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ECONOMIC BENEFITS OF UTILITY AIRCRAFT CRASHWORTHINESS.(U)

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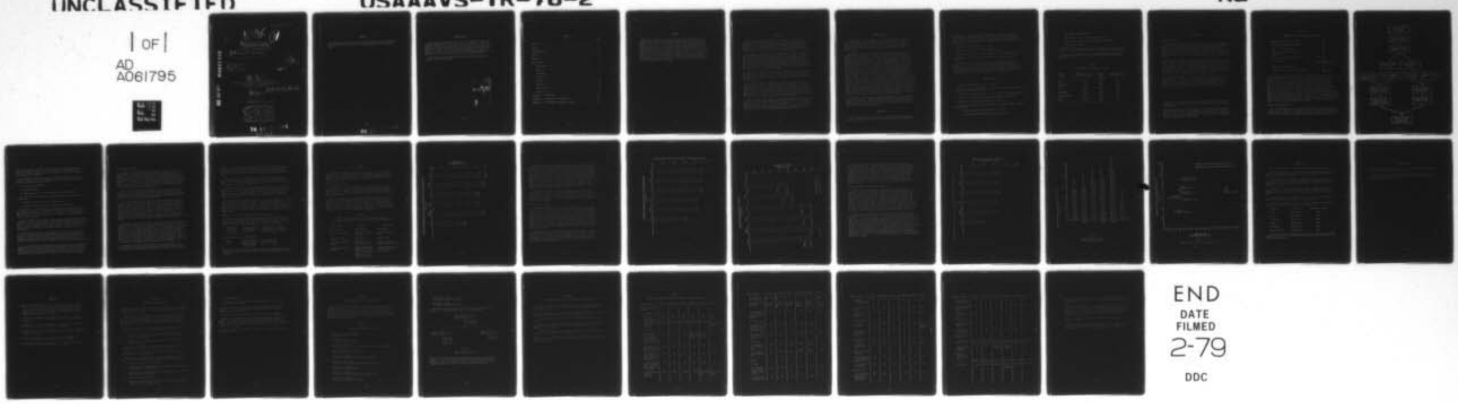

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Technical Report 76-2

LEVEL II

ECONOMIC BENEFITS OF UTILITY AIRCRAFT CRASHWORTHINESS

Technical repts

37 p.

by

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NOTICES

The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

ACKNOWLEDGMENT

This study was initiated at the request of the US Army Training and Doctrine Command (TRADOC). The analysis was performed by a study team with representation from various Army agencies and commands. The US Army Agency for Aviation Safety provided technical direction and management of the team. Participating agencies were HQ TRADOC, the US Army Aeromedical Research Laboratory, the US Army Aviation Systems Command and the Utility Tactical Transport Aircraft System Project Manager Office.

This report has been approved by the Commander, USAAAVS and by the Inspector General of the Army.

CONTENTS

ABSTRACT

This paper is the report of an analysis of the economic benefits of providing crashworthiness improvements within future Army utility helicopters. The analysis was performed for use in the Cost and Operational Effectiveness Analysis (COEA) for the Utility Tactical Transport Aircraft System (UTTAS). The analysis baseline is all UH-1H major aircraft accidents from Jan 1972 through Dec 1975. Major accident rates and losses due to accidents are derived for each COEA candidate aircraft. Losses are projected for a twenty year period of peacetime operation. Projections are derived based on each candidate's design features and the effectiveness of these features under the particular conditions in each UH-1H accident. Recommendations are made regarding use of accident losses within the UTTAS COEA and future similar studies.

SUMMARY

This report contains the results of an analysis of the effects of crashworthiness and other design features on aircraft life cycle costs. The analysis was performed to provide information to supplement the evaluation of the aircraft candidates in the UTTAS Cost and Operational Effectiveness Analysis (COEA). The aircraft studied are the UH-1H, UH-1H(PIP), UH-1N, UH-1N(MOD), Bell Model 214A(MOD) and the generic UTTAS.

The analysis took as a baseline all major UH-1H aircraft accidents from Jan 1972 through Dec 1975. These accidents were analyzed in detail by a study group formed by representatives from various Army agencies. This group determined the relative benefits of increased levels of crashworthiness and other design features in reducing either the number or severity of accidents. Major accident rates and losses due to accidents were then projected for each of the COEA candidates. The accident losses were projected over a twenty-year period of peacetime operation and included both personnel losses and aircraft damage.

All accidents regardless of cause were included in the study. However, only those cause factors which are influenced by aircraft design features were considered to have potential effect on reductions in the candidate accident rates. Other cause factors were included equally in the projections for all candidates.

The results indicate a significant reduction in both the accident rate and the total loss due to accidents for the generic UTTAS relative to the other COEA candidates. The projected major accident rate is 2.90 per 100,000 aircraft flight hours for the UTTAS versus 4.86 for the next lower candidate (UH-1H), or a reduction of 40 percent in the accident rate. The projected total loss due to accidents over a 20 year peacetime operation is $155 million for the UTTAS versus $265 million for the next lower candidate (UH-1H), or a reduction of $110 million in accident losses.

These accident losses constitute a significant portion of aircraft life cycle costs. The analysis concludes that crashworthiness and other aircraft design features can reduce these accident losses. It is recommended that the accident rates and losses derived herein be incorporated into the UTTAS COEA. It is further recommended that similar future studies of aircraft cost and effectiveness also include this type of analysis.

INTRODUCTION

Crashworthiness is that property of an aircraft which minimizes the damage to personnel and to hardware which result from a crash impact. It is a property which all aircraft possess to varying degrees and is determined by the structural design of the aircraft relative to the spectrum of its possible impact conditions and the human tolerance to acceleration.

The Request for Proposal for the Utility Tactical Transport Aircraft System (UTTAS) requires that a number of crashworthiness improvements be included as integral design requirements. These features include crashworthy airframe and fuel systems, shock-absorbing landing gear and seats and impact tolerant rotor systems. These crashworthiness features exist in the UTTAS prototype aircraft currently under government review. Crashworthiness features reduce accident losses and have a significant impact on aircraft life cycle costs. A study is presently being performed to evaluate aircraft design, performance and the effects on utility aircraft system effectiveness and life cycle costs. This Cost and Operational Effectiveness Analysis (UTTAS COEA) is being performed by the U. S. Army Training and Doctrine Command through a UTTAS Special Study Group. A previous study [1], conducted jointly by the U. S. Army Agency for Aviation Safety (USAAAVS) and the U. S. Army Aeromedical Research Laboratory (USAARL), concluded that crashworthiness improvements in the UTTAS aircraft are cost effective. Specifically, the study concluded that the total life cycle costs to provide crashworthiness are amortized by reduced accident losses within three to ten years after initial procurement of the aircraft. Based partially on the results of this previous study, the UTTAS COEA Special Study Group requested that information be provided for various aircraft concerning the losses due to aircraft accidents and the influence of aircraft crashworthiness on these losses. This information is to be used to support the evaluation of the UTTAS candidates being considered in the UTTAS COEA.

In response to this request, a crashworthiness analysis task force was convened at Fort Rucker, Alabama, with participation from various Army agencies and commands. USAAAVS provided technical direction and management of the task force. The analysis contained within this report represents the results derived by the task force.

OBJECTIVES

The overall goal of the study was to establish the expected economic losses due to aircraft accidents for each of the candidate aircraft under consideration by the UTTAS Special Study Group. The relative magnitude of these losses is an indication of the influence of crashworthiness and safety design features in the various aircraft designs. Accident losses were calculated for a 20 year period of peacetime operation to be consistent with the overall UTTAS COEA.

The specific objectives were as follows:

(1) Determine candidate aircraft accident rates.

(2) Determine the mean cost per accident for each candidate aircraft.

(3) Determine the losses due to accidents over the total period of operation.

The crashworthiness features and other safety improvements in each of the aircraft designs considered herein have benefits far beyond their economic effects. The total effects of prevention of crash injury include improvements in unit operational readiness and personnel morale, for example, which cannot be evaluated from an economic standpoint. Evaluation of their economic effects is the sole purpose of this study.

ASSUMPTIONS

The major assumptions used were as follows:

(a) The baseline for the analysis was major aircraft accidents occurring to UH-1H aircraft during peacetime.

(b) Losses were projected over a 20 year period of peacetime operation.

(c) All aircraft accidents, regardless of cause, were included.

(d) Losses were projected in constant 1975 dollars.

(e) Aircraft considered were the UTTAS COEA candidates. These included the following:

(1) The present Army UH-1H (baseline aircraft).

(2) UH-1H aircraft with product improvements (PIP).

(3) The Navy UH-1N aircraft.

(4) A modified version of Navy UH-1N aircraft.

(5) A modified version of the Bell Model 214A aircraft.

(6) The generic UTTAS.

(f) The only safety improvements to be considered were those designed into the candidate aircraft as described in official system documentation.

(g) Losses were calculated based on aircraft acquisition costs, fleet size and flying hours information used in the UTTAS COEA as summarized in Table I.

TABLE I

Candidate Aircraft Fleet Parameters

Aircraft Type	Unit Acquisition Cost (1975 Dollars)	Projected Fleet Size	Flying Hours Per Aircraft Per Year
UH-1H	$ 591K	1695	324
UH-1H(PIP)	708K	1695	324
UH-1N	1,042K	1695	324
UH-1N(MOD)	1,134K	1695	324
Model 214A(MOD)	1,280K	1769	324
UTTAS	1,792K	1107	324

METHODOLOGY

Overall Approach

The first step in the overall approach was to establish an accident rate* for each of the candidate aircraft. Design features which would influence the accident rate were taken into account. Second, a mean cost (i.e., average economic loss due to hardware damage and personnel injury) was established for each of the candidates taking into account its particular crashworthiness features. Finally, the accident costs for each candidate were derived by multiplying the accident rates by the respective average loss per accident.

The basic data analyzed for this study was all major aircraft accidents which occurred to US Army UH-1H aircraft during calendar years 1972 through 1975. This was a period of primarily peacetime operation of this aircraft. A total of 138 accidents** occurred during this period as summarized in Table II. Army Regulation 10-29 [2] designates USAAAVS as the repository of reports of all Army aircraft accidents. Accident data used was taken from the USAAAVS files at Fort Rucker, Alabama. Appendix A contains definitions of terms used in Table II and other sections of this report.

Investigations of Army aircraft accidents are performed according to the requirements of AR 95-5 [3]. Typically, several cause related factors are identified for each accident. No one factor is defined as "the" cause. Instead the accident cause is considered to be the summation of all the listed cause factors. Therefore, accounting of multiple cause factors was required during the analysis of the accident reports for this study.

* Army aviation accident rates are computed by dividing the total number of accidents in a given period by the total aircraft flight hours in units of 100,000 hours.

** One additional major aircraft mishap occurred during this period which was not included because of the particular circumstances surrounding it. In this mishap, a UH-1H aircraft was impacted in flight by an antiaircraft artillery round fired by friendly forces. This mishap was not considered in this study due to its combat nature.

TABLE II

UH-1H Major Aircraft Accidents, CY 72-75

Number of Survivable Accidents	120
Number of Nonsurvivable Accidents	19
Number of Major Accidents	139
Number of Accidents Analyzed in this Study	138
Number of Aircraft Flight Hours:	2,837,653
Accident Rate:	4.86 per 100,000 flight hours
Number of Occupants Aboard	683
Number of Occupants Killed or Injured	304 or 44.5% of total

Each step in the overall methodology is identified in Figure 1. As shown, the USAAAVS computerized data bank was used to provide a listing of all UH-1H accidents and the total aircraft flight hours during CY 72-75. The file copies of the Technical Report of US Army Aircraft Accident (DA Form 2397-Series) were assembled along with any previous USAAAVS review comments. These were used in a "manual," case-by-case accident analysis by the task force. The total analysis was composed of two parts: a crashworthiness analysis and an accident rate analysis. These two analyses were performed in parallel by two respective subgroups of the task force. The organization of the task force is contained in Appendix B. The crashworthiness subgroup essentially answered the question "Given that the accident has occurred, would the occupants have been injured?" The accident rate analysis essentially answered the question "would the accident have occurred at all?" A preprinted analysis sheet was used to summarize the findings of the two subgroups and to make the analysis of each accident more uniform.

Crashworthiness Evaluation

The crashworthiness analysis assessed the performance of certain design features of the candidate aircraft under the same crash conditions experienced in the 138 UH-1H accidents. Crashworthiness was summarized for each candidate by computing a mean loss per accident. This included both hardware damage

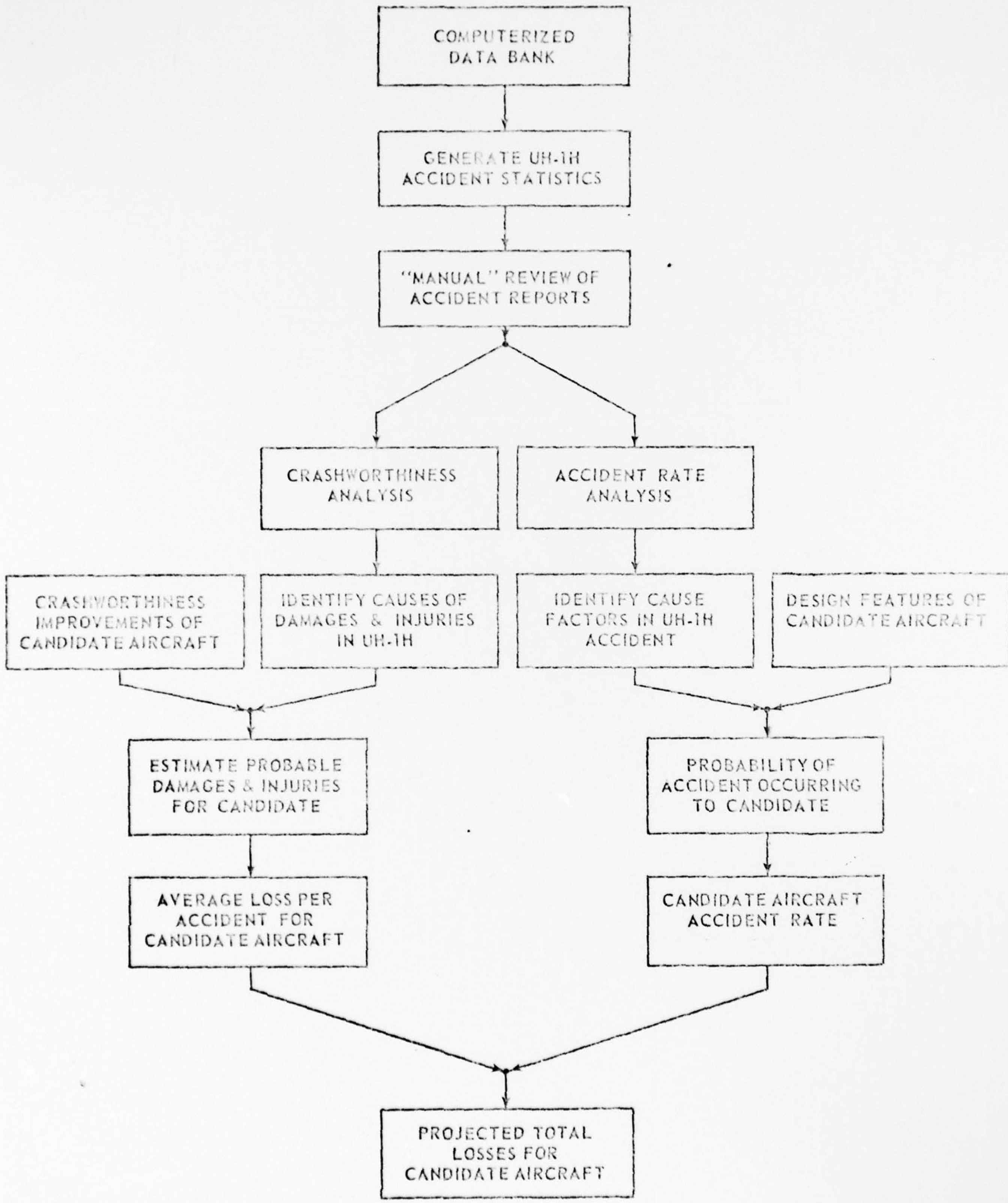

Fig. 1

Sequence of Analysis

and personnel injury. Personnel injury losses were computed using the cost figures contained in Department of the Army Circular 385-48 [4]. To be consistent with other losses, these cost figures (listed in 1974 dollars) were adjusted to 1975 dollars.

Each individual accident report was studied to identify the causes of injury and hardware damage. The following accident characteristics were studied as a minimum for each accident:

a. Degree of survivability.

b. Impact kinematics.

c. Terrain characteristics and features of the crash sequence.

d. Total UH-1H aircraft damage (component damaged, location, degree of damage).

e. Occupant location in aircraft at time of crash.

f. Occupant injury (type, cause and degree) in the UH-1H.

One member of the crashworthiness subgroup analyzed each accident report. The result of his analysis, as contained in the completed analysis sheet, was reviewed independently by the other team members. The completed summaries thus represent a consensus of opinion. This technique minimized the subjectivity of the results.

Next, the hardware damage and personnel injury preventable by the improved technology of each of the candidate aircraft were evaluated relative to that experienced in the UH-1H accidents. During analysis of the losses which would be preventable by improved technology, a conscious effort was made toward conservatism. No benefits were "claimed" unless a reasonably clear-cut case was apparent.

The primary rationale used to determine the benefits of improved crashworthiness is discussed in US Army Air Mobility Research and Development Laboratory Technical Report 71-22 [5]. Crashworthiness requirements for new military helicopters are specified in Military Standard 1290 [6]. The capabilities/requirements of the candidate aircraft are summarized in Appendix C.

After analysis of all accident reports, the personnel losses and hardware damages were totaled and divided by the total number of accidents (138) to calculate the mean loss per accident for each candidate aircraft. The mean loss per accident was used with results of the accident rate evaluation as discussed below to determine the total loss over the period of operation.

Accident Rate Analysis

As indicated in Figure 1 accident rates were established for each of the candidate aircraft by review of the 138 UH-1H accidents and consideration of design features in each candidate which (potentially) could have prevented the accident from occurring. A wide variety of cause factors and design features were considered. The design features are summarized in Appendix C. The cause factors were grouped into two types termed "Hardware Factors" and "Human Factors". A team of analysts with expertise in these areas was formed for each type. These two teams together comprised the Accident Rate Analysis subgroup (Appendix B).

The first step in projecting accident rates was to study each UH-1H accident report and determine all the detailed accident cause factors. These cause factors were weighted by a percentage allocation based on their estimated relative importance within the accident. (The sum of all cause factors for each accident equalled 100 percent).

Next, the probability that each cause factor would have been present for each candidate aircraft was estimated. This estimate considered the design features of each aircraft relative to the particular circumstances of the accident being studied. This analysis considered the influences of only those features designed into the candidate aircraft. The myriad of other accident causes, such as improper command supervision in the aviation unit, were considered to apply equally to all candidates. Consideration of "eliminating" an accident was made only when evidence was available (system specifications, design requirements, etc) indicating that aircraft design features would lessen the potential for the accident to occur.

During this process each candidate was "subjected" to the same emergency situation which immediately preceded the UH-1H accident. For accidents following engine failure due to compressor stall for example, each candidate was placed into the same flight conditions as the UH-1H with one engine inoperative. It was assumed that the single engine aircraft attempted an immediate forced landing. For the twin engine aircraft, the probable results were estimated based on the particular flight condition at the time of power loss versus the aircraft performance capabilities with one engine inoperative. For accidents following loss of engine power due to fuel starvation, on the other hand, complete loss of power was uniformly assumed and each candidate aircraft attempted an immediate forced landing.

In addition, no judgments were made regarding the suitability of the candidate aircraft to the mission assigned to the UH-1H at the time of its accident. The assumption was made that all aircraft would be equally likely to be performing the mission at hand. For example, for an accident occurring during a practice touchdown autorotation, each aircraft was assumed to be equally likely to be performing that training mission and the influence of its own safety features was evaluated from that point onward.

After the percentage estimate was made for all the cause factors in one accident, the cause factors were summed for each candidate aircraft. This sum is a measure of the probability of the accident occurring with the candidate, relative to the baseline UH-1H.

This estimate process was performed by both the human factors and hardware factors teams. The teams analyzed each accident independently. Then their findings were consolidated and coordinated. This was to insure that all factors were considered in their proper context and to enhance the objectivity of the analysis by providing a system of checks and balances between the two groups.

This process was repeated for each of the accidents. After all accident reports were analyzed, the cause factor totals were summed to provide a grand total for each candidate aircraft. The candidate grand total represents the probability of all the accidents occurring relative to the total UH-1H experience. This projection for the total accident experience was used together with results from the crashworthiness analysis to establish the total fleet losses.

Calculation of Accident Losses Over Twenty Year Period

The accident rate and crashworthiness data derived above were used together to establish total accidental losses to be expected over a twenty year period of operation. This was accomplished by determining the total number of accidents expected during this period by the following:

$$\text{Total Number of Accidents Over 20 Year Period} = \left\{\begin{matrix}\text{Accident Rate}\\ \text{of Candidate}\\ \text{Aircraft}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Total Number of Candidate}\\ \text{Flying Hours in 20 Year}\\ \text{Period Divided by 100,000}\\ \text{Hours}\end{matrix}\right\}$$

Then the total loss was calculated by

$$\text{Total Loss} = \left\{\begin{matrix}\text{Total Number}\\ \text{of Accidents}\\ \text{Over 20 Year}\\ \text{Period}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Average Loss}\\ \text{Per Accident}\end{matrix}\right\}$$

The first term on the right hand side of this final equation comes from the accident rate analysis and the second term comes from the crashworthiness evaluation.

RESULTS

Results of the analysis performed by the task force are summarized in the tables and graphs below. First, the accident rates are projected, next the average cost of an accident is discussed and finally these two pieces of information are combined to calculate the total loss over the period of operation.

Projected Accident Rate

Accident rate projections (peacetime environment) for each of the candidate aircraft are summarized in Figure 2. Accident rates are depicted in terms of number of accidents per 100,000 aircraft flight hours. These projections vary from a high value of 4.86 for the UH-1H to a low of 2.90 for the UTTAS.

There are a number of specific design features which contributed to the decrease in the projected accident rate from the UH-1H to the UTTAS. Those features which contributed most frequently to this reduction are listed in Table III in decreasing order of importance. Some improvements in these same areas also are provided in other candidate aircraft and the accident rates reflect these improvements. However, their benefits in many cases were judged less significant than for the UTTAS.

TABLE III

UTTAS Design Features Having Most Significant Influence in Reducing Accidents, Listed in Decreasing Order of Importance

Design Feature	UH-1H	Generic UTTAS
No. of Engines	Single engine	Twin engine
Tail rotor location	Low tail rotor, not shielded	High shielded tail rotor
Landing gear type	Skid gear	Wheeled gear
Location of throttle control	Throttle controls on collective	Throttle controls separate from collective
Dual Instrumentation/ Controls	Copilot instrumentation/controls not complete. Different instruments for pilot and copilot (e.g. attitude indicator)	Full instrumentation/ controls for pilot and copilot

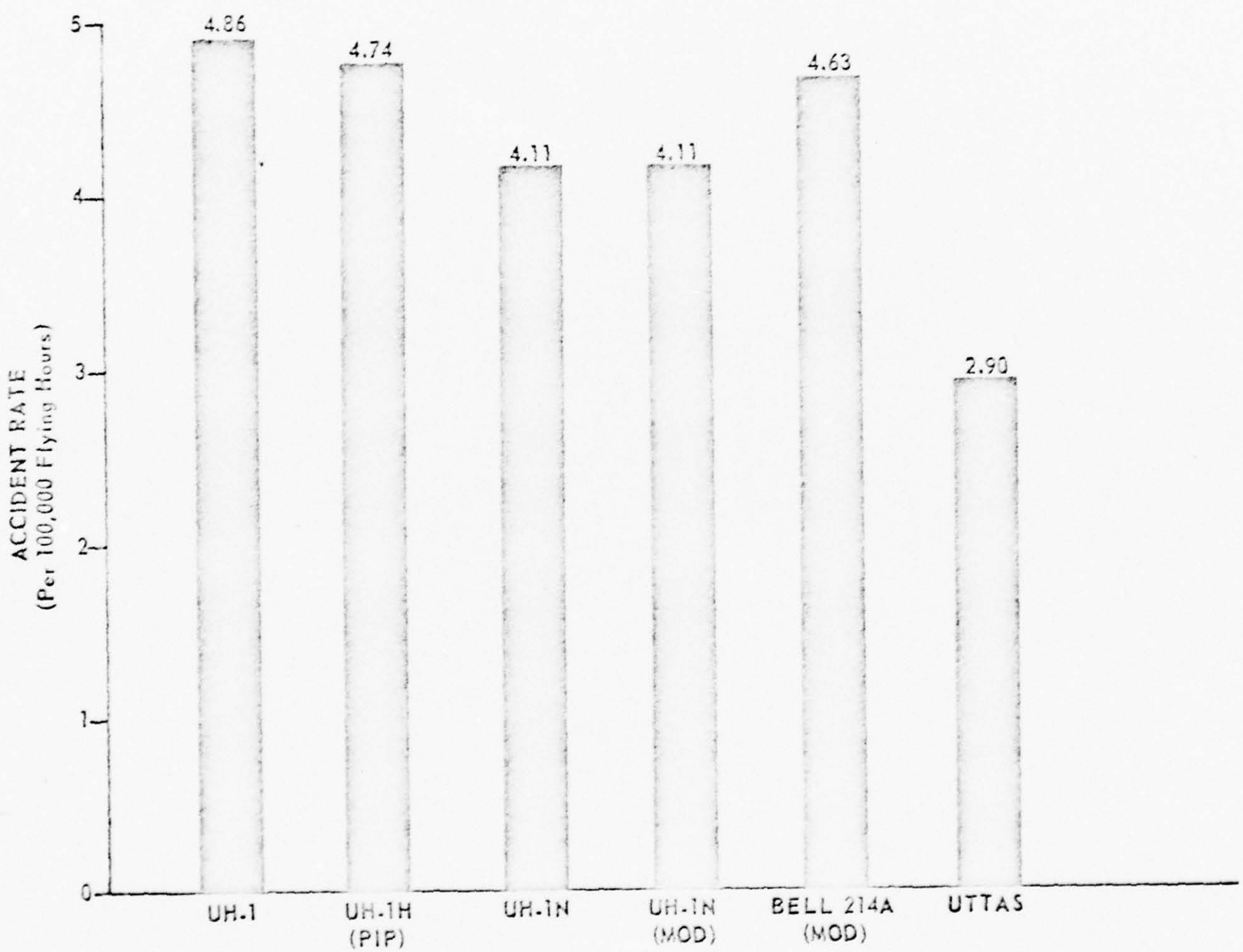

FIGURE 2
PROJECTED PEACETIME ACCIDENT RATES FOR CANDIDATE AIRCRAFT

The UTTAS feature with the greatest influence in accident reduction is the twin engine design with its substantial performance with one engine inoperative. The twin engine design of the UH-1N models also was judged to assist but in a smaller number of instances (reflected in a smaller reduction in the UH-1N accident rate). The major difference between the UTTAS and UH-1N twin engine designs is the aircraft performance with one engine inoperative. The assistance provided by the remaining UH-1N engine generally was judged to be limited to making the forced landing a somewhat more controllable situation, whereas the UTTAS frequently was judged capable of continuing flight to return to base or to a more suitable landing area. Again, these judgments were made on an individual basis by considering the prevailing conditions of altitude above ground level, airspeed, aircraft gross weight, density altitude and type of terrain.

It should be noted that the UH-1H accident rate depicted in Figure 2 is historical fact while the rates for the other aircraft are projections from the present study. In particular, the UH-1N rate is not the historical U. S. Navy accident rate for this aircraft but is an estimate of what the rate would be for utilization of the Navy UH-1N aircraft within the Army operational environment.

Mean Loss Per Accident

The primary objective of crashworthiness improvements is prevention of crash injury. The need for and benefit of this improvement is depicted in Figure 3 which shows the projected number of casualties for each candidate as percentages of the total occupants aboard. The percentages shown include all fatal and non-fatal injuries from all causes. These figures may be considered the probability that a servicemember will be injured or killed given that he is an occupant (pilot, crew or passenger) in a major aircraft accident. The UH-1H figure reflects the historical experience during CY 72-75. The smaller figures for the other candidates reflect the estimated effectiveness of crashworthiness improvements in these aircraft. Relative to the UH-1H, UTTAS crashworthiness will result in approximately 1/3 fewer casualties.

These reductions in crash injury plus the hardware benefits of crashworthiness both contribute to the projections for the mean loss per accident as shown in Figure 4. The expected loss per accident is a minimum for the UH-1H and a maximum for the 214A(MOD). The increased total loss for the more expensive aircraft is a direct result of their significantly increased unit acquisition costs.

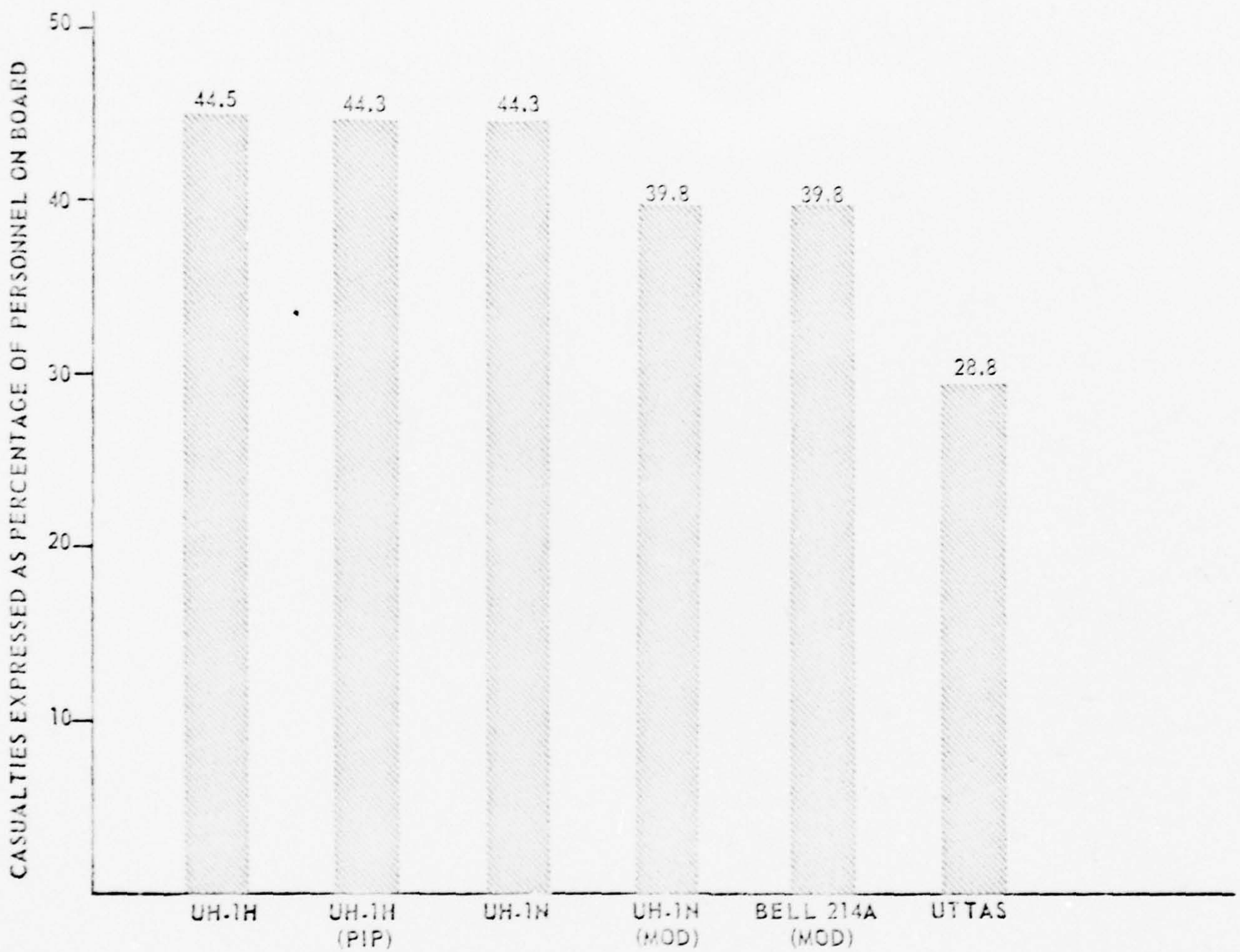

FIGURE 3
PROJECTED CASUALTIES FOR CANDIDATE AIRCRAFT

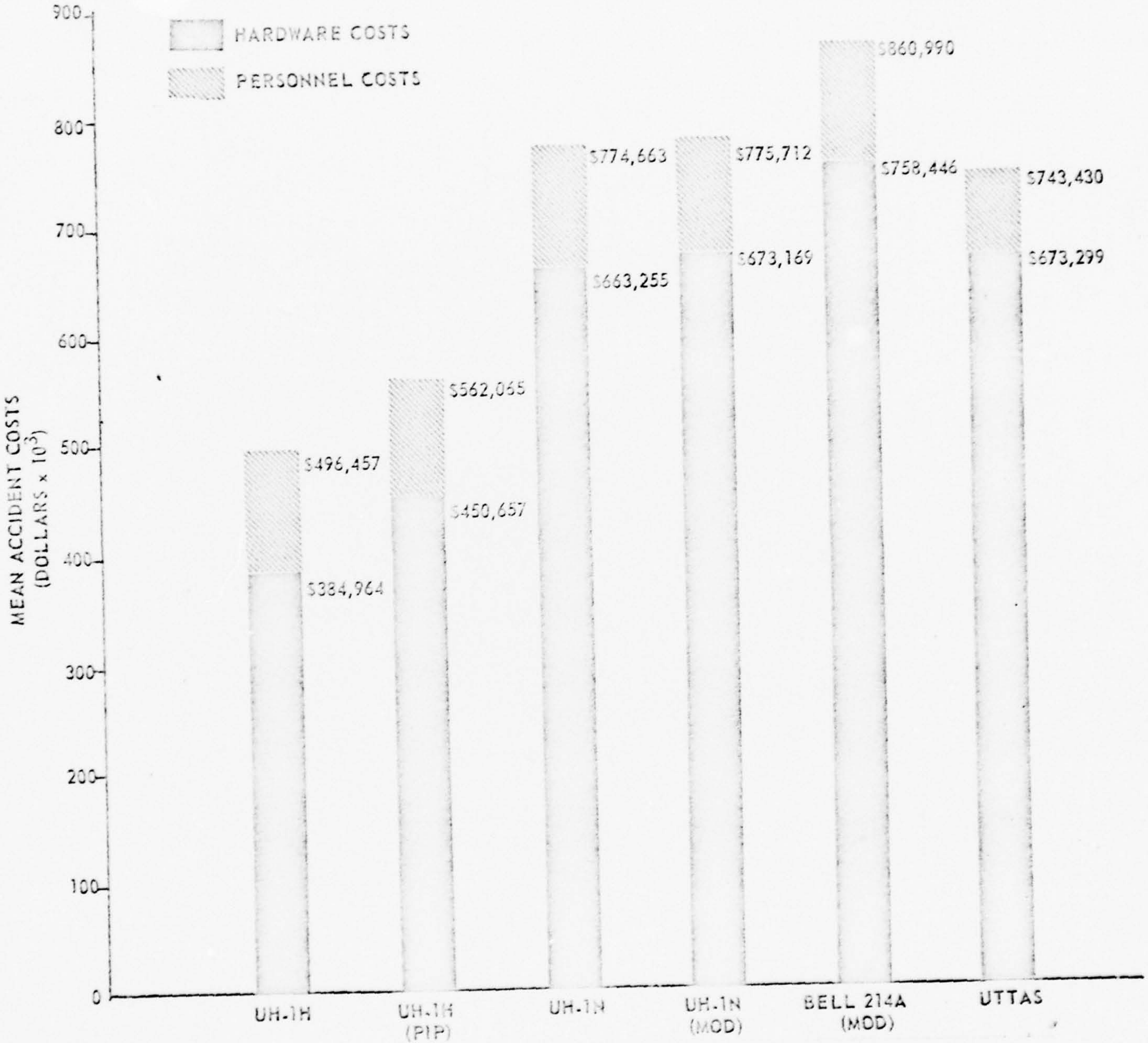

FIGURE 4
PROJECTED MEAN COSTS PER AIRCRAFT

The hardware losses were also studied in terms of a percentage of these acquisition costs. Results of this analysis is shown in Figure 5. The losses depicted in this figure are the mean hardware damages divided by the respective acquisition costs for each candidate. The influence of the crashworthiness improvements in each aircraft can be clearly seen in this figure. The data indicates that whereas in the average UH-1H accident the Army would lose approximately 65 percent of a new UH-1H in hardware damages, for the average UTTAS accident the Army's losses would be reduced to 38 percent of a new UTTAS. The difference in these two percentages is a direct result of the increased crashworthiness in the UTTAS design.

Total Accident Losses Over 20 Year Operation

Figure 6 shows the total losses (hardware plus personnel) from accidents over a 20 year operation of a fleet of each of the candidate aircraft. These totals reflect the influences of both the accident rates and crashworthiness features discussed above. The losses are expected to be a minimum for the UTTAS ($155 million in constant 1975 dollars) and a maximum for the 214A(MOD) ($457 million, or approximately 2.9 times the UTTAS). The remaining candidates cluster around an intermediate value (approximately $325 million). Compared to the UH-1H, the UTTAS is expected to have a total savings (i.e., reduction) in accident losses of 40 percent, or $110 million over the 20 year operation. This dramatic savings in spite of significant increases in the aircraft acquisition cost is a result of the design features included as integral parts of the UTTAS aircraft.

To put all the analysis results into perspective, the total accident losses and the accident rates for each candidate were plotted together in Figure 7. Each aircraft type is represented by one point in this figure, that point reflecting historical fact for the UH-1H and projections for the other candidates. Merely for comparison purposes, the historical experience of a prior generation aircraft (Army CH-34) is also shown. This graph demonstrates that the total UTTAS benefit to the Army is the combined influence of both a reduced accident rate and a lower accident cost. These together result in a clear distinction between the UTTAS and the other candidates. This distinction results from the new generation of design requirements incorporated into the UTTAS. Demonstration that benefits of this magnitude are possible is shown by the similar distinction between the CH-34 and UH-1H accident statistics.

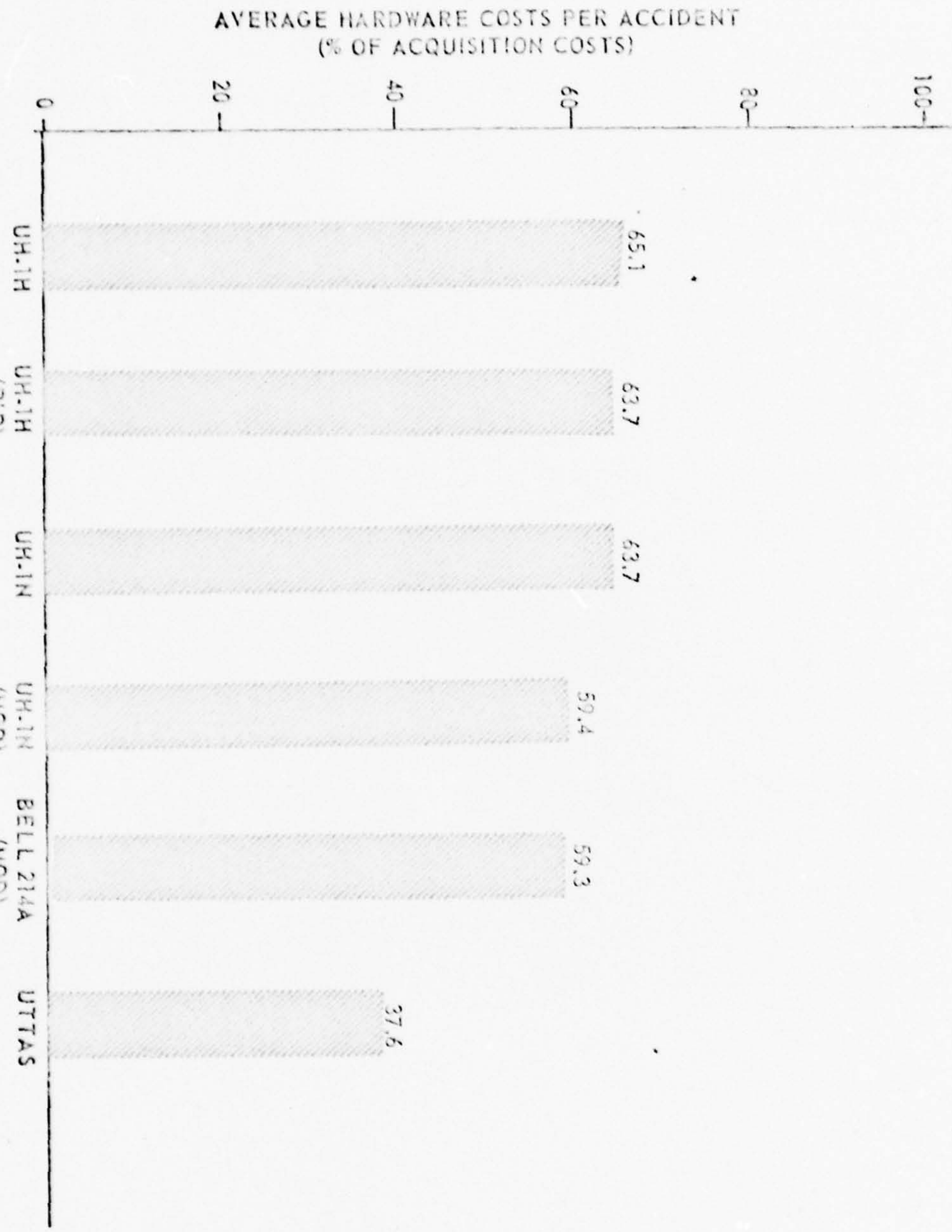

Fig. 5

Projected Mean Loss Per Accident as a Percentage of Unit Acquisition Cost

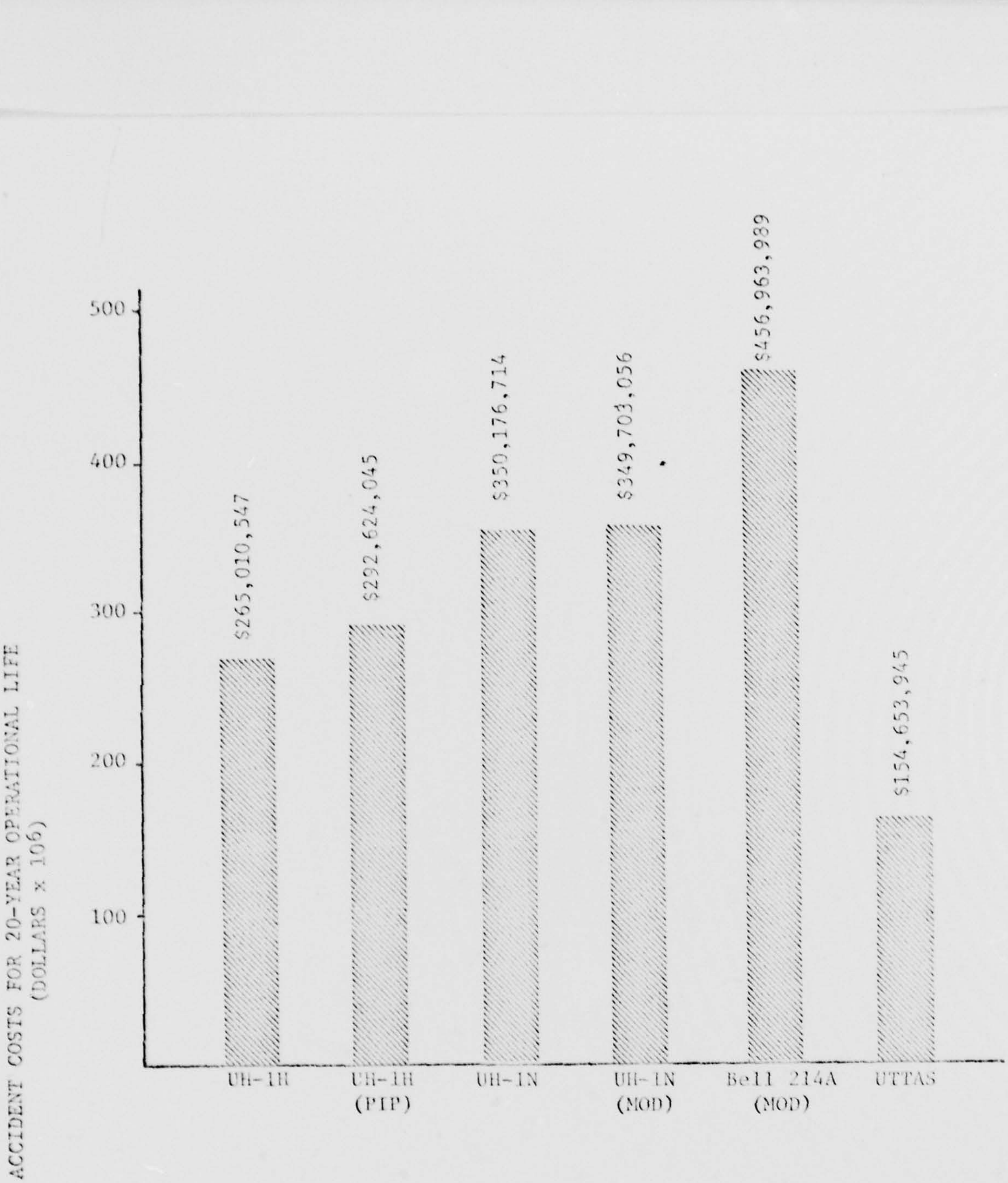

Fig. 6

Total Accident Costs for
20 Year Operational Life

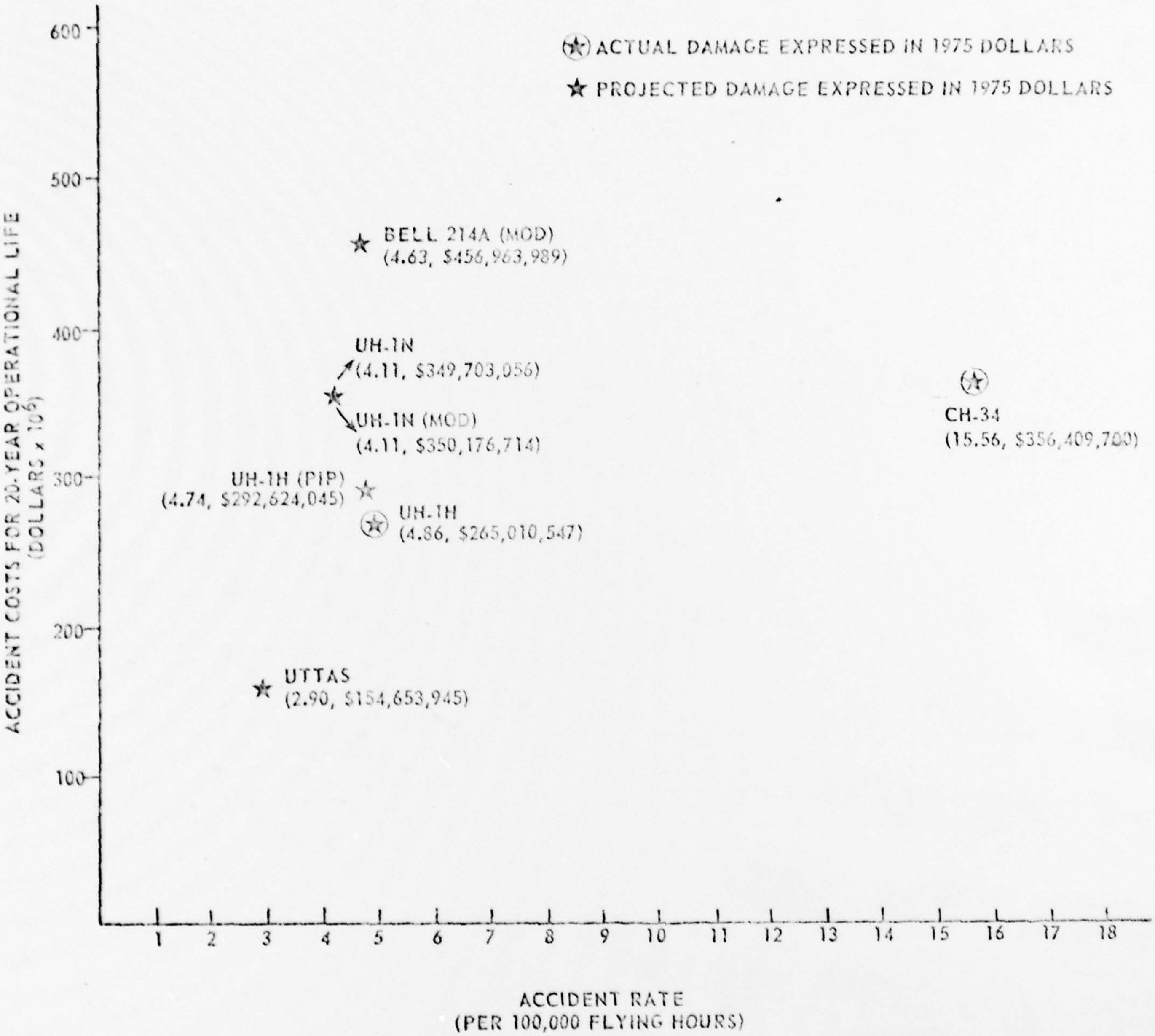

Fig. 7

Projected Accident Rates and 20 Year Losses

CONCLUSIONS

Study of UH-1H accident records supports the following conclusions:

(1) Accidents constitute a significant portion of aircraft life cycle costs. Crashworthiness improvements reduce these losses in spite of increased initial acquisition costs.

(2) Crashworthiness improvements and other safety features are most efficiently included in an aircraft as integral system requirements in the conceptual design stage. This design technique provides the most dramatic reductions in accident losses.

(3) Compared to other UTTAS COEA candidates, the UTTAS will have fewer accidents and lower total accident losses. This results in a clear distinction between the UTTAS and the other candidates in terms of economics alone.

(4) In addition, UTTAS crashworthiness would provide other significant benefits by reducing the frequency of personnel injury.

(5) The total economic losses due to accidents for 20 year operation of each of the candidates relative to the baseline UH-1H are

Candidate	Total Loss	% of Baseline (UH-1H)
UTTAS	$155 million	58%
UH-1H	$265 million	100%
UH-1H(PIP)	$293 million	111%
UH-1N	$350 million	132%
UH-1N(MOD)	$350 million	132%
Model 214A(MOD)	$457 million	173%

(6) The total UTTAS savings compared to the next lower candidate (UH-1H) would be a reduction in accident losses of 42 percent or $110 million over the 20 year operation.

RECOMMENDATIONS

(1) Recommend that TRADOC incorporate the aircraft accident rates and losses contained herein into the UTTAS COEA.

(2) Recommend that TRADOC incorporate similar analyses of accident losses and crashworthiness influences into all future studies of aircraft cost and operational effectiveness.

REFERENCES

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APPENDIX A

DEFINITIONS AND TERMINOLOGY

Aircraft Accident - Damage which occurs to one or more aircraft while flight was intended. Damage as a direct result of hostile fire is not an accident but a combat loss.

Major Accident - An aircraft accident is classified major when the aircraft is destroyed, or damage sustained is in excess of prescribed limits as to required repair manhours (e.g., 500 repair manhours for UH-1 aircraft) or a major component (e.g., fuselage section or tail boom) is destroyed beyond economical repair, or the aircraft is lost or abandoned.

Survivable Accident - An accident in which the following statements are satisfied for at least one occupant aboard the aircraft:

a. The forces transmitted to the occupant through his seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations.

b. The fuselage structural container maintains a livable volume around the occupant.

Nonsurvivable Accident - An accident in which neither of the above statements is satisfied for all occupants aboard the aircraft.

Major Impact - The impact which results in the largest deceleration forces transmitted to the aircraft.

Major Injury - Any injury requiring five days of hospitalization or any of the following symptoms without regard to hospitalization:

a. Unconsciousness due to head trauma.

b. Fracture (open or closed) of any bone, other than closed fractures of the phalanges or nasal bones.

c. Traumatic dislocation of any joint, excluding phalanges, or internal derangement of the knee.

d. Injury to any internal organ.

e. Moderate-to-severe lacerations which cause extensive hemorrhage or require extensive surgical repair.

f. Third-degree burns.

g. First- and second-degree burns involving more than five percent of the body surface.

Thermal Injury - A fatal or non-fatal injury caused by exposure to combustion effects: heat, noxious gas inhalation, and medical complications caused by thermal burns.

Impact Injury - All injury causes other than thermal or drowning.

Crash Force Attenuation - The attenuation of impact force through the medium of structural deformation. The protective fuselage should deform but not collapse. For example, landing gears should absorb energy "limit loads" prior to failure, and occupant seats must "limit" torso decelerations to non-injurious levels.

Unless otherwise specified, other terminology is as defined in Military Standard 1290 [6].

APPENDIX B

ORGANIZATION OF THE ANALYSIS TASK FORCE

An eleven-man task force performed the required analysis. This group contained experience in a wide variety of engineering, psychological and aircraft operational fields. As listed in Table B-I below, representatives from the Army Agency for Aviation Safety, the Army Aeromedical Research Laboratory, the UTTAS Project Manager Office, the Army Aviation Systems Command, TRADOC Systems Analysis Activity and Headquarters, TRADOC participated in the task force.

TABLE B-I

Crashworthiness Analysis Task Force

Dr. James E. Hicks, (Chairman)
Aerospace Engineer, USAAAVS

Mr. Billy H. Adams
Aerospace Engineer, USAAAVS

Mr. Joseph L. Haley, Jr.
Aerospace Engineer, US Army Aeromedical Research Lab (USAARL)

CPT Larry H. Hamre
Aviation Staff Officer, HQ, TRADOC

Mr. Joseph L. Hendrix
Industrial Engineer (Human Factors), USAAVSCOM

Mr. Servando Hernandez
General Engineer, TRADOC Systems Analysis Activity

Mr. Patrick J. Hollifield
Aerospace Engineer, USAAAVS

Mr. Nelson K. Itterly
Aerospace Engineer, UTTAS Project Manager Office

Mr. William C. McDaniel
Research Psychologist, USAAAVS

Mr. Laurel D. Sand
Air Safety Specialist, USAAAVS

Dr. Robert H. Wright
Research Psychologist, USAARL

The eleven total people were organized into working teams by field of expertise. The organization used is shown in Figure B-1.

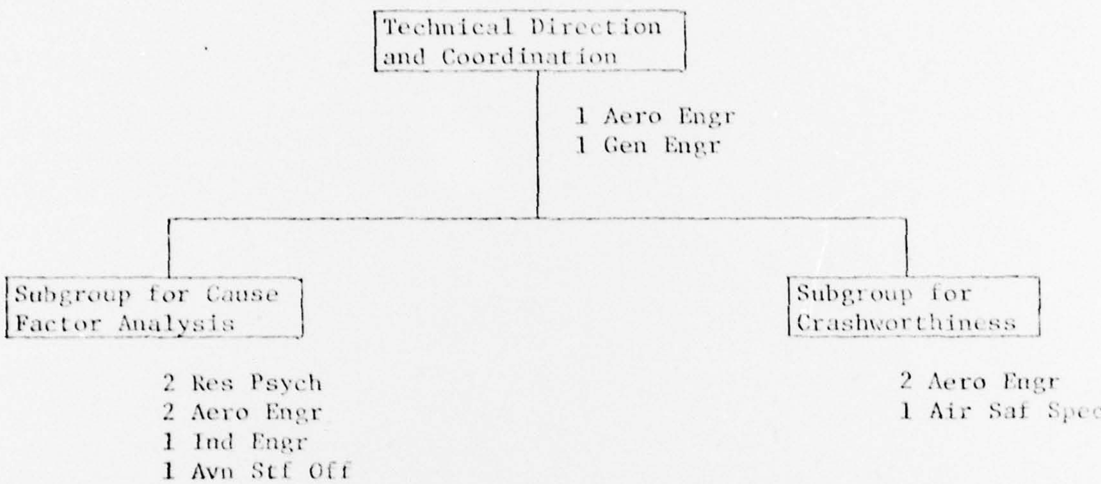

Fig. B-1

Task Force Organization

The task force contained two major subgroups, one group to evaluate the cause factors of each accident and the other group to evaluate the crashworthiness aspects. The subgroup for cause factor analysis was further subdivided into material factors and human factors working teams.

APPENDIX C

DESCRIPTION OF DESIGN FEATURES OF CANDIDATE AIRCRAFT

Description of the pertinent design features of each candidate aircraft is contained in Table C-1. This technical data was assembled from a number of sources, including:

(1) Department of the Army Technical Manual TM 55-1520-221-10, Operator's Manual for the UH-1D/H Helicopter, November 68 with revisions.

(2) Bell Helicopter Company Model 212 Field Maintenance Training Manual, 1 Jan 72.

(3) Naval Air Systems Command Technical Manual NAVAIR 01-110HCE-1, NATOPS Flight Manual for the Navy Model Utility Helicopter, UH-1N, 1 Jan 73, with VH-1N Supplement, 15 Dec 75.

(4) US Army Aviation Systems Command RFP DAAJ01-72-R-0254(P40), Utility Tactical Transport Aircraft System, 10 Mar 72.

The accuracy of the technical data contained in Table C-1 has been verified by the U. S. Army Aviation Systems Command, Directorate for Research, Development and Engineering.

TABLE C-1

Comparison of Pertinent Design Features of Candidate Aircraft

Design Feature	UH-1H	UH-1H(PIP)	UH-1N	UH-1N(MOD)	214A(MOD)	UTTAS
1. Crashworthiness Design						
a. Landing Gear						
1. Type	Skid	Skid	Skid	Skid	Skid	Wheel
2. Design Sink Speed (fps)	8	8	8	15	15	15
3. Longitudinal & Lateral Strength	MIL-S-8698	MIL-S-8698	MIL-S-8698	MIL-S-8698	MIL-S-8698	15 fps with 10 deg roll or pitch
b. Fuselage						
1. Maintain livable volume in 95th Percentile Survivable Crash Loading (Reference [5])	No	No	No	50% of Energy Absorption Capability of UTTAS	50% of Energy Absorption Capability of UTTAS	Yes
2. Withstand Fuselage Plowing (Reference [5])	No	No	No	No	No	Yes
3. Withstand 15 fps Longitudinal Wall Impact w/o Pilot Injury	No	No	No	No	No	Yes
4. Withstand 40 fps Longitudinal Wall Impact w/o Troop Injury	No	No	No	No	No	Yes
5. Transmission Tie-Down Strength	8G	8G	8G(a)	8G(a)	$8G_x$, $8G_y$,(b) $16G_z$	$20G_x$, $18G_y$, $^{+20}_{-10}$ G_z

Design Feature	UH-1H	UH-1H(PIP)	UH-1N	UH-1N(MOD)	214A(MOD)	UTTAS
6. Engine Tie-Down Strength	$8G_x$, $1.5G_y$, $8G_z$	$8G_x$, $1.5G_y$, $8G_z$	8G	8G	8G	$20G_x$, $18G_y$ $20G_z$
7. Fuselage Roof Strength	$4G_z$ (Unknown G_x, G_y)	$4G_z$ (Unknown G_x, G_y)	$4G_z$ (Unknown G_x, G_y)	50% of UTTAS Strength	50% of UTTAS Strength	$4G_x$, $2G_y$, $4G_z$ acting simultaneously
8. Withstand 100 fps, 5 deg Impact with Terrain	No	No	No	No	No	Yes
c. Fuel System						
1. Crashworthy Main Fuel System Including Rollover Vent Valves	Yes	Yes	Yes	Yes	Yes	Yes
2. Crashworthy Auxiliary Fuel System	Yes	Yes	Yes	Yes	Yes	Yes
d. Seating						
1. Crashworthy Crew Seats Per [5]	No	No	No	Yes (c)	Yes (c)	Yes
2. Crashworthy Troop Seats Per [5]	No	No	No	No (d)	No (d)	Yes
2. Rotors						
a. Main						
1. Frangible Tips to Reduce Load on Transmission	No	No	No	No	No	Yes
2. Low Crack Propagation Rate	No	No	No	No	No	Yes

Design Feature	UH-1H	UH-1H(PIP)	UH-1N	UH-1N(MOD)	214A(MOD)	UTTAS
3. Moderate Icing Protection	No	No	No	No	No	Yes
4. -0.5G Capability	No	No	No	No	No	Yes
5. 5000 Hr Fatigue Design Life	No	No	No	No	No	Yes
b. Tail Rotor						
1. Simplified Flex Beam	No	No	No	No	Yes	Yes (Also bearingless)
2. Protected from Ground Strike	No	No	No	No	No	Yes
3. Tolerant to Ground Strike	No	No	No	No	No	Yes
4. 5000 Hr Fatigue Design Life	No	No	No	No	No	Yes
3. Hydraulic/Flight Controls						
a. Dual Mechanical Nonrotating Flight Controls	No	No	No	Yes	Yes	Yes
b. Dual Hydraulic Systems	No	No	No	No	Yes	Yes
4. Drivetrain						
a. Transmission & Gear Box 30 Min, Dry Run Capability	No	No	No	No	Yes	Yes

Design Feature	UH-1H	UH-1H(PIP)	UH-1N	UH-1N(MOD)	214A(MOD)	UTTAS
b. Low Crack Propagation Rate	No	No	No	No	No	Yes
c. Self-sealing XMSN Lub Tank and Lines	No	No	No	No	No	Yes
d. Twin Engine Powered	No	No	Yes	Yes	No	Yes
5. Fuel System						
a. Suction Feed from Tanks to Engines	No	No	No	No	No	Yes
b. Engine Fire Extinguishing	No	No	Yes	Yes	Yes	Yes
6. Maneuverability/ Performance						
a. Aero/Structural Limits	2.1G's at 9500 lbs	2.1G's at 9500 lbs	2.3G's at 10,000 lbs	2.3G's at 10,000 lbs	3.5G's at 10,500 lbs	3.5G's at 16,000 lbs
b. One Engine Inoperative Performance	No	No	Limited/ Limited	Limited/ Limited	No	Yes
7. Avionics (Differences Only Noted)						
a. IFF	AN/APX-72	AN/APX-72	AN/APX-72	AN/APX-100	AN/APX-100	AN/APX-100
b. ABS Alt	None	AN/APN-209	AN/APN-171	AN/APN-171 and AN/APN-209	AN/APN-209	AN/APN-209

NOTES:

a. These aircraft contain added reinforcement at the transmission shock attachment locations, but the specification does not claim the strength increase.

b. The 214 Nodal Beam transmission attachment is tied to the fuselage structure near the transmission c.g.; therefore, transverse inertia loads do not apply the high moment that is applied to other UH-1-type transmissions. Assume fuselage penetration by transmission is eliminated, but main blade penetration can still occur because of the teetering high mass design.

c. Meets MIL-S-58095 requirements except that vertical seat stroke is 8" rather than 12".

d. Ceiling supported, crashworthy troop seats are not feasible for these aircraft, because of the roof reinforcement required. Existing MIL-S-5804 troop seats with 50% strength improvement are assumed.