acceleration field pertaining to crash injury, certain key questions of interest to the designer are lacking. For example, human tolerance data are seemingly being collected at a faster rate than people can analyse and assess the accuracy of the data, yet the effects of variations in restraint system configuration, positioning, and tightness are virtually unexplored.

3. Little if any specific published data are available relative to tradeoffs between weight, safety, and cost concerning seat design.

4. A very encouraging trend exists to attack the problem of crash load determination analytically as well as through full-scale tests or through derivation of data from actual accidents. This is significant from an economy point of view, since it allows flexibility in design for crashworthiness early in an aircraft's development. This field, however, has only been probed, with the results meriting close scrutiny as to their immediate value.

5. A degree of unplanned duplication of effort has existed between various agencies as well as occasional lack of communication within a given agency itself as to what research is being done and by whom. As a simplified example of this, there could be much progress made in the collection and coordination of crash injury data from accidents through the expedient of using the same or
similar accident report forms.

6. Applying the lessons learned from crash injury research continues
to be the most difficult part of crash injury prevention. One
needs only to review some of the early work by DeHaven and
compare it with existing specifications and/or most aircraft to
appreciate this point.

It is recommended that:

1. This report be disseminated to all individuals and agencies
involved in aviation crash injury prevention.

2. The Aviation Crash Injury Steering Committee, under the Chair-
manship of Mr. Jerome Lederer, Director of the Cornell-
Guggenheim Aviation Safety Research Center, be encouraged to
utilize this report and the data collected hereby as a basis for
future committee efforts in the field of crash injury safety research
coordination.

3. The crash injury bibliography and information retrieval system
developed in this study be refined and expanded to include other
facets of the survival problem, such as fire prevention and control,
emergency evacuation, rescue/survival, and the many other
stresses inherent in the crash episode in addition to acceleration.

4. Additional effort be made in correlation and interpretation of
the information acquired in this study to provide meaningful data
to the systems manager, the designer, and the user. Specifically,
consideration should be given to the areas of additional study
relative to crash injury prevention as described in the Evaluation
section of this report.
A U. S. Air Force C-131E Cargo Transport crashed on a gently sloped mountain side in a western state in early February 1963. A total of twenty people were on board the aircraft; nineteen of them survived the accident.

The decelerative forces on the aircraft in this accident were relatively moderate; however, the failure of passenger and crew seat tiedowns resulted in personnel injuries ranging from minor to severe. The one fatality was caused by lack of any body restraint at the moment of the crash.

The investigation revealed the need for increased protection for the cockpit occupants in the form of shoulder harnesses attached to basic structure. It was also noted that an excessive amount of time (about 15 minutes) was required to evacuate the aircraft. The passengers were hampered in evacuating the aircraft by:

1. Disorientation as a result of seat failures.
2. Lack of emergency illumination.
3. Inaccessibility of emergency exits.

As a result of the crash injury investigation it is recommended, in part, that:

1. Passenger seat anchorages be increased in strength by means of the modification recommended in this report.
2. Consideration be given to the addition of an emergency lighting system, and to the practice of preflight emergency briefings.
3. Crew seat anchorages be reinforced as indicated.
On the basis of the evidence gathered in this investigation, it was concluded that:

1. The C-131E appears to be a "crashworthy" aircraft. Its crashworthiness is primarily a result of the very strong cabin floor which reinforces the fuselage structure.

2. Head and upper torso injuries could have been considerably reduced for the cockpit occupants if the aircraft had been equipped with shoulder harnesses attached to basic structure.

3. The design strength of 1.5G for lateral loads on crew seats, as specified in the Civil Aeronautics Manual (CAM-4B), is too low when compared with the loads measured in survivable aircraft crashes.

4. The modification of the passenger seats, to fit the 20-inch grid tiedown fittings of the cargo floor, resulted in reduced longitudinal seat rigidity which caused failure of the floor anchorages.

5. The tiedown strength of interior equipment, such as plywood panels and a folding table, was inadequate; this loose equipment was inherently dangerous to the passengers because it was torn completely free in the accident.

6. Excessive time was required by the occupants to evacuate the aircraft. If a postcrash fire had developed, some passengers and the trapped cockpit occupants would undoubtedly have perished.

7. The time required for evacuation would undoubtedly have been reduced by the following three factors:

   a. Retention of the seats to the cabin and cockpit floors.
   b. Adequate emergency illumination.
   c. Easily accessible emergency exits.
Based upon the foregoing conclusions it was recommended that:

1. Shoulder harnesses be installed in the three crew seats of the cockpit and that these harnesses be attached to basic aircraft structure.

2. Consideration be given to the use of crash helmets by crew members of transport aircraft.

3. The lateral strength of the crew seats be increased by reinforcing the clip angle attachments as illustrated in the Interior Damage Section of this report.

4. The passenger seats be modified to include a diagonal tension member as discussed in the Interior Damage Section of this report.

5. The tiedown strength of interior equipment be made at least equal to the strength of the personnel restraint systems.

6. The service trays in the seat backs be replaced by lighter and more ductile units.

7. All passengers be briefed on emergency evacuation procedures before each flight.

8. An emergency illumination system be installed in the aircraft as required by the "Handbook of Instructions For Aircraft Designers (HIAD), Volume 1."

*Handbook of Instructions for Aircraft Designers (HIAD) Volume 1, Piloted Aircraft. Wright-Patterson Air Force Base, Ohio.

28
The objective of this study is to determine significant indices of crashworthiness as related to the structure of light aircraft. The question for which an answer is sought is simply: How may proposed changes in a given structure, intended to increase crashworthiness, be evaluated most meaningfully? It is not intended that these indices be used to rate crashworthiness of various makes and models of aircraft relative to one another [as other factors would enter into such a rating] but rather that these indices should serve to point directions of potential improvement in a given structural design.

Structural changes that alter the possibility of improved crashworthiness might take the form of any of the following:

1. General strengthening of a given bay to increase its collapse load.
2. Increase in energy-absorption capacity of a given bay without necessarily changing the collapse load.
3. General geometric changes, such as lengthening a bay or relocating cabin.
4. Change in component design, such as change in main landing gear type.
5. Seat or seat tie-down changes.
6. Minor structural changes - changing a single tube or addition of a brace.
7. Changes designed to reduce effective mass of aircraft upon impact.
8. Cabin modifications to increase cabin strength or perhaps produce a more favorable mode of collapse.

Each of these is considered separately in this report, in the light of the analysis and computations made.

In summary, the preliminary study reveals that the crashworthiness indices selected are potentially useful in evaluating structural modifications such as the eight items discussed.
This report presents an evaluation of the crashworthiness characteristics of two modified XH-40 crew seats. The seats were installed and dynamically tested along with other equipment in a full scale crash test of a CH-21 helicopter on 18 April 1963. The test was conducted by Aviation Safety Engineering and Research (AvSER) under contract to the U. S. Army Transportation Research Command.

In this dynamic test the results obtained with an anthropomorphic dummy were corroborated by the data obtained from an animated dummy of approximately the same proportions; herein referenced to as a terranaut. The two dummies were restrained by a lap belt and shoulder straps. Accelerometers were mounted to record accelerations in the occupants and the seats. Tensiometers were mounted to record belt forces. A high speed camera recorded the action during the crash sequence.

The seats were prototypes of the crew seats used in the UH-1A series of helicopters, incorporating modifications as called out in AvSER report 62-27, Personnel Restraint Systems Study - HU-1A and HU-1B Bell Iroquois.

The test results showed that the modified XH-40 seats can be expected to maintain proper position and orientation during a severe yet survivable crash. The seat pans of the seats, however, are not sufficiently strong to resist high vertical decelerations, particularly when combined with
The results also indicate that the use of anthropomorphic dummies with rigid appendages to simulate live occupants gives a good first approximation of reaction to the initial impact when compared with a dummy with non-rigid appendages. The subsequent reactions are not absolutely valid, however, due to the differing spring mass responses.

Based on the data presented in this report it was concluded that:

1. Field modifications as called out in AvSER report 62-27 increase the frame strength in UH-1 type crew seats.

2. The seat pans in use in UH-1 type seats are not strong enough to withstand the stresses from high vertical deceleration crashes.

3. The submarining action resulting from the failure of the seat pan and the longitudinal decelerations negate a good portion of the strength capabilities of the seat.

4. Alderson anthropomorphic dummies offer reasonable correlation with non-rigid specimens during the initial impact of a dynamic test. The response characteristics are such however, at subsequent readings are not realistic when compared to non-rigid test specimens.

Based on the foregoing conclusions, it was recommended that:

1. Steps be taken to implement the changes recommended in AvSER 62-27 in the Army's fleet of UH-1 type helicopters.
2. Seat pans of higher strength be fabricated and installed in UH-1 series helicopters.

3. A crotch strap be incorporated in seats of this type to prevent submarining.

4. More mathematical analyses be undertaken to specify a test dummy that will be a closer approximation of non-rigid specimens.
Publication of the Design for Safety Memos continues. The memos are distributed to a list of approximately 4000 recipients. Copies of the new memos are attached as enclosure No. 1. The schedule for the printing of these Memos is one per month, provided sufficient information is obtained from various sources to maintain this schedule. It would be appreciated if all members of the NASA Committee would provide us with their ideas for the Design Memos on the basis of their past experience.
Test No. 8: This test was conducted on 9 January 1963. The test involved environmental studies of aircraft occupiable areas subjected to postcrash fire. The objective of this particular test was to quantitatively evaluate the postcrash fire environment related to occupant survival. The test objective was accomplished by conducting a gasoline fire, utilizing the H-21 helicopter wreckage of the crash test vehicle (Test No. 7), which was crashed on 12 September 1962, as the test article. The test was conducted at the Phoenix fire department training area at the Sky Harbor Airport with the Airport fire fighting group supplying the necessary support for the test.

Temperature instruments were installed in the aircraft and connected to an oscillograph through an umbilical cable protected by asbestos pipe. Ambient and calorimeter temperatures were measured at the ceiling and floor of the aircraft, in the cockpit, mid-cabin, and aft cabin sections of the fuselage. Structural temperatures were also measured on the right and left hand side of the aircraft in addition to external ambient temperatures.

The gas sampling system designed for Test No. 6 was utilized, and 30 gas samples were drawn from within the structure. One pickup point was located in the cockpit, one at mid-cabin ceiling, and one at mid-cabin floor. Ten gas samples were obtained from each of the three above locations at the rate of one sample each 15 seconds.

One normal speed and two high-speed cameras were utilized to record the action photographically.
Two open ended 15-gallon fuel drums were mounted, one on each side of the fuselage at the fuel tank location. Each drum contained 14 gallons of aviation gasoline. A simple tipping device was used to dump the fuel drums on command, and the fuel was ignited by an electrical signal from the ground control point.

The data obtained from this fire test is being analyzed and compared with the data obtained from crash test No. 6 which involved the burning of an H-21 aircraft after crash from flight.

One of the interesting preliminary findings of this test is that the cabin fuselage skin was consumed approximately 75 percent by the fire after only 45 seconds of burning time with only 23 gallons of total fuel involved in the burning.

**Test No. 9:** On 18 April 1963 an obsolete, fully instrumented H-21A helicopter was crashed from actual flight simulating a typical crash. The aircraft was controlled during flight through a radio link remote control system developed for this purpose.

The objectives of this dynamic crash test were as follows:

a. To measure the acceleration and forces on standard and experimental pilot and passenger seats, litter installations, seat tiedown structure, and other aircraft components.

b. To obtain acceleration and physiological data from live animal subjects and anthropomorphic dummies during the crash.
This test was a cooperative effort involving Holloman Air Force Base (USAF), The Armed Forces Institute of Pathology, USABAAAR, TRECOM, Dr. W. J. Frajola of North American Aviation, and AvSER.

During the flight, the aircraft reached a height of 110 feet and a forward speed of 45 miles per hour. Vertical velocity at impact was 52.5 feet per second and the horizontal velocity was 64 feet per second. The conditions at impact were the most violent that have been developed during any of the series of crash tests conducted to date. The crash conditions rendered the cockpit totally nonsurvivable inasmuch as the transmission and forward bulkhead collapsed into this area destroying all living space. The fuselage section of the aircraft was considered survivable. Although the fuselage collapsed to some extent, approximately 4-1/2 - 5 feet of vertical living space remained after the crash.

A total of 64 channels of acceleration and force data and 10 channels of physiological data were obtained from the test. A total of 7 high-speed cameras were mounted aboard the aircraft and 6 high-speed and normal speed cameras (16 and 35 mm) were mounted at strategic locations on the ground covering the test.

Although the data is just being reduced for analysis, an examination of the various experiments indicates that the experimental and some of the modified seats fared exceptionally well under the extremely severe conditions to which they were subjected.
Test No. 10: This test was conducted on 3 July 1963. The test involved environmental studies of aircraft occupiable areas subjected to postcrash fires and is a continuation of Test 6 and Test 8.

Fuel, spilled in a pattern which approximates normal tank rupturing was ignited. Temperature air flow and air sampling instruments were installed throughout the test article and the data was recorded. Thirty white rats in groups of ten, were installed next to each of the three gas sampling inlets for the purpose of measuring the assimilation of carbon monoxide and other dangerous gasses. Each rat was electrocuted after a corresponding mechanical gas sample was taken. After the test their blood was analyzed and the results are being correlated with the analysis of the gas samples, in order to determine the rate of assimilation of the toxic gasses by the rats in relation to the percent of those gasses in the atmosphere at the predetermined intervals.

Normal and high-speed cameras were utilized to record the action photographically.

As a side experiment, once the interior of the test helicopter reached the nonsurvivable limit, an H-43 helicopter was hovered into a fire fighting position to determine if the downwash was capable of bringing the then existing non-survivable environment back to a survivable environment. The results of this side experiment are as of yet not determined.

Test No. 11: The objective of this test was to continue the quantitative evaluation of the postcrash fire environment as related to occupant survival in helicopter structure. On 4 September 1963, the test article was equipped by utilizing the repaired aircraft fuselage from Test No. 10. Fuel spilled in a pattern
which would approximate normal tank rupturing was ignited. Temperature
air flow and air sampling instruments were installed on the test article
and the data was recorded. Thirty white rats in groups of ten each were
located next to each of the gas sampling inlets for the purpose of measuring
the assimilation of carbon monoxide and other toxic gases. The rats were
electrocuted after each gas sample was taken. Their blood was then analyzed
and when the results are known it will be correlated with the analysis of the
contents of the gas sampling system in order to determine the rate of
assimilation of the toxic gases by the rats in relation to the percentage of
those gases in their environment. All of these samples, both animal and
mechanical, were taken at predetermined time intervals starting with the
onset through the extinguishing of the fire.
The SITUATION

While making an instrument let-down, the pilot flew the aircraft inadvertently into soft ground in a wings-level, slightly nose-low attitude. The lower forward bulkhead dug into the ground, resulting in heavy plowing action and severe deceleration. The seat belts and seat anchorages of both front seats failed and the occupants sustained fatal head and upper torso injuries.

The HAZARD

Blunt or square edges on the lower forward bulkhead may cause excessive gouging during low-angle accidents on unprepared surfaces or in heavy, flat impacts on soft ground. (Figures 1, 2). This is a common cause of high decelerations, which may affect the integrity of the floor structure, or the occupant tiedown chain and will bring the upper body of the crew members, restrained by a seat belt only, in violent contact with the controls and the instrument panel.

CORRECTIVE ACTION

The "digging" action of the nose and forward fuselage section can be prevented by designing a clean, sturdy keel, forward of the main bulkhead or wing spar, curved to match the existing contours of the nose section. (Figure 3).
The shoulder harness in a current high-wing aircraft is attached to an inertia reel, as illustrated in Figure 1. The attaching cable, between the reel and the shoulder straps, is routed over a pulley which is attached to a V-brace; the V-brace is attached between the wing and the fuselage behind the occupiable area. Accident records have shown repeatedly that whenever the wings move forward and downward at impact, the braces are torn free (Figure 2). As a result, the shoulder harness pulley also moves forward and the "tiedown chain" is compromised to the extent that it is ineffective.

A designer can increase the crash protection of aircraft occupants in the initial design phase if the following principle is used as a guideline:

Links in the personnel "tiedown chain" should not be attached to aircraft structure which, because of its mass or location, can be expected to break free or fail in a survivable type accident, but rather, should be tied to structure which can be expected to remain substantially intact in these type accidents.

*The "tiedown chain" includes all the components of the restraint system; the lap belt, the shoulder harness, the seat structure, the floor and all related anchorages.
CRASH FORCE ATTENUATION
Protection Against Vertical Crash Loads

The SITUATION

Four occupants of an aircraft received dangerous and critical spinal injuries of the dorsal and lumbar areas when their fully-loaded aircraft failed to remain airborne after takeoff from a private strip. The aircraft stalled and impacted, with wheels retracted, in a flat attitude on the upgrade of a ravine, sliding to a stop in 30 feet.

The HAZARD

In accidents such as this, large forces are transmitted vertically through the floor and seat to the occupant. The situation can be further aggravated when the occupant is allowed to "bottom out" through the use of a thick soft seat cushion.

CORRECTIVE ACTION

The designer can exercise some control over the crash force transmitted to the occupants through the use of energy-absorbing material in the seat cushion. Several crushable materials appear to have promise, such as treated paper honeycomb, urethane and polystyrene foams; however, in order to utilize the ultimate benefits of these materials, their crushing strength must be closely controlled between 9 and 11 psi. If the strength is lower than 9 psi, the cushion does not offer maximum energy absorption; if the strength is greater than 11 psi, the occupant is likely to be exposed to high vertical forces and subsequent injury to the spinal column. The thickness of the energy-absorption material to be used will depend on the practical limit of the seat pan and cockpit geometry.