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CRASH INJURY INVESTIGATION

U. S. ARMY HU-1A

BELL IROQUOIS HELICOPTER ACCIDENT

Fort Bragg, North Carolina

20 August 1960

FSF

AVIATION CRASH INJURY RESEARCH
A DIVISION OF
FLIGHT SAFETY FOUNDATION, Inc.
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TREC Technical Report 60-71
AvCIR 13-PR-123

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U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER ACCIDENT
Fort Bragg, North Carolina
20 August 1960

REPORT OF CRASH INJURY INVESTIGATION

For
U. S. Army
Transportation Research Command
Contract DA 44-177-TC-624

AVIATION CRASH INJURY RESEARCH
A Division of
Flight Safety Foundation, Inc.

30 December 1960

CRASH INJURY INVESTIGATION

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The crash injury analysis and preparation of this report were accomplished by the above investigators in coordination with the AvCIR staff.

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SUMMARY

A U. S. Army Bell helicopter crashed on 20 August 1960 at approximately 1500 hours while participating in the field exercise "Bright Star" at Fort Bragg, North Carolina. The crash occurred in a wooded area on the military reservation.

A total of six persons were aboard the aircraft at the time of the crash, including two crew members and four passengers. All occupants were injured, with injuries ranging from minor to critical.

An investigation conducted by Aviation Crash Injury Research (AvCIR) revealed that the predominant cause of injury was failure of the seats. Contributing factors were loose gear stowed aboard the aircraft and failure of the side and rear roof support members. Failure of these support members permitted the roof to collapse downward into the occupied area of the cabin in the same manner as experienced in previous HU-1A accidents.

As a result of the investigation, it was concluded that re-occurrence of the injuries experienced in this accident could be prevented through appropriate changes to the basic aircraft structure and seats.

Figure 1. Aerial view of accident scene

BACKGROUND

On 20 August 1960 a U. S. Army HU-1A Bell helicopter (Serial No. 38-3019) crashed in a wooded area on the Fort Bragg Military Reservation in North Carolina. A crash injury investigation, by AvCIR, was conducted on 22-24 August 1960.

The pilot, crew chief, and four passengers received injuries ranging from minor to critical. (AvCIR Scale of Injuries is contained in this report as Appendix III.) One of the passengers occupied the copilot seat and throughout the remainder of this report will be referred to as the copilot.

The aircraft was examined at the crash site. Photographs of the wreckage and of the essential components and equipment were obtained during the course of the investigation. Statements of the pilot and of the occupants assisted the investigation team in estimating the flight path, the impact conditions, and the principal vertical and horizontal forces during the crash.

This is the final report on the investigation.

Figure 2. Side view of an HU-1A in flight

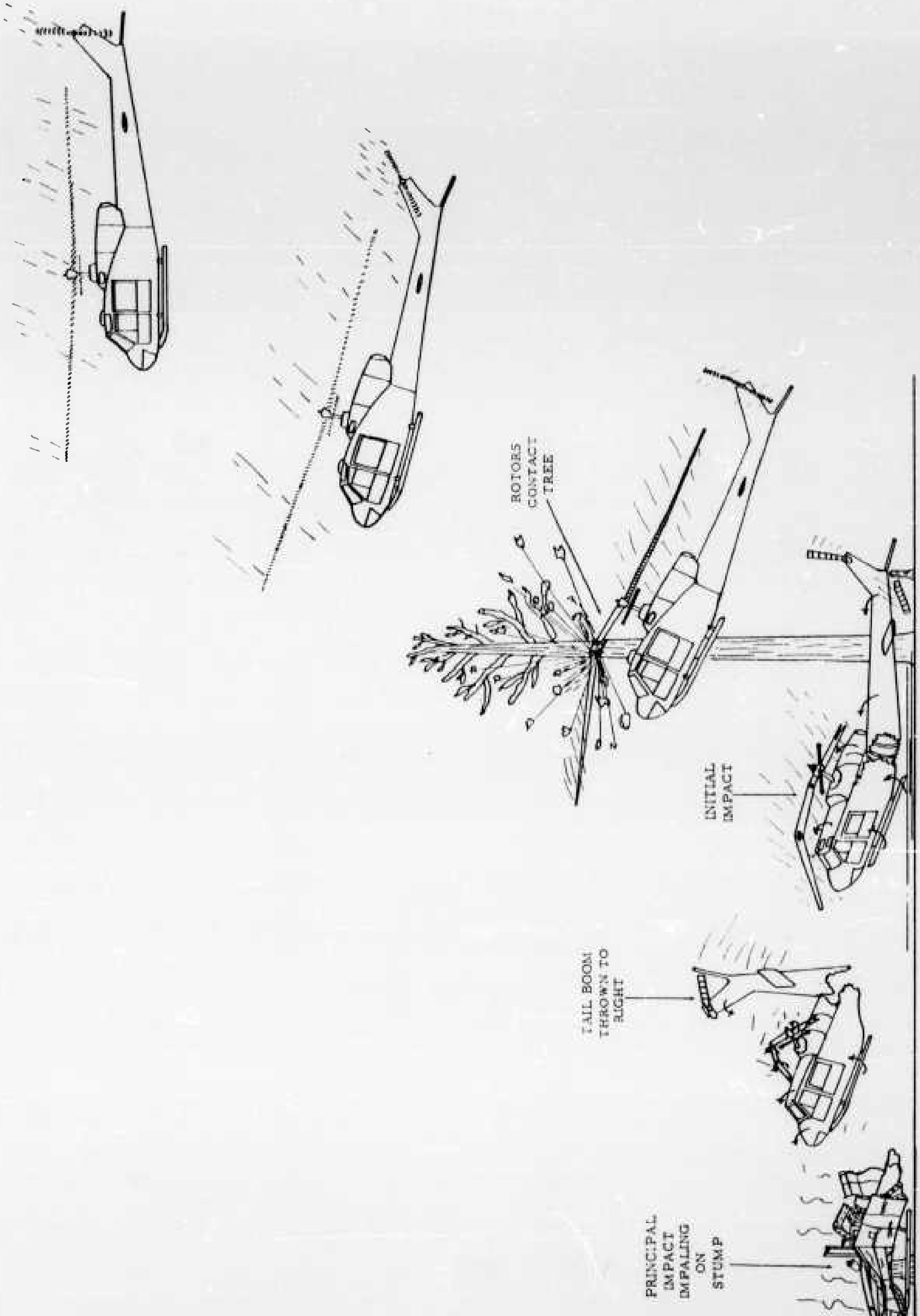


Figure 3. Kinematics of crash sequence

DESCRIPTION OF THE ACCIDENT

CRASH SEQUENCE

The aircraft had completed its mission and was returning to a tactical airstrip for landing. As the aircraft entered the downwind leg at an altitude of approximately 150 feet, a complete power failure was experienced. Because of the low altitude, the pilot immediately executed a full flare (nose high) and committed the aircraft to a forced landing in a densely wooded area.

As the aircraft settled, in the nose high attitude, the main rotor blades struck near the top of a tall pine tree and were demolished. The aircraft then began to yaw and roll to the left; however, before any significant yaw or roll developed, the aircraft contacted the ground in a nose high attitude. As the tail boom contacted the ground and a tree stump simultaneously, it was torn free from the main fuselage. The main body of the aircraft fuselage then bounced approximately 20 feet. At this point (still in a slightly nose high attitude) it contacted a tree stump which was driven up through the under-belly and through the cabin floor near the right center of the cabin as the aircraft settled to the ground (principal impact). Upon contact with the stump, the forward end of the fuselage section was whipped downward with the entire section coming to an abrupt stop. Figure 3 illustrates the kinematics of the crash sequence. Figure 4 is a view of the aircraft after it came to rest.

Figure 4. View of left side of the aircraft

EVACUATION

At principal impact the pilot and crew chief seats failed and both were thrown clear of the aircraft still fastened to their seats. Because of their dazed condition, they required assistance in releasing themselves from their seats.

Some difficulty was encountered in removing the occupant of the copilot's seat from the wreckage. At principal impact the rear seat supports of the copilot's seat failed, permitting the seat and occupant to rotate forward, causing him to become wedged, head and feet forward, in the torque pedal well. It was necessary to tear the seat completely free from its forward supports to extricate the occupant.

The passenger who occupied the left rear troop seat was able to release himself and render assistance by freeing the two remaining passengers from their troop seats.

Evacuation of all personnel was expedited by ground troops who were in the immediate vicinity. Access to the occupants was also simplified as a result of the side supports and doors tearing free during the impact.

CRASH FORCES

A complete analysis of the crash forces involved in this accident is contained in Appendix I. The analysis revealed that the mean crash force resultant was relatively moderate. Based upon the information available, it is estimated that the forces were approximately 12-13G at an angle of 75 degrees to the longitudinal axis of the aircraft.

DAMAGE TO THE AIRCRAFT

EXTERIOR

The major damage to the exterior of the aircraft during the crash was as follows: (1) complete destruction of the main rotor blades when they contacted the pine tree; (2) tail boom assembly torn free from the main fuselage structure when it contacted the tree stump and the ground; (3) upper transmission assembly mast and rotor torn free, rearward and to the right; (4) side and rear roof support member failed, permitting the roof to move forward and downward; (5) all doors torn free at principal impact; (6) left forward landing skid support torn free; and (7) penetration of the under-belly and cabin floor by the tree stump.

A discussion of the most significant damage from a crash injury point of view follows:

Transmission Assembly

The transmission assembly failed in this accident in the same manner as experienced in previous HU-1A accidents. The significant failure point in all HU-1A accidents is the magnesium casting which serves as a cradle supporting the transmission assembly. In this instance, the transmission

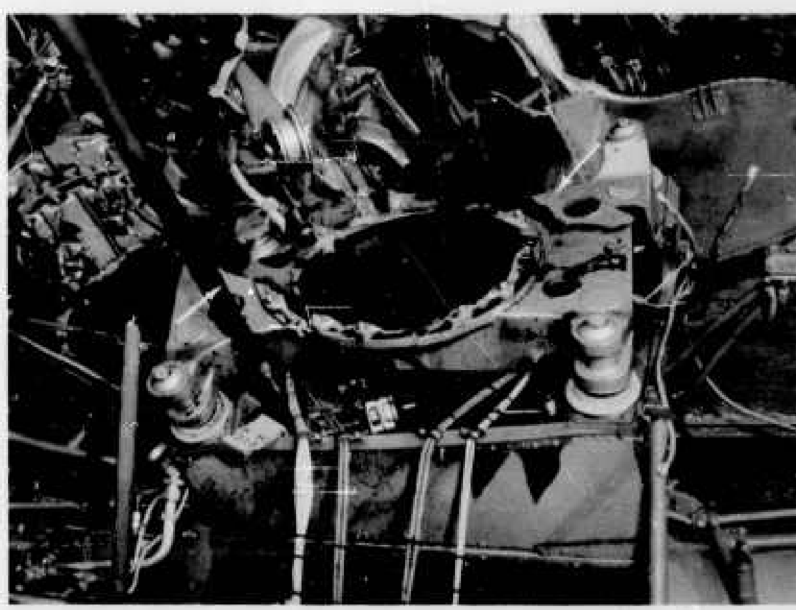


Figure 5. Transmission torn free from its cradle support. Note the fractures in the magnesium casting (arrows).

failed rearward and to the right and was, therefore, not a contributing factor insofar as injuries are concerned in this accident. Had the direction of the crash forces been such that the failed transmission moved forward, it would have penetrated the rear bulkhead of the cabin area, as experienced in a previous HU-1A accident. This is a hazard which has been pointed out on several occasions. During a recent evaluation of the HU-1D helicopter, it was found that Bell Aircraft was providing for a fifth transmission mount to prevent the transmission from moving forward during a crash. It is questionable, however, whether this will resolve the problem because the failures have not occurred at the mounts, but rather in the magnesium casting which serves as a cradle for the transmission assembly. The failure experienced in this accident is shown in Figure 5.

Side and Rear Roof Support Members

At principal impact, the side roof support members failed completely. This contributed to the failure of the aft roof support member permitting the roof to move forward and downward into the occupiable area of the cabin, reducing the occupiable height within the cabin from 4'8" to 2'8". The failure of these members is shown in Figures 6 through 9.

As the rear roof support member failed, it caused the rear bulkhead to tear and rip, with a jagged point striking the occupant of the rear troop seat at the base of the skull, injuring him critically.

Figure 6. Close-up view of left side of aircraft. The upper arrow depicts the rear bulkhead failure. The broken side supports can also be seen (lower arrows).

Figure 7. Failure of the left vertical side support at the floor. Cables are holding the support to the floor structure.

Figure 8. Side view showing failure of left vertical side support at the upper attachment to the roof structure.

Figure 9. Side view showing failure of right vertical side support at the upper attachment to the roof structure.

Failure of these support members has occurred in every HU-1A accident experienced to date, indicating an inherent weakness in the design of these members. This has been pointed out in previous accident reports and has resulted in "Request for Alteration" studies by the Army. As a result of the requests, Bell Helicopter has conducted the studies and submitted recommended solutions to this problem. The results of the Bell studies are set forth below:

> "RFA #11 requested that the contractor study the aft cabin bulkhead to improve the structure. As a result of these studies, the contractor is of the opinion that the most logical approach to improving the strength of this bulkhead would be to change the structure above W. L. 54 to a honeycomb-type structure. In order to effect this change, it would be necessary to make extensive tooling changes, such as fabrication of a bonding fixture, and to re-engineer the mounting of those items such as hydraulic and electrical equipment which are attached to the bulkhead. By changing the sheet metal structure to honeycomb type construction, the pure vertical load carrying capability of the bulkhead would be increased from 14,900 pounds to 35,000 pounds. It should be noted that these are comparative figures only and do not take into account lateral

or fore and aft displacement of the bulkhead under crash-loading conditions. Displacement of the bulkhead would materially reduce the vertical load capability of the bulkhead; therefore, the true crash load capabilities of the bulkhead cannot be calculated.

RFA #12 requested that the contractor study the problem of adding vertical support members to prevent collapse of the roof structure upon occupants during a crash landing of survivable "G" forces. As a result of these studies, it is the opinion of the contractor that the most logical approach would be one of making a general increase of gauge thickness of the sheet metal structure of the door post to increase its column load capabilities. The weight increases per helicopter would be approximately 3.5 pounds. The column strength would increase from 1,750 pounds to 2,690 pounds per door post for a total increase in strength of approximately 54%. This change could be accomplished on production HU-1B's and does not involve serious tooling problems. A second approach which the contractor investigated was the addition of roll-over structure to the pilot and copilot seats. This change would add approximately 3.5 pounds per helicopter and would provide a structure capable of withstanding a vertical load of 3,500 pounds per seat. This change could be incorporated into production aircraft or retrofitted to aircraft already built, with changes to the seat assembly."

Information has become available that the recommendations submitted by Bell Helicopter Company under RFA #12 on the side support members have been approved and are being incorporated in all HU-1B helicopters and that the recommendations submitted under RFA #11 have also been approved and that the new rear support member is being incorporated in HU-1B helicopters beginning with ship #47. These modifications are expected to eliminate the problem of the roof collapsing into the occupiable area in HU-1B helicopters; however, this potentially dangerous situation still exists in all HU-1A helicopters in the system. A solution to this problem would be the acceptance of the second approach submitted in the Bell study under RFA #12 involving the addition of roll-over structure to prevent the roof from collapsing down onto the seat backs.

INTERIOR

The major damage experienced in the interior of the aircraft during the crash was the failure of all occupied seats. The pilot and crew chief seats failed completely, permitting these two occupants to be thrown clear

HU-1A FORT BRAGG, NORTH CAROLINA
20 AUGUST 1960
SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)

PILOT
Degree of Injury - SERIOUS

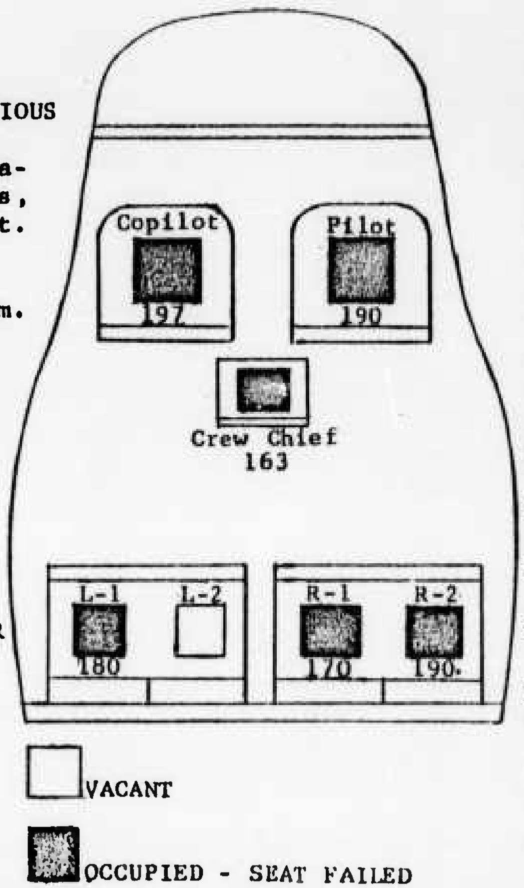
1. Compression fracture of T 11 & 12.
2. Fracture, base of 1st metacarpal.
3. Abrasions and contusions of face and extremities.

COPILOT
Degree of Injury - SERIOUS

1. Abrasions and lacerations of extremities, lower back and chest.
2. Depressed xiphoid.
3. Hematoma of left buttock into scrotum.

CREW CHIEF
Degree of Injury - SEVERE

1. Mild concussion.
2. Numerous facial and scalp lacerations.
3. Lacerations of right hand and leg.
4. Comminuted fracture of right leg.



R-1
Degree of Injury - CRITICAL

1. Severe laceration of scalp.
2. Depressed skull fracture occipital area.
3. Partial maceration of brain, occipital area.

L-1
Degree of Injury - MINOR

1. Contusion of left shoulder blade.

R-2
Degree of Injury - SERIOUS

1. Facial and neck abrasions.
2. Tenderness of upper abdomen.
3. Tenderness of lower back.
4. Contusion of right buttock.
5. Internal injuries.

Figure 10. Seating Arrangement - Injury Chart - Seat Failure

of the aircraft at principal impact while still attached to their seats. All other occupied seats failed in place. Figure 10 illustrates the seating arrangement, injuries sustained by each occupant, and the seat failures.

The manner in which the pilot, copilot, and crew chief seats failed indicates that a considerable amount of vertical velocity was translated to longitudinal velocity as the body of the fuselage came in contact with the tree stump, causing the forward portion of the fuselage to whip forward and downward.

Following is a discussion of the seat failures:

Pilot Seat

At principal impact the floor and lower seat frame were distorted due to high vertical forces and penetration of the floor by the tree stump. Because of the longitudinal velocity caused by the whipping action of the fuselage, the pilot apparently slid down and forward, deforming the forward lip of the seat pan as illustrated in Figure 11, and popping the rivets along the right side. As a result of the force applied to the seat by the pilot, and the distortion of the lower seat frame, the seat ripped free from the frame and was thrown forward and to the right out of the aircraft. Figure 12 is a view of the lower seat frame still attached to the floor.

Figure 11. Bottom view of seat pan - pilot. The dotted line indicates bent seat pan lip and popped rivets on the right seat. Arrows show locations of seat support failures.

Figure 12. View depicting lower seat frame distortion and floor collapse. Arrows 1 through 4 indicate locations of vertical and diagonal seat frame failure.

Copilot Seat

The occupant of the copilot seat apparently also slid downward and forward at principal impact, causing distortion of the forward seat pan lip in the same manner as the pilot's seat (Figure 13). The longitudinal force applied by the occupant of the copilot's seat at principal impact caused the rear seat support members to fail, permitting the seat to pivot forward and wedge the occupant head first in the torque pedal well. Figure 14 illustrates the portion of the copilot's seat frame remaining attached to the floor after removal of the occupant.

An additional item in regard to the pilot's and copilot's seats is the excessive width of the shoulder harness guide (Figure 13). This excessive width permits considerable lateral movement. It is suggested that the shoulder harness guide be reduced to the narrowest practical width.

Medical Attendant's Seat

The medical attendant's seat used in this aircraft is designed to be installed in either the forward or rearward facing position. In this accident the seat was facing forward and was occupied by the crew chief.

Figure 13. View of the broken seat pan - copilot. Note the forward and downward bending of the seat pan lip and the tension failure of the left corner of the seat pan (arrow). Also, note excessive width of shoulder harness guide.

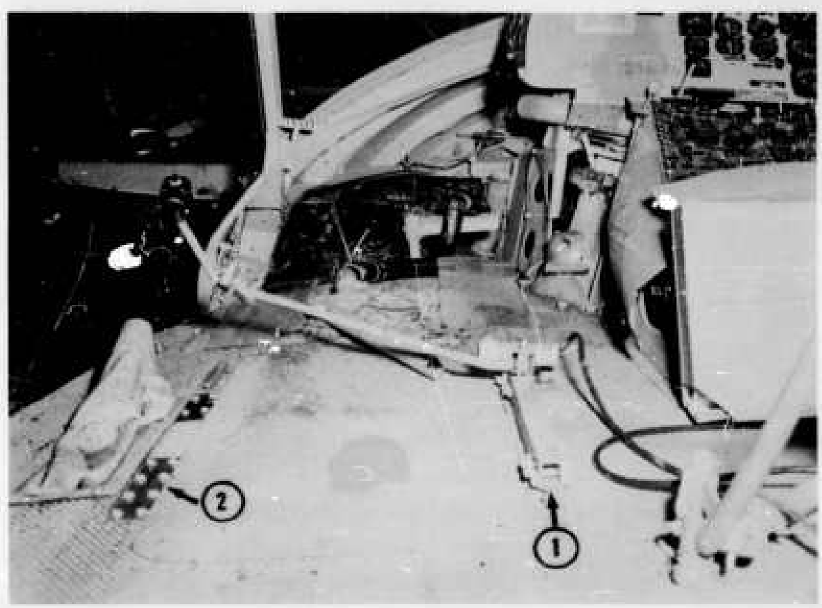


Figure 14. Copilot's seat failure. Removal of the left front occupant necessitated removal of the entire seat and, therefore, is not shown in this photograph. Arrow 1 depicts the manner in which the right rear anchorage failed and Arrow 2 shows how the rear portion of the left seat track pulled free from its floor anchorage.

The longitudinal force exerted on the seat by the crew chief at principal impact caused the seat pan to tear free from the seat support. The seat supports apparently absorbed a considerable amount of energy by buckling and distortion before the seat pan tore free, as shown in Figure 15. Additional views of the medical attendant's seat are shown in Figures 16 and 17.

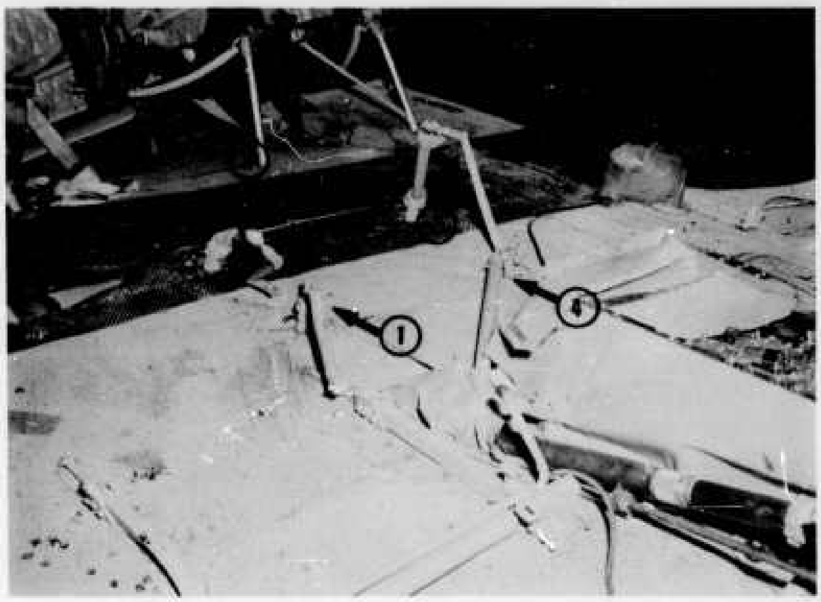


Figure 15. Buckling of the seat supports of the Medical Attendant's seat. (Arrows 1 through 4)

Figure 16. View of broken Medical Attendant's seat. Arrows denote points of support failure.

Figure 17. Seat belt attachment of Medical Attendant's seat (arrow). Notice how stress elongated the "O" ring, yet did not fail.

Troop Seats

Standard military troop seats, designed to MIL-S-5804B, were installed in this aircraft as shown in Figure 18. The seat frame consists of upper, rear, and front support tubes to which is attached the nylon seat back and seat pan. The legs are attached to the front support tube. Curved spreaders maintain the distance between the front and rear support tubes.

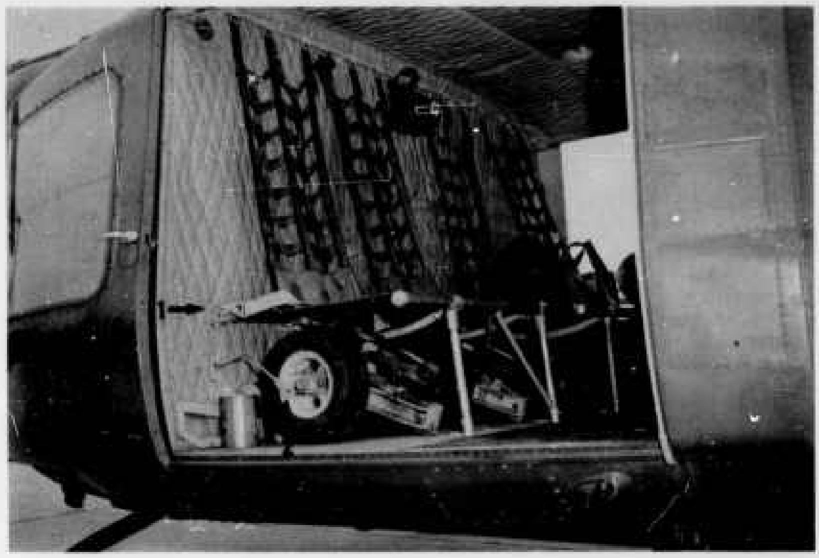


Figure 18. Correct and incorrect belt installation. Over-all view of the cabin area depicting the troop seats and the loose equipment stowed beneath the seats. Arrow 1 denotes the incorrect method of attaching the safety belts. The belts should be attached to the cables which are provided (arrow 2).

Since these seats were located to the rear of the point where the tree stump penetrated and broke the floor structure, it appears that the force acting upon the troop seat occupants was primarily vertical.

The left rear two-man seat shown in Figure 19 was occupied by one passenger on the outboard side. At impact the seat pan ripped from the rear lateral support tube. This support tube pulled out of the clamp on the left side of the bulkhead and moved two inches to the right, as shown by Arrow 1 of Figure 19. The hooks, which suspend the seat back from the upper support tube tore free from the upper support tube. The upper support tube failed at a drill hole where it is attached to the rear bulkhead, shown by Arrow 2, Figure 19. Failure of the seat pan and the downward force exerted by the occupant caused the front support member to break at a drill hole near the diagonal brace attachment. Failure is shown by

Arrow 3, Figure 19. Both front seat legs were also torn free from their floor attachments.

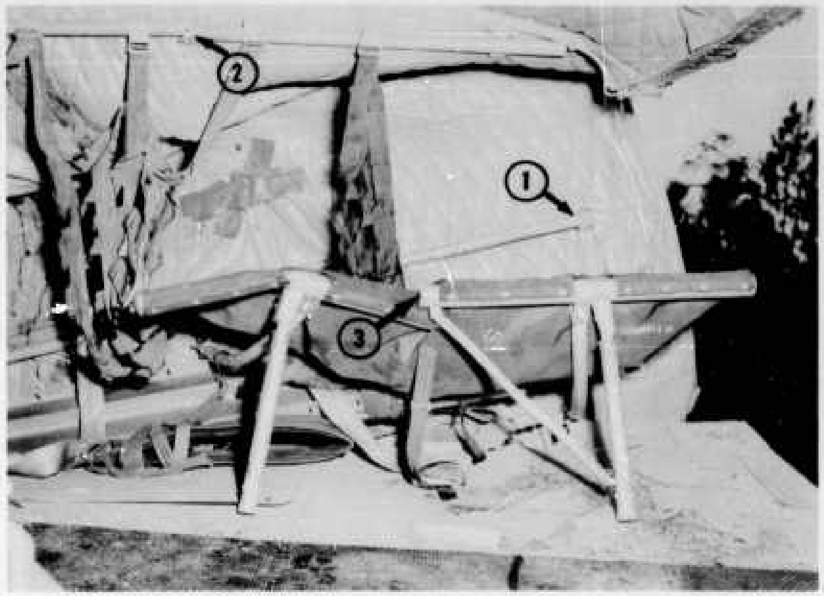


Figure 19. Failure of left rear troop seat. This seat was set up for photographic purposes. It was originally collapsed on the floor. Arrow 1 shows the clamp where the rear support tube was anchored. Arrow 2 shows the failure of the upper longitudinal tube where the seat backs are attached. Arrow 3 shows the failure of the front support tube at the drill hole.

The right rear two-man seat shown in Figure 20 was occupied by two passengers. At impact the floor just ahead of this seat heaved upward as the aircraft impaled itself on the tree stump. The upheaval of the floor, plus the downward force exerted by the two passengers, caused distortion and failure of the vertical seat legs, permitting the seat pan to come into contact with the handle of the hydraulic pump on a set of ground handling wheels stowed under the seat, causing the seat pan to rip longitudinally. The seat spreader under the inboard occupant broke and the diagonal brace failed. The seat back support assembly also failed on this seat.

An analysis of the seat failures in this accident reveals that the seats will not withstand even moderate impact forces. This is particularly true of the troop seats, which have a history of gross failure in every accident in which these seats were involved. This indicates that the strength

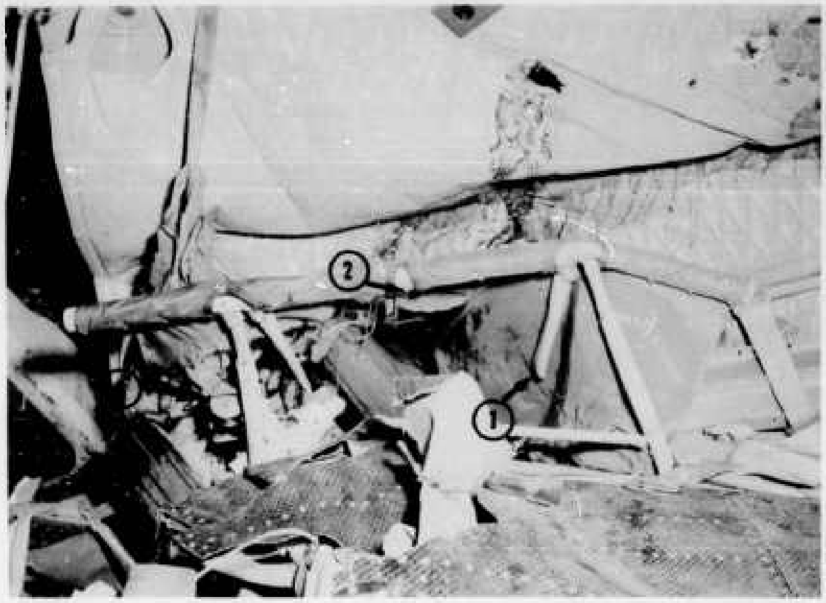


Figure 20. Failure of right rear troop seat. Note the ground handling wheels under the outboard seat. Arrow 1 indicates the broken seat spreader. Arrow 2 shows the failure of the diagonal brace. Arrow 3 indicates the position of the ground handling wheels.

requirements contained in the specifications for these seats are not adequate.

Failure of the seats, particularly with regard to the crew seats, could be reduced somewhat, and increased occupant protection provided, if occupant restraint systems (seat belts and shoulder harness) were anchored to basic aircraft structure. The present system of anchoring both seat belts and shoulder harness inertia reels to the crew seats subjects the seats to the force of deceleration plus the load imposed by the seat occupants through their restraint systems. If the restraint systems were anchored to the basic aircraft structure, it would relieve the seats of the loads imposed by the occupants and would undoubtedly result in fewer seat failures. In any event, it would provide the occupants with some measure of protection in the event the seat did fail. When the restraint system is attached to the seat itself, it is completely ineffective in event of seat failure, as illustrated by this accident.

A recommendation to attach seat belts and shoulder harness to basic aircraft structure was submitted in a previous HU-1A accident report. The recommendation resulted in an RFA study request. Bell Helicopter conducted the study and submitted the following comments:

"RFA #24 requested the contractor to study the possibility of anchoring the crew safety belt and shoulder harness to some structure other than the pilot and copilot seats. The safety belts and shoulder harness could be anchored to the floor structure without involving serious changes to the basic airframe. This arrangement would, of course, relieve the seat of almost all forward crash loads, but the contractor would like to point out that if this change is recommended for incorporation, it has the disadvantage that the seat belt and shoulder harness would have to be adjusted with changes in seat position."

The comment that the seat belt and shoulder harness would require adjustment every time the seat position was changed applies only to the seat belt. The operation principle of an inertia reel provides for movement of the shoulder harness with seat adjustment when the inertia reel is unlocked. The type inertia reel recommended is the mechanical "rate of extension" locking type which is normally unlocked and which locks only when the rate of extension exceeds a given setting, such as caused by rapid deceleration. With reference to the seat belt, it is recognized that this may cause some inconvenience; however, it is suggested that a survey be made to determine the frequency with which the pilot or copilot seats are adjusted once the flight has begun. It may be possible that seat adjustments are so infrequent, in a helicopter, that this slight inconvenience would not be a significant factor.

With reference to the troop seats, it was noted that the seat belts were attached to clamps of the rear longitudinal seat support member, as shown by Arrow 1 of Figure 18. Attachment of the belts at this point overloads this member and frequently causes failure of the support member. Arrow 2 in Figure 18 shows the cable which is provided in this aircraft for seat belt attachment. These cables are tied directly to primary structure. Attachment of the belts to the cables provided would reduce the crash loads on the seat structure and would eliminate some of the failures experienced in the past. *

* Reported in Crash Injury Bulletin, AvCIR Report No. 69-O-120, November 1960, Part I.

CRASH INJURY ANALYSIS

GENERAL

The direction of the principal crash force in this accident was upward and from the front in the forward part of the cabin, while in the rear of the aircraft the crash force was mainly upwards. The direction of crash forces acting upon the occupants were caused by the aircraft impacting on the aft part of the fuselage in a nose high attitude, causing the forward part of the fuselage to rotate downward as it impaled itself on a tree stump at the rear center of the floor.

The six occupants received injuries ranging from critical to minor. (See Appendix III, AvCIR Scale of Injury.) The major contributing cause of the injuries experienced was failure of the seats.

OCCUPANT ANALYSIS

Pilot

At impact, the pilot's seat failed, permitting the seat and its occupants to be thrown forcibly forward, down, and to the right. The pilot apparently struck the right front door post with his helmet and right side of his body and was then thrown clear of the aircraft (Figure 21).

Figure 21. Front right view of the aircraft showing the door post and the position where pilot and crew chief came to rest.

The unpredictable kinematic behavior of occupants being thrown clear makes it impossible to accurately correlate the injuries with their causative factors. Undoubtedly, the helmet saved the pilot from serious head injuries if not from fatal injuries.

In addition to general abrasions and contusions, the pilot suffered a comminuted fracture of the first metacarpal of the left hand, probably caused by bracing himself on the collective pitch stick. The wedge-type compression fractures of the 11th and 12th thoracic vertebrae were probably caused by flexing of the spinal column when the pilot slid under his seat belt, deforming the front of the seat pan, while being subjected to the combination of vertical deceleration and the downward whipping action of the fuselage when it impaled itself on the tree stump.

The injuries sustained by the pilot resulted mainly from failure of the seat supporting structure and the ineffectiveness of his restraint system (seat belt and shoulder harness). Had his shoulder harness and seat belt been attached to basic airframe structure, the injuries would undoubtedly have been reduced.

Copilot

The occupant of the copilot seat suffered serious injuries when the rear seat supports failed, permitting the seat to rotate forward and downward, wedging him head first into the torque pedal well.

In addition to numerous abrasions and contusions over his entire body, this occupant suffered a depression of the xiphoid, sustained by striking the cyclic stick (Figure 22). He also sustained a hematoma of the left buttock extending into the scrotum, and an abrasion of the perineal area. This injury was received when sliding forward and under his safety belt, deforming the front of the seat pan and contacting the cyclic stick.

The injuries sustained by this passenger resulted from failure of the rear seat anchorages and the ineffectiveness of his restraint system. Had his shoulder harness and seat belt been attached to basic airframe structure, the injuries would probably have been reduced to minor or none.

Crew Chief

The crew chief occupied the medical attendant seat which is normally aft facing and is placed just aft and between the pilot and copilot seats. In this case it was facing forward and at impact was torn free from its supports. The seat and crew chief were thrown forward and to the right out of the aircraft.

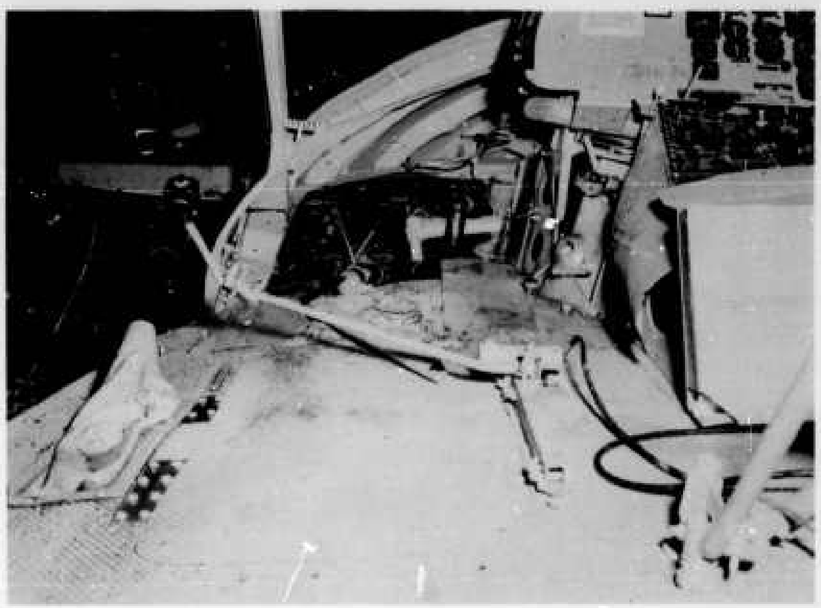


Figure 22. View of the left torque pedal-well after seat was removed. Note the broken cyclic stick.

As stated in the case of the pilot, it is impossible to accurately correlate injuries with their causative factors because of the unpredictable kinematic behavior of occupants that are thrown clear of the aircraft.

The crew chief received a mild concussion and numerous facial and scalp lacerations when thrown, with his seat, through the right windshield. These injuries could have been lessened considerably had he been wearing a crash helmet.

In addition to the above, he suffered a comminuted fracture of the right fibula and a fracture of the posterior tip of the tibia. Had the safety belt been attached to the floor structure, the crew chief probably would not have been thrown out of the aircraft, and his injuries may have been greatly reduced.

Passenger - Seat L-1

The occupant of this troop seat escaped with a minor injury. The sewn portion of the nylon seat pan ripped from the rear support tube, allowing this occupant to fall through his seat while being held by his safety belt. Failure of the seat pan probably saved him from serious head injuries because the roof structure collapsed downward approximately 25 inches. The contusion over the left shoulder blade was most likely caused by the rear bulkhead when the seat pan ripped from the rear support tube.

Passenger - Seat R-1

The occupant of this troop seat received critical head injuries when the top of the rear bulkhead failed and collapsed inward and down. At impact one of the structural members supporting the bulkhead broke and a sharp edge pierced the bulkhead and fabric, striking the head of this passenger while he was jackknifed in his partially collapsed seat. (See Figure 23.)

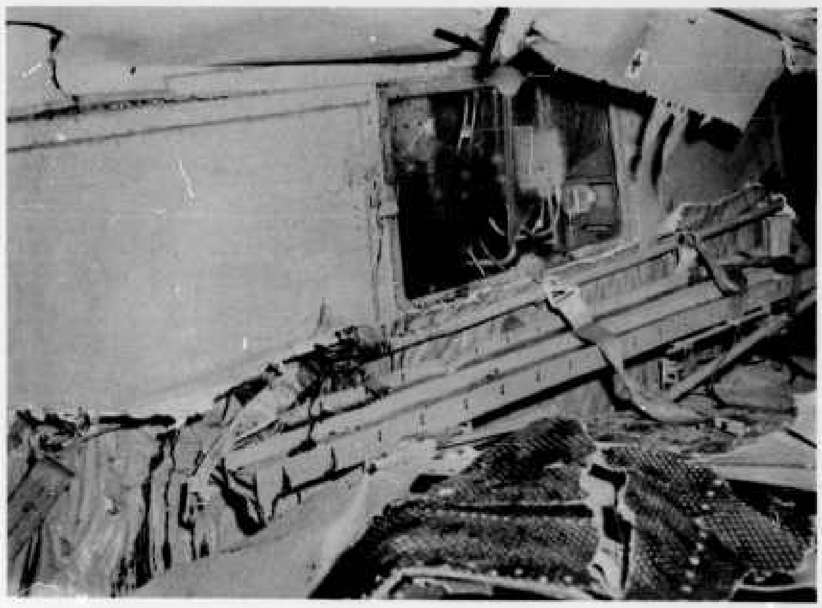


Figure 23. View of the aft bulkhead after it was stripped of the fabric. The arrow shows the sharp piece of metal that critically injured one of the occupants.

The jagged metal penetrated the skull, causing a serious laceration of the scalp, a depressed fracture at the base of the skull, and macerated brain tissue.

Passenger - Seat R-2

The occupant of this troop seat suffered serious injuries. At impact the nylon seat pan ripped longitudinally in the center. This was caused by the handle of the hydraulic pump equipment on a pair of ground handling wheels that were stowed under his seat (Figure 24, Arrow 1). The occupant received extensive contusions of the right buttock when he fell through the ripped seat pan and contacted these ground handling wheels.* His safety

* Reported in Crash Injury Bulletin AvCIR Report No. 69-O-120, November 1960, Part II.

belt slipped up and caused a red streak across the chest. There was a tender area over both sides of the lower rib cage caused by contacting his knees when he jackknifed in his seat. In addition to facial abrasions and a minor laceration of his neck, this person received internal injuries resulting from the seat belt and the fact that his knees contacted his lower chest when he was forced into the jackknife position. Had the seat belt been attached to the cables provided in the aircraft, instead of the "O" rings on the rear seat support member, the belt would have been riding across the iliac crest at an angle of approximately 45 degrees, which is the ideal location. This may have resulted in less severe internal injuries.*

Figure 24. View of the right rear troop seat. Arrow 1 shows where the seat pan tore across the ground handling wheels. Arrow 2 indicates the structural member that pierced the bulkhead, injuring the occupant of the inboard seat.

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* Reported in Crash Injury Bulletin AvCIR Report No. 69-O-120, November 1960, Part I.

CONCLUSIONS

After examination and analysis of the wreckage and injuries sustained by the occupants, it is concluded that:

1. The breaking away of cockpit and cabin doors is a desirable feature for rapid evacuation;

2. The rear bulkhead strength and the overhead structure support is inadequate;

3. The structural integrity of the magnesium casting support for the transmission is inadequate;

4. The design requirements for the crew seats and the troop seats as specified in MIL-S-7832A, MIL-S-5804B, and MIL-S-27174 offer the occupants inadequate crash protection. (Past experience underlines these deficiencies);

5. Improved crash safety can be provided for the pilot, copilot, and crew chief by attachment of the restaint systems to primary structure;

6. Improved crash safety can be provided for the pilot and co-pilot by reducing the width of the shoulder harness guide;

7. The safety belts on the troop seats are incorrectly installed on this aircraft when anchored to the "O" rings on the clamps of the rear longitudinal support tube; and

8. The stowage of equipment under troop seats constitutes a serious hazard under crash conditions.

RECOMMENDATIONS

Based on the foregoing conclusions, it is 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 downward into the occupied area of the aircraft;

2. Consideration be given to the utilization of a more ductile material to replace the brittle casting presently used to support the transmission;

3. The specifications for both crew and troop seats be revised to provide increased occupant protection under survivable crash force conditions;

4. Consideration be given to anchoring the crew seat restraint systems to primary structure and the shoulder harness guide be reduced to the narrowest practical width;

5. The safety belts on the troop seats be attached to the cables, which are provided in this aircraft, to afford the occupant maximum protection and guide the belt over the hips at an angle of approximately 45 degrees; and

6. Attention be given to stowage of equipment in places other than the area under the troop seats. Furthermore, if equipment has to be carried under unoccupied troop seats, it should be of a non-rigid type and securely anchored to prevent it from becoming a missile in the event of a forward deceleration.

APPENDIX I

CRASH FORCE ANALYSIS

APPENDIX I

CRASH FORCE ANALYSIS

Because of heavy rain and the spongy condition of the terrain at the crash site, measurements cf gouge marks were unobtainable.

The crash forces were partly absorbed by the soft terrain and the left landing skid. Additional force was absorbed by the tail boom. The aforementioned factors preclude an accurate crash force analysis of this accident.

However, due to the tail low descent of the aircraft, and the manner in which the cabin contacted the tree stump, it was possible to obtain some measurements of approximate G forces.

Assuming the horizontal velocity of the aircraft at principal impact as 10 miles per hour or 14.7 feet per second and the stopping distance as 12 inches, the horizontal G is computed as 3.37G. $\left(G = \frac{V^2 - Vo^2}{64S} \right)$

Also, by taking the vertical velocity as 1,500 feet per minute or 25 feet per second and the stopping distance as 10 inches, this being the distance of yielding of the bottom structure, the vertical G is computed to be 12.2G.

Combining these two components the resultant is computed to be 12.7G at an angle of 75 degrees to the longitudinal axis of the aircraft.

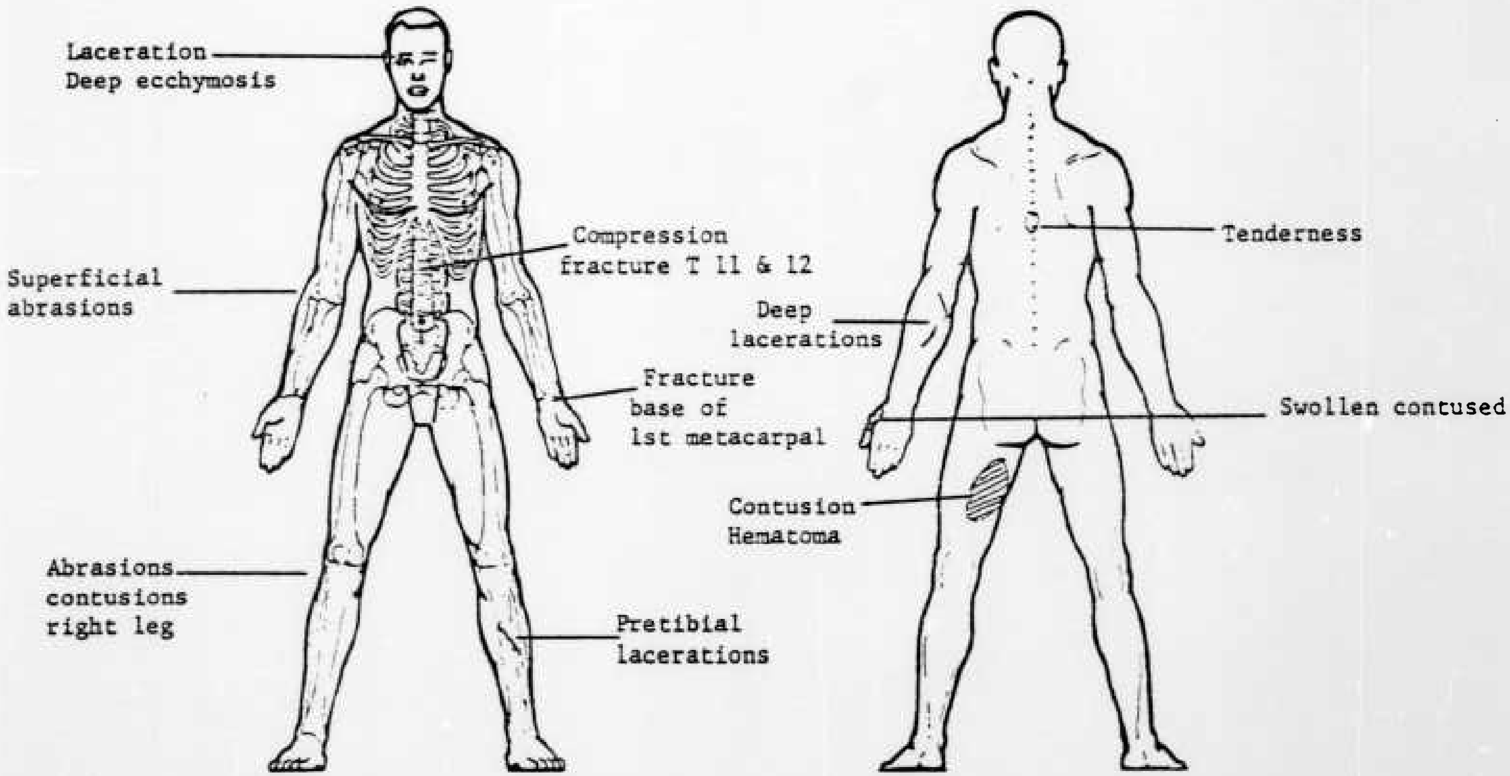
After reviewing the over-all condition of the fuselage structure, the damage sustained by the seats, plus previous experience with this type of accident, it was estimated that the crash force in this accident may have been in the order of 10G to 15G, which coincides with the above computations.

The calculated magnitude represents a mean acceleration at the point of impact on the tree stump. It should be kept in mind, however, that the forces are approximations, and only speculation can indicate the magnitudes, experienced by the occupants.

APPENDIX II

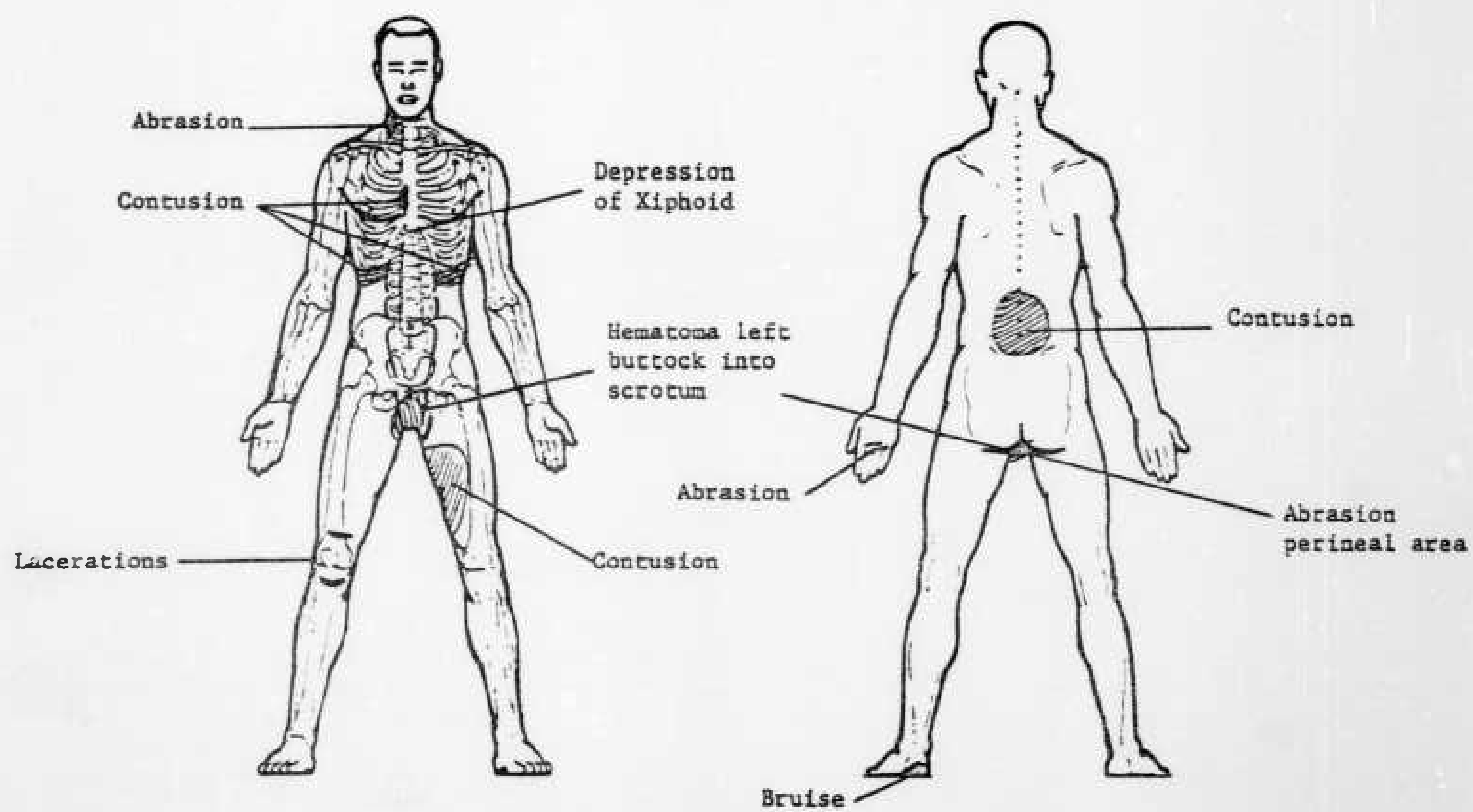
MEDICAL SUMMARIES

PILOT - RIGHT SEAT



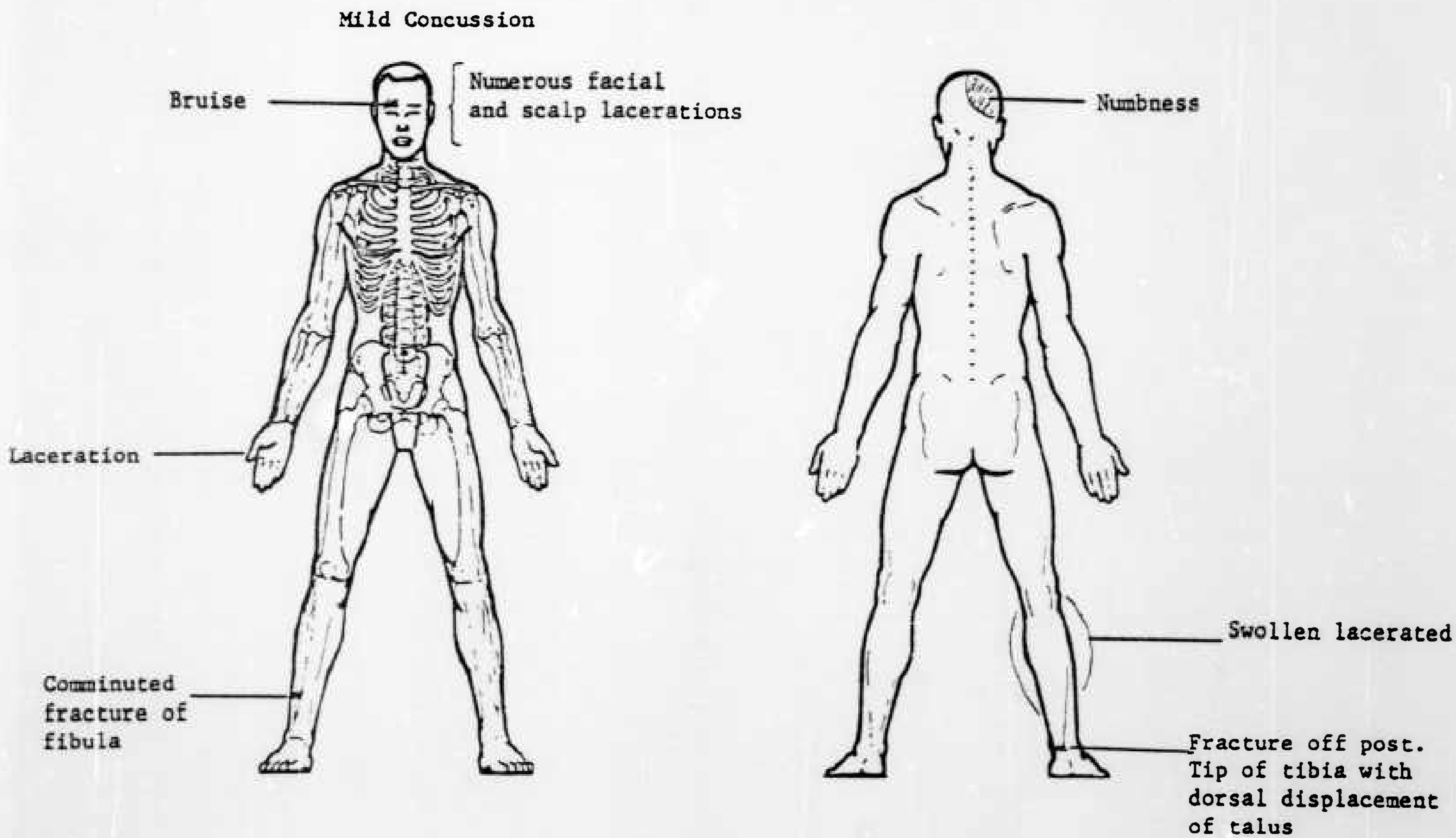
Age 25 Height 6'2" Weight 190 lbs.

PASSENGER - COPILOT SEAT



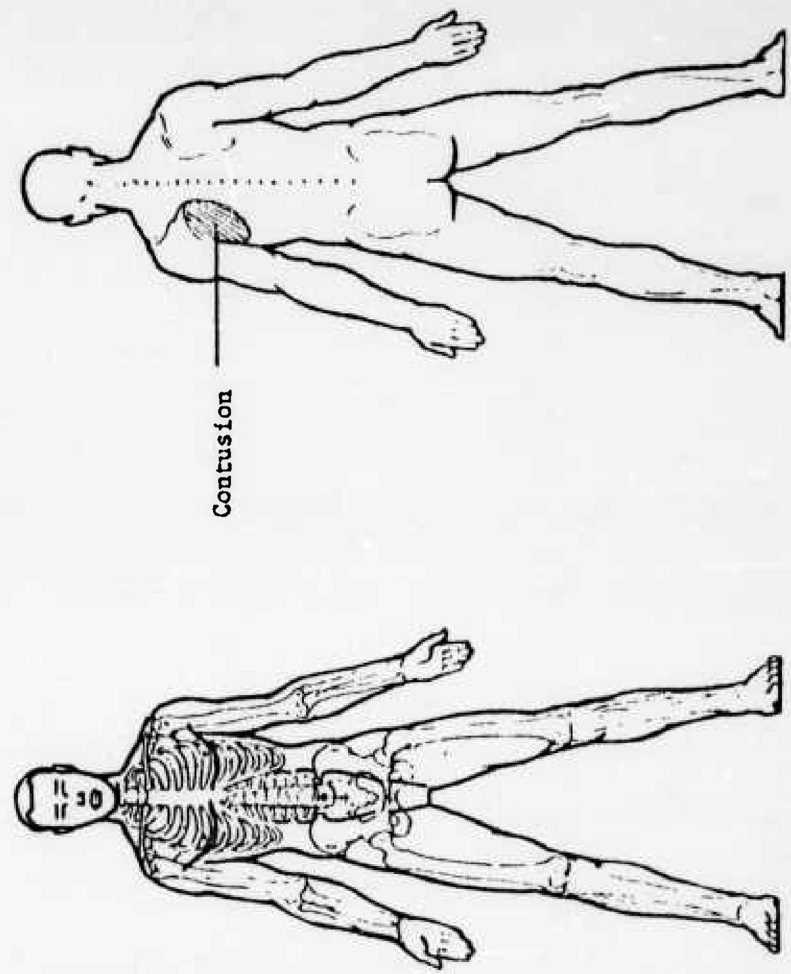
Age 44 Height 5'11" Weight 195 lbs.

CREW CHIEF - CENTER SEAT



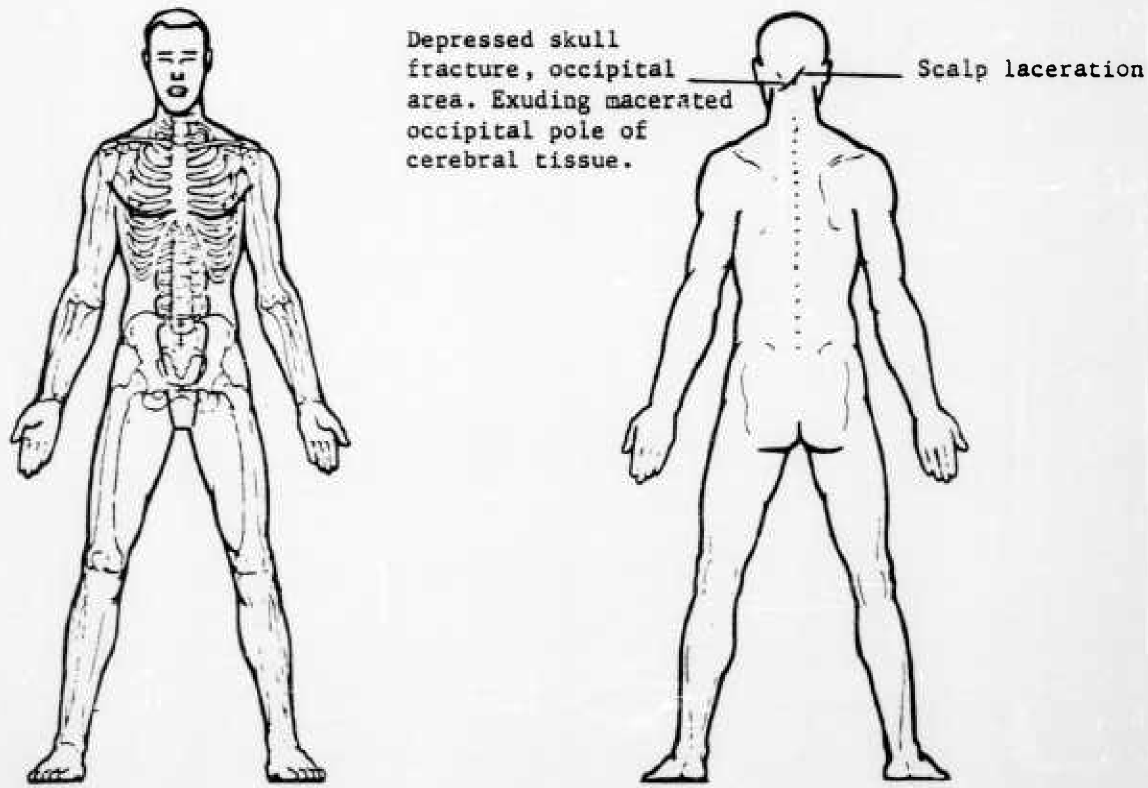
Age 31 Height 5'7" Weight 163 lbs.

PASSENGER - L-1



Age 27 Height 5'11" Weight 190 lbs.

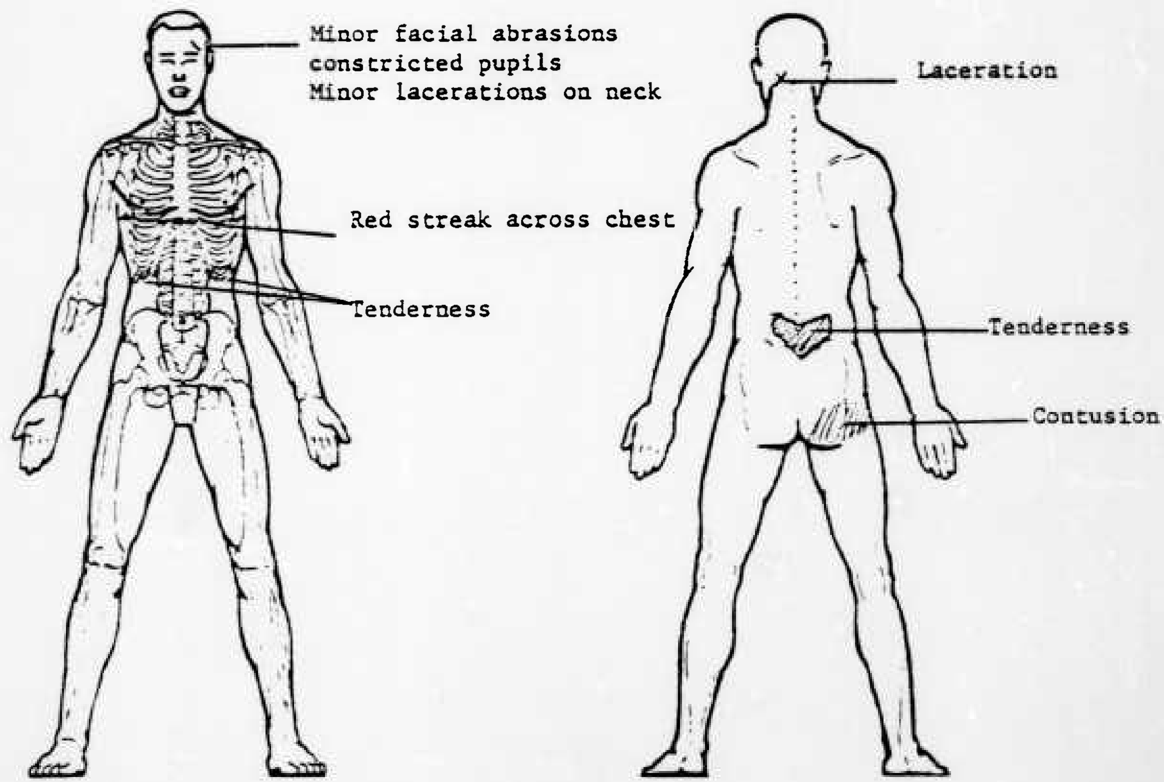
PASSENGER - R-1



Age 34 Height 5'11" Weight 170 lbs.

APPENDIX II

PASSENGER - R-2



Age 27 Height 5'11" Weight 190 lbs.

APPENDIX III

AvCIR SCALE OF INJURY

SCALE OF INJURY* USED BY AvCIR

(Revised 4/60)

Degree of Injury	Classification and Description of Injury
None or Trivial	No Injury - Abrasions or scratches of a superficial nature.
Minor	"Minor" contusions, lacerations, abrasions in any area(s) of the body. Sprains, fractures, dislocations of fingers, toes, or nose. Dazed or slightly stunned. Mild concussion as evidenced by mild headache, with no loss of consciousness.
Moderate	"Moderate" contusions, lacerations, abrasions in any area(s) of the body. Sprains of the shoulders or principal articulations of the extremities. Uncomplicated, simple, or green-stick fractures of extremities, mandible and rib cage (excluding spine). Concussion as evidenced by loss of consciousness not exceeding 5 minutes, without evidence of other intracranial injury.
Severe (survival normally assured with prompt medical care and without complications)	Extensive lacerations without dangerous hemorrhage. Compound or comminuted fractures, or simple fractures with displacements. Dislocations of the arms, legs, shoulders or pelvisacral processes. Fractures of the facial bones excluding mandible. Severe sprains of the cervical spine. Fractures of transverse and/or spinous processes of the spine, without evidence of spinal cord damage. Fractures of vertebral bodies of the dorsal and/or lumbar spine, without evidence of spinal cord damage, or compression fractures of L-3-4-5 without evidence of damage to nervous system. Skull fracture without evidence of concussion or other intracranial injury. Concussion as evidenced by loss of consciousness of over 5 and up to 30 minutes, without evidence of other intracranial injury.
Serious (but survival probable)	Lacerations with dangerous hemorrhage. Fractures or dislocations of vertebral bodies of the cervical spine, without evidence of spinal cord damage. Compression fractures of vertebral bodies of dorsal spine and/or of L-1 and L-2 without evidence of spinal cord damage. Compression fractures of L-3-4-5 with

*Based on observations during first 48 hours after injury and previously normal life expectancy.

APPENDIX III

Degree of Injury	Classification and Description of Injury
Serious (cont'd)	evidence of damage to nervous system. Crushing or multiple fractures of the extremities and/or of the chest. Indication of moderate intrathoracic or intra-abdominal injury. Skull fracture with concussion as evidenced by loss of consciousness up to 30 minutes. Concussion as evidenced by loss of consciousness of over 30 minutes to 2 hours, without evidence of other intracranial injury.
Critical (survival uncertain or doubtful. Includes fatal termination beyond 24 hrs.)	Evidence of dangerous intrathoracic or intra-abdominal injury. Fractures or dislocations of vertebral bodies of cervical spine with evidence of cord damage. Compression fractures of vertebral bodies of dorsal spine, and/or L-1, L-2, with evidence of spinal cord damage. Skull fracture with concussion as evidenced by loss of consciousness beyond 30 minutes. Concussion as evidenced by loss of consciousness beyond 2 hours. Evidence of critical intracranial injury.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with or without other injuries classed as Severe.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with other injuries classed as Serious or Critical.
Fatal	Fatal lesions in two regions of the body, with or without other injuries elsewhere.
Fatal	Fatal lesions in three or more regions of the body - up to and including demolition of the body.

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