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UNITED STATES ARMY

TRAINING AND DOCTRINE COMMAND

UNITED STATES ARMY MATERIEL COMMAND

LIGHT HELICOPTER FAMILY
TRADE-OFF ANALYSIS

APPENDICES V, W, X, AND Z

VOLUME X

ACN: 69396

107

15 May 1985

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
ACN 69396

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
LIGHT HELICOPTER FAMILY (LHX) TRADE-OFF ANALYSIS (TOA), APPENDICES V, W, X, AND Z, VOLUME X OF XI, Safety, Cost, Commonality, and Downwash Analyses

5. TYPE OF REPORT & PERIOD COVERED
Final Study Report, 10th of 11 volumes

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Barry Roberts, Joe Parrish, Berman J. Watts, Nathan Cleek, Plint Hickman, Stephen Kee, George Nepperény

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
LHX Study Group
ATTN: ATZQ-D-C(LHX)
Fort Rucker, AL 36362-5000

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
HQ US Army Training and Doctrine Command
ATTN: ATCD-A
Fort Monroe, VA 23651-5000

12. REPORT DATE
15 May 85

13. NUMBER OF PAGES
212

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
The safety analysis and report contained in this volume was produced by the US Army Aviation Safety Center, Fort Rucker, AL.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Safety
Accident
Accidents
TOD
LHX
SCAT
Utility
TOA
Aircraft
Helicopter
Tilt rotor
FSD
Cost
Development
Investment
Flyaway
Baseline
Estimate
Force
Commonality
O&S
R&D
LCC
Disk
Load
LCCE
Vision
Damage
Field
Flow
Test
Performance
Downwash
Horizontal
Transducer
Operational
(Cont'd on reverse.)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume of the Light Helicopter Family (LHX) Trade-Off Analysis (TOA) report gives the details of four substudies done within the TOA. These substudy areas were: Safety, Cost, Commonality, and Downwash. The findings/conclusions reached by the Safety Analysis included: (1) The LHX should be planned for two crewmembers; (2) The LHX should be designed with two engines; (3) These important safety design features should be included in the LHX: (a) twin engines with an OEI flight capability; (b) Effective antitorque control under all mission flight environments; (Cont'd on reverse.)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ITEM 19, Cont'd:

Pressure
Particle
Terrain
Aerodynamic
Velocity

Cont.

ITEM 20, Cont'd:

(c) No tail rotor or a high degree of protection for the tail rotor; (d) Visionics system for use during reduced visibility conditions; (e) Wire strike protection system (WSPS); (f) Backup or redundant flight control system; (g) Wheeled landing gear; (h) Rigid or redundant flight control system; (i) Maintenance and flight data recorders; (j) Performance planning computer; (k) Automated systems to reduce pilot workload; (4) The following crashworthiness items are important and should be features of the LHX: (a) Crashworthy fuel systems; (b) High mass item retention; (c) High-energy absorption gear (fixed or automatic extension) and fuselage; (d) Crew seat and restraint system; (e) Troop seat and restraint system; (f) Noninjurious cockpit environment; (g) Emergency locator transmitter (ELT).

The major findings of the LHX Cost Analysis were: (1) R&D costs will be nearly the same for all candidates; (2) From least costly to most costly (LCCE), the order of the LHX candidates was:

Helicopter
Compound Helicopter
Advancing blade concept helicopter
Tilt rotor
Compound ABC helicopter

The Commonality Analysis ranked the LHX candidates based on the greatest potential for airframe and equipment commonality as follows:

Helicopter
Compound Helicopter
ABC helicopter
Compound ABC helicopter
Tilt rotor

The Downwash Analysis was a literature search that revealed expected forces involved in the effects of working near turning rotor blades. Although conclusions about rotorcraft in general were known, it was realized that particulars about any LHX candidate aircraft would not be known until such an aircraft was produced.

UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND

UNITED STATES ARMY MATERIEL COMMAND

LIGHT HELICOPTER FAMILY TRADE-OFF ANALYSIS

APPENDICES V, W, X, AND Z

VOLUME X

ACN: 69396

15 May 1985

NOTICES (U)

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LIGHT HELICOPTER FAMILY
TRADE-OFF ANALYSIS
(LHX TOA)

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GLOSSARY (U)

ABC	advancing blade concept
ABC-C	advancing blade concept-compound
AF	airframe
AFPCH	Army Force Planning Cost Handbook
AHIP	Army Helicopter Improvement Program - OH-58D
AH-1 AH-1G AH-1S AH-1S(MC) AH-1S(ECAS) AH-1S(MOD) AH-1S(PROD)	Different versions of the Cobra attack helicopter
ASE	aircraft survivability equipment
ATHS	airborne target handoff system
AVSCOM	Aviation Systems Command
BP	battle point
CAB	Combat Aviation Brigade
CBAA	Cavalry Brigade, Air Attack
CER	cost estimating relationship
COA	Office of the Comptroller of the Army
DADS	digital audio distribution system
EMP	electromagnetic pulse
eng	engine
EOTADS	electro-optical target acquisition designation system
FAAO	field artillery aerial observer

FCIS	force cost information system
FSD	full-scale development
FY	fiscal year
GSE	ground support equipment
HEL	helicopter
HEL-C	compound helicopter
HIGE	hover in ground effect
HOGE	hover out of ground effect
ICNIA	integrated communication navigation identification
IPS	inlet air particle separator
IR	infrared
IRP	intermediate rated power
LCC	life cycle costs
LCCE	life cycle cost estimate
LHX	Light Helicopter Family
LSA	Logistics Support Analysis
MEP	mission equipment package
MFD	multifunction display
MFPK	multifunction programable keyboard
MICOM	US Army Missile Command
MWO	modification work order
NOE	nap of the earth
nonrec	nonrecurring costs
NVPS	night vision pilotage system
OEI	one engine inoperative
OGE	out of ground effect

O&S	operating and support
PDSS	post development software support
PM-TRADE	Program Manager-Training Aids
PNVS	pilot night vision system
PSE	peculiar support equipment
R&D	research and development
rec	recurring costs
RF	radio frequency
SAD	Systems Attributes Document
SL	sea level
SL/STP	sea-level standard atmospheric conditions
STD	standard (as in standard day)
TADS	target acquisition designation system
TAMC	transportation aircraft maintenance company
TOA	trade-off analysis
TOD	trade-off determination
TOE	tables of organization and equipment
T/R	tilt rotor
VHSIC	very high speed integrated circuit
VROC	vertical rate of climb
wpns	weapons

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APPENDIX V

SAFETY (U)

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APPENDIX V - SAFETY (U)

V-1. (U) PURPOSE.

a. (U) Substudy. This substudy is a portion of the Trade-Off Analysis (TOA) devoted to the Light Helicopter Family (LHX) projected for inclusion in the US Army inventory by 1995. In general, this appendix will examine design features that are likely to be critical to the safety of the LHX candidates. It will further examine these features and attempt to project both associated accident rates and costs. Implicit in such an examination is the implied assumption that those features that result in fewer accidents are highly desirable from a safety point of view. However, it is also noted that each feature will have associated costs (and projected cost savings) that must be considered.

b. (U) Essential Elements of Analysis.

(1) (U) Which critical design features should be incorporated in an LHX candidate to reduce the projected accident rates and 20-year accident costs?

(2) (U) What is the minimum acceptable level of crashworthiness?

(3) (U) (B-13) Should the LHX have one or two engines?

(4) (U) (B-22) Should the LHX have a one- or two-member crew?

(5) (U) (B-25) What are the safety implications for each subsystem and system under consideration?

V-2. (U) BACKGROUND. The Trade-Off Determination (TOD) Board conducted a study to establish the expected economic losses due to aircraft accidents for a wide range of LHX candidate aircraft. The candidates and their design features are summarized in annex II. A 5-year, class A accident baseline (see annex III) was used to project accident rates. The projected accident rates and 20-year accident costs determined by the TOD Board are contained in annex IV. The relative magnitude of these rates and 20-year costs provide an indication of the influence of various design features in these candidates.

V-3. (U) ASSUMPTIONS.

a. (U) Losses were projected for peacetime operation.

b. (U) Losses were based on constant fiscal year (FY) 84 dollars.

c. (U) For retractable gear aircraft, the gear was assumed to be down during the accident.

d. (U) A utilization rate of 240 hours per aircraft per year was used.

e. (U) Losses were based on aircraft acquisition costs and fleet sizes shown in annex V.

f. (U) Only class A accidents were used by the TOD Board.

V-4. (U) LIMITATIONS. This analysis does not include quantification of the cost and weight penalties which result from incorporation of the critical design features or a minimum crashworthiness level.

V-5. (U) METHOD. The TOD Board determined that selected critical design features will significantly reduce accident costs and rates. Analysis of the TOD data indicates that the ranking of the LHX baseline and its variations was a function of the critical features which each variation possessed. The Trade-Off Analysis (TOA) approach is to incorporate safety design features into a candidate rather than selecting the safest candidate. This method gives greater flexibility to the TOA Board so that performance can be the ultimate criterion.

V-6. (U) RESULTS/ANALYSIS.

a. (U) The features summarized in figure V-1 should be incorporated into any LHX design. Each of these features would contribute to a reduction of hardware and personnel losses in the proposed LHX.

b. (U) One cannot reasonably expect that incorporation of these features would result in the complete elimination of all accidents. The statistics are cited to demonstrate potential accident reduction if the design features are completely effective in eliminating the baseline accident causes.

c. (U) Any deletion or reduction in the effectiveness of these design features will result in an increase in the projected accident rates and costs for the LHX. In some cases, the increase in accident rates and costs will be small and may be justifiable when compared to the cost/weight required to achieve a particular design feature. A decision to trade off by deleting or reducing the effectiveness of a feature should only be made after consideration of the associated risk.

(1) (U) Twin engine with one-engine inoperative (OEI) flight capability. The largest single contributor to accident costs in the areas of materiel or design deficiency is engine failure in single-engine helicopters. Unsuccessful real and practice autorotations are also significant accident types for single-engine helicopters. These accidents would be substantially reduced by twin-engine design. The TOD Board determined that a 55.9-percent scout-attack (SCAT)/38.4-percent utility reduction in projected 20-year accident costs could be realized by incorporating a twin-engine design with an OEI. Twin engines without an OEI would result in reductions of 6.4-percent SCAT/ 3.9-percent utility (see figure V-IV-11).

Flight Safety	Crashworthiness (Modified Military Standard (MIL-STD) 1290)
Twin engines with an OEI flight capability	Crashworthy fuel systems
Effective antitorque control under all mission flight environments	High mass item retention
No tail rotor or a high degree of protection for the tail rotor	High energy absorption gear (fixed or automatic extension) and fuselage
Visionics system for reduced visibility	Crew seat and restraint system
Wire strike protection system (WSPS)	Troop seat and restraint system
Backup or redundant flight control system	Noninjurious cockpit environment
Wheeled landing gear	Emergency locator transmitter (ELT)
Rigid or articulated rotor heads to eliminate mast bumping	
Maintenance and flight data recorders	
Performance planning computer	
Automated systems to reduce pilot workload	

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Figure V-1. (U) Design features critical for reducing accidents.

(2) (U) Effective antitorque control under all mission flight envelopes. This feature will eliminate accidents due to loss of tail rotor authority. Anticipation by the TOD Board that the LHX would be adequately designed to minimize this problem was a major factor in reduction of the accident rate of the base data SCAT to the LHX baseline helicopter SCAT from 4.46 to 1.86 (see figure V-IV-1).

(3) (U) No tail rotor or a high degree of protection for the tail rotor. The benefits of shielding or eliminating the tail rotor were quantified by the TOD Board. Figures V-IV-11 and V-IV-12 show there is a direct correlation between the amount of protection provided to the tail rotor and the reduction of accident costs. The ring fin-type tail rotor with the small amount of protection showed an accident cost reduction of 16.8-percent SCAT/6.9-percent utility. The fan in the fin-type tail rotor, which provides a high degree of protection, showed savings of 25.5-percent SCAT/12.0-percent utility. The no tail rotor type of antitorque system showed a reduction of 42.6-percent SCAT/21.1-percent utility.

(4) (U) Visionics system for reduced visibility. The benefit of such a system would be in its ability to penetrate clouds, fog, battlefield obscurants, blowing dust, and snow for a minimum of 200 meters. The TOD Board noted that such a system decreases the accident rate associated with inadvertent instrument meteorological condition (IMC) by approximately 10 percent (see figure V-III-2). Care should be exercised to ensure such a visionics system is reliable and adequate attention is paid to the man-machine interface or the accident rate may actually increase.

(5) WSPS. The TOD Board determined an adequate WSPS would account for a 16.1-percent SCAT/20.1-percent utility reduction in the accident rate for the LHX (see figures V-IV-11 and V-IV-12). The low cost of such a system indicates that the prevention of just one class A LHX accident would pay for the fleet installation.

(6) (U) Backup or redundant flight control. The TOD Board determined a potential accident reduction of 6 percent could be realized with redundant or backup flight controls on the present fleet (see figure V-III-2). For the LHX, this feature will be extremely critical since fly-by-wire or fly-by-light systems are being considered. If no backup system is used, the redundancy must be complete throughout the flight control system. The routing of control lines must be devised to prevent simultaneous interruption of each redundant system.

(7) (U) Wheeled landing gear (fixed or automatic gear extension). Skids tend to get caught in the trees, runways, or obstructions (such as wires). The TOD Board determined a 3.2-percent reduction in accident rates could be achieved if such accidents were eliminated (see figure V-III-2). Wheel-type gear are much less likely to get caught.

(8) (U) Rigid or articulated rotor heads to eliminate mast bumping. The elimination by design of potential mast bumping caused by pilot input (not flight control system failure) would reduce accident rates by approximately 4 percent (see figure V-III-2).

(9) (U) Maintenance and flight data recorders. With the projected increase in complexity of the LHX, it will become increasingly difficult to establish the cause of the accident, thus preventing corrective actions. Currently, 11 percent of all accidents are unsolved. A much greater percentage of LHX accidents may be unsolved without the incorporation of flight data/maintenance recorders. The TOD Board noted that 20-year savings of $237 million (FY 82 dollars) could be expected for the AH-64 if such recorders were installed. The LHX savings would be at least as great. There would be additional cost savings not included in the AH-64 figure from reductions in unnecessary maintenance actions and cost savings from the identification of maintenance problems that would otherwise escape attention.

(10) (U) Performance planning computer. A performance planning computer will aid in the elimination of accidents caused by the crew placing the aircraft in situations that require power in excess of system limits. The present system for performance planning is cumbersome at best. As greater performance requirements are established due to the air-to-air combat mission, the crew will need a more sophisticated method of performance planning. An automated system is an excellent method of relieving the crew of an arduous task.

(11) (U) Automated systems to reduce pilot workload. Such systems must be "user friendly" so as not to reduce the number of tasks only to increase the complexity of those tasks which remain. Graceful degradation of electronic systems should be used to ensure aircraft control remains the highest priority.

(12) (U) Crashworthiness.

(a) (U) Modified MIL-STD-1290 level of crashworthiness. The TOD Board reported that a relaxation of the level of crashworthiness from a 42-feet-per-second (ft/sec) vertical rate of descent throughout the 20 degrees (°) by 20° pitch and roll (20 x 20 P&R) envelope, as currently required by MIL-STD-1290, to 42 ft/sec for a 10 x 10 P&R and down to 36 ft/sec for the remainder of the 20 x 20 P&R envelope had no effect on the projected accident rates for either version of the LHX. This was a result of the fact that no class A accidents which occurred during the 5-year baseline used in the TOD occurred in the boundary between the 10 x 10 and 20 x 10 P&R envelopes. Based on this data, it appears that a relaxation to the modified MIL-STD-1290 level of crashworthiness would have little, if any, effect on future accident rates.

(b) (U) The TOD Board recommended a TOA methodology which required the selection of the characteristics for landing gear, airframe, and seats. This methodology was rejected. A system approach to crashworthiness should be used to attain a modified MIL-STD-1290 level of crashworthiness. This approach conforms to the performance-oriented nature of the LHX and allots a degree of flexibility to the developer. It permits trade-off between the crashworthiness of the landing gear, airframe, and seats so as to ensure the reduction of crash forces which reach the occupants to a level consistent with the requirements of modified MIL-STD-1290.

(c) (U) The LHX baseline aircraft with a UH-60/AH-64 crashworthiness level performed well when put into the crash conditions of the baseline accident aircraft. The TOD baseline accident data is derived primarily from aircraft with performance levels similar to the UH-1/AH-1 (see figure V-III-1). Only a few UH-60 accidents were available to include in the accident baseline. As a rule, the UH-60 crashes are much "harder" (i.e., greater impact velocities, etc.) than the UH-1/AH-1 crashes, due primarily to the greater performance capabilities (higher autorotative sink rates) of the UH-60. It is reasonable to expect that the LHX will crash under conditions even more extreme than the UH-60 due to the anticipated increase in performance. Therefore, in order for the LHX to achieve the same level of effectiveness despite more extreme crash conditions, the level of crashworthiness must also be increased. An increase to the level of the modified MIL-STD-1290 should compensate for the expected performance increase. It is recommended that the LHX performance capabilities be analyzed in order to establish expected crash conditions so that the recommended modified MIL-STD-1290 level of crashworthiness can be empirically validated.

(d) (U) Crashworthiness design features.

1. (U) Crashworthy fuel system. This feature has been proven effective in many previous aircraft designs. Any external fuel systems for the LHX should be designed to MIL-T-27422B. No relaxation of this standard should be allowed. Any external fuel tanks considered for use on the LHX should also be adequately crashworthy.

2. (U) High mass item retention. High mass items, particularly those above the crew or passenger area, should not break loose during any crash sequence as defined by MIL-STD-1290. The attachment parts of such items must, therefore, be appropriately strengthened.

3. (U) High energy absorption gear (fixed or automatic extension) and fuselage. The LHX should, as a goal, meet the level of crashworthiness as outlined in MIL-STD-1290. It appears, however, that trade-offs to a modified version of MIL-STD-1290 level of crashworthiness are the most desirable approach to providing for crew survivability. Fixed or automatic landing gear extension is a desirable feature to ensure gear extension during a crash sequence and to preclude the failure of the pilot to extend the gear prior to landing. Any automatic gear extension feature will require some function time for the gear to extend; therefore, partially extended or gear-up crashes can be anticipated. The ultimate level of crashworthiness will be heavily dependent on the status of the gear on impact. If a design incorporating retractable gear with automatic extension is selected, the airframe and seats must be sufficiently crashworthy to prevent fatalities and to minimize injuries in impacts where the gear is fully or partially retracted. The airframe should provide energy attenuation in the subfloor, allow retention of high mass items, and provide a protective shell for the occupant.

4. (U) Crew seat and restraint system. This feature has a tremendous impact on the number and severity of injuries associated with a crash and should conform to MIL-STD-58095. The technology for the Inflatable Body and

Head Restraint System (IBAHRS) should be developed so that the system can be incorporated into the LHX.

5. (U) Troop seat and restraint system. Premature failure of troop seats has been a problem in many utility aircraft, including the UH-60. Troop seats should be designed to meet MIL-STD-85510. If roof-mounted, particular attention should be given to crash loads on roof structures to prevent premature collapse.

6. (U) Noninjurious cockpit environment. The cockpit environment should be designed so that a restrained crewmember will not be subjected to injury due to a cockpit feature. Control configurations that allow the pilot to maintain proper posture (back support and arm rest) should be used in order to reduce the incidence and severity of lower back pain associated with conventional flight control systems. Conventional control systems tend to cause the pilot to lean forward, thus failing to provide adequate lower back support. The likelihood that the cockpit will be as compact as current designs increases the need for the IBAHRS in order to minimize the occupant's crash impact motion envelope.

7. (U) ELT. The weight and cost penalties are small compared to the added benefit of reducing the time that the survivors have to spend on the ground before rescue.

d. (U) There are two issues which have generated a debate in the development/user community as to their effectiveness versus cost. Decisions on the minimum acceptable approach to these features/issues can only be made after a careful risk analysis.

(1) (U) One versus two crewmembers.

(a) (U) No conclusion has been reached by the TOD Board on this issue due to the limited accident data available. Crew work overload has been identified as a significant hazard and a "driver" of pilot error-associated accidents. The removal of the second crewmember would require the automation of his workload so as not to overload the remaining crewmember. It may be feasible to reduce this workload through automated systems such as voice activated systems, automatic fire control, etc. Crucial to this analysis is whether the current state of technology allows the necessary workload reduction. Systems which are designed to perform tasks normally associated with the second crewmember must be designed so as not to overload a single crewmember even when the system is in a failure mode or operating with degraded capability. It is the opinion of the TOA Board that current technology is not sufficiently sophisticated to meet these safety requirements. In addition, the second crewmember reduces the likelihood of an accident since he is able to validate the actions of the pilot. He provides a second set of eyes to watch for unsafe acts or conditions which might ordinarily be overlooked by a single crewmember and thus lead to an accident. Unless the single crewmember concept can be empirically demonstrated, the LHX should be planned for two crewmembers.

(b) (U) It is not necessary for both crewmembers to be rated pilots; however, redundancy of flight controls would be desirable for training and survivability considerations. Consideration should be given to training the nonrated crewmember to make emergency visual flight rule (VFR) approaches and landings. It is imperative that the second crewmember be adequately trained to perform his duties. Insufficient training of the second crewmember leads to pilot work overload and accidents.

(2) (U) One versus two engines. The reduction in projected accident rates and costs associated with two engines with an OEI capability is contained in annex IV. Power-off, autorotative flight performance would become an important characteristic if a single-engine LHX were selected. This performance characteristic is heavily dependent on the aircraft configuration but, within certain bounds, is determined by detailed aircraft design requirements. The power-off performance for a single-engine LHX must be adequate to allow autorotative descent and landing to level terrain without damage. The TOA Board concluded that a single engine LHX is not acceptable due to the magnitude of the accident rates and costs associated with single-engine aircraft.

V-7. (U) FINDINGS.

a. (U) The features summarized in figure V-1 should be incorporated into any LHX design.

b. (U) The minimum acceptable level of crashworthiness is defined by the modified MIL-STD-1290.

c. (U) The LHX should be planned for two crewmembers.

d. (U) The LHX should be designed for two engines.

e. (U) It is recommended that the LHX performance capabilities be analyzed by the developer in order to establish expected crash conditions. This would allow the modified MIL-STD-1290 level of crashworthiness to be empirically validated.

ANNEX I TO APPENDIX V

REFERENCES (U)

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ANNEX I TO APPENDIX V

REFERENCES (U)

V-I-1. (U) Nepereny, G. J.; Hicks, J. E.; Projected Accident Costs for the LHX Aircraft, US Army Safety Center Technical Report 83-8, September 1984.

V-I-2. (U) Shanahan, D. F., Back Pain in Helicopter Flight Operations, Advisory Group for Aerospace Research and Development Lecture Series No. 134, April 1984.

V-I-3. (U) LHX Trade-Off Determination, Annex J (Safety), October 1983.

V-I-4. (U) LHX Trade-Off Determination, Section CC (Crashworthiness), October 1983.

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ANNEX II TO APPENDIX V

CANDIDATE AIRCRAFT DESCRIPTIONS (U)

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ANNEX II TO APPENDIX V

CANDIDATE AIRCRAFT DESCRIPTIONS (U)

(U) Descriptions of the pertinent design features of each candidate aircraft were assembled from technical data received from the Light Helicopter Family (LHX) Trade-Off Determination Board. A summary of the descriptive data is contained below and in figure V-II-1.

a. (U) Scout-Attack (SCAT) Candidates.

(1) (U) AOH-58D. The AOH-58D is a modified Army/Bell OH-58D helicopter. The following modifications and features will be incorporated:

(a) (U) A four-bladed rigid rotor system.

(b) (U) A 250-C30R engine.

(c) (U) Communication equipment: nap-of-the-earth (NOE), ultra high frequency (UHF), very high frequency (VHF), Single-Channel Ground and Airborne Radio System (SINCGARS).

(d) (U) Navigation equipment: Global Position System (GPS), Doppler, Attitude and Heading Reference System (AHARS).

(e) (U) Visionics: Pilot's Night Vision System (PNVS), radar-millimeter (mm), forward-looking infrared (FLIR), television (TV).

(f) (U) Crashworthiness of the OH-58D.

(2) (U) AH-1X. The AH-1X is a modified Army/Bell AH-1S helicopter. The following modifications and features will be incorporated:

(a) (U) A four-bladed rigid rotor system (412).

(b) (U) A single T700-GE-701 engine.

(c) (U) Remove the telescope sight unit (TSU) and replace with a cathode ray tube (CRT).

(d) (U) Suction feed from tank to engine.

(e) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(f) (U) Navigation equipment: GPS, Doppler, AHARS.

(g) (U) Visionics: PNVS, radar-mm, FLIR, TV.

(h) (U) Crashworthiness of the AH-1S.

(i) (U) A wire strike protection system (WSPS).

(3) (U) AH-64X. The AH-64X is a modified Army/Hughes AH-64 helicopter. The following modifications and features will be incorporated:

(a) (U) Twin T700-GE-701 engines.

(b) (U) Remove the optical relay tube (ORT) and replace with a CRT.

(c) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(d) (U) Navigation equipment: GPS, Doppler, AHARS.

(e) (U) Visionics: PNVS, radar-mm, FLIR, TV.

(f) (U) Crashworthiness of the AH-64.

(g) (U) A WSPS.

(4) (U) A-129X. The A-129X is a modified Agusta Aviation Corporation A-129 helicopter. The following modifications will be incorporated:

(a) (U) Twin TM 333B engines.

(b) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(c) (U) Navigation equipment: GPS, Doppler, AHARS.

(d) (U) Visionics: PNVS, radar-mm, FLIR, TV.

(e) (U) Crashworthiness of the A-129.

(f) (U) A WSPS.

(5) (U) LHX-SCAT. This is a new development program with the following assumed features:

(a) (U) Twin ATE engines.

(b) (U) Crashworthiness levels of the AH-64/UH-60A.

(c) (U) Two pilots.

(d) (U) Retractable wheeled gear.

(e) (U) A WSPS.

(f) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(g) (U) Navigation equipment: GPS, Doppler, AHARS.

(h) (U) Visionics: PNVS, radar-mm, FLIR, TV.

(i) (U) A fly-by-wire or fly-by-light flight control system.

(j) (U) Conformally mounted stores.

b. (U) Utility Candidates.

(1) (U) UH-60X. The UH-60X is a modified Army/Sikorsky UH-60A helicopter. The following modifications and features will be incorporated:

(a) (U) Crashworthiness of the UH-60A.

(b) (U) A WSPS.

(c) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(d) (U) Navigation equipment: GPS, Doppler, AHARS.

(e) (U) Visionics: PNVS, radar-mm.

(2) (U) UH-1X. The UH-1X is a modified Army/Bell UH-1H helicopter. The following modifications and features will be incorporated:

(a) (U) A four-bladed rigid rotor system (412).

(b) (U) A single T700-GE-701 engine.

(c) (U) Crashworthiness of the UH-1H.

(d) (U) Suction feed from tank to engine.

(e) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(f) (U) Navigation equipment: GPS, Doppler, AHARS.

(g) (U) Visionics: PNVS, radar-mm.

(h) (U) A WSPS.

(3) (U) UH-76. The UH-76 is a modified Sikorsky S-76 helicopter. The following modifications and features will be incorporated:

(a) (U) An ACAP fuselage.

(b) (U) Twin GEM2-3 engines.

(c) (U) ACAP crashworthiness.

(d) (U) A crashworthy fuel system.

(e) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(f) (U) Navigation equipment: GPS, Doppler, AHARS.

(g) (U) Visionics: PNVS, radar-mm.

(h) (U) A WSPS.

(4) (U) LHX-Utility. The LHX-Utility is a new development program with these assumed features:

(a) (U) Twin ATE engines.

(b) (U) Crashworthiness levels of "AH-64/UH-60A."

(c) (U) Two pilots.

(d) (U) Retractable wheeled gear.

(e) (U) A WSPS.

(f) (U) Communication equipment: NOE, UHF, VHF, SINCGARS.

(g) (U) Navigation equipment: GPS, Doppler, AHARS.

(h) (U) Visionics: PNVS, radar-mm.

(i) (U) A fly-by-wire or fly-by-light flight control system.

(j) (U) Six-passenger capacity.

	SCAT					UTILITY			
DESIGN FEATURE	AQH-58D	AH-1X	AH-64X	AH-129	LHX	UH-60X	UH-1X	UH-76	LHX
1. Crashworthiness Design a. Landing gear (1) Type	Skid	Skid	Wheel	Wheel	Wheel (Retractable)	Wheel	Skid	Wheel	Wheel (Retractable)
(2) Impact Capability (fps)	12	8-10	24	15	20	30	8-10	30	20
(3) Longitudinal and lateral strength	CAR 6	MIL-S-8698	15°R 12°P	10°R 10°P	±10°R ±15° to -5°P	±10°R ±10°P	MIL-S-8698	±10°R + 5° to -5°P	±10°R +15 to -5° P
b. Fuselage (1) Maintain livable volume in 95th percentile crash loading	No	No	Yes	90th % Crash	Yes	Yes	No	Yes	Yes
(2) Withstand fuselage plowing	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
(3) Withstand 15 fps longitudinal wall impact w/o pilot injury	No	No	Yes	90th %	Yes	Yes	No	Yes	Yes
(4) Transmission tie-down strength	$13G_x$ $6G_y$ $13G_z$	$16G_x$ $8G_y$ $16G_z$	$\pm 20G_x$ $\pm 20G_y$ $+20G_z-10G_z$	$16G_x$ $15G_y$ $16G_z-8G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$	$16G_x$ $8G_y$ $16G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$
(5) Engine tie-down strength	$16G_x$ $8G_y$ $16G_z$	$15G_x$ $5G_y$ $15G_z$	$\pm 16G_x$ $\pm 15G_y$ $+15G_z-10G_z$	$16G_x$ $15G_y$ $16G_z-8G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_y$	$16G_x$ $8G_y$ $16G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$	$\pm 20G_x$ $\pm 18G_y$ $+20/-10G_z$
(6) Fuselage roof strength for rollover	No	No	4G	4G	4G	4G	No	4G	4G
(7) Tailboom design sink speed (fps)	8	8	20	15	20	20	8	20	20
(8) WSPS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(9) Withstand 100 fps, 5 deg impact with terrain	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
c. Fuel System (1) Crashworthy main fuel system	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(2) Rollover vent valves or equivalent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(3) Crashworthy auxiliary fuel system	No	No	No	No	Yes	Yes	Yes	Yes	Yes

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Figure V-II-1. (U) Comparison of pertinent design features of candidate aircraft (continued on next page).

	AOH-58D	AH-1X	AH-64X	AH-129	LHX	UH-60X	UH-1X	UH-76	LHX
d. Seating									
Crashworthy crew seats	No	No	Yes	Yes 8" stroke	Yes	Yes	No	Yes	Yes
2. Rotors									
a. Main	4-blade	4-blade (412)	4-blade	4-blade	5-blade	4-blade	4-blade (412)	4-blade	5-blade
(1) Frangible tips to reduce load on transmission	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(2) Low crack propagation rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(3) Moderate icing protection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(4) -0.5G capability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(5) 4500 fatigue design life	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Tail Rotor									
(1) Simplified flex beam	No	No	Yes	No	Yes	Yes	No	Yes	Yes
(2) Protected from ground strike	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
(3) Protected from tree strike	No	No	No	No	No	No	No	No	No
(4) Tolerant to ground strike	No	No	Yes	Yes	No	Yes	No	Yes	No
(5) 4500 hour fatigue life	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
3. Hydraulic Flight Controls									
a. Dual mechanical non-rotating flight controls	No	No	Yes (back up fly by wire)	Yes (back up fly by wire)	N/A	No	No	No	N/A
b. Redundant fly-by-wire flight controls	N/A	N/A	N/A	N/A	Yes	N/A	N/A	N/A	Yes
c. Dual hydraulic systems	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Figure V-II-1. (U) (continued)

	AOH-58D	AH-1X	AH-64X	AH-129	LHX	UH-60X	UH-1X	UH-76	LHX
4. Drivetrain									
a. Transmission and gearbox 30 min. dry run capability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Low crack propagation rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c. Twin engine powered	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
5. Fuel System									
a Suction feed from tank to engine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Engine fire extinguishing	No	No	Yes	Yes	Yes	No	No	Yes	Yes

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Figure V-II-1. (U) (concluded)

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ANNEX III TO APPENDIX V

TRADE-OFF DETERMINATION (TOD) LIGHT HELICOPTER FAMILY (LHX) DATA (U)

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ANNEX III TO APPENDIX V

TRADE-OFF DETERMINATION (TOD) LIGHT HELICOPTER FAMILY (LHX) DATA (U)

	Scout-Attack	Utility
Aircraft	AH-1G/S, OH-58A/C, UH-1M	UH-1H/V, UH-60A
Accidents	90	96
Flight hours	2,017,434	3,818,220
Accident rate	4.46	2.51
Crewmembers aboard	165	353
Crewmembers injured, nonfatal	84 (51%)	182 (52%)
Crewmember fatalities	40 (24%)	79 (22%)

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Figure V-III-1. (U) TOD LHX study baseline, calendar years 78-82.

Category	Number of Accidents (percent of total)	Materiel-Related Accidents (percent of total)	Human Performance-Related Accidents (percent of total)
1. Malfunctions or inadequacies of tail rotors	39 (21)	20 (10.8)	19 (10.2)
2. Engine failures	26 (14)	13 (7.0)	13 (7.0)
3. Inadvertent instrument meteorological condition	18 (9.7)		18 (9.7)
4. Wire strikes	15 (8.1)		15 (8.1)
5. Inadequate performance planning	12 (6.4)		12 (6.4)
6. Main rotor blade strikes	12 (6.4)		12 (6.4)
7. Inadequately performed practice autorotations	12 (6.4)		12 (6.4)
8. Violation of flight discipline	12 (6.4)		12 (6.4)
9. Flight control malfunctions	11 (5.9)	11 (5.9)	
10. Dynamic rollover	10 (5.4)		10 (5.4)
11. Malfunctions or inadequacies of night vision goggles	7 (3.8)	2 (1)	5 (2.8)
12. Inadequacies of skid gear	6 (3.2)		6 (3.2)
13. Mast bumping	4 (2.2)		4 (2.2)
14 Unknown	2 (1.1)		
Total	186 (100%)	46 (24.7%)	138 (74.2%)

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Figure V-III-2. (U) TOD baseline accident categories.

ANNEX IV TO APPENDIX V

PROJECTED ACCIDENT RATES AND COSTS (U)

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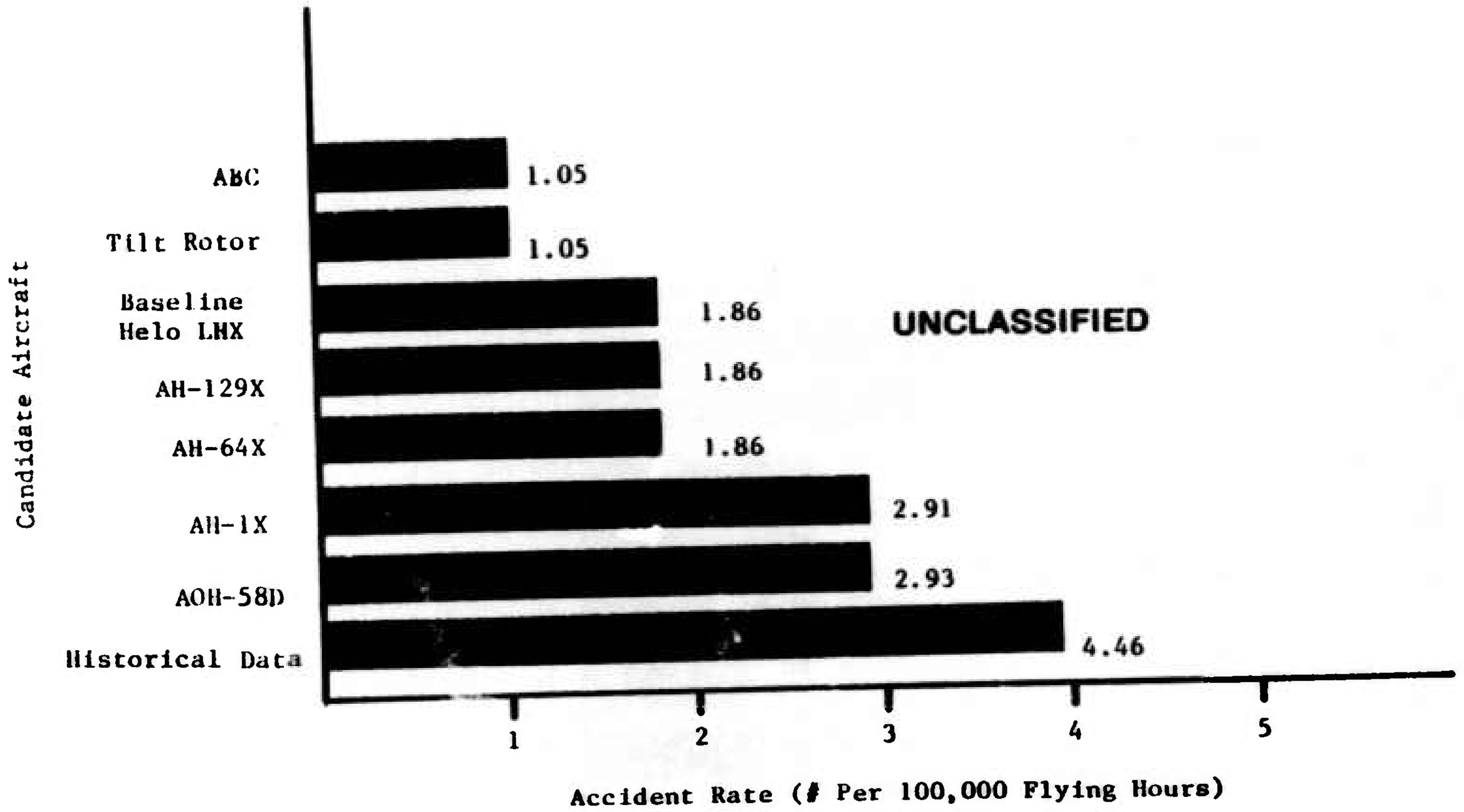

Figure V-IV-1. (U) Projected peacetime accident rates (scout-attack (SCAT) aircraft).

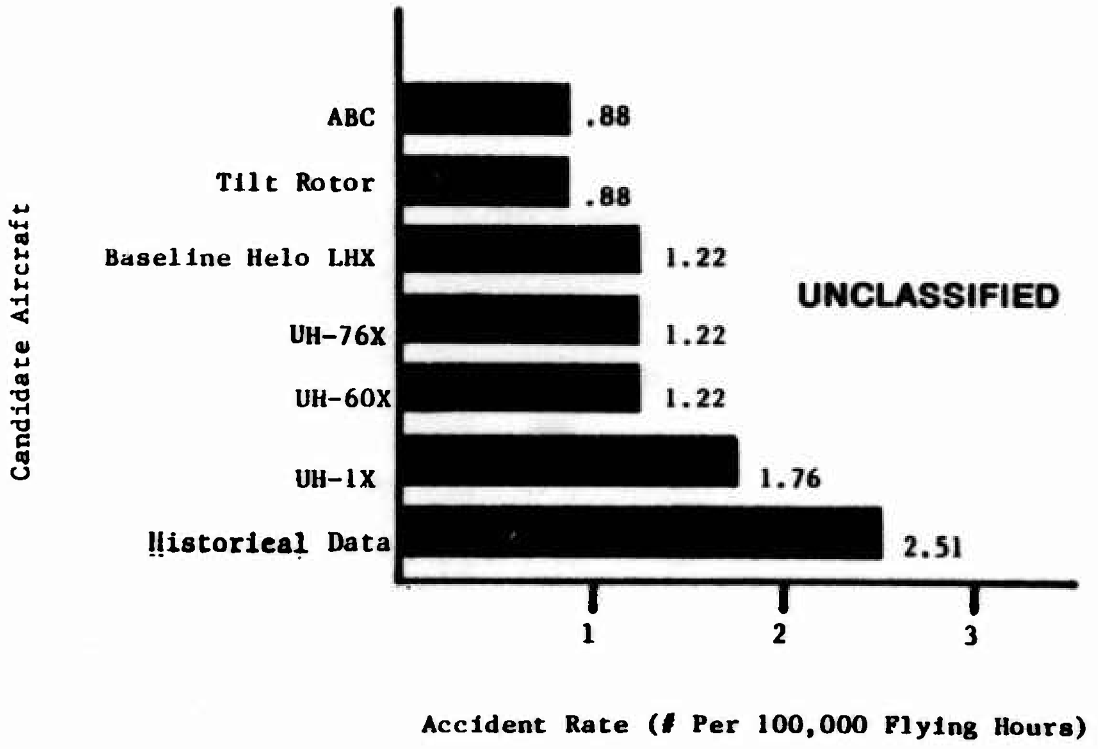

Figure V-IV-2. (U) Projected peacetime accident rates (utility aircraft).

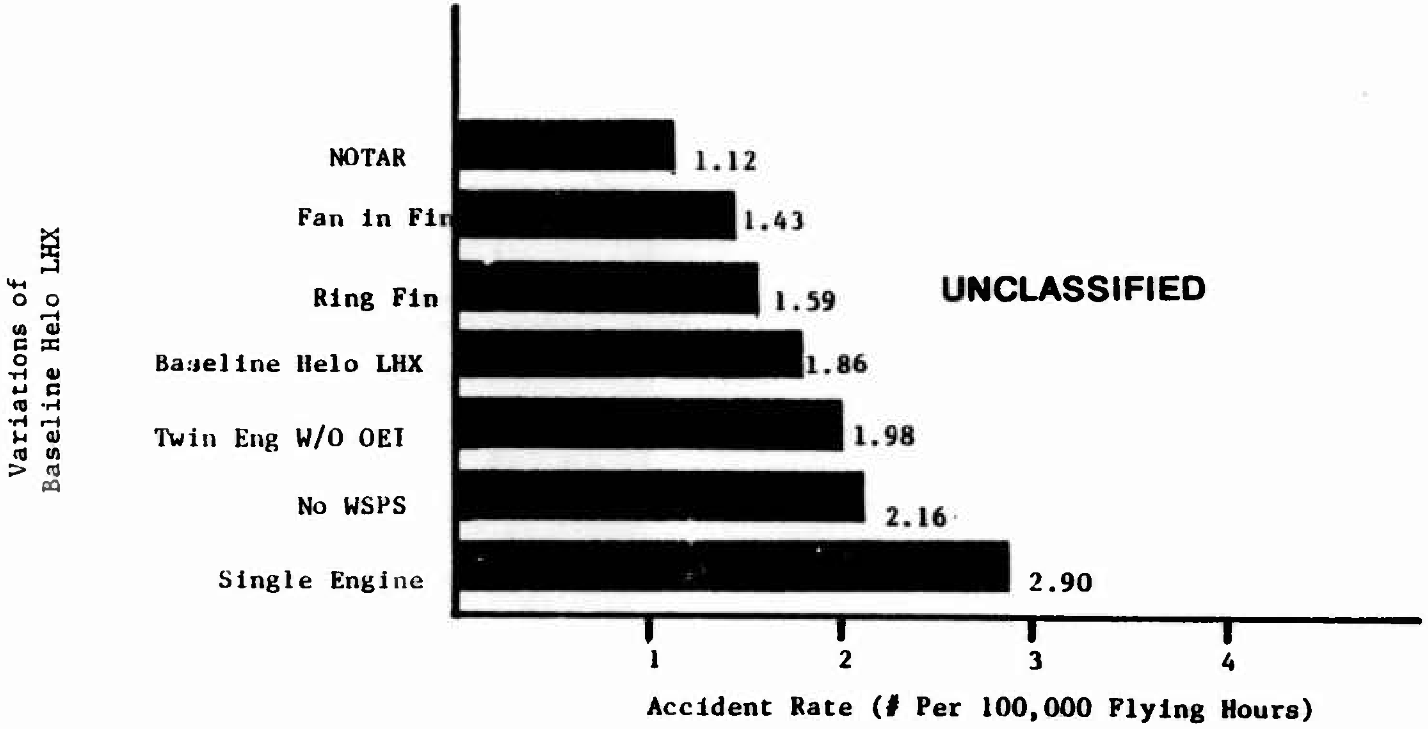

Figure V-IV-3. (U) Influence of variations in SCAT aircraft on projected peacetime accident rates.

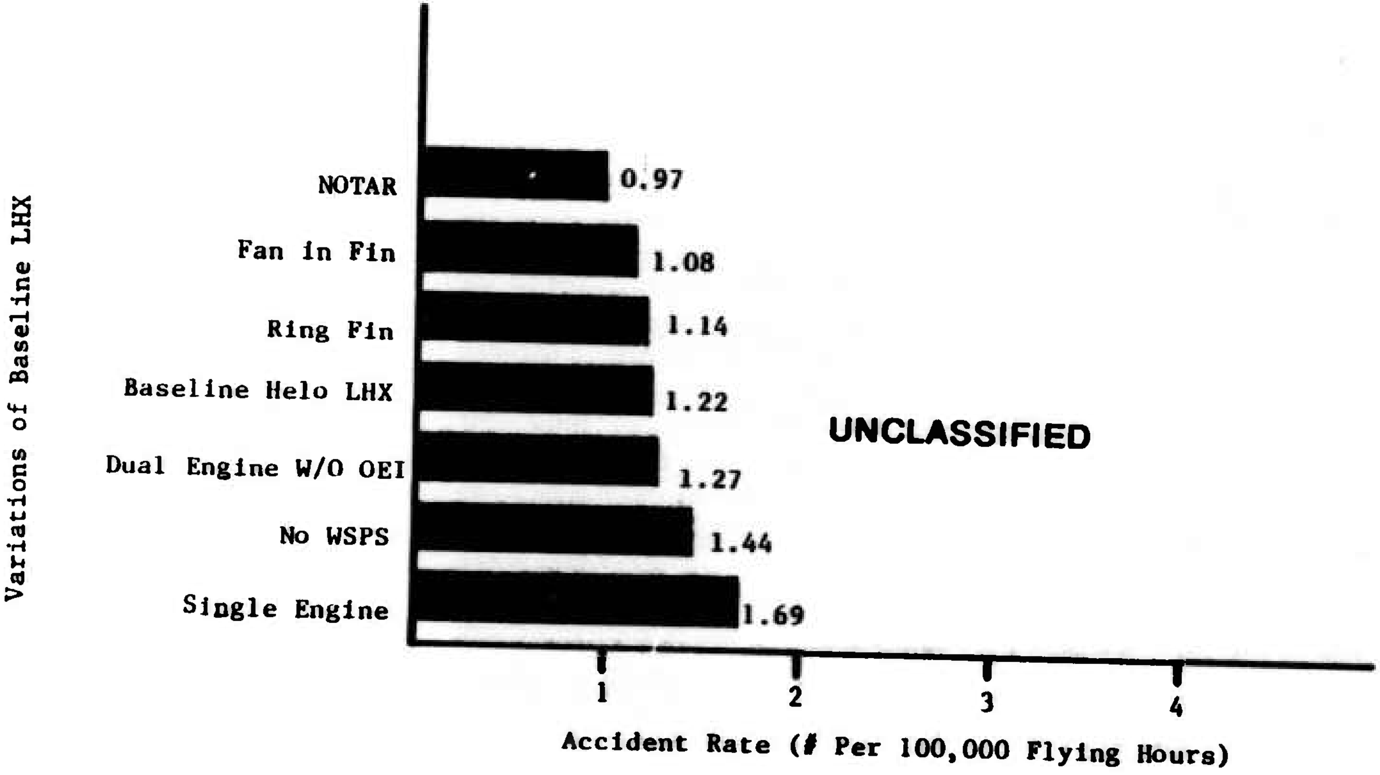

Figure V-IV-4. (U) Influence of variations in utility aircraft on projected peacetime accident rates.

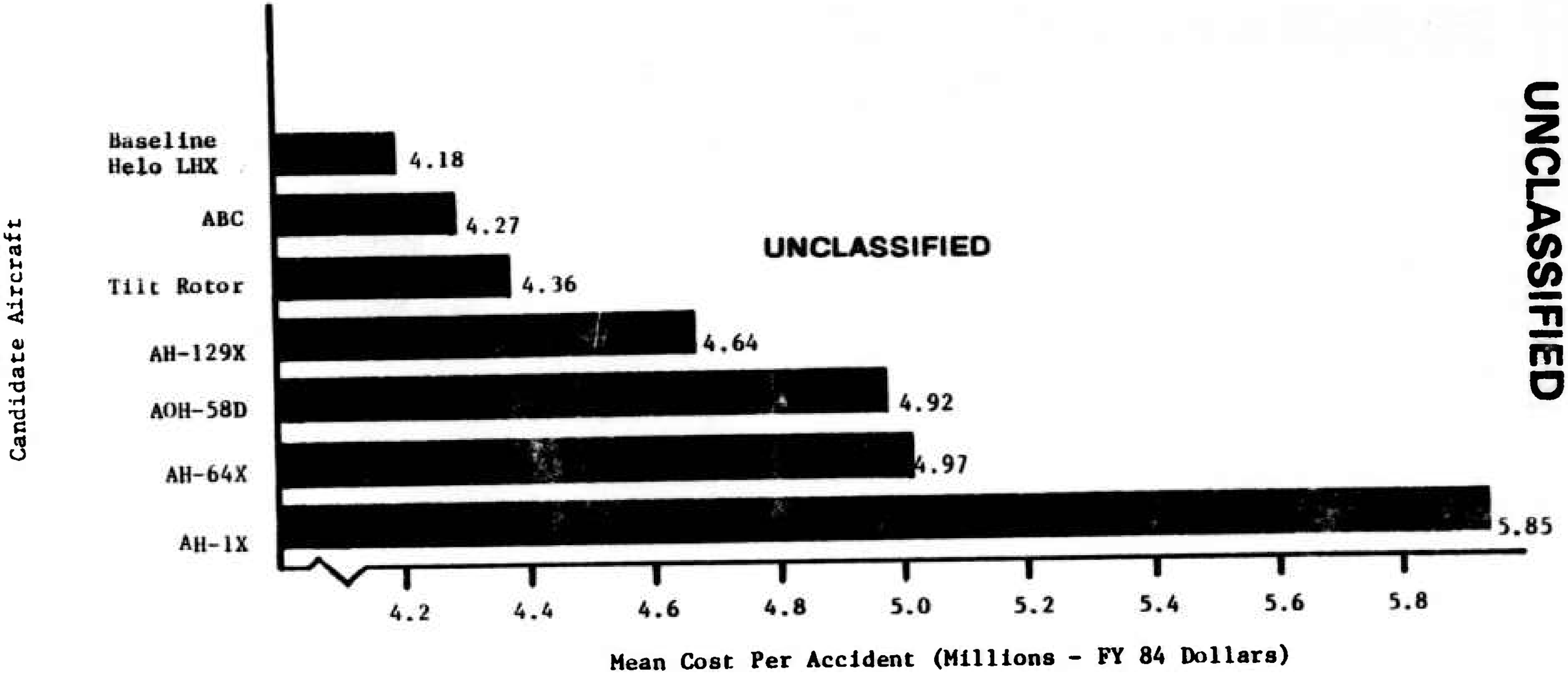

Figure V-IV-5. (U) Projected mean accident costs (SCAT aircraft).

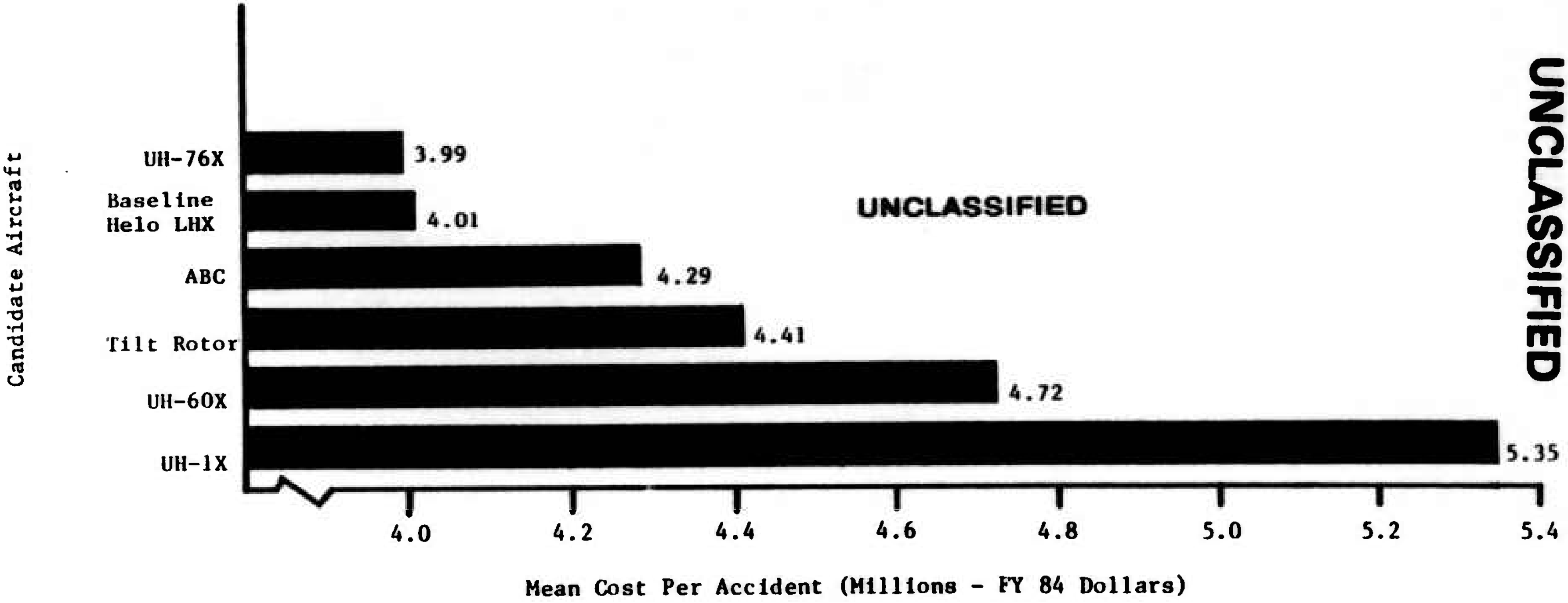

Figure V-IV-6. (U) Projected mean accident costs (utility aircraft).

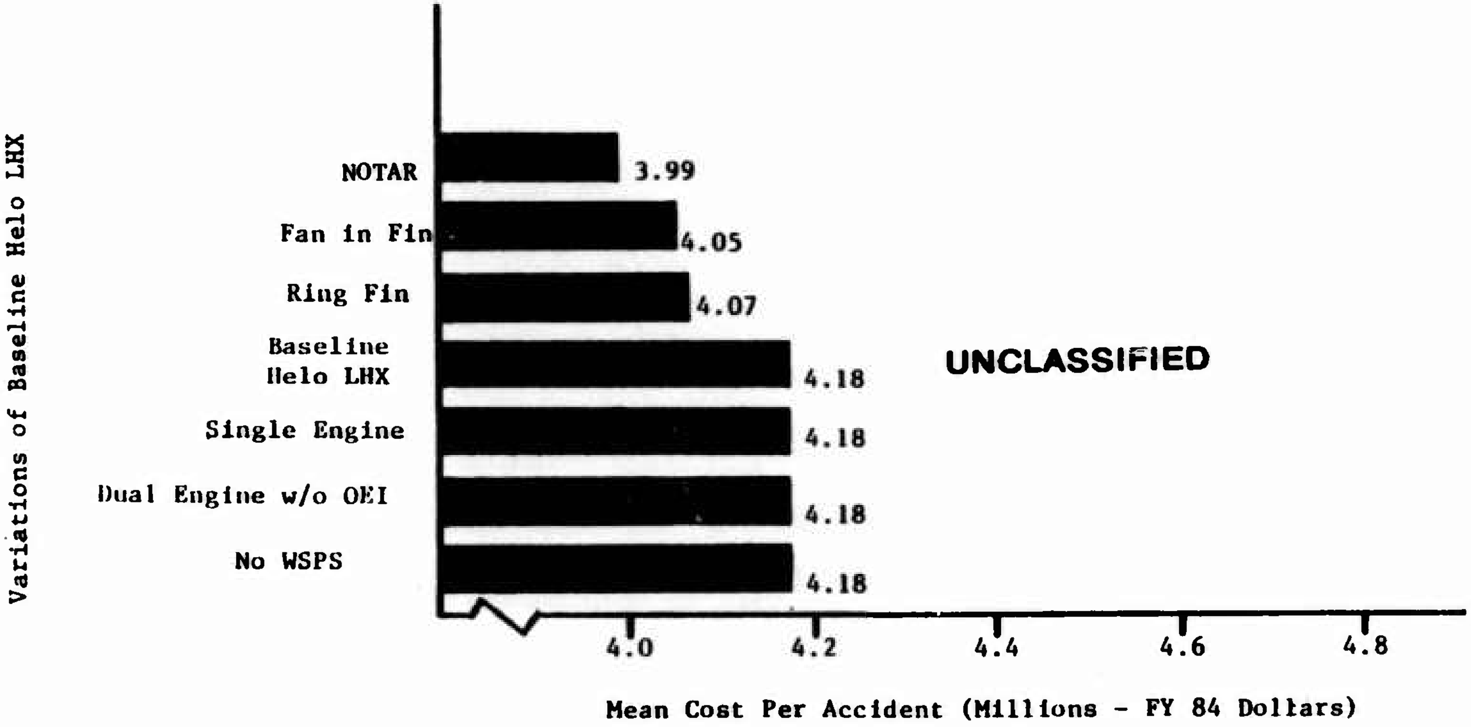

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Figure V-IV-7. (U) Influence of variations in SCAT aircraft on projected mean accident costs.

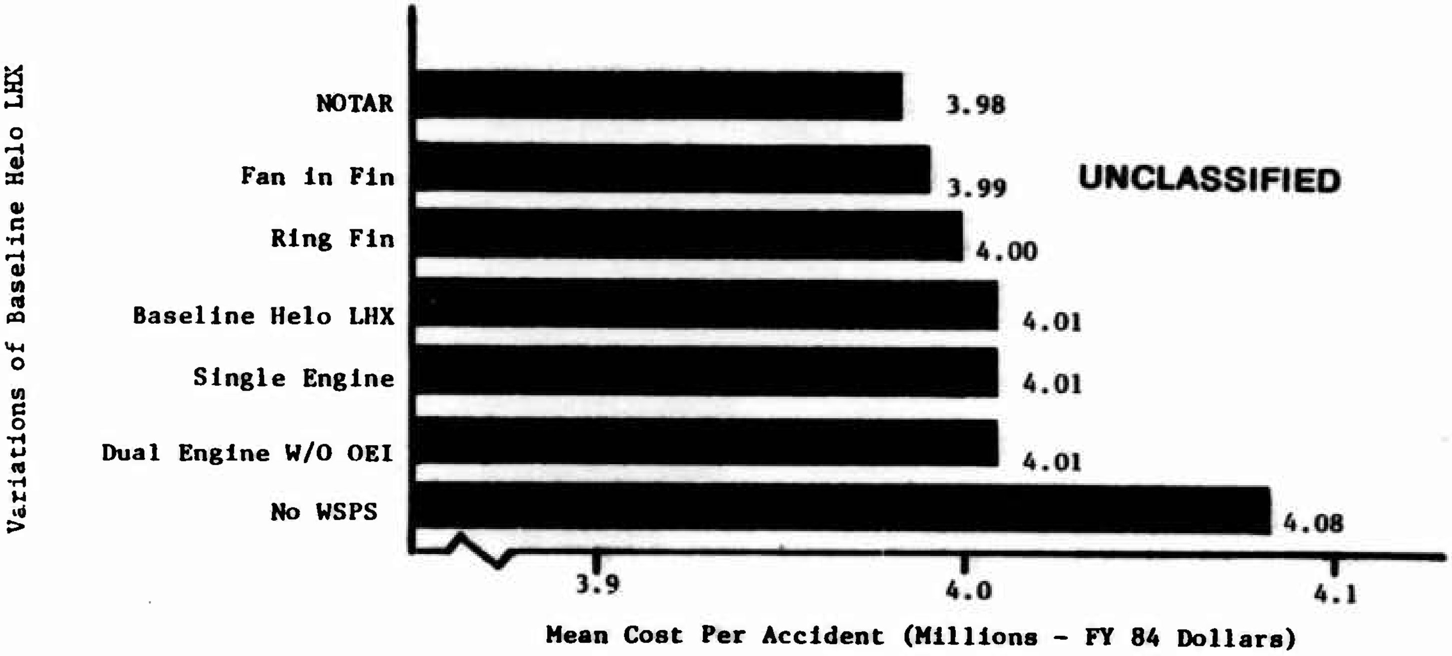

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Figure V-IV-8. (U) Influences of variations in utility aircraft on projected mean accident costs.

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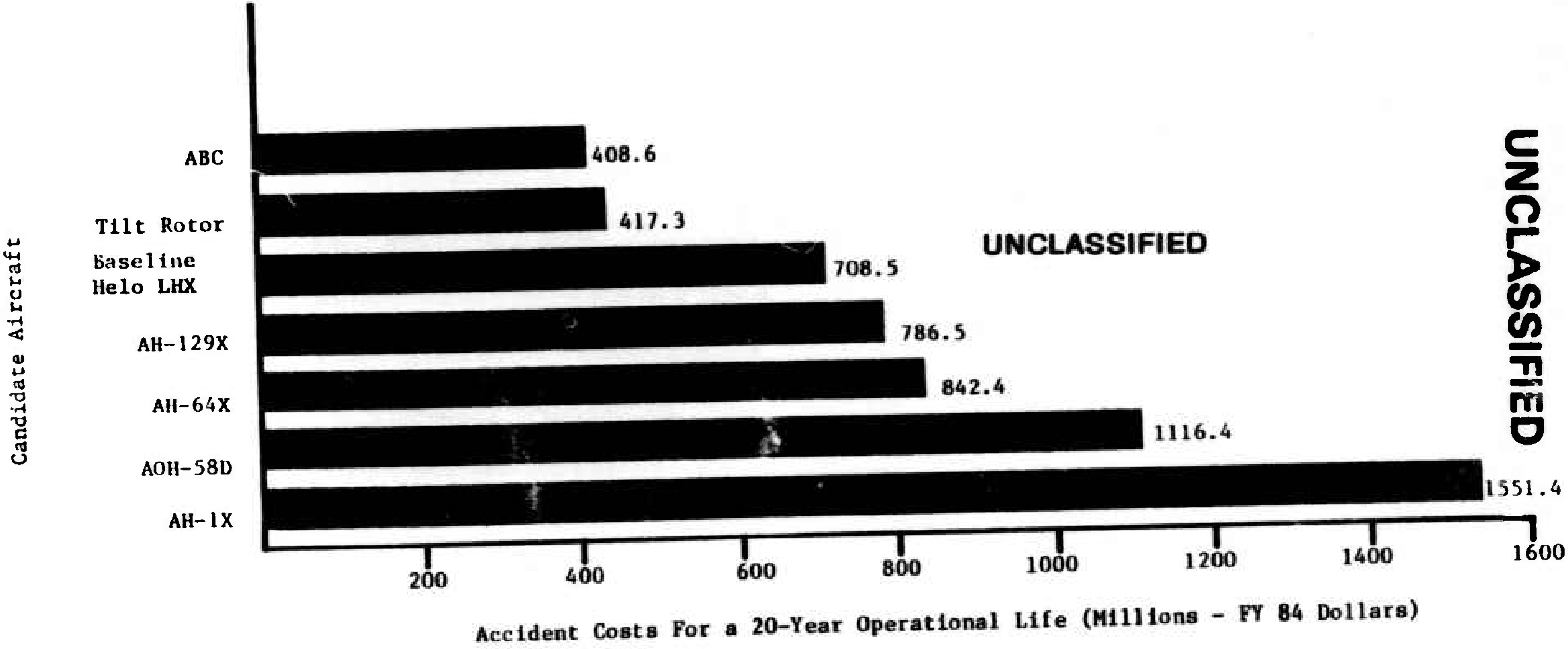

Figure V-IV-9. (U) Total peacetime accident costs for a 20-year operational life (SCAT aircraft).

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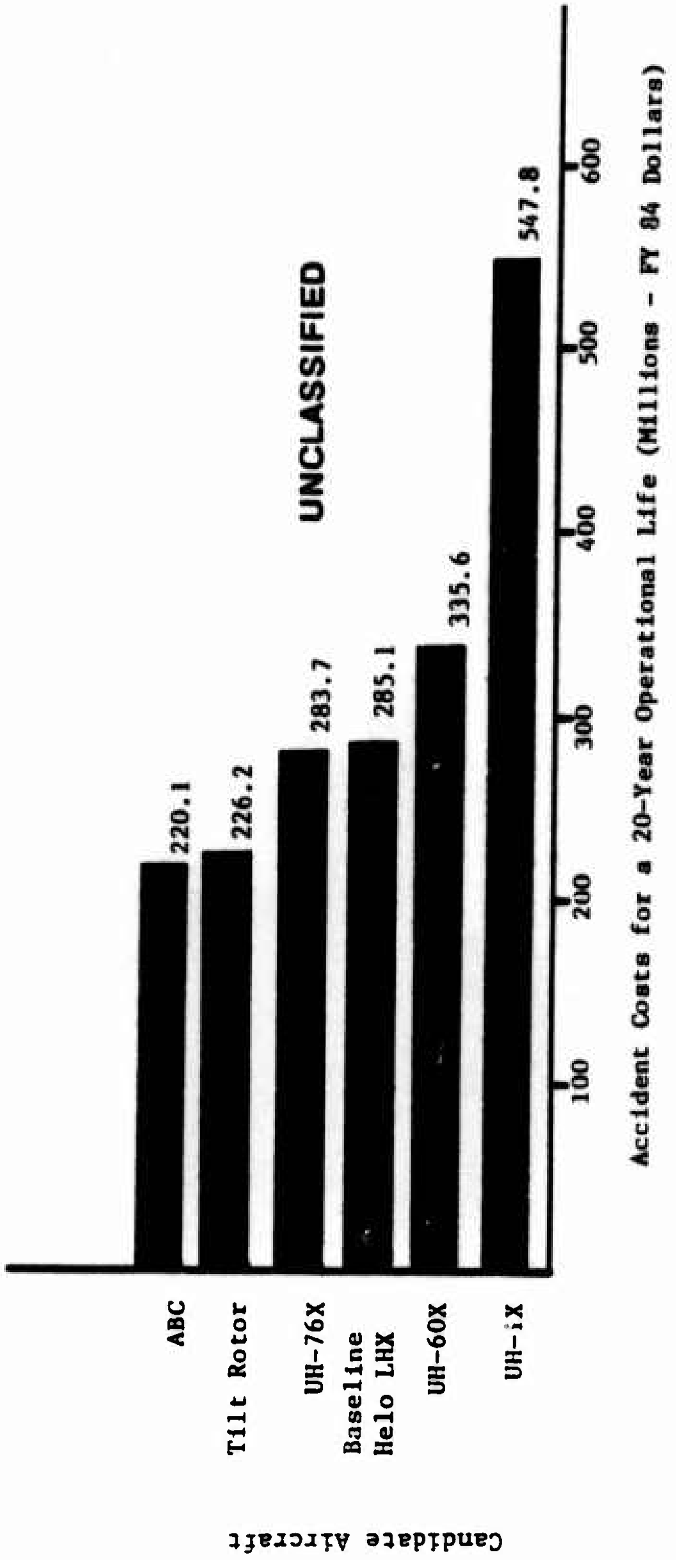

Figure V-IV-10. (U) Total peacetime accident costs for a 20-year operational life (utility aircraft).

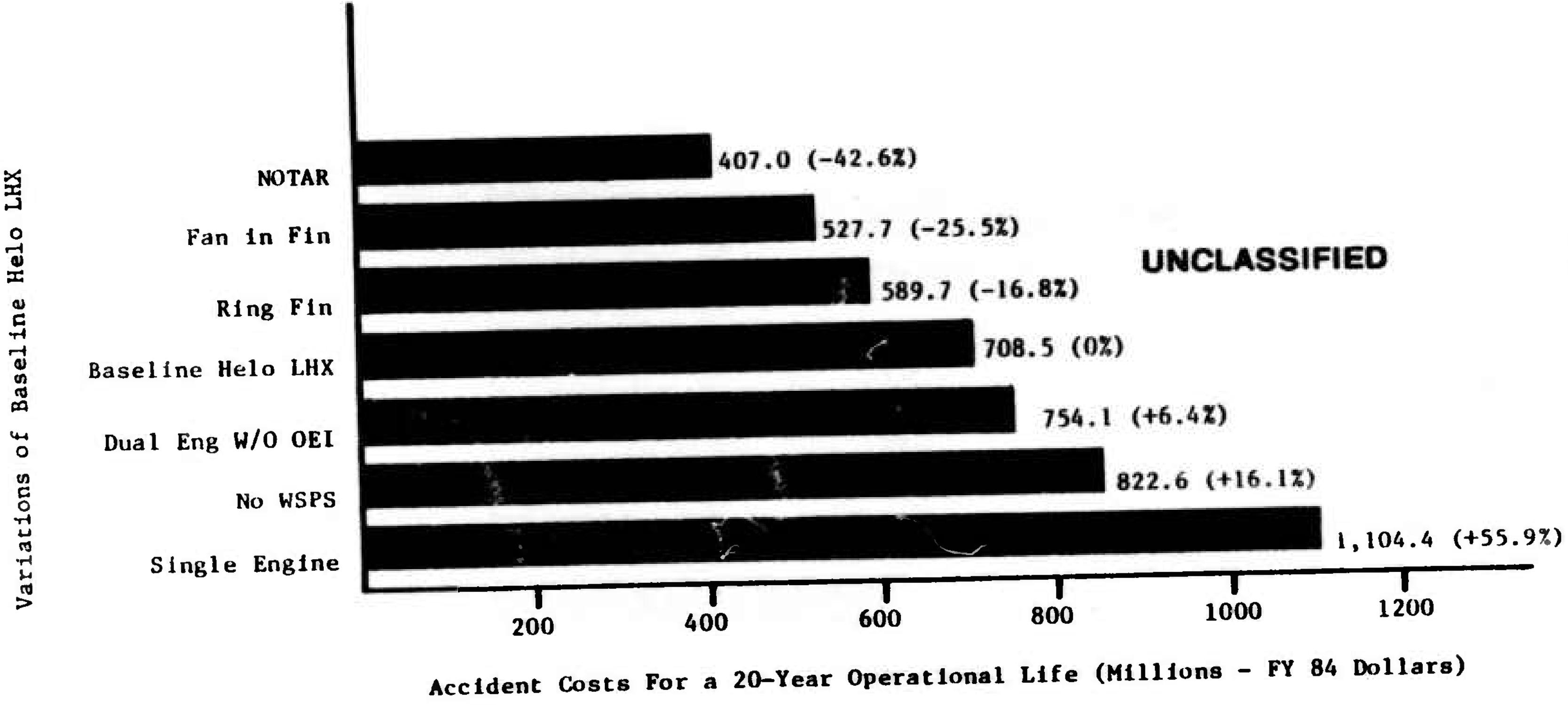

Figure V-IV-11. (U) Influence of variations in SCAT helicopters on total peacetime accident costs.

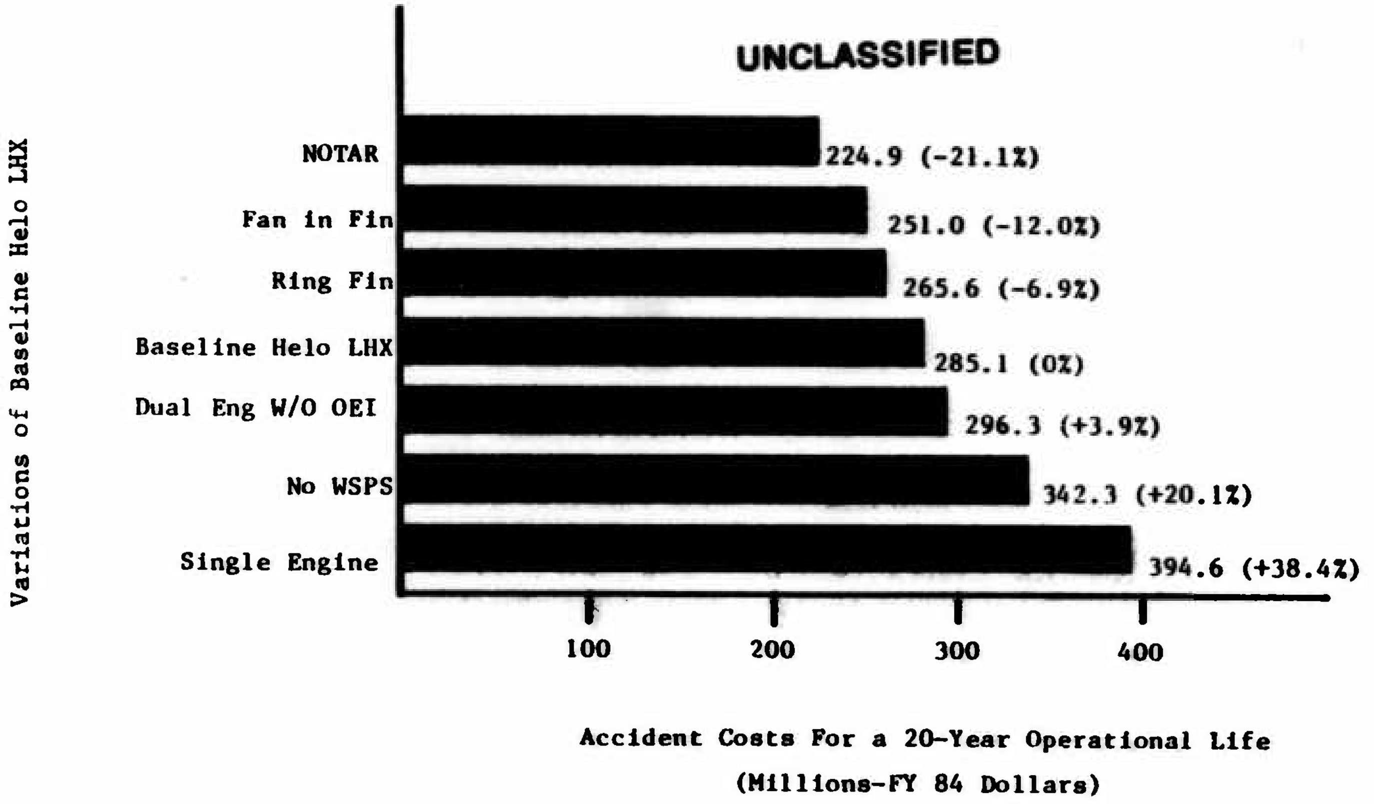

Figure V-IV-12. (U) Influence of variations in utility helicopters on total peacetime accident costs.

ANNEX V TO APPENDIX V

CANDIDATE AIRCRAFT FLEET SIZES AND COSTS (U)

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ANNEX V TO APPENDIX V

CANDIDATE AIRCRAFT FLEET SIZES AND COSTS (U)

Aircraft	Quantity	Aircraft Replacement Cost (millions of dollars)*
Light Helicopter Family (LHX) Scout-Attack (SCAT)	1,898	7.4**
Advancing blade concept (ABC) SCAT	1,898	7.9**
Tilt-SCAT	1,898	8.1
AOH-58D	1,898	5.4
AH-1X	1,898	6.7
AH-64X	1,898	8.8
A-129X	1,898	7.3
LHX-Utility	1,213	6.3**
ABC-Utility	1,213	6.8**
Tilt-Utility	1,213	7.0
UH-1X	1,213	5.5
UH-60X	1,213	7.5
UH-76X	1,213	6.3

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*Cost data provided by US Army Aviation Research and Development Command.
**Single- and dual-engine LHX version costs are essentially the same.

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Figure V-V-1. (U) Candidate aircraft fleet sizes and costs (fiscal year 84 dollars).

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APPENDIX W

COST ANALYSIS (U)

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APPENDIX W

COST ANALYSIS (U)

W-1. (U) PURPOSE. The purpose of this appendix is to document the cost data provided to the Trade-off Analysis (TOA) substudy elements. It also serves to document the Trade-off Determination (TOD) Light Helicopter Family (LHX) life cycle cost estimates (LCCE), post-TOD cost excursions, and LHX TOA force costing efforts. The appendix also presents the findings and emerging results of the TOA cost analysis.

W-2. (U) BACKGROUND. The TOD cost report was received at the US Army Aviation Center (USAAVNC) in January 1984 and provided LCCE for the pure helicopter and tilt rotor. In late January 1984, the report was expanded to include LCCE for the compound helicopter, advancing blade concept (ABC), and ABC compound versions. During the March to May 1984 time frame, various cost excursions were produced by the LHX Program Manager's (PM) Office, i.e., lightweight designs, speed variations, etc. The cost impacts of introducing the LHX into the force structure were analyzed during the June-December 1984 time frame. Finally, findings and emerging results of the TOA cost analysis were produced using life cycle and force cost data.

W-3. (U) ASSUMPTIONS. The cost assumptions applicable to LCCE and force cost estimates are enumerated in each specific section.

W-4. (U) METHOD.

a. (U) The TOA cost analysis is divided into three primary analytical areas: (1) TOD cost summary, (2) post-TOD cost excursions, and (3) force cost analysis. The cost analysis examined all costs that could be isolated and estimated for each LHX design trade-off configuration. Generally, the total system cost and standard requirements code (SRC) cost associated with the operation of the LHX aircraft were the primary cost indicators produced by the cost analysis. The cost analysis used the total system cost and SRC cost to compare and evaluate each of the LHX design trade-offs. Input data for the cost analysis was provided from two primary sources: (1) the TOD life cycle costs (LCC) and post-TOD cost excursions produced by the LHX PM's Office, Aviation Systems Command (AVSCOM), and (2) the LHX force costs produced using the TOA force cost information system (FCIS). The LCCEs were produced in FY 84 constant dollars. Force costs results were inflated to FY 84 dollars using information guidance provided by Department of the Army, 19 April 1984. Elements of the LCC and force cost were estimated by one or several of the following means:

(1) (U) Application of AVSCOM cost estimating relationships (CER) which by statistical analysis of historical data define cost as a function of a characteristic of an aircraft system (e.g., weight, speed, etc.).

(2) (U) Use of engineering estimates generated by subject matter experts (SME) assigned to the TOD.

(3) (U) Use of estimates developed for similar aircraft programs.

(4) (U) Use of the TOA FCIS to compute unit cost of the SRCs affected by introduction of the LHX into the Army inventory.

(5) (U) Use of the Army Force Planning Cost Handbook (AFPCH) for derivation of FCIS cost factors.

b. (U) Likewise, during the cost analysis process, incremental design costs were provided to the various substudy elements for the purpose of sharing the relationship that exists between cost and effectiveness for each design associated with a particular trade-off parameter. Therefore, cost/effectiveness data associated with particular trade-offs will appear throughout each substudy appendix.

W-5. (U) ANALYSIS.

a. (U) LHX TOD. The information contained within this section was obtained or derived from the cost section of the LHX TOD. Costs are presented for the three life cycle cost areas: (1) research and development (R&D), (2) investment, and (3) operating and support (O&S). R&D costs, in general, are costs resulting from applied research, engineering design, analysis, development, test, evaluation, and managing development efforts related to the LHX system. Investment costs are the costs resulting from the production and introduction of the LHX system into the Army's operational inventory. O&S costs are those costs resulting from the operation, maintenance, and support (including personnel support) of the system after it is accepted into the Army inventory. All costs presented here and throughout the report are shown in constant FY 84 dollars.

(1) (U) R&D estimates. Costs presented for R&D are shown in accordance with the work breakdown structure specified for the LHX TOD. A detailed discussion of the methodology used to derive LHX R&D costs will not be presented here, but such a discussion is contained within the TOD. Figure W-1 shows the full-scale engineering development R&D estimate for each of the five alternative aircraft. The cost data is shown in the form of range, rather than point data, and the ranges shown do not vary significantly between the various alternatives.

Work Breakdown Structure	Heli-copter	Compound Helicopter	ABC	ABC Compound	Tilt Rotor
Airframe	1058.4- 1478.1	1062.5- 1482.2	1067.8- 1487.5	1085.9- 1505.6	1082.6- 1502.3
Engine (less CIP)	369.8- 379.8	379.8- 404.8	379.8- 404.8	404.8- 437.7	379.8- 404.8
Mission Equipment Package (MEP)	206.5- *	206.5- *	206.5- *	206.5- *	206.5- *
Weapons	120.1- 513.1	120.1- 513.1	120.1- 513.1	120.1- 513.1	120.1- 513.1
Integrated Logistics Support (ILS)	195.8- 380.0	196.0- 380.0	195.8- 380.0	195.8- 380.0	195.8- 380.0
FSIM	63.1- 96.7	63.1- 96.7	63.1- 96.7	63.1- 96.7	63.1- 96.7
Other (in-house) **	93.4	93.4	93.4	93.4	93.4
Total	2100.4- 3147.8	2121.4- 3176.7	2126.5- 3182.0	2169.6- 3233.0	2141.3- 3196.8

*Requirements were undetermined at time of publication.
**In-house for airframe and engine; weapons and FSIM in-house costs are included in the WBS element.

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Figure W-1. (U) Full-scale development (FSD) cost, baseline configurations (FY 84 dollars, millions).

(2) (U) Investment estimates. DA Pamphlet 11-3, Investment Cost Guide for Army Materiel Systems, was used as a basis for cost definitions contained in the investment section. The cost elements and associated methodologies for costing of each element are shown in figure W-2. These methodologies include the use of CERs, analogies to other Army aircraft, engineering judgment, historical data, and expert opinion. Cost comparisons of the five alternatives for both the two-man baseline and one-man variation are shown in figures W-3 and W-4. Figure W-3 compares scout/attack (SCAT) average flyaway costs for the first 1,000 production units, and figure W-4 provides the same information for the Utility version. Until total aircraft requirements are established for the LHX, comparisons of the first 1,000 production units are used. A comparison of the two-man baseline alternatives on figures W-3 and W-4 reveals that although cost variations occur primarily in airframe and engine areas, the MEP is the most costly of all subsystems. The MEP cost is approximately 50 percent of the total flyaway cost for the two-man helicopter (see figure W-5). The least costly two-man alternative is the conventional helicopter ($7.1 million flyaway), and the most expensive is the compound ABC helicopter ($8.0 million flyaway). The one-man variation is typically $200 thousand less costly from an investment standpoint. Figure W-6 shows a cost breakout of the full baseline MEP suite. The major cost driver within the MEP is the millimeter wave (MMW) radar costing more than $700 thousand per unit. This is followed by communications/navigation and target acquisition equipment. Several high-risk technology areas are contained within the MEP and costs for these items could vary considerably from the costs shown. Costs for selected derivative aircraft systems which could emanate from currently deployed aircraft systems are compared with baseline designs in figure W-7. A derivative aircraft, as defined in the TOD, is a notional aircraft having technically, to the greatest extent possible, "LHX capability." The analysis did not explore the feasibility of the concept or the assumed technical capability of the derivatives, but costed each derivative as equipped with LHX MEP, engines, weapons, and comparable airframe major dynamic components.

Element	Methodology (Flyaway elements)[a]
1. Nonrecurring (2.01)[b]	
a. Airframe	CER calibrated to Black Hawk experience used to develop costs for one production line. Costs for second line assumed 60 percent of the first-line costs. Test equipment and related software costs were developed by analogy to Apache Lots 1 and 2 contracts. Preplanned product improvement (P^3I) costs based upon engineering judgment.
b. Engine	CER calibrated to T-700 experience.
c. MEP	Air Force historical data and engineering judgment.
d. Weapons	Analogy with other aircraft systems currently in production plus engineering judgment.
2. Production (2.02)	
a. Air vehicle	Analogy to Black Hawk on cost-per-pound basis for Black Hawk Lots 3, 4, and 5 (271 units). Learning curve of 90 percent applied to first 1,000 units; flat curve thereafter. Technology factors and complexity factors then applied.
b. Engine	Analogy to T-700 experience using CER with learning curve of 93.3 percent applied to first 1,000 units; flat curve thereafter.
c. MEP	Expert opinion, engineering estimates, contractor estimates, consultant estimates with learning curves applied.
d. Weapons	Analogy with advanced attack helicopter (AAH) equivalent systems and engineering judgment.

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[a] See footnote a, figure W-3, for definition of flyaway costs.

[b] Numbers in parentheses indicate cost element number specified in DA Pam 11-4.

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Figure W-2. (U) Methodology for development of LHX investment costs. (continued on next page)

Element	Methodology (Flyaway elements)[a]
e. Missile and ammunition costs	Analogy with AAH equivalent systems for helicopter-launched fire and forget (HELLFIRE) missile system and 30 millimeter (mm) ammunition and data from Stinger PM at Missile Command (MICOM) for Stinger cost.
3. Engineering changes (2.03)	Five percent of airframe, engine, mission equipment, and weapons total production costs. This was derived by analogy to Apache program.
4. System project management (2.06)	Core system project management estimated using 5.5 percent of recurring airframe, engine, MEP, and weapons costs. Logistics Support Analysis (LSA) developed in analogy to LSA costs projected by Hughes Helicopter First Year Logistics Support Plan for Apache and Martin Marietta Lot 1 and 2 Production Contracts for the target acquisition and designation system (TADS)/pilot's night vision system (PNVS). Site activation support costs from Black Hawk PM Office.
5. System test and evaluation (2.04)	Estimate of 1.5 percent of airframe, engine, MEP, and weapons total production costs. ILS estimate assumed 20 percent of total costs of this element. These estimates based on analogy to Apache program.
	Nonflyaway elements
6. Data (2.05)	Estimated at 2.5 percent of total airframe, engine, MEP, and weapons production costs. ILS estimates assumed 20 percent of total costs of this element. These estimates based on analogy to Apache program.
7. Training (2.08)	Data provided by LHX TOD training element with input from PM Training Devices (TRADE) and USAAVNC.
8. Peculiar support equipment (PSE) (2.11)	PSE list compiled from Apache and Black Hawk PSE requirements.

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Figure W-2. (U) (continued)

Element	Methodology (Flyaway elements)[a]
9. Initial spares and repair costs (2.09)	Estimated as a percent of total production costs and calculated as follows: engine - 18.5 percent, avionics - 12.75 percent, aircraft survivability equipment (ASE) - 7.5 percent, weapons - 10 percent, and PSE - 10 percent.
10. In-house (2.12)	Analogy to AAH and TADS/PNVS PMOS and data supplied by MICOM.
11. Other (2.13)	Includes all LHX costs associated with Post Development Software Support (PDSS), special mission kits, cargo utility hooks, etc. These costs estimated at 5 percent of total production costs.

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Figure W-2. (U) (concluded)

Alternative	Cockpit Design	Airframe[b]	Engine	MEP	Weapons	Other	Total
Helicopter	2-man baseline	1.8	.6	3.6	.3	.8	7.1
	1-man variation	1.7	.6	3.6	.3	.7	6.9
Compound	2-man baseline	2.1	.8	3.6	.3	.8	7.6
Helicopter	1-man variation	2.0	.8	3.6	.3	.8	7.4
ABC	2-man baseline	2.2	.7	3.6	.3	.8	7.6
Helicopter	1-man variation	2.0	.7	3.6	.3	.8	7.4
Compound ABC	2-man baseline	2.3	.9	3.6	.3	.9	8.0
Helicopter	1-man variation	2.2	.9	3.6	.3	.8	7.7
Tilt Rotor	2-man baseline	2.2	.8	3.6	.4	.8	7.8
	1-man variation	2.1	.8	3.6	.4	.8	7.6

NOTE: In some cases, individual numbers may not sum to total due to rounding.

[a] Flyaway costs include total recurring and nonrecurring procurement costs required to produce a usable end item of military hardware. It includes tooling costs, fabrication and production costs of components shown here, and of installed, government-furnished equipment. Also included are costs for engineering changes, system test and evaluation, and project management.

[b] Cost to integrate engine, weapons, and items other than MEPs is included in airframe cost. Integration cost for MEP is included in MEP cost.

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Figure W-3. (U) SCAT aircraft cost comparison - average unit flyaway[a] cost for 1,000 units (constant FY 84 dollars, millions).

Alternative	Cockpit Design	Airframe[b]	Engine	MEP	Weapons	Other	Total
Helicopter	2-man baseline	1.8	.6	2.8	<.1	.6	5.9
	1-man variation	1.8	.6	2.8	<.1	.6	5.8
Compound Helicopter	2-man baseline	2.1	.8	2.8	<.1	.7	6.4
	1-man variation	2.1	.8	2.8	<.1	.7	6.3
ABC Helicopter	2-man baseline	2.2	.7	2.8	<.1	.7	6.4
	1-man variation	2.1	.7	2.8	<.1	.6	6.3
Compound ABC Helicopter	2-man baseline	2.4	.9	2.8	<.1	.7	6.8
	1-man variation	2.3	.9	2.8	<.1	.7	6.7
Tilt Rotor	2-man baseline	2.2	.8	2.8	<.1	.7	6.6
	1-man variation	2.2	.8	2.8	<.1	.7	6.5

NOTE: In some cases, individual numbers may not sum to total due to rounding.

a. Flyaway costs include total recurring and nonrecurring procurement costs required to produce a usable end item of military hardware. It includes tooling costs, fabrication and production costs of components shown here, and of installed, government-furnished equipment. Also included are costs for engineering changes, system test and evaluation, and project management.

b. Cost to integrate engine, weapons, and items other than MEPs is included in airframe cost. Integration cost for MEP is included in MEP cost.

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Figure W-4. (U) Utility aircraft cost comparison - average unit flyaway[a] cost for 1,000 units (constant FY 84 dollars, millions).

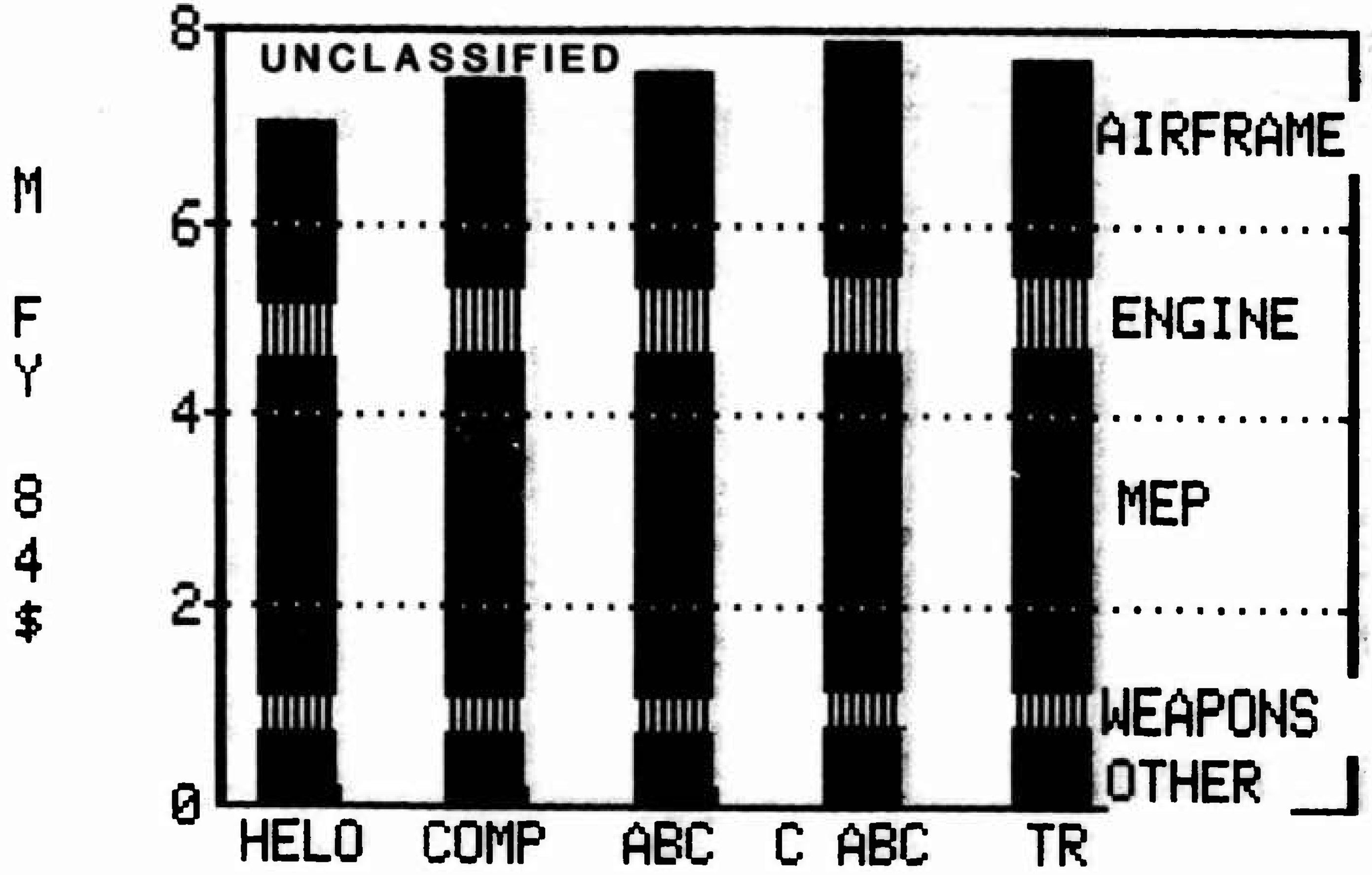

Figure W-5. (U) SCAT unit flyaway cost for 1,000 units.

		Cost (Thousands of FY 84 Dollars)	Percent of Total
Communications/navigation		671.89	17
ICNIA	248.01		
DADS	27.79		
Voice security	10.69		
Doppler velocity sensor	26.73		
Inertial reference system	213.80		
Digital map NNAPS	80.18		
Radar altimeter (APN-209)	10.69		
Cockpit management		385.38	11
MFPK (keyboard)	12.83		
VIA 14 Processor	1.07		
MFD (cockpit display)	32.07		
VHSIC	320.70		
Data load verifier	8.02		
Flight data recorder	10.69		
Radar		855.21	24
MMW radar	721.58		
Radar frequency interferometer	133.63		
Target acquisition		596.05	17
Air data sensor	17.10		
Weapons interface	22.00		
EOTADS and laser range	555.88		
Airborne target handoff system (ATHS)	1.07		
Night vision pilotage system		301.46	9
NVPS	114.38		
Helmet-mounted display	187.08		
Integration (non-ASE)		358.28	10

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Figure W-6. (U) SCAT MEP baseline flyaway cost.

(continued on next page)

		Cost (Thousands of FY 84 Dollars)	Percent of Total
Electromagnetic pulse (EMP) hardening		82-68	2
ASE		340.76	10
Radar warning	26.73		
Laser warning	32.07		
Infrared (IR) jammer	32.07		
radio frequency (RF) jammer	200.00		
ASE processor	10.69		
Integration	39.20		
		3,537.71	

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Figure W-6. (U) (concluded)

	Average Unit Flyaway (1,000 Units) FY84 dollars, millions	
LHX-SCAT	**SCAT**	**Utility**
Helicopter	7.1	5.9
Compound	7.6	6.4
ABC	7.6	6.4
ABC Compound	8.0	6.8
Tilt Rotor	7.8	6.6
Derivatives		
AH-64X	8.8	
AH-60X	7.5	
OH-58EX (SCAT)	5.4	
OH-58FX (Utility)	4.6	
AH-1X	6.7	
UH-1X	5.5	
AS-75	7.5	
US-75	6.3	
AH-129X	7.3	

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Figure W-7. (U) Flyaway cost comparison - LHX baseline and derivative aircraft.

(3) (U) O&S estimates. DA Pam pamphlet 11-4, Operating and Support Cost Guide for Army Materiel Systems, was used as a basis for cost definitions in the O&S portion of the cost TOD. O&S costs seek to quantify those costs associated with the operation of a fielded fleet. Data and methodology from other estimates such as Black Hawk, AAH, and the Army Helicopter Improvement Program (AHIP) were used when possible to provide a basis for comparison. Key assumptions and methodology are shown in figure W-8. Figures W-9 and W-10 present O&S cost comparisons for SCAT and Utility versions on a per-flight-hour basis. The percent share of the total for each cost element is shown in figures W-11 and W-12. The helicopter alternative is the least costly of the five alternatives at $2,950 per flight hour for the SCAT version; however, O&S costs for the most costly, the compound ABC, are less than 10 percent higher than those for the helicopter. In all cases, the one-man cockpit design is less costly to operate, usually $200 per flight hour less than the two-man cockpit for the SCAT version, and is attributable mostly to a decrease in personnel costs. Military personnel costs are the largest single cost element shown, comprising around 40 percent for the SCAT version and, in some cases, nearly 50 percent for the Utility version. Costs for consumption and depot maintenance rank in order behind costs for military personnel. Costs for materiel modifications are on the order of 12-13 percent of the total for the SCAT version and 13-14 percent for the Utility version. Figure W-13 compares O&S costs for LHX-SCAT and Utility versions with those for current aircraft systems and derivative aircraft systems. The numbers shown are not total O&S costs. Some costs have been excluded in order to provide a more equitable basis for comparison.

(4) (U) LCC summary. Figure W-14 provides a total LCC summary for each of the five alternative LHX aircraft. This estimate assumes a production program of 2,903 SCAT and 1,946 Utility aircraft. R&D costs are virtually identical for all alternatives. The helicopter is the least costly alternative to procure and operate followed in order by the compound helicopter, ABC, tilt rotor, and ABC compound configurations. This ordering applies to either two-crew or one-crew aircraft. When comparing the costs of the two-crew to the one-crew aircraft, one should consider that the cost difference between these two versions is attributed primarily to the number of crew stations. The one-crew aircraft has no additional MEP or survivability equipment to compensate for a possible increased workload over that of the two-crew aircraft.

(5) (U) Weapons cost summary.

(a) (U) Purpose. This section summarizes and consolidates the LHX TOD weapons cost data in order to provide a quick reference source for LHX TOA weapons costing.

(b) (U) Background. LHX weapons cost data for this summary was extracted from the LHX TOD weapons report and from additional cost data provided by MICOM. More detailed information may be obtained by referring to the TOD weapons report.

Operational fleet size:	2,218 SCAT; 1,226 Utility
Annual flying time per aircraft:	240 hours
O&S period:	FY 1992 through 2023 with fleet phase-in and phase-out; each aircraft has 20-year life
Table of organization and equipment (TOE) for personnel costs:	17-201J210 (Cav Bde Air Attack, Hvy Div), CONUS
Maintenance:	Mostly on-condition with minimal scheduled overhauls and other scheduled maintenance
Missile costs:	Provided by MICOM
Missile training:	1 HELLFIRE per year SCAT; 1 Stinger each for SCAT and Utility
Total accumulated aircraft years:	44,360 for SCAT; 24,520 for Utility
Total accumulated flying hours:	10,646,400 for SCAT; 5,884,800 for Utility
Fuel consumption (gallons (gal)/ hour):	73 for SCAT; 75 for Utility (fuel weight assumption is 6.5 pounds (lb)/gal)

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Figure W-8. (U) Assumptions and methodology for LHX O&S costs.

Alternative	Cockpit Design	Military[a] Personnel	Consumption[b]	Depot Maint[c]	Materiel Mods[d]	Other Direct Support[e]	Indirect Support[f]	Total
Helicopter	2 Crew	1,284	773	461	353	57	15	2,947
	1 Crew	1,086	762	454	344	62	15	2,723
Compound Helicopter	2 Crew	1,292	811	508	375	62	15	3,062
	1 Crew	1,093	801	502	367	62	15	2,839
ABC Helicopter	2 Crew	1,284	837	518	375	58	15	3,087
	1 Crew	1,086	821	508	366	58	15	2,853
Compound ABC Helicopter	2 Crew	1,292	872	554	391	58	15	3,182
	1 Crew	1,093	858	546	382	58	15	2,951
Tilt Rotor	2 Crew	1,301	855	542	385	59	15	3,156
	1 Crew	1,102	843	539	378	59	15	2,936

NOTE: In some cases, individual numbers may not sum to total due to rounding.

a. Includes pay and allowances for crew, maintenance personnel, and indirect support personnel.

b. Includes spares, petroleum oil and lubricants, unit training, ammunition, and missiles.

c. Includes depot costs for labor (civilian and military), materiel, and transportation to and from depot to unit.

d. Includes cost of the materiel associated with any official alteration made to a system by way of a modification work order (MWO), redraft, conversion, remanufacture, or engineering change after acceptance by the Army.

e. Cost of civilian maintenance labor at any level below depot and other direct costs not included in previously mentioned cost areas.

f. Includes cost for personnel replacement; transients, patients, and prisoners; quarters maintenance and utilities and medical support; and any other indirect costs, such as general supplies to force units, cost of program offices or product improvement offices, if they exist, and ammunition for small arms qualification.

Figure W-9. (U) LHX-SCAT O&S cost per flight hour (constant FY 84 dollars).

Alternative	Cockpit Design	Military Personnel[a]	Consumption[b]	Depot Maint[c]	Materiel Mods[d]	Other Direct Support[e]	Indirect Support[f]	Total
Helicopter	2 Crew	1,352	533	412	346	58	15	2,716
	1 Crew	1,122	524	408	341	58	15	2,467
Compound Helicopter	2 Crew	1,360	560	459	371	58	15	2,824
	1 Crew	1,130	554	456	367	58	15	2,579
ABC Helicopter	2 Crew	1,352	594	469	372	57	15	2,858
	1 Crew	1,122	582	462	366	57	15	2,603
Compound ABC Helicopter	2 Crew	1,360	619	506	390	57	15	2,945
	1 Crew	1,130	623	500	384	57	15	2,708
Tilt Rotor	2 Crew	1,368	610	488	381	57	15	2,918
	1 Crew	1,138	601	485	377	57	15	2,673

NOTE: In some cases, individual numbers may not sum to total due to rounding.

a. Includes pay and allowances for crew, maintenance personnel, and indirect support personnel.

b. Includes spares, petroleum oil and lubricants, unit training, ammunition, and missiles.

c. Includes depot costs for labor (civilian and military), materiel, and transportation to and from depot to unit.

d. Includes cost of the materiel associated with any official alteration made to a system by way of a MWO, redraft, conversion, remanufacture, or engineering change after acceptance by the Army.

e. Cost of civilian maintenance labor at any level below depot and other direct costs not included in previously mentioned cost areas.

f. Includes cost for personnel replacement; transients, patients, and prisoners; quarters maintenance and utilities and medical support; and any other indirect costs, such as general supplies to force units, cost of program offices or product improvement offices, if they exist, and ammunition for small arms qualification.

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Figure W-10. (U) LHX-Utility O&S cost per flight hour (constant FY 84 dollars).

Alternative	Cockpit Design	Military[a] Personnel	Consumption[b]	Depot Maint[c]	Materiel Mods[d]	Other Direct Support[e]	Indirect Support[f]	Total	Total in Millions of FY84 Dollars
Helicopter	2 Crew	43.6	26.3	15.6	11.9	2.1	0.5	100.0	31,376
	1 Crew	39.9	28.0	16.7	12.6	2.3	0.5	100.0	28,987
Compound Helicopter	2 Crew	42.2	26.5	16.6	12.2	2.0	0.5	100.0	32,597
	1 Crew	38.5	28.2	17.7	12.9	2.2	0.5	100.0	30,226
ABC Helicopter	2 Crew	41.6	27.1	16.8	12.1	1.9	0.5	100.0	32,865
	1 Crew	38.1	28.8	17.8	12.8	2.0	0.5	100.0	30,377
Compound ABC Helicopter	2 Crew	40.6	27.4	17.4	12.3	1.8	0.5	100.0	33,874
	1 Crew	37.0	29.1	18.5	12.9	2.0	0.5	100.0	31,418
Tilt Rotor	2 Crew	41.2	27.0	17.2	12.2	1.9	0.5	100.0	33,604
	1 Crew	37.5	28.7	18.4	12.9	2.0	0.5	100.0	31,257

NOTE: In some cases, individual numbers may not sum to total due to rounding.

a. Includes pay and allowances for crew, maintenance personnel, and indirect support personnel.

b. Includes spares, petroleum oil and lubricants, unit training, ammunition, and missiles.

c. Includes depot costs for labor (civilian and military), materiel, and transportation to and from depot to unit.

d. Includes cost of the materiel associated with any official alteration made to a system by way of a MWO, redraft, conversion, remanufacture, or engineering change after acceptance by the Army.

e. Cost of civilian maintenance labor at any level below depot and other direct costs not included in previously mentioned cost areas.

f. Includes cost for personnel replacement; transients, patients, and prisoners; quarters maintenance and utilities and medical support; and any other indirect costs, such as general supplies to force units, cost of program offices or product improvement offices, if they exist, and ammunition for small arms qualification.

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Figure W-11. (U) LHX-SCAT O&S cost comparison - components as percent of total.

Alternative	Cockpit Design	Military[a] Personnel	Consumption[b]	Depot Maint[c]	Materiel Mods[d]	Other Direct Support[e]	Indirect Support[f]	Total	Total in Millions of FY84 Dollars
Helicopter	2 Crew	49.8	19.6	15.2	12.7	2.1	0.6	100.0	15,982
	1 Crew	45.5	21.2	16.5	13.8	2.4	0.6	100.0	14,520
Compound Helicopter	2 Crew	48.2	19.8	16.3	13.1	2.1	0.5	100.0	16,616
	1 Crew	43.8	21.5	17.7	14.2	2.2	0.6	100.0	15,178
ABC Helicopter	2 Crew	47.3	20.8	16.4	13.0	2.0	0.5	100.0	16,824
	1 Crew	43.1	22.4	17.7	14.0	2.2	0.6	100.0	15,316
Compound ABC Helicopter	2 Crew	46.2	21.0	17.2	13.2	1.9	0.5	100.0	17,333
	1 Crew	41.7	23.0	18.4	14.2	2.1	0.6	100.0	15,935
Tilt Rotor	2 Crew	46.9	20.9	16.7	13.1	1.9	0.5	100.0	17,174
	1 Crew	42.6	22.5	18.2	14.1	2.1	0.5	100.0	15,727

NOTE: In some cases, individual numbers may not sum to total due to rounding.

a. Includes pay and allowances for crew, maintenance personnel, and indirect support personnel.

b. Includes spares, petroleum oil and lubricants, unit training, ammunition, and missiles.

c. Includes depot costs for labor (civilian and military), materiel, and transportation to and from depot to unit.

d. Includes cost of the materiel associated with any official alteration made to a system by way of a MWO, redraft, conversion, remanufacture, or engineering changer after acceptance by the Army.

e. Cost of civilian maintenance labor at any level below depot and other direct costs not included in previously mentioned cost areas.

f. Includes cost for personnel replacement; transients, patients, and prisoners; quarters maintenance and utilities and medical support; and any other indirect costs, such as general supplies to force units, cost of program offices or product improvement offices, if they exist, and ammunition for small arms qualification.

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Figure W-12. (U) LHX-Utility O&S cost comparison - components as percent of total.

Design	Flying Hour Cost[a] (FY 84 Dollars)
LHX-SCAT (2-man)	2,650
LHX-SCAT (1-man)	2,430
AH-64A	3,275
AH-64X	3,490
AH-1S	2,965
AH-1X	3,020
OH-58C	1,320
OH-58D	1,515
OH-58EX (SCAT)	2,510
LHX-Utility (2-man)	2,400
LHX-Utility (1-man)	2,155
UH-60A	2,405
UH-60X	2,995
OH-58FX (Utility)	2,275
UH-1	2,220
UH-1H	2,805

NOTE: Numbers shown are rounded to nearest $5. "X" denotes derivative aircraft system. A derivative aircraft, as defined in the TOD, is a notional aircraft, having technically, to the greatest extent possible, "LHX capability."

a. Costs shown are not total O&S costs, for some costs have been excluded to provide a more equitable comparison.

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Figure W-13. (U) O&S cost comparison, LHX, existing, and derivative aircraft systems.

Configuration	Cockpit Design	R&D	Investment[a]	O&S
Helicopter	2 Crew	2.1-3.1	42.7	47.4
	1 Crew	2.1-3.1	41.6	43.5
Compound Helicopter	2 Crew	2.1-3.2	45.5	49.2
	1 Crew	2.1-3.2	44.3	45.4
ABC	2 Crew	2.1-3.2	45.6	49.7
	1 Crew	2.1-3.2	44.2	45.7
ABC Compound	2 Crew	2.2-3.2	47.6	51.2
	1 Crew	2.2-3.2	46.3	47.4
Tilt Rotor	2 Crew	2.1-3.2	46.6	50.8
	1 Crew	2.1-3.2	45.7	47.0

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a. Investment costs shown are based upon a production program of 2,903 SCAT and 1,946 Utility aircraft and include missile and ammunition costs.

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Figure W-14. (U) LCC for TOD aircraft (FY 84 dollars, billions).

(c) (U) Methodology. The TOD weapons report presented LCCE for 16 candidate missile systems. The cost estimates were prepared in constant FY 84 dollars and were generated using CER for R&D and investment costs and analogy to the HELLFIRE semiactive laser (SAL) missile system for O&S costs. A detailed discussion of the methodology used will not be presented here, but is contained within the TOD report.

(d) (U) Results. Figure W-15 shows the LCCE for each of the candidate missile systems presented in the TOD.

b. (U) Post-TOD Cost Excursions.

(1) (U) This section discusses the cost impact of aircraft designs for which vertical rate of climb (VROC) performance varies from that of baseline designs at specified pressure altitude and intermediate rate of power (IRP) conditions. The systems attribute document for the LHX specifies that VROC for the SCAT version be not less than 500 feet per minute (fpm) at maximum gross weight, 4,000 feet (ft) pressure altitude, 95°F, and 95 percent IRP conditions. All baseline designs well exceed this VROC requirement and range from 648 fpm climb for the tilt rotor to 795 fpm for the compound ABC configuration. The sensitivities discussed here analyze the cost differences of aircraft for which VROC is 500 fpm but at varying altitudes of 4,000 ft, 6,000 ft, and 8,000 ft with power settings of 95 percent IRP and 90 percent IRP; i.e., the 500-fpm VROC is constant, but designs vary on the basis of altitude and IRP conditions. The data figures which support this section are contained in annex II to this appendix. These figures provide a limited cost overview of the performance variations shown. Additional cost and performance discussion is contained in appendix N. As the 500 fpm VROC requirement is desired at higher pressure altitudes and lower IRP settings, a noticeable penalty results in the form of increased weight, higher drive system rating, and higher flyaway cost. Cost for MEP and weapons is not affected but airframe and engine costs both increase as the 500 fpm VROC requirement is implemented at higher altitudes. These results are summarized in figure W-16.

(2) (U) Weight sensitivities. This section analyzes designs for which aircraft weight is less than that of baseline aircraft due primarily to variations in MEP, payload and, for SCAT aircraft, VROC performance. Two sensitivities from baseline aircraft (for all five aircraft types) are provided for both one-crew and two-crew, SCAT and Utility versions (see figures W-II-6 through W-II-15). The first sensitivity includes a reduced MEP and weapons package which primarily excludes ICNIA, radar warning receiver (RWR), RF jammer, and gun system. The primary cost reduction in these sensitivities takes place in the MEP area, although cost reduction naturally takes place due to excluding a gun system and allowing a lighter aircraft to accommodate less weight. The second sensitivity is configured so that a significant reduction in MEP and VROC performance results in a considerably lighter and less costly aircraft, but mission capability is reduced in a like manner. These results are summarized in figure W-17 for the SCAT versions and figure W-18 for the Utility versions.

Quantity		System	Category	R&D	Investment	O&S	Total
Msls	Lchrs						
65,000	8,000	Wireless TOW	A	267.4	814.9	333.1	1,415.4
65,000	8,000	HELLFIRE F&F I^2R	B-1	270.8	2,719.3	567.5	3,487.6
65,000	8,000	HELLFIRE F&F MMW	B-2	413.7	5,103.3	512.6	6,029.6
65,000	8,000	MLMS IR (Stinger)	C	N/A	2,592.7	479.1	3,071.8
65,000	8,000	MLMS RF/IR	No #	244.1	4,514.6	485.7	5,244.4
65,000	8,000	HUM Laser Cmd	D	489.2	1,820.4	572.8	2,882.4
65,000	16,000	All Aspect Msl I^2R	E	471.1	2,645.7	557.2	3,674.0
65,000	8,000	HTDM RF/IR	F	447.2	3,439.8	506.8	4,393.8
65,000	8,000	FOG-M TV	G-1	290.4	1,609.9	376.0	2,276.3
65,000	8,000	FOG-M I^2R	G-2	329.1	1,934.2	378.7	2,642.0
65,000	8,000	LOAL Inertial/MMW	H	403.8	4,073.6	527.6	5,005.0
65,000	8,000	LOAL Inertial/I^2R	I	406.8	3,436.3	523.0	4,366.1
65,000	8,000	LOAL Inertial/IR	J	361.6	2,973.6	513.8	3,849.0
65,000	8,000	LOAL Inertial/MMW/IR	K	409.1	5,744.8	533.4	6,687.3
65,000	16,000	LOBL I^2R	L	419.9	2,399.3	647.3	3,366.5
65,000	16,000	LOBL RF/I^2R	M	389.6	4,989.3	567.4	5,946.3
65,000	8,000	FOM-AW-TV		276.9	1,629.8	376.0	2,282.7
65,000	8,000	FOM-AW-CAT	G-3	311.1	1,837.8	378.7	2,527.6

NOTES: R&D cost estimated using teletype Brown R&D CER.
Missile manufacturing costs estimated using MICOM missile CER. All hardware estimates calculated using 90 percent learning slope. TOW estimate based on on MOUT study and MLMS (Stinger) estimates based on July 83 Stinger BCE.
O&S cost estimates developed using Feb 83 HELLFIRE BCE O&S cost as a base and factoring to adjust for LHX diffferences.

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Figure W-15. (U) LHX weapon system cost estimates.

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		500 fpm VROC[a]						
Configuration	TOD Baseline[b]	90% IRP 4K'/95°	95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Helicopter (SCAT)	7.091	-----	7.046	7.281	7.582	7.123	7.374	7.699
Compound Helicopter (SCAT)	7.587	7.719	7.561	7.837	8.257	7.669	7.969	8.449
Compound Helicopter (Util)	6.419	6.546	-----	-----	-----	-----	-----	-----
ABC Helicopter (SCAT)	7.611	7.706	7.544	7.781	8.390	7.649	7.908	8.553
ABC Helicopter (Utility)	6.445	6.536	-----	-----	-----	-----	-----	-----
Compound ABC (SCAT)	7.970	8.121	7.883	8.472	8.878	8.035	8.640	9.085
Compound ABC (Utility)	6.805	6.954	-----	-----	-----	-----	-----	-----
Tilt Rotor (SCAT)	7.776	7.878	7.746	8.043	8.471	7.850	8.179	8.672
Tilt Rotor (Utility)	6.610	6.714	-----	-----	-----	-----	-----	-----

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F.

[a] These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

[b] VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95°F is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

Figure W-16. (U) Performance excursions - altitude and IRP average unit flyaway cost for 1,000 units (FY 84 dollars, millions).

	Two-Crew Aircraft[a]			One-Crew Aircraft[b]		
Configuration	Baseline 1,288 lb MEP, 1,030 lb Payload	1,108 lb MEP, 680 lb Payload	790 lb MEP, 680 lb Payload	Baseline 1,282 lb MEP, 1,030 lb Payload	1,102 lb MEP, 680 lb Payload	784 lb MEP, 700 lb Payload
Helicopter	7.091	6.347	5.384	6.893	6.113	5.127
Compound helicopter	7.587	6.806	5.861	7.394	6.509	5.566
ABC helicopter	7.611	6.722	5.766	7.379	6.437	5,461
Compound ABC	7.970	7.076	6.058	7.748	6.783	5.705
Tilt rotor	7.776	6.947	6.018	7.631	6.698	5.766

a. VROC under 4,000'/95°F, 95% IRP conditions for these aircraft varies along with MEP and payload. VROC values in fpm associated with these sensitivities are as follows: helicopter - 712, 822, 500; compound helicopter- 779; ABC helicopter - 713, 500, 500; compound ABC - 795; and tilt rotor - 648.

b. VROC values for one-crew under same altitude, temperature, and IRP conditions shown in above footnote are as follows: helicopter - 993, 950, 500.

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Figure W-17. (U) SCAT weight excursions - MEP, payload, and performance (FY 84 dollars, millions).

	Two-Crew Aircraft			One-Crew Aircraft		
Configuration	Baseline 945 lb MEP Payload	786 lb MEP Payload	790 lb MEP Payload	Baseline 945 lb MEP Payload	786 lb MEP Payload	758 lb MEP Payload
Helicopter	5.927	5.116	4.829	5.822	4.972	4.671
Compound helicopter	6.419	5.570	5.314	6.336	5.376	5.126
ABC helicopter	6.445	5.486	5.220	6.309	5.292	5.006
Compound ABC	6.805	5.844	5.514	6.694	5.657	5.265

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Figure W-18. (U) Utility weight excursions - MEP and payload (FY 84 dollars, millions).

c. (U) Force Cost.

(1) (U) Introduction. This section provides an analysis of the cost impact of introducing LHX aircraft into Active Army forces and comparisons of alternative systems with LHX aircraft. Force costs for three LHX alternatives are compared with those for selected current aircraft systems in a light division Combat Aviation Brigade (CAB) and a heavy division Cavalry Brigade Air Attack (CBAA), along with supporting Transportation Aircraft Maintenance Company (TAMC) units. These units were selected as a basis for force cost comparison because they are considered to be representative of typical units where current aircraft systems are considered deficient to meet the anticipated threat.

(2) (U) Methodology. The FCIS was the primary tool used to generate comparative force cost data used in this study. FCIS is an automated system designed and maintained by the Office of the Comptroller of the Army and the US Army Management System Support Agency. It contains planning factors used to estimate resource requirements and costs associated with Army TOE units. The primary output data from FCIS used in this analysis is one-time nonrecurring and annual recurring costs. Some adjustments were required of FCIS data in order to provide a meaningful basis for force costs comparison. For example, in order to obtain TOE force costs for LHX and derivative aircraft systems, it became necessary to substitute cost data for these aircraft in the place of costs for current aircraft. In addition, application of inflation factors were needed to produce cost data in FY 84 dollars. Also, cost data for some current systems in FCIS needed revision to reflect more current cost

data for these systems. To accomplish these tasks and provide summary data outputs, the Force Cost Comparison Code (FCCC), designed and developed by the Cost Substudy, LHX Study Group, Directorate of Combat Developments (DCD), was applied. A schematic flowchart which summarizes the methodology used to produce comparative force cost data is shown in figure W-19.

(3) (U) Assumptions. Figure W-20 provides a list of the primary assumptions employed to produce this analysis. Figures W-21 and W-22 show TOE unit structures for CAB and CBAA which were used to develop force cost data for the analysis. The figures also provide anticipated LHX aircraft substitution patterns to replace current aircraft. An important assumption not made in this analysis is equal effectiveness. The systems compared here were simply identified as possible candidates with no effectiveness data yet generated. Effectiveness will be the subject of a subsequent study, the LHX COEA, and the aircraft selected in that study may reflect different configurations.

(4) (U) Results.

(a) (U) Force costs for three LHX alternatives--the helicopter, ABC compound helicopter, and tilt rotor--are compared with force costs for current aircraft systems, derivative systems, and additional purchases of AH-64, Army AHIP, and UH-60 aircraft in figures W-23 through W-33. These figures summarize one-time nonrecurring costs and annual recurring costs for all units in the light division CAB and heavy division CBAA including the TAMC which supports each brigade. The TAMC units are included in order to capture the effect of cost savings due to fewer maintenance personnel attributable to LHX commonality. Also shown is the aircraft portion of total TOE nonrecurring and recurring costs and 20-year force costs for each scenario. The delta factor shown reflects the estimated increase (or decrease) in total 20-year force cost which results from employing LHX aircraft as opposed to the other alternative system. Figures W-23 through W-28 provide comparisons for the CAB and figures W-29 through W-33 address comparisons for the CBAA.

(b) (U) Current aircraft include AH-1, OH-58, and UH-1 as currently configured. Analysis of costs for current aircraft systems with those for LHX aircraft are provided only to serve as a point of departure for more meaningful comparisons which follow. Current systems and LHX aircraft are by no means equally effective. As shown in figure W-22, 20-year force costs for the three LHX alternatives in the CAB are estimated to be about 29 percent to 34 percent higher than those for current aircraft systems.

(c) (U) Figures W-24, W-25, and W-26 compare the three LHX alternatives with certain derivative aircraft systems in the CAB which could be improved to provide, to the greatest extent possible, "LHX capability." These aircraft were costed as equipped with LHX MEP, engines, weapons, and comparable airframe major dynamic components, but neither the concept feasibility nor technical capability of each derivative is addressed. As shown in figure W-23, force costs for the LHX helicopter are lower than those for all derivatives shown except the OH-58EX and OH-58FX. Figure W-23 shows that the ABC compound, for which force costs are the highest of the three LHX alternatives,

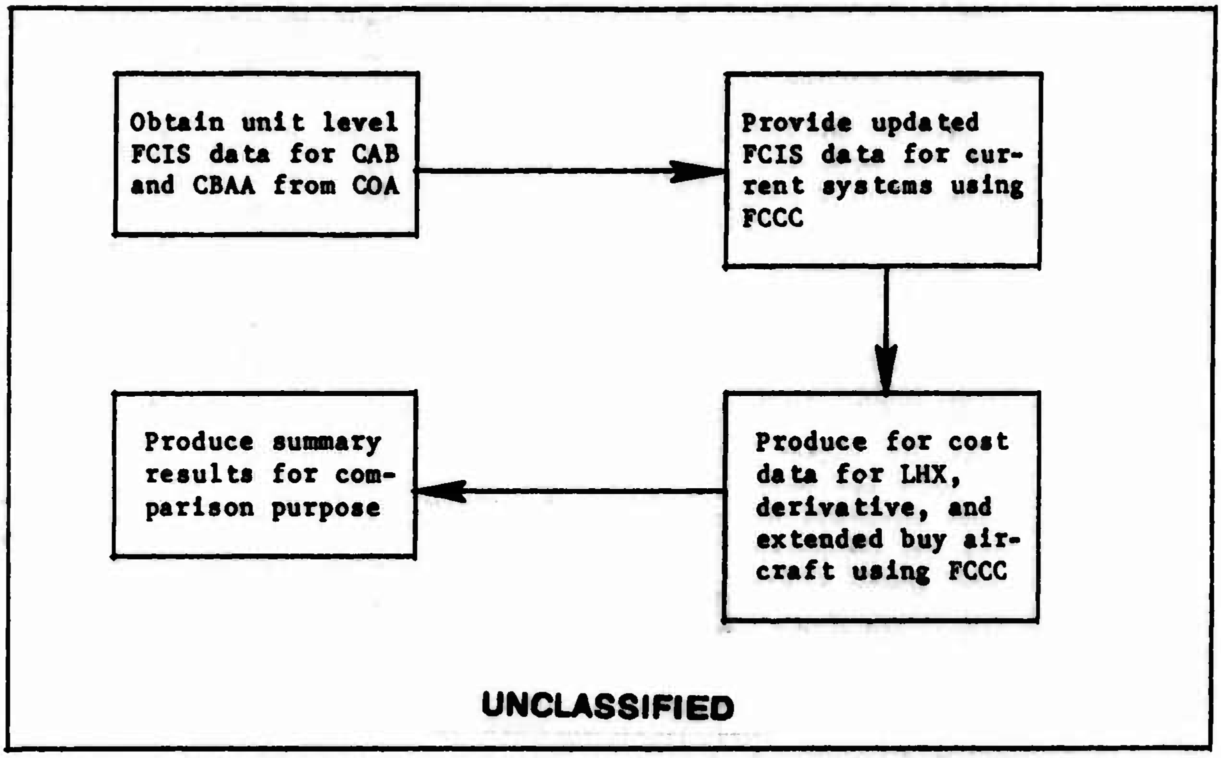

Figure W-19. (U) LHX TOA force cost methodology.

TOE:	Light Infantry Division Units: CAB, TOE 01-105J400, and TAMC, TOE 55-428J400. Heavy Division Units: CBAA, TOE 17-201J410, and TAMC, TOE 55-427J410.
Aircraft substitution:	One LHX for AH-1, OH-58, or UH-1 except in Attack Helicopter Battalion, CAB, where 21 LHX's replace 13 OH-58's and 21 AH-1's. LHX aircraft will complement AH-64, AHIP, and UH-60 aircraft but not replace these aircraft.
Weapons and ammunition:	LHX-SCAT aircraft will fire one live HELLFIRE and one live Stinger per company per year for training purposes. Also, 1,120 rounds of 30mm ammunition per aircraft per year.
Personnel savings:	No reduction in crewmembers; however, some maintenance personnel reduction is experienced due to LHX commonality. See annex I for more details on maintenance personnel reductions due to LHX fleet.
Cost/effectiveness comparisons:	No equal effectiveness assumptions are made in these force cost comparisons. Cost effectiveness will be addressed in a subsequent report, the LHX Cost and Operational Effectiveness Analysis (COEA).
Cost data sources:	TOE force cost data was obtained from the FCIS, Office of the Comptroller of the Army. LHX, derivative, AH-64, AHIP, and UH-60 force cost data was also obtained using FCIS based upon system costs obtained from the LHX system costs obtained from the LHX TOD and AVSCOM PM offices.

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Figure W-20. (U) Assumptions and data sources.

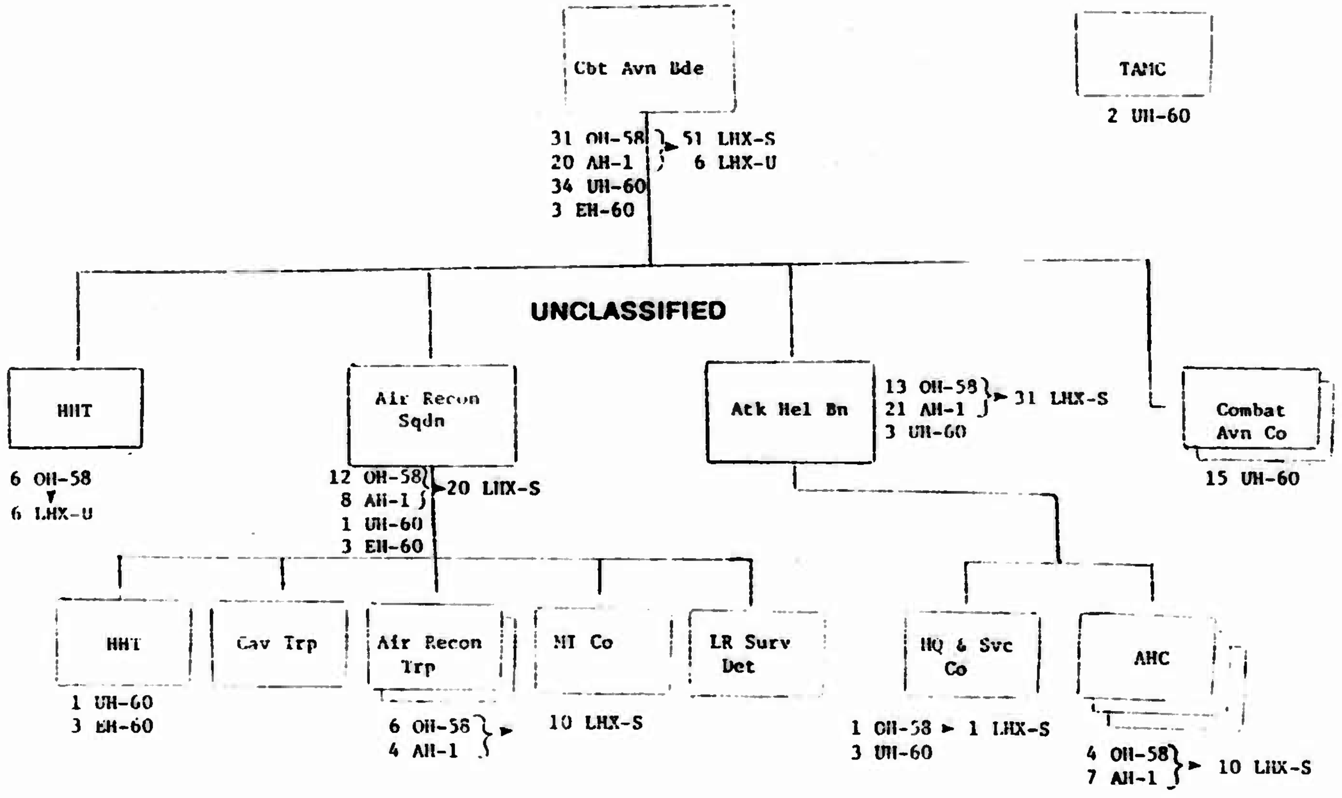

Figure W-21. (U) Proposed LHX replacement strategy in combat aviation brigade, light division.

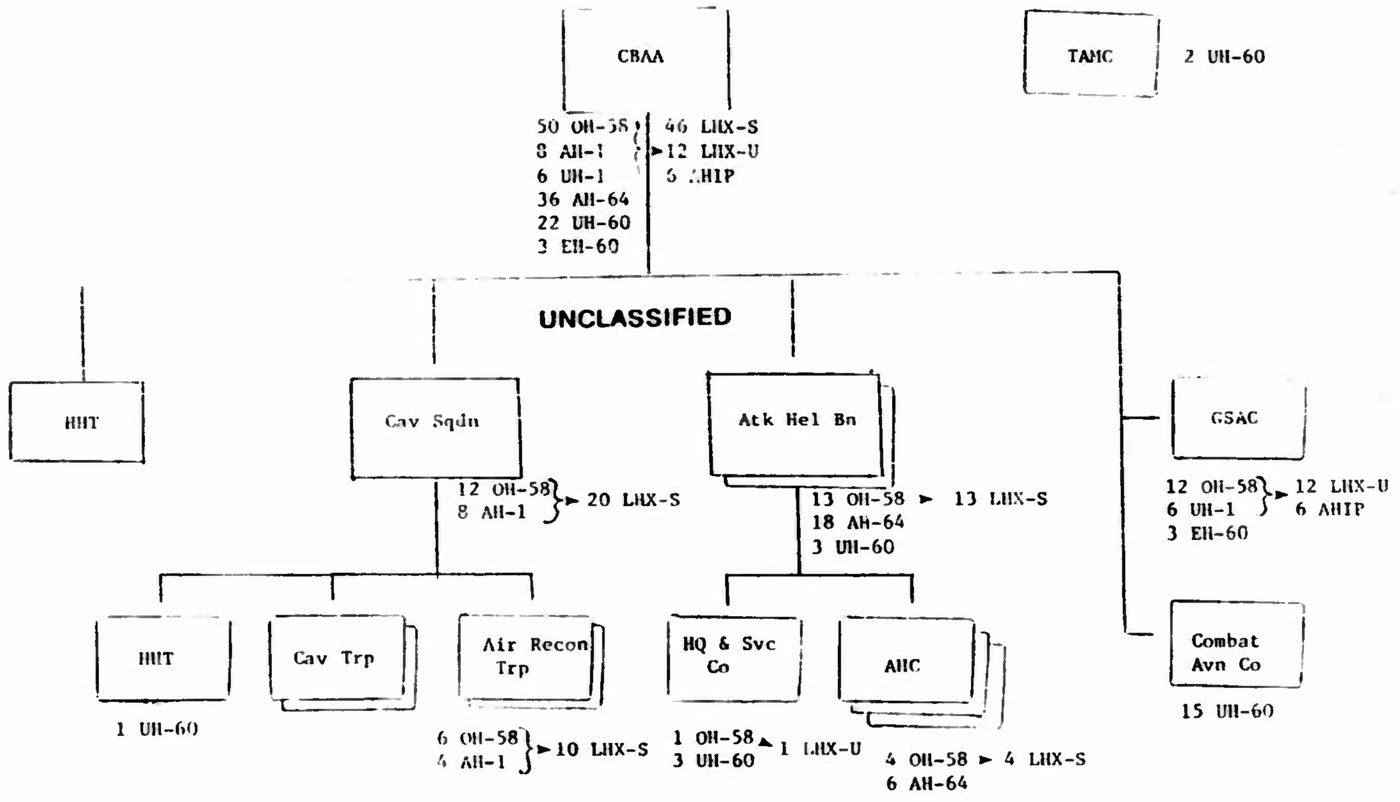

Figure W-22. (U) Proposed LHX replacement strategy in cavalry brigade air attack (CBAA), heavy division.

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	904	113	758	39	3,164	
Current aircraft	482	99	335	23	2,462	
Delta	422	14	423	16	702	0.29
LHX ABC-C	970	117	823	42	3,310	
Current aircraft	482	99	335	23	2,462	
Delta	488	18	488	19	848	0.34
LHX tilt rotor	955	116	809	42	3,275	
Current aircraft	482	99	335	23	2,462	
Delta	473	17	474	19	813	0.33

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-23. (U) Force cost comparison in CAB & TAMC (light division) LHX and current systems (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	904	113	758	39	3,164	
Derivative (AH-64X & UH-60X)	1,028	127	881	51	3,568	
Delta	-124	-14	-123	-12	-404	-0.11
LHX helicopter	904	113	758	39	3,164	
Derivative (OH-58EX & OH-58FX)	787	108	640	32	2,947	
Delta	117	5	118	7	217	0.07
LHX helicopter	904	113	758	39	3,164	
Derivative (AH-1X & UH-1X)	875	122	729	46	3,315	
Delta	29	-9	29	-7	-151	-0.05
LHX helicopter	904	113	758	39	3,164	
Derivative (AS-75 & US-75)	934	115	787	39	3,234	
Delta	-30	-2	-29	0	-70	-0.02
LHX helicopter	904	113	758	39	3,164	
Derivative (AH-129X & US-75)	921	123	774	47	3,381	
Delta	-17	-10	-16	-8	-217	-0.06

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-24. (U) Force cost comparison in CAB & TAMC (light division) LHX helicopter and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX ABC-C	970	117	823	42	3,310	
Derivative (AH-64X & UH-60X)	1,028	127	881	51	3,568	
Delta	-58	-10	-58	-9	-258	-0.07
LHX ABC-C	970	117	823	42	3,310	
Derivative (OH-58EX & OH-58FX)	787	108	640	32	2,947	
Delta	183	9	183	10	363	0.12
LHX ABC-C	970	117	823	42	3,310	
Derivative (AH-1X & UH-1X)	875	122	729	46	3,315	
Delta	95	-5	94	-4	-5	0.00
LHX ABC-C	970	117	823	42	3,310	
Derivative (AS-75 & US-75)	934	115	787	39	3,234	
Delta	36	2	36	3	76	0.02
LHX ABC-C	970	117	823	42	3,310	
Derivative (AH-129X & US-75)	921	123	774	47	3,381	
Delta	49	-6	49	-5	-17	-0.02

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-25. (U) Force cost comparison in CAB & TAMC (light division) LHX ABC-C and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX tilt rotor	955	116	809	42	3,275	
Derivative (AH-64X & UH-60X)	1,028	127	881	51	3,568	
Delta	-73	-11	-72	-9	-293	-0.08
LHX tilt rotor	955	116	809	42	3,275	
Derivative (OH-58EX & OH-58FX)	787	108	640	32	2,947	
Delta	168	8	169	10	328	0.11
LHX tilt rotor	955	116	809	42	3,275	
Derivative (AH-1X & UH-1X)	875	122	729	46	3,315	
Delta	80	-6	80	-4	-40	-0.01
LHX tilt rotor	955	116	809	42	3,275	
Derivative (AS-75 & US-75)	934	115	787	39	3,234	
Delta	21	1	22	3	41	0.01
LHX tilt rotor	955	116	809	42	3,275	
Derivative (AH-129X & US-75)	921	123	774	47	3,381	
Delta	34	-7	35	-5	-106	-0.03

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-26. (U) Force cost comparison in CAB & TAMC (light division) LHX tilt rotor and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	904	113	758	39	3,164	
Ext buy (AH-64, AHIP, & UH-60)	751	114	604	39	3,031	
Delta	153	-1	154	0	133	0.04
LHX ABC-C	970	117	823	42	3,310	
Ext buy (AH-64, AHIP, & UH-60)	751	114	604	39	3,031	
Delta	219	3	219	3	279	0.09
LHX tilt rotor	955	116	809	42	3,275	
Ext buy (AH-64, AHIP, & UH-60)	751	114	604	39	3,031	
Delta	204	2	205	3	244	0.08

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-27. (U) Force cost comparison in CAB & TAMC (light division) LHX and extended procurement (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	904	113	758	39	3,164	
LHX ABC-C	970	117	823	42	3,310	
Delta	-66	-4	-65	-3	-146	-0.04
LHX helicopter	904	113	758	39	3,164	
LHX tilt rotor	955	116	809	42	3,275	
Delta	-51	-3	-51	-3	-111	-0.03
LHX ABC-C	970	117	823	42	3,310	
LHX tilt rotor	955	116	809	42	3,275	
Delta	15	1	14	0	35	0.01

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-28. (U) Force cost comparison in CAB & TAMC (light division) LHX (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	1,277	136	1,031	56	3,997	
Current aircraft	817	117	570	37	3,157	
Delta	460	19	461	19	840	0.27
LHX ABC-C	1,344	140	1,098	59	4,144	
Current aircraft	817	117	570	37	3,157	
Delta	527	23	528	22	987	0.31
LHX tilt rotor	1,329	138	1,083	59	4,089	
Current aircraft	817	117	570	37	3,157	
Delta	512	21	513	22	932	0.30

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-29. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX and current systems (FY 84$, millions).

	TOE Cost		A/C Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	1,277	136	1,031	56	3,997	
Derivative (AH-64X & UH-60X)	1,402	148	1,156	69	4,362	
Delta	-125	-12	-125	-13	-365	-0.08
LHX helicopter	1,277	136	1,031	56	3,997	
Derivative (OH-58EX & OH-58FX)	1,161	129	914	49	3,741	
Delta	116	7	117	7	256	0.07
LHX helicopter	1,277	136	1,031	56	3,997	
Derivative (AH-1X & UH-1X)	1,248	142	1,001	62	4,088	
Delta	29	-6	30	-6	-91	-0.02
LHX helicopter	1,277	136	1,031	56	3,997	
Derivative (AS-75 & US-75)	1,307	136	1,061	57	4,027	
Delta	-30	0	-30	-1	-30	-0.01
LHX helicopter	1,277	136	1,031	56	3,997	
Derivative (AH-129X & US-75)	1,295	143	1,049	63	4,155	
Delta	-18	-7	-18	-7	-158	-0.04

NOTES: Definitions for above terms are as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-30. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX helicopter and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX ABC-C	1,344	140	1,098	59	4,144	
Derivative (AH-64X & UH-60X)	1,402	148	1,156	69	4,362	
Delta	-58	-8	-58	-10	-218	-0.05
LHX ABC-C	1,344	140	1,098	59	4,144	
Derivative (OH-58EX & OH-58FX)	1,161	129	914	49	3,741	
Delta	183	11	184	10	403	0.11
LHX ABC-C	1,344	140	1,098	59	4,144	
Derivative (AH-1X & UH-1X)	1,248	142	1,001	62	4,088	
Delta	96	-2	97	-3	56	0.01
LHX ABC-C	1,344	140	1,098	59	4,144	
Derivative (AS-75 & US-75)	1,307	136	1,061	57	4,027	
Delta	37	4	37	2	117	0.03
LHX ABC-C	1,344	140	1,098	59	4,144	
Derivative (AH-129X & US-75)	1,295	143	1,049	63	4,155	
Delta	49	-3	49	-4	-11	0.00

NOTES: Definitions for above terms ae as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-31. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX ABC-C and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX tilt rotor	1,329	138	1,083	59	4,089	
Derivative (AH-64X & UH-60X)	1,402	148	1,156	69	4,362	
Delta	-73	-10	-73	-10	-273	-0.06
LHX tilt rotor	1,329	138	1,083	59	4,089	
Derivative (OH-58EX & OH-58FXO	1,161	129	914	49	3,741	
Delta	168	9	169	10	348	0.09
LHX tilt rotor	1,329	138	1,083	59	4,089	
Derivative (AH-1X & UH-1X)	1,248	142	1,001	62	4,088	
Delta	81	-4	82	-3	1	0.00
LHX tilt rotor	1,329	138	1,083	59	4,089	
Derivative (AS-75 & US-75)	1,307	136	1,061	57	4,027	
Delta	22	2	22	2	62	0.02
LHX tilt rotor	1,329	138	1,083	59	4,089	
Derivative (AH-129X & US-75)	1,295	143	1,049	63	4,155	
Delta	34	-5	34	-4	-66	-0.02

NOTES: Definitions for above terms ae as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-32. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX tilt rotor and derivative (FY 84$, millions).

	TOE Cost		Aircraft Cost		20-Year	Delta
	Nonrec	Rec	Nonrec	Rec	Force Cost	Factor
LHX helicopter	1,277	136	1,031	56	3,997	
Extended buy (AH-64, AHIP, and UH-60)	1,030	130	784	50	3,630	
Delta	247	6	247	6	367	0.10
LHX ABC-C	1,344	140	1,098	59	4,144	
Extended buy (AH-64, AHIP, and UH-60)	1,030	130	784	50	3,630	
Delta	314	10	314	9	514	0.14
LHX tilt rotor	1,329	138	1,083	59	4,089	
Extended buy (AH-64, AHIP, and UH-60)	1,030	130	784	50	3,630	
Delta	299	8	299	9	459	0.13

NOTES: Definitions for above terms ae as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-33. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX and extended procurement (FY 84$, millions).

ranges from 7 percent less to 12 percent higher than force costs for derivative aircraft. Figure W-26 shows that force costs for the LHX tilt rotor are less than those for derivative aircraft in three of the five derivative cases.

(d) (U) Figure W-27 compares LHX alternatives with an extended buy of AH-64, AHIP, and UH-60 aircraft. In this case, current aircraft systems are replaced by additional AH-64, AHIP, and UH-60 aircraft. None of these aircraft would be supplied by current Army purchase plans, but would require a purchase of additional aircraft. Also, force costs for these aircraft are as currently configured and are not necessarily "LHX capable." As shown, LHX force costs range from 4 percent to 9 percent higher than those for an extended buy of AH-64, AHIP, and UH-60 aircraft.

(e) (U) Figures W-29 through W-34 address force costs in the CBAA, heavy division, using the same scenarios as those in figures W-22 through W-27.

W-6. (U) FINDINGS AND CONCLUSIONS.

a. (U) TOD LCC. The analysis reveals that the helicopter is the least costly alternative in both investment and O&S costs. The helicopter was followed in order by the compound helicopter, ABC, tilt rotor, and ABC compound configurations. This ordering applies to either two-crew or one-crew aircraft.

b. (U) Force Costs. The helicopter was the least costly in 20-year force costs of the three LHX alternatives considered in the force cost analysis. The helicopter was followed by the tilt rotor and ABC compound configurations.

	TOE Cost Nonrec	TOE Cost Rec	Aircraft Cost Nonrec	Aircraft Cost Rec	20-Year Force Cost	Delta Factor
LHX helicopter	1,277	136	1,031	56	3,997	
LHX ABC-C	1,344	140	1,098	59	4,144	
Delta	-67	-4	-67	-3	-147	-0.04
LHX helicopter	1,277	136	1,031	56	3,997	
LHX tilt rotor	1,329	138	1,083	59	4,089	
Delta	-52	-2	-52	-3	-92	-0.02
LHX ABC-C	1,344	140	1,098	59	4,144	
LHX tilt rotor	1,329	138	1,083	59	4,089	
Delta	15	2	15	0	55	0.01

NOTES: Definitions for above terms ae as follows: TOE cost - These costs show one-time nonrecurring and annual recurring costs required to activate and sustain the brigade and transportation aircraft maintenance (TAMC) for the division shown in CONUS with full TOE equipment and full TOE trained strength. Aircraft cost - That portion of TOE force cost which is attributable to aircraft. 20-year force cost - Obtained by adding TOE nonrecurring cost to the product of recurring cost times 20. Delta factor - A factor which reflects the additional 20 year force cost impact to the unit which results by employing the force with the aircraft system shown on the first line of each subset as compared to the aircraft system shown on the second line.

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Figure W-34. (U) Force cost comparison in CBAA & TAMC (heavy division) LHX (FY 84$, millions).

ANNEX I TO APPENDIX W

REFERENCES (U)

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ANNEX I TO APPENDIX W - REFERENCES (U)

W-I-1. US Army Aviation Systems Command, Family of Light Rotorcraft (LHX) Trade-Off Determination, Cost, Section L, St. Louis, MO, January 1984.

W-I-2. US Army Aviation Systems Command, Family of Light Rotorcraft (LHX) Trade-Off Determination, Weapons, Section G, St. Louis, MO, October 1983.

W-I-3. Office of the Comptroller of the Army, Army Force Planning Cost Handbook (AFPCH), Washington, DC, November 1982.

W-I-4. Department of the Army, Research and Development Cost Guide, DA Pamphlet 11-2, Washington, DC, May 1986.

W-I-5. Department of the Army, Investment Cost Guide, DA Pamphlet 11-3, Washington, DC, April 1976.

W-I-6. Department of the Army, Operating and Support Cost Guide, DA Pamphlet 11-4, Washington, DC, April 1976.

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ANNEX II TO APPENDIX W

COST DATA (U)

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Technical Characteristic and Flyaway Cost	TOD Baseline[b]	500 fpm VROC Performance[a]					
		95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Dash speed @ 4,000'/95°F (kt)	181	178	186	193	182	190	199
Cruise speed @ 4,000'/95°F (kt)	164	163	169	177	166	174	181
HOGE @ .95 IRP, 4,000'/95°F (lb)	9,873	9,547	10,873	12,524	10,105	11,528	13,314
Engine drive system rating (shaft horse power)	1,917	1,838	2,155	2,563	1,973	2,321	2,413
Empty weight (lb)	6,402	6,336	6,718	7,208	6,446	6,852	7,372
Mission gross weight (lb)	9,097	9,012	9,494	10,118	9,153	9,671	10,336
Average flyaway cost for 1,000 units (FY 84 dollars, millions)							
Unit nonrecurring	.100	.100	.104	.108	.101	.105	.111
Recurring:							
Airframe	1.760	1.744	1.854	1.993	1.771	1.886	2.032
Engine	.600	.576	.672	.798	.617	.722	.861
MEP	3.538	3.538	3.538	3.538	3.538	3.538	3.538
Weapons	.324	.324	.324	.324	.324	.324	.324
Other	.769	.764	.789	.821	.772	.799	.833
Total flyaway	7.091	7.046	7.281	7.582	7.123	7.374	7.699

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F; HOGE - hover-out-of-ground effect, (i.e., weight shown is maximum at which aircraft will HOGE at .95 IRP, 4,000'/95°F condition).

a. These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

b. VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95° is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

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Figure W-II-1. (U) Altitude and IRP performance excursions - configuration: helicopter SCAT.

Technical Characteristic and Flyaway Cost	TOD Baseline[b]	500 fpm VROC Performance[a]					
		95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Dash speed @ 4,000'/95°F (kt)	200	197	202	207	201	206	209
Cruise speed @ 4,000'/95°F (kt)	185	181	186	192	186	190	195
HOGE @ .95 IRP, 4,000'/95°F (lb)	10,997	10,650	12,191	14,257	11,270	12,919	15,228
Engine drive system rating (shaft horse power)	2,382	2,340	2,680	3,228	2,522	2,895	3,514
Empty weight (lb)	6,402	7,370	7,877	8,599	7,534	8,077	8,906
Mission gross weight (lb)	9,097	10,302	10,881	11,762	10,512	11,133	12,134
Average flyaway cost for 1,000 units (FY 84 dollars, millions)							
Unit nonrecurring	.108	.107	.112	.118	.109	.114	.122
Recurring:							
Airframe	2.053	2.044	2.181	2.373	2.083	2.228	2.446
Engine	.741	.728	.833	1.010	.784	.902	1.105
MEP	3.538	3.538	3.538	3.538	3.538	3.538	3.538
Weapons	.324	.324	.324	.324	.324	.324	.324
Other	.823	.820	.849	.894	.831	.863	.914
Total flyaway	7.587	7.561	7.837	8.257	7.669	7.969	8.449

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F; HOGE - hover-out-of-ground effect, (i.e., weight shown is maximum at which aircraft will HOGE at .95 IRP, 4,000'/95°F condition).

a. These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

b. VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95° is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

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Figure W-II-2. (U) Altitude and IRP performance excursions - configuration: compound helicopter SCAT.

Technical Characteristic and Flyaway Cost	TOD Baseline^b	500 fpm VROC Performance^a					
		95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Dash speed @ 4,000'/95°F (kt)	187	185	193	202	189	197	206
Cruise speed @ 4,000'/95°F (kt)	171	169	177	185	172	181	191
HOGE @ .95 IRP, 4,000'/95°F (lb)	11,059	10,708	12,090	14,404	11,385	12,890	15,404
Engine drive system rating (shaft horse power)	2,262	2,175	2,528	3,097	2,346	2,734	3,361
Empty weight (lb)	7,388	7,302	7,656	8,481	7,464	7,847	8,729
Mission gross weight (lb)	10,292	10,184	10,642	11,653	10,389	10,889	11,968
Average flyaway cost for 1,000 units (millions of FY 84$)							
Unit nonrecurring	.112	.106	.110	.116	.108	.112	.119
Recurring:							
Airframe	2.300	2.081	2.179	2.367	2.120	2.226	2.428
Engine	.832	.677	.787	1.136	.730	.851	1.218
MEP	3.538	3.538	3.538	3.538	3.538	3.538	3.538
Weapons	.324	.324	.324	.324	.324	.324	.324
Other	.864	.818	.843	.909	.829	.857	.926
Total flyaway	7.970	7.544	7.781	8.390	7.649	7.908	8.553

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F; HOGE - hover-out-of-ground effect, (i.e., weight shown is maximum at which aircraft will HOGE at .95 IRP, 4,000'/95°F condition).

a. These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

b. VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95° is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

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Figure W-II-3. (U) Altitude and IRP performance excursions - configuration: ABC helicopter SCAT.

Technical Characteristic and Flyaway Cost	TOD Baseline[b]	500 fpm VROC Performance[a] 95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Dash speed @ 4,000'/95°F (kt)	204	201	211	219	207	214	222
Cruise speed @ 4,000'/95°F (kt)	186	182	193	202	188	199	208
HOGE @ .95 IRP, 4,000'/95°F (lb)	11,974	11,484	13,560	15,668	12,276	14,433	16,735
Engine drive system rating (shaft horse power)	2,678	2,538	3,079	3,675	2,773	3,344	4,004
Empty weight (lb)	8,069	7,928	8,735	9,354	8,175	8,994	9,670
Mission gross weight (lb)	11,182	11,003	11,991	12,783	11,343	12,319	13,176
Average flyaway cost for 1,000 units (millions of FY 84$)							
Unit nonrecurring	.112	.111	.117	.124	.113	.120	.127
Recurring:							
Airframe	2.300	2.266	2.445	2.613	2.326	2.508	2.688
Engine	.832	.789	1.130	1.130	.863	1.214	1.425
MEP	3.538	3.538	3.538	3.538	3.538	3.538	3.538
Weapons	.324	.324	.324	.324	.324	.324	.324
Other	.864	.855	.918	.961	.811	.936	.983
Total flyaway	7.970	7.883	8.472	8.878	8.035	8.640	9.085

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F; HOGE - hover-out-of-ground effect, (i.e., weight shown is maximum at which aircraft will HOGE at .95 IRP, 4,000'/95°F condition).

a. These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

b. VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95° is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

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Figure W-II-4. (U) Altitude and IRP performance excursions - configuration: compound ABC SCAT.

Technical Characteristic and Flyaway Cost	TOD Baseline[b]	500 fpm VROC Performance[a]					
		95% IRP 4K'/95°	95% IRP 6K'/95°	95% IRP 8K'/95°	90% IRP 4K'/95°	90% IRP 6K'/95°	90% IRP 8K'/95°
Dash speed @ 4,000'/95°F (kt)	252						
Cruise speed @ 4,000'/95°F (kt)	246						
HOGE @ .95 IRP, 4,000'/95°F (lb)	11,332						
Engine drive system rating (shaft horse power)	2,480	2,439	2,861	3,433	2,620	3,088	3,739
Empty weight (lb)	7,953	7,922	8,405	9,135	8,067	8,608	9,449
Mission gross weight (lb)	10,834	10,798	11,381	12,254	10,981	11,631	12,632
Average flyaway cost for 1,000 units (millions of FY 84$)							
Unit nonrecurring	.111	.110	.115	.122	.112	.118	.125
Recurring:							
Airframe	2.126	2.141	2.268	2.457	2.174	2.314	2.530
Engine	.800	.758	.891	1.078	.816	.964	1.181
MEP	3.538	3.538	3.538	3.538	3.538	3.538	3.538
Weapons	.359	.359	.359	.359	.359	.359	.359
Other	.842	.840	.872	.917	.851	.886	.939
Total flyaway	7.776	7.746	8.043	8.471	7.850	8.179	8.670

NOTE: Abbreviations are as follows: TOD - trade-off determination; VROC - vertical rate of climb; IRP - intermediate rate of power; XK'/95° - pressure altitude in thousands of feet at 95°F; HOGE - hover-out-of-ground effect, (i.e., weight shown is maximum at which aircraft will HOGE at .95 IRP, 4,000'/95°F condition).

a. These excursions compare costs for varying conditions of IRP and altitude/temperature where VROC of 500 fpm is constant, i.e., aircraft climb performance will meet the 500-fpm requirement for each IRP and altitude/temperature condition shown.

b. VROC performance for baseline SCAT alternatives under conditions of 95% IRP, 4,000'/95° is as follows: 712 for helicopter, 779 for compound helicopter, 713 for ABC, 795 for compound ABC, and 648 for tilt rotor.

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Figure W-II-5. (U) Altitude and IRP performance excursions - configuration: tilt rotor.

Technical Characteristic and Flyaway Cost	Two-Crew Aircraft			One-Crew Aircraft		
	Baseline 1,288 lb MEP	1,108 lb MEP	790 lb MEP	Baseline 1,282 lb MEP	1,102 lb MEP	784 lb MEP
Gross weight (lb)	9,097	8,042	7,297	8,252	7,239	6,470
Empty weight (lb)	6,402	5,803	5,128	5,879	5,323	5,630
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.100	.097	.088	.098	.094	.076
Recurring:						
Airframe	1.760	1.641	1.540	1.614	1.505	1.398
Engine	.600	.547	.480	.600	.504	.431
MEP	3.538	3.224	2.424	3.510	3.197	2.397
Weapons	.324	.149	.267	.324	.149	.267
Other	.769	.689	.585	.747	.664	.558
Total flyaway	7.091	6.347	5.384	6.893	6.113	5.127

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Figure W-II-6. (U) Weight excursions for MEP, payload, and VROC configuration: helicopter SCAT.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 945 lb MEP	786 lb MEP	758 lb MEP	Baseline 945 lb MEP	786 lb MEP	758 lb MEP
Gross weight (lb)	9,744	8,725	7,628	9,123	7,966	6,763
Empty weight (lb)	6,320	5,721	5,355	6,002	5,433	5,042
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.093	.082	.078	.091	.079	.075
Recurring:						
Airframe	1.811	1.688	1.594	1.719	1.605	1.504
Engine	.600	.547	.480	.600	.504	.431
MEP	2.761	2.217	2.124	2.761	2.217	2.124
Weapons	.055	.055	.055	.055	.055	.055
Other	.607	.527	.498	.596	.512	.482
Total flyaway	5.927	5.116	4.829	5.822	4.972	4.671

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Figure W-II-7. (U) Weight excursions for MEP, payload, and VROC configuration: helicopter Utility.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 1,288 lb MEP	1,108 lb MEP	790 lb MEP	Baseline 1,282 lb MEP	1,102 lb MEP	784 lb MEP
Gross weight (lb)	10,355	9,175	8,454	9,500	8,184	7,471
Empty weight (lb)	7,424	6,737	6,079	6,901	6,095	5,444
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.108	.104	.087	.106	.100	.083
Recurring:						
Airframe	2.053	1.916	1.821	1.911	1.742	1.646
Engine	.741	.674	.624	.741	.614	.567
MEP	3.538	3.224	2.424	3.510	3.197	2.397
Weapons	.324	.149	.267	.324	.149	.267
Other	.823	.739	.638	.802	.707	.606
Total flyaway	7.587	6.806	5.861	7.394	6.509	5.566

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Figure W-II-8. (U) Weight excursions for MEP, payload, and VROC configuration: compound helicopter SCAT.

Technical Characteristic and Flyaway Cost	Two-Crew Aircraft			One-Crew Aircraft		
	Baseline 945 lb MEP	786 lb MEP	758 lb MEP	Baseline 945 lb MEP	786 lb MEP	758 lb MEP
Gross weight (lb)	10,878	9,750	8,970	10,342	8,752	7,985
Empty weight (lb)	7,332	6,644	6,309	7,077	6,248	5,919
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.102	.090	.087	.101	.086	.084
Recurring:						
Airframe	2.102	1.960	1.876	2.028	1.852	1.767
Engine	.741	6.674	.624	.741	.614	.567
MEP	2.761	2.217	2.124	2.761	2.217	2.124
Weapons	.055	.055	.055	.055	.055	.055
Other	.658	.574	.548	.650	.554	.529
Total flyaway	6.419	5.570	5.314	6.336	5.376	5.126

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Figure W-II-9. (U) Weight excursions for MEP, payload, and VROC configuration: compound helicopter Utility.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 1,288 lb MEP	1,108 lb MEP	784 lb MEP	Baseline 1,282 lb MEP	1,102 lb MEP	784 lb MEP
Gross weight (lb)	10,292	8,915	8,168	9,325	7,976	7,198
Empty weight (lb)	7,388	6,520	5,839	6,758	5,925	5,220
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.107	.102	.084	.105	.098	.080
Recurring:						
Airframe	2.113	1.917	1.808	1.936	1.747	1.630
Engine	.704	.600	.555	.704	.547	.493
MEP	3.538	3.224	2.424	3.510	3.197	2.397
Weapons	.324	.149	.267	.324	.149	.267
Other	.825	.730	.628	.800	.699	.594
Total flyaway	7.611	6.722	5.766	7.379	6.437	5.461

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Figure W-II-10. (U) Weight excursions for MEP, payload, and VROC configuration: ABC helicopter SCAT.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 945 lb MEP	786 lb MEP	758 lb MEP	Baseline 945 lb MEP	786 lb MEP	758 lb MEP
Gross weight (lb)	10,954	9,295	8,520	10,249	8,370	7,460
Empty weight (lb)	7,319	6,434	6,076	6,913	6,043	5,654
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.100	.087	.084	.099	.083	.080
Recurring:						
Airframe	2.164	1.961	1.863	2.043	1.844	1.737
Engine	.704	.600	.555	.704	.547	.493
MEP	2.761	2.217	2.124	2.761	2.217	2.124
Weapons	.055	.055	.055	.055	.055	.055
Other	.661	.566	.539	.647	.546	.517
Total flyaway	6.445	5.486	5.220	6.309	5.292	5.006

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Figure W-II-11. (U) Weight excursions for MEP, payload, and VROC configuration: ABC helicopter Utility.

Technical Characteristic and Flyaway Cost	Two-Crew Aircraft			One-Crew Aircraft		
	Baseline 1,288 lb MEP	1,108 lb MEP	784 lb MEP	Baseline 1,282 lb MEP	1,102 lb MEP	784 lb MEP
Gross weight (lb)	11,182	9,779	8,899	10,236	8,777	7,785
Empty weight (lb)	8,069	7,184	6,400	7,459	6,532	5,660
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.112	.107	.089	.110	.103	.084
Recurring:						
Airframe	2.300	2.107	1.975	2.133	1.925	1.767
Engine	.832	.722	.645	.832	.673	.569
MEP	3.538	3.224	2.424	3.510	3.197	2.397
Weapons	.324	.149	.267	.324	.149	.267
Other	.864	.767	.658	.837	.736	.621
Total flyaway	7.970	7.076	6.058	1.748	6.783	5.705

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Figure W-II-12. (U) Weight excursions for MEP, payload, and VROC configuration: compound ABC SCAT.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 945 lb MEP	786 lb MEP	758 lb MEP	Baseline 945 lb MEP	786 lb MEP	758 lb MEP
Gross weight (lb)	11,838	10,268	9,200	11,183	9,414	8,010
Empty weight (lb)	8,004	7,105	6,637	7,667	6,714	6,143
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.107	.094	.090	.100	.090	.085
Recurring:						
Airframe	2.352	2.152	2.029	2.252	2.037	1.886
Engine	.832	.722	.645	.832	.673	.569
MEP	2.761	2.217	2.124	2.761	2.217	2.124
Weapons	.055	.055	.055	.055	.055	.055
Other	.698	.604	.571	.688	.585	.546
Total flyaway	6.805	5.844	5.514	6.694	5.657	5.265

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Figure W-II-13. (U) Weight excursions for MEP, payload, and VROC configuration: compound ABC Utility.

	Two-Crew Aircraft			One-Crew Aircraft		
Technical Characteristic and Flyaway Cost	Baseline 1,288 lb MEP	1,108 lb MEP	784 lb MEP	Baseline 1,282 lb MEP	1,102 lb MEP	784 lb MEP
Gross weight (lb)	10,767	9,608	8,958	10,049	8,772	8,109
Empty weight (lb)	7,863	7,203	6,602	7,480	6,686	6,078
Average flyaway cost for 1,000 units (FY 84 dollars, millions)						
Unit nonrecurring	.111	.106	.089	.110	.103	.086
Recurring:						
Airframe	2.126	2.002	1.923	2.025	1.862	1.785
Engine	.800	.678	.639	.800	.626	.583
MEP	3.538	3.224	2.424	3.510	3.197	2.397
Weapons	.359	.183	.288	.359	.183	.288
Other	.842	.754	.655	.827	.727	.627
Total flyaway	7.776	6.947	6.018	7.631	6.698	5.766

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Figure W-II-14. (U) Weight excursions for MEP, payload, and VROC configuration: tilt rotor SCAT.

APPENDIX X

COMMONALITY SUBSTUDY (U)

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APPENDIX X - COMMONALITY SUBSTUDY (U)

X-1. (U) PURPOSE. The effect of commonality on each of the design variants is compared for the following elements of analysis:

a. (U) Compare the effects of commonality options on business implications, military operations, and engineering implications.

b. (U) Determine actual values for the parameters of the commonality type and variants considered.

c. (U) Identify the design variants that incorporate commonality and meet performance requirements.

d. (U) Identify the design/variant with the best combination of performance and savings within the mandatory commonality constraints.

X-2. (U) BACKGROUND.

a. (U) LHX commonality options are based on three basic aircraft missions: attack, scout, and utility. The possible degree of commonality varies from three separate aircraft (attack, scout, utility) to a single combination of aircraft for all missions. The combination of scout and attack versions in a single "SCAT" aircraft allows a two-aircraft (SCAT, utility) degree of commonality. Such aircraft type combinations or commonality were compared to determine the best choice. That choice was the two-airframe option. Figure X-1 shows the comparison of commonality options. The business implications of the commonality basis are shown in figure X-2. Figure X-3 shows the military operation implications of the commonality basis. Finally, the engineering implications of the commonality basis are shown in figure X-4.

b. (U) The Systems Attributes Document (SAD) and Trade-off Determination (TOD) were completed for the Light Helicopter Family (LHX). As part of the LHX concept formulation package, the Trade-off Analysis (TOA) continues this examination of the effect of commonality.

(1) (U) Two aircraft types, scout-attack (SCAT) and utility, are involved.

(2) (U) Commonality variations include pure variants with no commonality, a scout-attack (SCAT) with utility derivative, a utility with SCAT derivative, and a combined SCAT/utility aircraft.

(3) (U) In each baseline design, the rotorcraft were designed so that the SCAT and utility versions would use maximum commonality. In general, such procedure resulted in common engines, rotors, and drive components but separate fuselages to accommodate the SCAT and utility mission functions. The design variants are:

COMMONALITY OPTIONS COMPARISON*

Three Separate Airframes	Two Separate Airframes	One Common Vehicle
Scout Attack Utility	SCAT Utility	
Common	Common	Common

. All vehicles
  . Substantial mission equipment and subsystems
. Attack and utility
  . Engines
  . Rotor system
  . Drive train
  . Transmission
	. Engines
	. Rotor system
	. Drive train
	. Transmission
	. Substantial mission equipment and subsystems
		. Airframe
		. Engines
		. Rotor system
		. Drive train
		. Transmission
		. Mission equipment and subsystems

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*Helicopter used for comparisons.

Figure X-1. (U) Comparison of commonality options.

Three Separate Airframes	Two Separate Airframes	One Common Airframe
	Advantages	
• Scout cost/flying hour unit flyaway cost less than SCAT.	• Provides extensive commonality. • Requires only one engine development program.	• Lowest development cost. • Lowest maintenance and pilot training. • Allows coincident SCAT/Utility IOC.
	Disadvantages	
• Highest development cost. • Requires two engine development programs. • Results in least commonality.	• Scout cost/flying hour and unit fly-away cost more than separate scout.	• Highest unit cost.

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Figure X-2. (U) Business implications of the commonality basis.

Three Separate Airframes	Two Separate Airframes	One Common Airframe
	Advantages	
• Vehicles optimized for specific missions. • Lowest fleet fuel consumption. • Scout and attack smaller and optimized for survivability.	• Flexibility in scout and attack missions. • Capablity for coincident target detection and engagement. • Attack surge capability by simply rearming all SCATs. • Commonality for improved sustainability/supportability.	• Most flexible mission loading alternatives. • Coincident target detection and engagement. • Maximum attack surge capability by rearming SCAT/Utility. • Maximum commonality for sustainment/supportability. • Requires only one training system.
	Disadvantages	
• Least flexible air vehicle for mission variations. • Requires largest training burden. • Less sustainable.	• Requires two training systems. • More fuel consumption than three separate vehicles.	• Highest fuel consumption option. • Side-by-side seating is a major detriment for attack missions. • Larger size results in less survivability.

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Figure X-3. (U) Military operation implications of the commonality basis.

Three Separate Airframes	Two Separate Airframes	One Common Airframe
	Advantages	
• Most optimized designs. • Provides lightest weight designs.	• Required only one rotor system - drive train design. • Results in highly maneuverable/agile SCAT.	• Requires only one design.
	Disadvantages	
• Larger design effort.	• Results in a slightly non-optimized SCAT and Utility design.	• Scout and attack have reduced maneuverability/agility/survivability. • Design not optimized to mission requirements. • Most difficult MEP/weapons integration. • Highest gross weight design, least fuel efficient.

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Figure X-4. (U) Engineering implications of the commonality basis.

(a) (U) Advanced helicopter.

(b) (U) Advancing blade concept (ABC).

(c) (U) Compound helicopter.

(d) (U) Compound ABC.

(e) (U) Tilt rotor.

(4) (U) Those operational characteristics analyzed for incorporation into the LHX are divided into three categories: (I) mandatory, characteristic; (II) mandatory, parameter negotiable; and (III) desired. (See figures X-5 and X-6.)

Z-3. (U) ASSUMPTIONS.

a. (U) Minimizing costs will make the selected LHX design concept affordable in large numbers. To achieve affordability, low production costs are necessary. In keeping with this objective and the Army Aviation Modernization Plan (AAMP), the goal is to minimize the cost of the LHX design selected. Reduced production costs result from the LHX-SCAT and LHX-Utility versions use of common rotors, engines, drive systems, and core mission avionics. Low operating cost with emphasis on reduced maintenance man-hours per flight hour at field maintenance levels is to be achieved.

b. (U) High reliability, availability, and maintainability (RAM) is to be achieved. To achieve the goal of RAM that will allow the LHX to operate under sustained combat with little or no required maintenance, the following commonality characteristics should be considered in the aircraft design:

(1) (U) Improve logistic supportability in a combat environment over that programed for the current fleet.

(2) (U) Reduce the quantity and complexity of test equipment and tools required for maintenance and repair.

(3) (U) Incorporate component concepts of commonality for--

(a) (U) Low manufacturing costs/high producibility.

(b) (U) Repairability.

(4) (U) Ensure that the achievement of commonality characteristics does not compromise performance criteria. The performance characteristics are shown in figure X-7.

(I) (U) Mandatory, characteristic. This is a characteristic which must be provided but the range of attainability may be unknown, undefined, or the combat developer is unable to provide a range of parameters.

(II) (U) Mandatory, parameter negotiable. This represents an area where preliminary concept exploration has resulted in definition of a critical need that can be stated in terms of a parameter baseline used for evaluation or in terms of variations from that baseline. Analysis of the baseline and variations would contribute to the TOA which, in conjunction with the best technical approach, would eventually result in requirements articulation.

(III) (U) Desired. These characteristics are those which are very desirable if they can be achieved within technology and cost constraints.

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Figure X-5. (U) Characteristics category definitions.

No.	Characteristic/ Criteria	I	II	III	Parameter
	SCAT/Utility variant commonality:				Baseline: Common components and common functional requirements as much as possible.
	a. Rotors	X			
	b. Drive system	X			
	c. Engines (Note 1)	X			a. Baseline: Twin engine ATE.
	d. Cockpit (integrated core avionics)		X		**UNCLASSIFIED**
	e. Landing gear		X		(Note: Common mission equipment as much as possible.)
	f. Mission equipment		X		
	g. Electrical subsystems	X			

NOTE 1. All configurations will explore the effects of one or more engines being inoperable.

Figure X-6. (U) Operational characteristics analyzed for the LHX.

No.	Requirement/ Criteria	I	II	III	Parameter
1	Self-deployable (ferry range)		X		a. Baseline: 740 NM (Northern route) plus reserve.
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2	Range		X		Consistent with mission profiles.
3	Endurance		X		Consistent with mission profiles.
4	100 percent intermediate rated power (IRP) speed		X		Baseline: 180-300 knots.
5	Vertical rate of climb (VROC) (SCAT, MGW, 4,000'/95°, 95% intermediate rated power (IRP) (see note)	X			a. NLT 500 fpm. b. Variance: NLT 500 fpm, 6,000', 8,000'/95°. c. Variance: 500 fpm, 4,000'/95° IRP.
6	VROC (utility variant, MGW 4,000'/95°, 95% IRP)	X			a. HOGE.

Figure X-7. (U) Performance characteristics.

d. (U) A review of the mission profiles, with the definitions and groupings, to determine the air vehicle requirements, shows that only a few missions drive the design weight. Figure X-8 lists the definitions and groupings. Figure X-9 includes a listing of missions that indicates payload, range, and takeoff requirements. The missions that normally drive the LHX design gross weight (range, endurance, and performance) are mission 16 for the SCAT and mission 35 for the utility. Aircraft fully capable of performing these missions can normally perform all other SCAT or utility missions at or below their design weight limitations. A detailed description of the SCAT and utility critical design missions is provided in figure X-10. The new development LHX commonality designs (baseline designs) are sized by the requirement to perform the utility mission 35, and the resulting commonality SCAT has a small excess VROC capability on mission 16.

All LHX designs shall have the capability to attain 500 feet per minute (FPM) vertical rate of climb (VROC), 4,000'/95° F at 95 percent intermediate rate power (IRP) at design gross weight. Missions are to be flown as follows:

Group I.

a. Mideast mission profiles 4,000'/95° F for all segments.

b. European mission profiles 2,000/70° F for all segments.

Group II.

a. Initial takeoff requirement may be reduced to hover-out-of-ground environment (HOGE) at 4,000'/95° F at 95 percent IRP at mission gross weight.

b. One-hundred percent IRP speed capability after 25 kilometers (km) must be greater than 150 knots true airspeed (KTAS) at specified cruise altitude.

c. VROC must be at least 500 FPM (at 95 percent IRP) at battle position.

Group III.

a. Initial takeoff requirements may be reduced to HOGE at 95 percent IRP sea level (95° F Mideast, 70° F European) at mission gross weight.

b. One hundred percent IRP speed capability after 25 km must be greater than 150 KTAS at specified cruise altitude.

c. VROC must be at 500 FPM (at 95 percent IRP) at battle position.

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Figure X-8. (U) Definitions of LHX mission profile groups.

SCAT				
Group	Theater	Mission	Mission Title	Criteria
I	Europe	4	Antipersonnel/ Materiel	500 FPM VROC at 4,000' (PA)/95° F, 95 percent IRP.
		3	Antiarmor	
		10	Suppression of Enemy Air Defense (SEAD)	
		23	Air-to-Air	
		24	Offensive Air	
		7	Security	
		9	Rear Area Combat Operations (RACO)	
		6	Reconnaissance	
	Mideast	12	Antiarmor	
		19	SEAD	
		25	Air-to-Air	
		26	Offensive Air	
		16	Security	
		18	RACO	
		15	Reconnaissance	
II	Europe	5	Special Operations Strike	HOGE at 4,000' (PA)/95° F, 95 percent IRP. 100 percent IRP after 25 km > 150 KTAS. 500 FPM VROC at BP.
		8	Deep Strike	
	Mideast	13	Antipersonnel/ Materiel	
		17	Deep Strike	
		14	Special Operations Strike	
III	Europe	11	Amphibious Assault	HOGE AT SL (PA) 95° F, 95 percent IRP. 100 percent IRP after 25 km > 150 KTAS. 500 FPM VROC at BP.
	Mideast	20	Amphibious Assault	

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Figure X-9. (U) LHX mission profile groupings.
(continued on next page)

UTILITY

Group	Theater	Mission	Mission Title	Criteria
I	Europe	28	Transport Communications Equipment	500 FPM VROC at 4,000' (PA)/95° F, 95 percent IRP.
		31	Team Insertion	
		1	C^2 Liaison	
		37	Courier	
		41	Combat Service Support for Missile Systems	
		40	Aerial Radiological Survey	
		38	Resupply	
		39	Search and Rescue	
	Mideast	45	Aerial Radiological Survey	
		30	Transport Communications Equipment	
		34	Team Insertion	
		46	Combat Service Support for Missile Systems	
II	Europe	21	Field Artillery Aerial Observer (FAAO)	HOGE at 4,000' (PA)/95° F, 95 percent IRP. 100 percent IRP after 25 km > 150 KTAS. 500 FPM VROC at BP.
		32	Special Operations Forces (SOF) Insertion/ Extraction Resupply	

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Figure X-9. (U) (Continued)

UTILITY

Group	Theater	Mission	Mission Title	Criteria
II	Mideast	22	FAAO	
		2	C^2 Liaison	
		42	Courier	
		44	Search and Rescue	
		43	Resupply	
		29	Communication Relay	
		35	SOF Insertion/Extraction Resupply	
III	Europe	33	Amphibious Assault	HOGE AT SL/95° F 95 percent IRP. 100 percent IRP after 25 km > 150 KTAS. 500 FPM VROC at BP.
	Mideast	36	Amphibious Assault	

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Figure X-9. (U) (concluded)

The 48 system mission profiles and the system attributes documents define the total LHX system requirements including the weapons systems, mission equipment, survivability, etc. In order to facilitate the preliminary design process, a subset of critical design missions expressed in engineering terms has been developed. These critical design missions define performance capabilities which must be met or exceeded. The 48 mission profiles should be considered in the design process according to the criteria in the definitions and groupings of LHX mission profiles. The critical design missions labeled 12A, 13A, 14A, 15A, 16A, 17A, and 18A have been developed from mission profiles 12 through 18, respectively. These are shown in figures X-11 through X-17.

a. Engineering Version. Mission profiles 12 through 18 are defined in engineering terms in the following figures. The A version of these profiles represent the engineering version of the graphical profiles included in the system mission profiles and are must-satisfy profiles.

b. LHX Mission Profiles. The contractor may convert the remaining LHX mission profiles into engineering mission profiles for any missions except 12 through 18. The following rules shall be used in this process:

(1) All nap-of-the-earth (NOE) flown at 40 knots.

(2) HOGE/NOE means half HOGE and half NOE.

(3) Aircraft refuels and rearms at every forward arming and refueling point (FARP) stop.

(4) V best range means 99 percent on the high-speed side.

(5) One minute at HOGE for each initial takeoff.

(6) Thirty minutes at V best endurance for reserve.

(7) All Mideast missions flown at 4,000'/95° F, except amphibious missions takeoff at SL/103° F and fly to 3,000'/91.5° F at midpoint. Alternate conditions of 6,000'/95° F and 8,000'/95° F may be considered for these missions.

(8) All European missions flown at 2,000'/70° F, except amphibious missions takeoff at SL/95° F and fly to 2,000'/70° F at midpoint.

(9) Self-deployment missions takeoff conventional takeoff and landing (CTOL) from SL/STD and cruise/climb for best range in a standard atmosphere.

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Figure X-10. (U) Critical design mission ground rules.

LHX-SCAT MISSION 12A, ANTIARMOR (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity Knots)	Time/ Distance	Payload		Power	IR
						Lb	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	150 km	500	0.5	100% MCP	ON
3	Cruise	4,000	95	40	2 km	500	0.5	100% MCP	ON
4	Cruise	4,000	95	40	10 min	500	0.5	100% MCP	ON
5	Hover (OGE)	4,000	95	0	10 min	500	0.5	95% IRP	ON
6	Cruise	4,000	95	40	2 km	0	0.0	100% MCP	ON
7	Cruise	4,000	95	VBR	25 km	0	0.0	100% MCP	ON
8	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON
	Time at hover or for reserve				51 min				
	Total distance				171 km				

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Figure X-11. LHX-SCAT mission 12A, antiarmor (Mideast).

LHX-SCAT MISSION 13A, ANTIPERSONNEL/MATERIEL (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload		Power	IR
						Lb	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	200 km	500	0.5	100% MCP	ON
3	Cruise	4,000	95	40	2 km	500	0.5	100% MCP	ON
4	Cruise	4,000	95	40	7.5 min	500	0.5	100% MCP	ON
5	Hover (OGE)	4,000	95	0	7.5 min	500	0.5	95% IRP	ON
6	Cruise	4,000	95	40	2 km	0	0.0	100% MCP	ON
7	Cruise	4,000	95	VBR	200 km	0	0.0	100% MCP	ON
8	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON
	Time at hover or for reserve				46 min				
	Total distance				404 km				

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Figure X-12. (U) LHX-SCAT mission 13A, antipersonnel/materiel (Mideast).

LHX-SCAT MISSION 14A, SOF STRIKE (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload Lb.	Payload Sq Ft	Power	IR
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	300 km	500	0.5	100% MCP	ON
3	Cruise	4,000	95	40	10 min	500	0.5	100% MCP	ON
4	Hover (OGE)	4,000	95	0	10 min	500	0.5	95% IRP	ON
5	Cruise	4,000	95	VBR	300 km	0	0.0	100% MCP	ON
6	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON
Time at hover or for reserve					51 min				
Total distance					600 km				

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Figure X-13. (U) LHX-SCAT mission 14A, SOF strike (Mideast).

LHX-SCAT MISSION 15A, RECONNAISSANCE (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload		Power	IR
						Lb	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	125 km	500	0.5	100% MCP	ON
3	Cruise	4,000	95	VBR	120 km	500	0.5	100% MCP	ON
4	Cruise	4,000	95	VBR	125 km	500	0.5	100% MCP	ON
5	Reserve (30 min)	4,000	95	VBE	30 min	500	0.5	100% MCP	ON
	Time at hover or for reserve				31 min				
	Total distance				370 km				

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Figure X-14. (U) LHX-SCAT mission 15A, reconnaissance (Mideast).

LHX-SCAT MISSION 16A, SECURITY (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload		Power	IR
						Lb.	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	40 km	500	0.5	100% MCP	ON
3	Cruise	4,000	95	40	7.5 min	500	0.5	100% MCP	ON
4	Hover (OGE)	4,000	95	0	7.5 min	500	0.5	95% IRP	ON
5	Cruise	4,000	95	VBE	30 km	375	0.4	100% MCP	ON
6	Cruise	4,000	95	40	7.5 min	375	0.4	100% MCP	ON
7	Hover (OGE)	4,000	95	0	7.5 min	375	0.4	95% IRP	ON
8	Cruise	4,000	95	VBE	30 km	250	0.2	100% MCP	ON
9	Cruise	4,000	95	40	7.5 min	250	0.2	100% MCP	ON
10	Hover (OGE)	4,000	95	0	7.5 min	250	0.2	95% IRP	ON
11	Cruise	4,000	95	VBE	30 km	125	0.1	100% MCP	ON
12	Cruise	4,000	95	40	7.5 min	125	0.1	100% MCP	ON
13	Hover (OGE)	4,000	95	0	7.5 min	125	0.1	95% IRP	ON
14	Cruise	4,000	95	VBR	60 km	0	0.0	100% MCP	ON
15	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON

Time at hover or for reserve	91 min
Total distance	190 km

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Figure X-15. (U) LHX-SCAT mission 16A, security (Mideast).

LHX-SCAT MISSION 17A, DEEP STRIKE (MIDEAST)

Seg	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload		Power	IR
						Lb	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	25 km	500	0.5	100% MCP	ON
3	Dash	4,000	95	VIRP	5 km	500	0.5	100% MCP	ON
4	Cruise	4,000	95	VBR	300 km	500	0.5	100% MCP	ON
5	Cruise	4,000	95	40	2 km	500	0.5	100% MCP	ON
6	Cruise	4,000	95	40	10 min	500	0.5	100% MCP	ON
7	Hover (OGE)	4,000	95	0	10 min	500	0.5	95% IRP	ON
8	Cruise	4,000	95	40	1 km	0	0.0	100% MCP	ON
9	Dash	4,000	95	VIRP	4 km	0	0.0	100% IPR	ON
10	Cruise	4,000	95	VBR	290 km	0	0.0	100% MCP	ON
11	Dash	4,000	95	VIRP	5 km	0	0.0	100% IRP	ON
12	Cruise	4,000	95	VBR	25 km	0	0.0	100% MCP	ON
13	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON
	Time at hover or for reserve				81 min				
	Total distance				658 km				

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Figure X-16. (U) LHX-SCAT mission 17A, deep strike (Mideast).

LHX-SCAT MISSION 18A, RACO (MIDEAST)									
Seg.	Activity	Altitude (Feet)	Temperature (° F)	Velocity (Knots)	Time/ Distance	Payload		Power	IR
						Lb	Sq Ft		
1	Hover (OGE)	4,000	95	0	1 min	500	0.5	95% IRP	ON
2	Cruise	4,000	95	VBR	45 km	500	0.5	100% MCP	ON
3	Dash	4,000	95	VIRP	60 km	500	0.5	100% IRP	ON
4	Cruise	4,000	95	40	10 min	500	0.5	100% MCP	ON
5	Hover (OGE)	4,000	95	0	10 min	500	0.5	95% IRP	ON
6	Cruise	4,000	95	VBR	75 km	0	0.0	100% MCP	ON
7	Reserve (30 min)	4,000	95	VBE	30 min	0	0.0	100% MCP	ON
	Time at hover or for reserve				51 min				
	Total distance				180 km				

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Figure X-17. (U) LHX-SCAT mission 18A, RACO (Mideast).

4,000' ALT, 95°

Takeoff/Hover	Time	Distance	Payload
HOGE, .95 IRP	1.0 min		1,530 lbs
Contour flight at x 99% velocity for best range (high side)		162 NM	1,530 lbs
HOGE, .95 IRP	1.0 min		1,530 lbs
HOGE, .95 IRP	1.0 min		1,488 lbs
Contour flight at .99% velocity for best range (high side)		162 NM	1,488 lbs
Reserve (cruise) at .99% velocity for best range	30 min		1,488 lbs

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Figure X-18. (U) Utility mission 35.

X-4. (U) LIMITATIONS. This study is limited to the comparison of the pure SCAT and utility designs and their associated "fallout" utility and SCAT designs. While additional data was available on pure scout, attack, and utility aircraft, such data is not directly comparable (being of a one-man rather than two-man configuration).

X-6. (U) ANALYSIS/RESULTS.

a. (U) Criteria. The weight empty, MGW, unit cost, operating cost, SCAT VROC at 4,000'/95°F, utility payload capability at 4,000'/95°F hover out of ground effect (HOGE), and 100 percent IRP speed were chosen as factors critical to the comparison of the rotorcraft.

b. (U) Commonality Variants. The corresponding characteristics for each commonality variant were tabulated. The aircraft involved are the advanced helicopter, compound helicopter, advancing blade concept, advancing blade concept compound, and tilt rotor. Two commonality variants available for all rotorcraft were a SCAT-based (rotor, drive, engines) design with utility fallout and utility-based design with SCAT fallout. For the helicopter, a combination utility/SCAT aircraft was also examined.

c. (U) Comparison. Tabulation of those critical design parameters deemed decisive allows comparison (figure X-19). By normalization and weighting, rankings are determined among the commonality variants. Variant characteristics were normalized. Weights were normalized with respect to the baseline design within each rotorcraft type.* Unit costs were normalized with respect to the cost goal of $5M. Operating costs were normalized with respect to the baseline aircraft. VROC and payload were normalized with respect to the design criteria. The normalized value of criteria whose minimization is sought were subtracted from 1. Thus, a higher but less desirable actual value of a criteria corresponds to a lower normalized value in the comparison (figure X-20). Such criteria includes the empty weight, gross weight, unit cost, and operating cost.

(1) (U) The normalized value of those criteria whose greater magnitude is sought is not subtracted from 1. Those criteria include VROC, payload, and 100 percent IRP speed. Since design criteria were mission-derived, criteria weights were established from the frequency and importance rankings generated

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*Empty weight figures were normalized for the commonality variations with respect to the baseline (SCAT derived from utility) design within each rotorcraft type. Weight cross normalization between rotorcraft types was not deemed justifiable. That is because a particular rotorcraft type designed to meet the mission-derived performance criteria will have varying weights if it is a helicopter, compound, ABC, or tilt rotor. Those weight variations are inherent in the rotorcraft type chosen and have negligible effects on any of the expressed mission-derived design criteria. In short, empty weights were normalized only within each rotorcraft type to avoid artificially penalizing rotorcraft types that require a greater weight to achieve the performance criteria.

	Empty Weight (lb)	Mission Gross Weight (lb)	HP Engine	HP Trans	Unit Cost $M 1984	Operating Cost 1984 $	VROC (ft/min)	Payload (lbs)	100% IRP Speed
Helicopter									
*S/D/U	6402.00	9096.00	1918.00	1672.00	7.09	2947.10	715.00	1030.00	180.00
SCAT	6336.00	9012.00	1838.00	1602.00	7.05	2932.40	500.00	1030.00	178.00
Utility	6321.00	9747.00	1918.00	1672.00	5.93	2715.80		1536.00	175.00
*U/D/S	6242.00	9421.00	1838.00	1602.00	5.88	2699.60		1324.00	182.00
Com SCAT	7261.00	10776.00	2216.00	1932.00	7.44	3029.30	500.00	1693.00	180.00
Com Utility	7261.00	10862.00	2216.00	1932.00	7.09	2789.70	461.00	1530.00	180.00
Compound Helicopter									
S/D/U	7482.00	10444.00	2578.00	2148.00	7.59	3061.80	771.00	1030.00	200.00
SCAT	7370.00	10302.00	2340.00	2040.00	7.56	3056.70	500.00	1030.00	197.00
Utility	7371.00	10959.00	2578.00	2148.00	6.46	2823.30		1530.00	200.00
U/D/S	7257.00	10542.00	2390.00	2040.00	6.39	2815.50		1275.00	197.00
ABC									
S/D/U	7388.00	10292.00	2262.00	1972.00	7.61	3087.00	713.00	1030.00	187.00
SCAT	7302.00	10184.00	1897.00	2176.00	7.54	3068.30	500.00	1030.00	185.00
Utility	7319.00	10954.00	2262.00	1972.00	6.45	2858.00		1531.00	184.00
U/D/S	7213.00	10605.00	1897.00	2176.00	6.37	2835.60		1341.00	183.00
Compound ABC									
S/D/U	8069.00	11182.00	2678.00	2335.00	7.97	3181.70	795.00	1030.00	204.00
SCAT	7928.00	11003.00	2538.00	2213.00	7.88	3159.70	500.00	1030.00	201.00
Utility	8004.00	11383.00	2678.00	2335.00	6.81	2945.30		1531.00	202.00
U/D/S	7845.00	11365.00	2538.00	2213.00	6.80	2914.30		1301.00	204.00
Tilt Rotor									
S/D/U	7962.00	10850.00	2488.00	2163.00	7.78	3156.40	653.00	1030.00	270.00
SCAT	7922.00	10799.00	2439.00	2126.00	7.75	3136.70	500.00	1030.00	252.00
Utility	8028.00	11371.00	2480.00	2163.00	6.61	2918.30		1546.00	270.00
U/D/S	7988.00	11204.00	2440.00	2126.00	6.58	2894.60		1433.00	251.00

*S/D/U - SCAT derived from Utility.
U/D/S - Utility derived from SCAT.
.Developmental costs are roughly equal ranges of (2.1-3.2 billion) and are therefore not considered.

Figure X-19. (U) Commonality comparison.

	Empty Weight (lb)	Mission Gross Weight (lb)	HP Engine	HP Trans	Unit Cost	Operating Cost	VROC	Payload	100% IRP Speed
Helicopter									
*S/D/U	1.00	1.14	1.00	1.00	1.42	1.00	1.43	1.00	1.20
SCAT	0.99	1.13	0.96	0.96	1.41	1.00	1.00	1.00	1.19
Utility	0.99	1.22	1.00	1.00	1.19	0.92	0.00	1.00	1.17
*U/D/S	0.98	1.18	0.96	0.96	1.18	0.92	0.00	0.87	1.21
Com SCAT	1.13	1.35	1.16	1.16	1.49	1.03	1.00	1.11	1.20
Com Utility	1.13	1.36	1.16	1.16	1.42	0.95	0.92	1.00	1.20
Compound Helicopter									
S/D/U	1.00	1.31	1.00	1.00	1.52	1.04	1.54	1.00	1.33
SCAT	0.99	1.29	0.91	0.95	1.51	1.04	1.00	1.00	1.31
Utility	0.99	1.37	1.00	1.00	1.29	0.96	0.00	1.00	1.33
U/D/S	0.97	1.32	0.93	0.95	1.28	0.96	0.00	0.83	1.31
ABC									
S/D/U	1.00	1.29	1.00	1.00	1.52	1.05	1.43	1.00	1.25
SCAT	0.99	1.27	0.84	1.10	1.51	1.04	1.00	1.00	1.23
Utility	0.99	1.37	1.00	1.00	1.29	0.97	0.00	1.00	1.23
U/D/S	0.98	1.33	0.84	1.10	1.27	0.96	0.00	0.88	1.22
Compound ABC									
S/D/U	1.00	1.40	1.00	1.00	1.59	1.08	1.59	1.00	1.36
SCAT	0.98	1.38	0.95	0.95	1.58	1.07	1.00	1.00	1.34
Utility	0.99	1.42	1.00	1.00	1.36	1.00	0.00	1.00	1.35
U/D/S	0.97	1.42	0.95	0.95	1.36	0.99	0.00	0.85	1.36
Tilt Rotor									
S/D/U	1.00	1.36	1.00	1.00	1.56	1.07	1.31	1.00	1.80
SCAT	0.99	1.35	0.98	0.98	1.55	1.06	1.00	1.00	1.68
Utility	1.01	1.42	1.00	1.00	1.32	0.99	0.00	1.01	1.80
U/D/S	1.00	1.40	0.98	0.98	1.32	0.98	0.00	0.94	1.67

*S/D/U - SCAT derived from Utility.
U/D/S - Utility derived from SCAT.

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Figure X-20. (U) Commonality normalization.

	Empty Weight (lb)	Mission Gross Weight (lb)	HP[1] Engine	HP[1] Trans	Unit Cost	Operating Cost	VROC	Payload	100% IRP Speed
Helicopter									
*S/D/U	0.00	-0.14			-0.42	0.00	1.43	1.00	1.20
SCAT	0.01	-0.13			-0.41	0.00	1.00	1.00	1.19
Utility	0.01	-0.22			-0.19	0.08	0.00	1.00	1.17
*U/D/S	0.02	-0.18			-0.18	0.08	0.00	0.87	1.21
Com SCAT	-0.13	-0.35			-0.49	-0.03	1.00	1.11	1.20
Com Utility	-0.13	-0.36			-0.42	0.05	0.92	1.00	1.20
Compound Helicopter									
S/D/U	0.00	-0.31			-0.52	-0.04	1.54	1.00	1.33
SCAT	0.01	-0.29			-0.51	-0.04	1.00	1.00	1.31
Utility	0.01	-0.37			-0.29	0.04	0.00	1.00	1.33
U/D/S	0.03	-0.32			-0.28	0.04	0.00	0.83	1.31
ABC									
S/D/U	0.00	-0.29			-0.52	-0.05	1.43	1.00	1.25
SCAT	0.01	-0.27			-0.51	-0.04	1.00	1.00	1.23
Utility	0.01	-0.37			-0.29	0.03	0.00	1.00	1.23
U/D/S	0.01	-0.33			-0.27	0.04	0.00	0.88	1.22
Compound ABC									
S/D/U	0.00	-0.40			-0.59	-0.08	1.59	1.00	1.36
SCAT	0.02	-0.38			-0.58	-0.07	1.00	1.00	1.34
Utility	0.01	-0.42			-0.36	0.00	0.00	1.00	1.35
U/D/S	0.03	-0.42			-0.36	0.01	0.00	0.85	1.36
Tilt Rotor									
S/D/U	0.00	-0.36			-0.56	-0.07	1.31	1.00	1.80
SCAT	0.01	-0.35			-0.55	-0.06	1.00	1.00	1.68
Utility	-0.01	-0.42			-0.32	0.01	0.00	1.01	1.80
U/D/S	0.00	-0.40			-0.32	0.02	0.00	0.94	1.67

*S/D/U - SCAT derived from Utility.
U/D/S - Utility derived from SCAT.

1. Not directly used - reflected in other parameters.

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Figure X-21. (U) Rankings. (continued on next page)

	Weighted VROC	Weighted Payload	Weighted IRP Speed	Unweighted Rank	VROC Weight	Payload Weight
Helicopter						
*S/D/U	1.13	0.00	0.02	3.07	0.79	
SCAT	0.79	0.00	0.02	2.66	0.79	
Utility	0.00	0.53	0.03	1.78		0.53
*U/D/S	0.00	0.46	0.03	1.75		0.53
Com SCAT	0.00	0.00	0.02	2.34		
Com Utility	0.00	0.53	0.03	2.21		0.53
Compound Helicopter						
S/D/U	1.22	0.00	0.02	3.05	0.79	
SCAT	0.79	0.00	0.02	2.53	0.79	
Utility	0.00	0.53	0.03	1.69		0.53
U/D/S	0.00	0.44	0.03	1.58		0.53
ABC						
S/D/U	1.13	0.00	0.02	2.86	0.79	
SCAT	0.79	0.00	0.02	2.46	0.79	
Utility	0.00	0.53	0.02	1.58		0.53
U/D/S	0.00	0.46	0.02	1.52		0.53
Compound ABC						
S/D/U	1.26	0.00	0.02	2.96	0.79	
SCAT	0.79	0.00	0.02	2.41	0.79	
Utility	0.00	0.53	0.03	1.57		0.53
U/D/S	0.00	0.45	0.03	1.46		0.53
Tilt Rotor						
S/D/U	1.03	0.00	0.03	3.19	0.79	
SCAT	0.79	0.00	0.03	2.79	0.79	
Utility	0.00	0.54	0.04	2.06		0.53
U/D/S	0.00	0.50	0.03	1.89		0.53

*S/D/U - SCAT derived from Utility.
U/D/S - Utility derived from SCAT.

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Figure X-21. (U) (continued)

	100% IRP Speed Weight	Weighted Rank	Weighted Less Cost	SCAT/Utility Variant Combined		
				Design Basis	Combined Rank	Rank Less Cost
Helicopter				**Helicopter**		
*S/D/U	0.015	0.59	1.01			
SCAT	0.015	0.29	0.69	Util-based	0.83	1.36
Utility	0.02	0.24	0.35			
*U/D/S	0.02	0.24	0.33	SCAT-based	0.53	1.02
Com SCAT	0.015	-0.98	-0.46			
Com Utility	0.02	-0.30	0.06	Common	-1.28	-0.40
Compound **Helicopter**				Compound **Helicopter**		
S/D/U	0.015	0.38	0.93			
SCAT	0.015	-0.01	0.54	Util-based	0.33	1.14
Utility	0.02	-0.05	0.20			
U/D/S	0.02	-0.05	0.18	SCAT-based	-0.06	0.72
ABC				**ABC**		
S/D/U	0.015	0.29	0.86			
SCAT	0.015	0.00	0.55	Util-based	0.23	1.05
Utility	0.02	-0.06	0.19			
U/D/S	0.02	-0.05	0.19	SCAT-based	-0.05	0.73
Compound ABC				**Compound ABC**		
S/D/U	0.015	0.21	0.88			
SCAT	0.015	-0.20	0.45	Util-based	-0.01	1.02
Utility	0.02	-0.22	0.14			
U/D/S	0.02	-0.26	0.09	SCAT-based	-0.46	0.54
Tilt Rotor				**Tilt Rotor**		
S/D/U	0.015	0.08	0.70			
SCAT	0.015	-0.14	0.47	Util-based	-0.09	0.84
Utility	0.02	-0.17	0.14			
U/D/S	0.02	-0.17	0.13	SCAT-based	-0.32	0.60

*S/D/U - SCAT derived from Utility.
U/D/S - Utility derived from SCAT.

in the Delphi mission ranking process. The importance factors associated with all missions related to a particular criteria were totaled. Such totaled importance factors were summed over the involved performance criteria. The fraction of this total importance factor, due to each individual criterion, was then found.

(2) (U) Alternative methods and justifications follow. The method used for establishing relative rankings and weights was preferred since alternative weighting schemes lack the backing for the judgmental weights of each criteria derived from the extensive and justified Delphi mission ranking process.

X-6. (U) FINDINGS.

a. (U) A summation of weighted scores assigned to each rotorcraft commonality variant was obtained. The scores for the utility and SCAT of a particular variation were combined. The combinations for each commonality variant were ranked. No variant met the unit cost goal.

b. (U) All SCAT variants met a minimum VROC of 500 fpm under 4,000'/95°F conditions.

c. (U) No utility derivatives of SCAT-based designs achieved payload and HOGE requirements with the utility payload (1,530 lb). The following utility variants achieved a hover out of ground effect under 4,000'/95°F conditions:

(1) (U) Helicopter (pure) utility design.

(2) (U) Common utility helicopter design.

(3) (U) Compound helicopter utility design.

(4) (U) ABC utility design.

(5) (U) ABC compound (pure) utility.

(6) (U) Tilt rotor utility (pure) design.

d. (U) Those commonality variant combinations with SCAT and Utility craft meeting the performance criteria are all based on utility drive requirements with SCAT derivatives. Neglecting cost, rankings are:

(1) (U) Helicopter.

(2) (U) Compound helicopter.

(3) (U) ABC.

(4) (U) ABC-C.

(5) (U) Tilt rotor.

e. (U) Inclusion of cost results in the following rankings:

(1) (U) Helicopter.

(2) (U) Compound helicopter.

(3) (U) ABC.

(4) (U) ABC compound.

(5) (U) Tilt rotor.

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2. US Army Aviation Center. Light Helicopter Family (LHX) Mission Profile Prioritization, Fort Rucker, AL: September 1984.

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CONTRIBUTORS (U)

TOMAINE, Robert D., 3-2-1 Commonality Option Comparison, St. Louis, MO: AVSCOM.

APPENDIX Z

DOWNWASH TRADE-OFF ANALYSIS (TOA) SUBSTUDY (U)

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APPENDIX Z

DOWNWASH TRADE-OFF ANALYSIS SUBSTUDY (U)

Z-1. (U) PURPOSE. The purpose of the downwash substudy is to examine the effect of disk loading on operational factors associated with each design variant. The Essential Elements of Analysis (EEA) for this substudy include:

a. (U) Downwash effects on people and equipment.

b. (U) Dust, debris, snow, and vegetation effects.

c. (U) Signatures at hover and low speed.

d. (U) Operational visibility at hover and low speed.

e. (U) Number of repeated landings possible on different types of soil and in different conditions without signature or serious erosion.

Z-2. (U) BACKGROUND. The significant effects of disk loading on the operational characteristics of each proposed light helicopter family (LHX) variant will be examined. However, past empirical tests have not provided sufficient data to state with confidence the effects of high disk loadings on compact rotorcraft. Two aircraft types are involved: scout-attack (SCAT) and Utility. The design variants and their associated disk loadings are shown in figure Z-4.

Z-3. (U) ASSUMPTIONS. The primary assumption is that downwash characteristics can be predicted from experimental results for rotorcraft of similar disk loadings.

Z-4. (U) LIMITATIONS.

a. (U) Comparison of relative disk loading/downwash effects are based on test reports. Loads on individuals and objects in the downwash flow field are the result of flow velocities that vary in magnitude with height and direction. Other essential elements of analysis have not been addressed as test issues by rotorcraft sufficiently similar to the proposed LHX to yield reliable estimates.

b. (U) Analytical tools necessary to accurately design compact helicopters with high disk loadings are at present inadequate.[6]

Z-5. (U) EXISTING CRITERIA. Spacing of operating aircraft and servicing equipment are listed in FM 10-68. Such distances exceed the maximum downwash force distance (figure Z-4) for the rotorcraft. Reports of tests of rotorcraft in a similar disk loading range were compared with the candidates. As noted in limitations, such comparisons involved too many variables for a precise prediction but they can serve to give an idea of the effect on a LHX rotorcraft of similar disk loading.

Z-6. (U) ANALYSIS/RESULTS.

a. (U) Downwash Effects on People and Equipment. A means of determining downwash effects on personnel was developed in reference 3 and further developed in reference 4. By test, the force on various individuals was found at different points in the flow field. This method was used to evaluate the force on individuals in the flow field of the CH-53E and the XV-15 tilt rotor (T/R). Other rotorcraft were compared by use of the relation between the velocity of the flow field and dynamic force on individuals or objects in the field.

(1) (U) A means to determine maximum velocity (and dynamic pressure was found in reference 1, Structural Design Guide for Heliports).

(2) (U) Based on model and full-scale data:

$$_{H}V_{max} = \left[\frac{4DL}{\rho_{SL}}\right]^{1/2} \qquad \text{Equation \#1}$$

where: DL = disk load

ρ_{SL} = density of air at sea level

$_{H}V_{max}$ = maximum horizontal velocity

Maximum velocity is expected at:

Z/R = 0.5 and X/R = 1.5

where: R is rotor radius

X is horizontal distance from the center of rotation

Z is rotor height

Total force or pressure is made up of static and dynamic components and can be expressed as:

$$P_o = P + \frac{\rho_{SL}(HV)^2}{2}$$

where P = static pressure

$\frac{\rho_{SL}(HV)^2}{2}$ = dynamic pressure

HV = horizontal velocity

P_o = stagnation pressure (total pressure felt be an object or structure)

Since P = 0

$$\frac{\rho_{SL}\,(HV)^2}{2} = \text{dynamic pressure (wind force)} \qquad \#2$$

(stagnation pressure on a solid object)

Equation 1 was used to develop the graph of HV_{max} versus disk load[1] (figure Z-3). The relationships defined above were used to model HV_{max} and the associated P_o or maximum horizontal downwash force (figure Z-4).

(3) (U) The test methods of references 3 and 4 measure the actual force expended to remain erect in downwash. Such experimental method varies from 85 to 95 percent of the values on total force obtained by multiplying the frontal area of a 97.5 percentile man[12] by the dynamic pressure associated with the maximum horizontal velocity in the flow field. In consideration of aerodynamic effects and since in the actual flow field, a posture is assumed that reduces body frontal area such a lesser value is reasonable. A coefficient of .9 is therefore used to correct the human "flat plate" force to a force estimate using the calculated forces for the maximum horizonal velocity for a particular disk loading. An estimate of the maximum force on a human subject in the flow field is obtained. Such values are tabluated in figure Z-4.

(4) (U) To establish the experimental forces for a tilt rotor configuration, the analysis and results of references 3 and 4 were used.

(5) (U) Personnel in the downwash flow field are affected by a combination of the forces generated by the horizontal velocity, the height of the forces above ground, the pulsating nature of the forces, and the overturning forces exerted. It is difficult to analyze or assess the effects of velocity data since the velocity varies drastically with height and the dynamic pressure created by the downwash is a function of the velocity squared. In comparing data between flight conditions or comparing data with other types of vertical take off landing (VTOL) aircraft, the comparison of forces is much more significant than the comparison of velocities. Additionally, the force data can be used to compare various altitudes and gross weights and will generally correlate better than velocity data since the force data includes the variation of the entire velocity-height profile, but velocity data can only be compared at one velocity-height position. Therefore, to obtain a viable means to analyze and compare data, the downwash wind velocities were converted to forces on personnel. Forces on equipment or other objects could have also been computed based on a knowledge of the size and shape of the object. However, due to the large number of possible objects in the flow field, it was not within the scope of past tests to analyze equipment or other objects. However, specific analysis can be easily conducted for specific equipment and missions, if required.

(6) (U) Criteria for assessing the problems and hazards caused by the downwash forces on personnel was determined during tests in reference 3 to evaluate the CH-53E downwash. This criteria was used for analyzing forces on

personnel in the XV-15 downwash. The criteria was based on limited laboratory and field tests conducted to determine the ability of tests subjects to walk against the downwash wind force. Each test subject, who participated in the qualitative survey under the helicopter, was tested to determine how much horizontal force they could pull using a test fixture consisting of a harness, which distributed the load across the hips and the chest to a line tied 3 feet above ground level (AGL), and a weight which was lifted by forward movement of the subject. Figure Z-1 contains a list of the test subjects' weights and heights. Figure Z-2 is a bar chart indicating the amount of pull force each individual could exert. The pull test data do not exactly duplicate the dynamically applied downwash forces. However, dynamic forces were applied during the tests since the slightest forward or reverse movement of the body or trunk caused the weight to move up and down requiring the subject to dynamically respond to the change in load acceleration. The limits of postural stability were taken as the range of forces where the test subject could no longer maintain stable footing while making some forward progress with leg or trunk movement and are represented by the black bar in figure Z-2. This criteria only considers the person's ability to make forward progress by means of synchronized walking and body trunk movements. Although many other types of movement, efforts, or tasks could be considered, walking forward requires maintaining both body stability and traction with only one foot on the ground. This task was qualitatively considered a more difficult task than merely standing in the flow field or walking away from the flow field (wind at back). It was also found that personnel meeting the criteria limits were able to perform tasks in the flow field such as dragging large 25-foot long, 1 1/2-inch diameter braided steel cables and performing maintenance tasks such as mechanical adjustments using hand tools. This criteria would not necessarily apply to personnel carrying objects which add to the person's instability and add extra surface area into the wind.

(7) (U) Computation of force data included the velocity profile, the projected frontal area, drag coefficient of the test subjects while in the leaning forward attitude, and ambient temperature and pressure. The projected frontal area in the computation of force was based on subject 4. However, subjects 2, 3, and 4 had similar heights and frontal areas. This similarity allowed a comparison of subjects who would encounter similar forces but who had different strengths and weights. For the range of height and weight of subjects 2, 3, and 4, the computed forces varied no more than 6 percent. Therefore, relative strengths of the three subjects were compared to the computed forces which were nearly equal for the three subjects. Differences in computed forces as high as 15 to 20 percent were found in using the projected area of test subject 1 due to height. Therefore, force on subject 1 could not be accurately used for this analysis.

(8) (U) Force data were analyzed both as a function of distance from the (XV-15 tilt rotor) aircraft and variation around the aircraft. Peak downwash forces on personnel as a function of distance from the aircraft along the 0-, 270-, and 180-degree relative bearing were computed and are shown in figure Z-29. These data indicate that the forces gradually increase with decreased distance from the 91.1-ft position to the 41.1-ft position and then rapidly increase in force from the 41.1-ft position to a maximum at the

31.7-ft position. Figures Z-9, Z-10, and Z-11 indicate the forces as a function of distance at each relative bearing and also contain both the peak and mean forces to illustrate the dynamic range of the pulsating forces. Figure Z-6 is a plan view of the forces at a distance from the aircraft where the greatest forces occur (31.7-ft test position) as a function of relative bearing. These data indicate that the greatest forces are exerted at the forward and aft region as compared to the lower forces to the side. The region where the greatest force occurs is within a path approximately 10 feet wide on either side of the aircraft centerline (total of 20 feet wide). Although only the port side was measured, it is assumed that the other side is the same by symmetry since the flow is produced by counter-rotating rotors.

(9) (U) Qualitative tests were conducted during the 25- and 50-ft hover tests using subject 4 described in figures Z-1 and Z-2. The test subject's path of locations to walk and stand, both into and away from the flow direction, is shown in figure Z-12. The test subject had no problem walking or standing under the aircraft although his forward movement was slightly impeded by the flow field. The test subject had the most difficulty along the 0- and 180-degree relative bearing. He noticed the flow magnitude was composed of frequent large wind gusts. Neither the test subject nor test personnel observing the test subject could notice any differences in the relative difficulty due to hover height during the 25- to 50-ft hover heights. The limited qualitative observations were in good agreement with the comparable quantitative force analysis. No quantitative data were obtained under the aircraft within a 26-ft circle centered at the aircraft center. However, the test subject indicated that this area was considered to be in a region IV category. Both observations by test observers and movies of the test indicate the velocities in this central area to be relatively low in magnitude during the 25- and 50-ft hover tests. The test subject walked erect and relaxed in this region.

(10) (U) Downwash wind forces on personnel have been summarized by presenting the force data in figures Z-5 and Z-6 as four regions which have distinctive differences in degrees of difficulty for personnel to maintain stability in the flow field. These regions are shown in figure Z-7. The degree of difficulty relative to the region based on the criteria in figure Z-2 is shown in figure Z-8. Based on this limited analysis, the majority of the flow field represented by regions III and IV presents no significant problems for personnel walking, standing, or performing limited work in the flow field over the range of test conditions. However, regions I and II could potentially be hazardous for people weighing less than 150 pounds (lb) (25th weight percentile). As indicated previously, no quantitative data were measured directly beneath the aircraft within the 26-ft radius circle of figure Z-7. Qualitative data were not adequate to define this region since it was based on the one 220-lb (99th percentile) test subject. It is recommended that additional tests and evaluations be conducted in the region defined by a 26-ft radius circle around the aircraft center.

(11) (U) The XV-15 tilt rotor's downwash flow field is characterized by increased horizontal downwash velocities at the 0-degree and 180-degree negative relative bearing (nose and tail) but less intense flows laterally as

compared to a helicopter. Such velocity was at maximum 31.7 ft from the aircraft center for all heights and relative bearings. A peak velocity at the 25-ft hover height of 116 feet per second (fps) was recorded at the 0-degree relative bearing.

(12) (U) A region of less horizontal downwash velocity and resultant dynamic pressure is present from the 345° to 195° relative bearings so that a maximum dynamic force of 41 lb is experienced by ground personnel at the 270° relative bearing and 31.7 ft from the aircraft center. Maximums for the 0° and 180° relative bearings are 79 and 78 lb, respectively, just inside the limits of stability of a 25th weight percentile subject.

b. (U) Forces on Equipment. Detailed analysis of all objects that might be within the area of downwash was impractical due to the large number of possible objects. However, the maximum possible force on any specific item can be estimated by multiplying its frontal area by the force per square foot due to the maximum horizontal downwash velocity.

c. (U) Operational Signatures and Visibility. It is suspected that the movement of vegetation in downwash creates a radar signature, consisting of a disturbance in the ground clutter, apparently as significant as the rotor's radar signature. Analysis of the relationship between downwash characteristics and such signature must await tests. Visual operational signatures and visibility problems are subjectively assessed by the methods of reference 11. Using the disk load and dynamic pressure relationship, such effects can be extended to the LHX candidates by their disk loading values.

(1) (U) The operational problem severity data presented in the body of the test report shows definite trends which can be presented in graphical form. Therefore, a brief first order analysis of this data has been made based on the existing flow field data and is presented in figures Z-16 through Z-30.

(2) (U) A coarse grading system is required before further detail is considered. The grading system which has been used is as follows:

(a) (U) Unacceptable--based on approximately present day design and operational techniques and equipment, the specified function cannot, in general, be performed (with equipment as listed in operational limitations definition).

(b) (U) Limited--the specified function may be performed in a limited manner under emergency or combat conditions.

(c) (U) Tolerable--disturbance may be endured but is disconcerting and will reduce efficiency.

(d) (U) Satisfactory--the specific function can be performed unimpeded.

(3) (U) The coarse grading system is not adequately defined for the establishment of operational limitations and, therefore, further definitions are required. The problem areas are:

-- Pilot's vision.

-- Personnel (ground).

-- Equipment.

-- Aircraft.

-- Concealment.

In this section, the definitions required to establish limitations in each of these areas are given. Since the severity of the problem will depend somewhat on the equipment which is available, certain equipment has been assumed to be available and is listed under the definition which is influenced. Operational limitations for personnel or equipment depend on the location of the personnel or equipment. Therefore, zones were established to give a general location. The zones consist of concentric rings about the point of intersection of the propeller axis with the ground as shown in figure Z-16. It should be noted that, for operations with the propeller axis inclined, the operational problems are not quite as severe to either side as they are in the direction of the inclination.

(a) (U) Pilot's vision. It is assumed that the pilot will be located between one and two diameters from the rotor center and will be a distance of about 1/4 of the rotor diameter below the plane of the rotor. It is further assumed that the configuration of the pilot's windshield will be provided with adequate washers and wipers to provide a clear view through the windshield. With these assumptions, the proposed operational limitations, based on pilot's vision, have been defined as follows:

1. (U) Unacceptable--no visual contact with any reference point.

2. (U) Limited--objects distinguishable at 30 feet distance from the pilot but horizon not perceptable. NOTE: Automatic stabilization equipment is assumed to be available and the aircraft is likely to suffer damage during landing under these conditions.

3. (U) Tolerable--ground objects larger than 3 feet diameter are clearly distinguishable at 100 feet distance and a horizon is always perceptible.

4. (U) Satisfactory--vision unimpeded.

(b) (U) Personnel. The personnel which are considered include ground crew and disembarking troops.

1. (U) Vision of personnel. It is assumed in consideration given to the vision problem that personnel will have eye protection such as goggles or face shields. The proposed operational limitations based on ground crew vision are as follows:

a. (U) Unacceptable--ground objects larger than 3-feet diameter not distinguishable beyond 10 feet from the crewman.

b. (U) Limited--ground objects distinguishable at distances up to 50 feet.

c. (U) Tolerable--objects distinguishable at distances up to 200 feet.

d. (U) Satisfactory--vision unimpaired.

2. (U) Risk of injury from disturbed terrain or debris. If the personnel are adequately equipped with protective clothing, the risk of injury is small. Further study will be required to determine the amount of protection required. However, three limitation definitions were utilized, based on the protection required, as follows:

a. (U) Unacceptable--personnel will require extraordinary protection to ensure that they will not be injured.

b. (U) Limited--personnel will required padded clothing and face shields.

c. (U) Satisfactory--personnel would not risk injury when wearing only standard ground crew clothing.

3. (U) Motion restricted due to aerodynamic forces. Personnel functions may be made difficult due to downwash even though there is no disturbance of the terrain. The following limitations were devised to evaluate these conditions:

a. (U) Unacceptable--personnel would not be able to stand under these conditions.

b. (U) Limited--personnel would be able to be in area and would be capable of locomotion.

c. (U) Tolerable--motion would be slightly impeded.

d. (U) Satisfactory--no effect.

(c) (U) Equipment. The equipment which has been considered in the limitation devised for this problem area includes:

- -- Ground power units.
- -- Vehicles.
- -- Housing.
- -- Stored equipment.
- -- Parked aircraft.

It is assumed that this equipment will not be damaged by aerodynamic pressure loading and will be secured as required to prevent equipment from blowing away. With these assumptions, limitations were devised as follows:

1. (U) Limited--equipment will be subjected to severe environmental problems.

2. (U) Satisfactory--no perceptible change to operational environment due to downwash.

(d) (U) Aircraft. Due to the downwash, debris and terrain particles may be set in motion. These particles can cause physical damage to the aircraft. This damage includes:

- -- Denting and abrasion of propeller or rotor.
- -- Engine ingestion.
- -- Denting and abrasion of airframe.

The proposed operational limitations for these problem areas have been defined as given below:

1. (U) Propeller. It was assumed that the aircraft will have metal propellers. The limitations which were used are as follows:

a. (U) Unacceptable--risk of damage to propeller which would cause further operations to be unsafe.

b. (U) Limited--propeller is subjected to abnormal environmental conditions which may reduce propeller performance.

c. (U) Tolerable--not applicable.

d. (U) Satisfactory--no damage or abrasion to propeller.

2. (U) Engine. The engine problems will be much different for engines with an intake filter than for engines without such a filter. Some quantitative data on the size and amount of particles which should be removed by the filter was obtained in this program, as will be discussed in a following section. However, for the qualitative operational limitations, it was assumed that a filter will be used. The limitations which were used were defined as follows:

a. (U) Unacceptable--risk that terrain being recirculated may clog filter and stop engine.

b. (U) Limited--terrain being recirculated may reduce engine performance.

c. (U) Satisfactory--no apparent effect on engine operation.

3. (U) Airframe. It was assumed that the aircraft will consist of a light metal monocoque structure and will have helicopter-type landing gear. Since the sensitivity of the airframe to damage will depend on the configuration of the structure, the severity of the damage cannot be estimated at this time. Therefore, limitations were based on the occurrence of damage as follows:

a. (U) Limited--risk that damage may occur to airframe.

b. (U) Satisfactory--no risk of damage to airframe.

(e) (U) Concealment. It was assumed that only one aircraft was in operation in the area. Limits were defined based on the maximum height of the cloud of disturbed terrain as follows:

1. (U) Unacceptable--100 feet or more.

2. (U) Limited--less than 100 feet but more than 25 feet.

3. (U) Tolerable--less than 25 feet height but a cloud is formed.

4. (U) Satisfactory--no cloud formed.

(4) (U) At radial distances of two diameters or more, the surface dynamic pressure is almost independent of rotor height. This data is shown in figure Z-17 for the mid-radius of the test zones considered in the test program. It may be noted that the peak surface dynamic pressure is almost linear with rotor height in zone A, but is almost independent of rotor height in zone C. Also, the peak surface pressure is about one-half as large in zone B as in zone A, and about one-seventh as large in zone C as in zone A. These effects should be considered in the interpretation of the test data. This test was done with a rotor having no fuselage suspended below it. Velocities for empirical flows are generally 1.5 times greater due to the forced wake spreading of the normally contracted (71-percent rotor diameter) wake.

(5) (U) Visual problems are caused by the creation of an opaque cloud of terrain particles by the downwash. This depends on the number, size, density, and shape of the terrain particles, and the local downwash dynamic pressure at the particle. The tendency for a particle to become entrained in the downwash will be greater if the weight of the particle is small in comparison with its aerodynamic drag area. The ratio of these factors can be estimated by assuming the particles are spheres and have a drag coefficient of unity. Thus, the particle weight to drag area ratio can be estimated as:

$$W/C_DA = (41.6)\ (S.G.)d$$

where: W = weight of the particle, lb.

C_D = drag coefficient of particle.

A = frontal area of particle, ft^2.

$S.G.$ = specific gravity of particle.

d = particle diameter, ft.

This weight to drag area ratio and the number of terrain particles available for the formation of a cloud should provide a first order correlation of the visual problem data.

(6) (U) The particle size, average diameter, and specific gravity of the terrains tested have been measured or estimated and are presented in figure Z-15. The terrains are subdivided into groups depending on the number of particles which are available to the downwash per unit area of the ground surface. Since the terrains which have a large number of particles have about the same size, it would be expected that the specific gravity of the terrain is the parameter which will provide correlation of the visual problems with these terrains. It may also be noted from figure Z-15 that the product of specific gravity and size of the particles of the terrains which have few particles per unit area is at least a factor of 10 larger than the terrains with a large number of particles. Therefore, it would be expected that these terrains (earth, debris, gravel, and stone) would not tend to become entrained in the downwash even if there were a large number of particles present.

(7) (U) These conclusions as to the effects of the terrain characteristics on visual problems will be applied to the specific problem areas in the following discussion.

(a) (U) Pilot's vision. There is a problem of pilot's vision only for operations over the terrains with a large number of particles per unit area (water, sand, and snow). As shown in figure Z-21, the data correlates fairly well with the product of the rotor height-diameter ratio and the specific gravity of the terrain. This indicates that the data are consistent and can be extrapolated to other terrain with some confidence. The cloud which obscures the pilot's vision is apparently created in a region where the downwash intensity is fairly linear with rotor height.

(b) (U) Personnel vision. The data on the ground personnel vision problem is not consistent. This apparently is due to having a too finely divided grading system for the accuracy of the test method as well as specific problems that were more severe than the problem due to the terrain particle cloud. For example, when operations were over clay, earth, and wet sand, terrain particles would stick to the face shields of ground personnel and obscure their vision. This caused a visual problem since cleaning the face shields was not feasible in this environment.

1. (U) The data which were obtained are shown in figures Z-22, Z-23, and Z-24. Considerable overlap of the data is shown. The best correlation was obtained in zone A when the specific gravity of the terrain was not considered. Data obtained for zones B and C correlated best with consideration given to the specific gravity of the terrain.

2. (U) Further testing should be made with more accurate testing methods to determine the severity of this problem. The problem area may also have to be defined more carefully for these tests.

(c) (U) Concealment. The problem of concealment also is concerned with the opaque terrain particle cloud and therefore is also a visual problem. As shown in figure Z-25, the data on the severity of this problem correlates for various terrains when the product of the rotor height-diameter ratio and the specific gravity is used as a parameter. As with the pilot's vision problem, the terrains that were troublesome had a large number of particles per unit ground surface.

Z-7. (U) PROBLEMS OF DAMAGE DUE TO TERRAIN.

a. (U) The potential of a terrain particle for doing damage depends on its weight-drag area ratio (as defined previously) which will indicate the tendency of the particle to become entrained in the downwash. Also, once the particle is entrained, its momentum per unit frontal area will indicate the damage which the particle can cause if it collides with the aircraft or other equipment.

b. (U) If the particles are assumed to be spheres, the momentum per unit area can be estimated as follows:

$$mv/A = (37.4)\ (S.G.)d\ \sqrt{q_s}$$

where: m = Mass of particle, slugs

v = Velocity of particle, fps

A = Frontal area of particle, $ft.^2$

S.G. = Particle specific gravity

d = Particle diameter, ft.

q_s = Local downwash dynamic pressure, psf

A comparison of this relation with the relation given previously for the weight-to-drag area ratio shows that if the particle specific gravity or diameter is increased, its potential for doing damage is increased, but the tendency for the particle to become entrained in the downwash is reduced. It would, therefore, be expected that there is a certain size of particle which would cause the most damage and particles which are larger or smaller would cause less damage.

c. (U) The hardness and shape of the particle will also influence the damage which can be caused. There is some data on this subject available in NASA TN D-238 for metal particles. This NASA data can also be used to show the expected magnitude of the damage which would be caused by particles entrained by downwash. For example, the momentum per unit frontal area of a particle is 0.027 lb sec/in^2 if the following parameters are assumed:

$d = 0.08$ inches

$S.G. = 2$

$q_s = 60$ psf

Steel projectiles with this momentum per unit area will penetrate aluminum plates to a depth of 0.001 inches. This is of the same order of magnitude as the depth of the pitting of aluminum equipment by sand particles which occurred during testing.

d. (U) In general, it would be concluded from this discussion that the problem of damage caused by particles is more sensitive to particle size than the visual problems. However, other factors such as particle hardness will also be significant.

(1) (U) Personnel, risk of injury from terrain particles.

(a) (U) The risk of injury to personnel depends to a considerable extent on the particle size. In general, particles which are large enough to cause serious injury such as debris are too large to become entrained in the downwash. However, these objects bounce along the ground and achieve considerable velocity when the rotor is at low height and high disk loading. As shown in figures Z-26, Z-27, and Z-28, debris presents an unusual problem in that the particles are so large that the damage which they can cause would require extraordinary protection for the personnel.

(b) (U) For gravel and stone, sand and snow, personnel will require some protection for all conditions of rotor height and disk loadings tested and, therefore, conditions are limited. These smaller particles (only the smaller particles of gravel) become entrained in the downwash but are not large enough to cause injury to adequately protected personnel. Conditions which prevail when operating over earth, clay, sod, and water are as shown in figures Z-26, Z-27, and Z-28.

(2) (U) Possible damage to airframe. There was a risk of damage to the airframe when operating over sand, debris, gravel, and stone. The data which was obtained is shown plotted in figure Z-27. This data was consistent for the three terrains which were troublesome.

(3) (U) Possible damage to rotor. Operation over sand and gravel and stone terrain caused a risk of damage to the rotor at the higher disk loadings and lower rotor heights. This data is shown in figure Z-28.

(4) (U) Evaluation of risk of engine ingestion. The data obtained in the evaluation of ingestion problems is shown in figure Z-29. Snow was evaluated as limited for all conditions. Also, it should be noted that loose vegetation may present an unacceptable condition. It is likely that operations over salt water would be graded as a limited condition.

Z-8. (U) SURFACE EROSION.

a. (U) Erosion of a surface involves two critical parameters: the surface critical dynamic pressure and the field maximum dynamic pressure. Field maximum dynamic pressure varies with disk loading and inversely but nonlinearly with height [11,13] (figure Z-17).

b. (U) The surface critical dynamic pressures involve the movement of loose surface material such as snow, sand, leave, dust, etc. This value is from one to three psf. The field maximum dynamic pressure of virtually all Army rotorcraft and the LHX variants exceed this threshold value for exciting loose surface materials.

c. (U) At a constant disk loading, the field maximum dynamic pressure increases with decreasing Z/D.[11]

d. (U) A dust hazard exists if surface boundary layers exceed 120 fpm (20 fps) over dry, fine sand and 1,800 fpm over dust-sized particles of lean clay.[13]

e. (U) The number of possible repeated landings will vary considerably, depending on the nature of any surface underlying free materials and the steps taken to protect the surface. With the exception of loose or free surfaces, erosion due to repeated landings should not be a primary concern with present FARP use durations. Where dust clouds evolve, allowing time for dust to settle between landings and minimizing landing approach runs will contribute to reduced particle cloud size and persistency.

HEIGHT AND WEIGHT OF SUBJECTS USED DURING
THE QUALITATIVE DOWNWASH SURVEYS

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Subject No.	Height		Weight	
	Inches	Percentile	Pounds	Percentile
1	67	25th	133	10th
2	73	95th	150	25th
3	74	98th	171	75th
4	74	98th	220	99th

Figure Z-1. (U) Height and weight of subjects used during the qualitative downwash surveys.

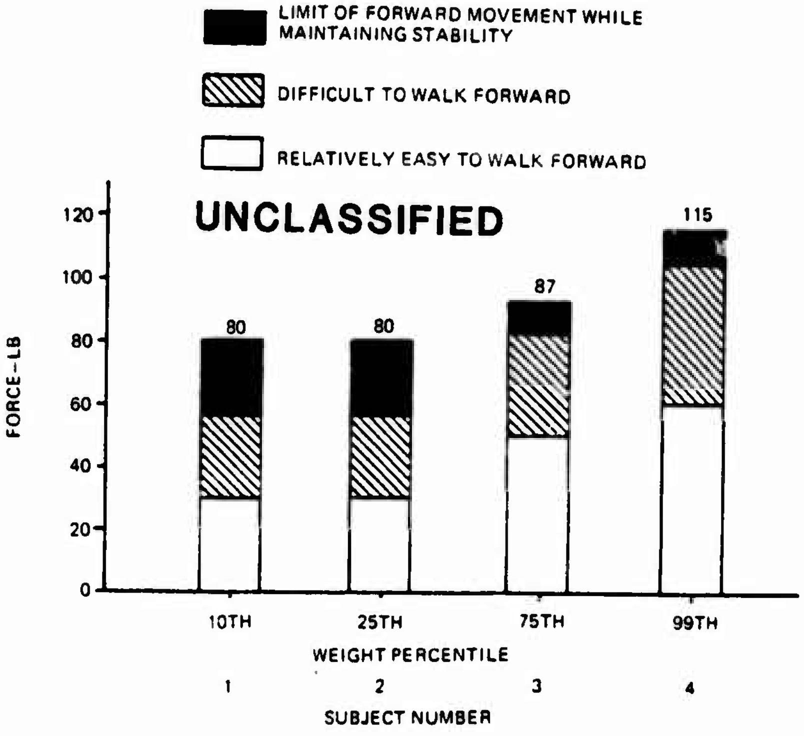

Figure Z-2. (U) Capabilities of test subject to walk or move forward under various amounts of horizontal restraint loads applied at a position 3 ft AGL (US Marine Corps weight percentile).

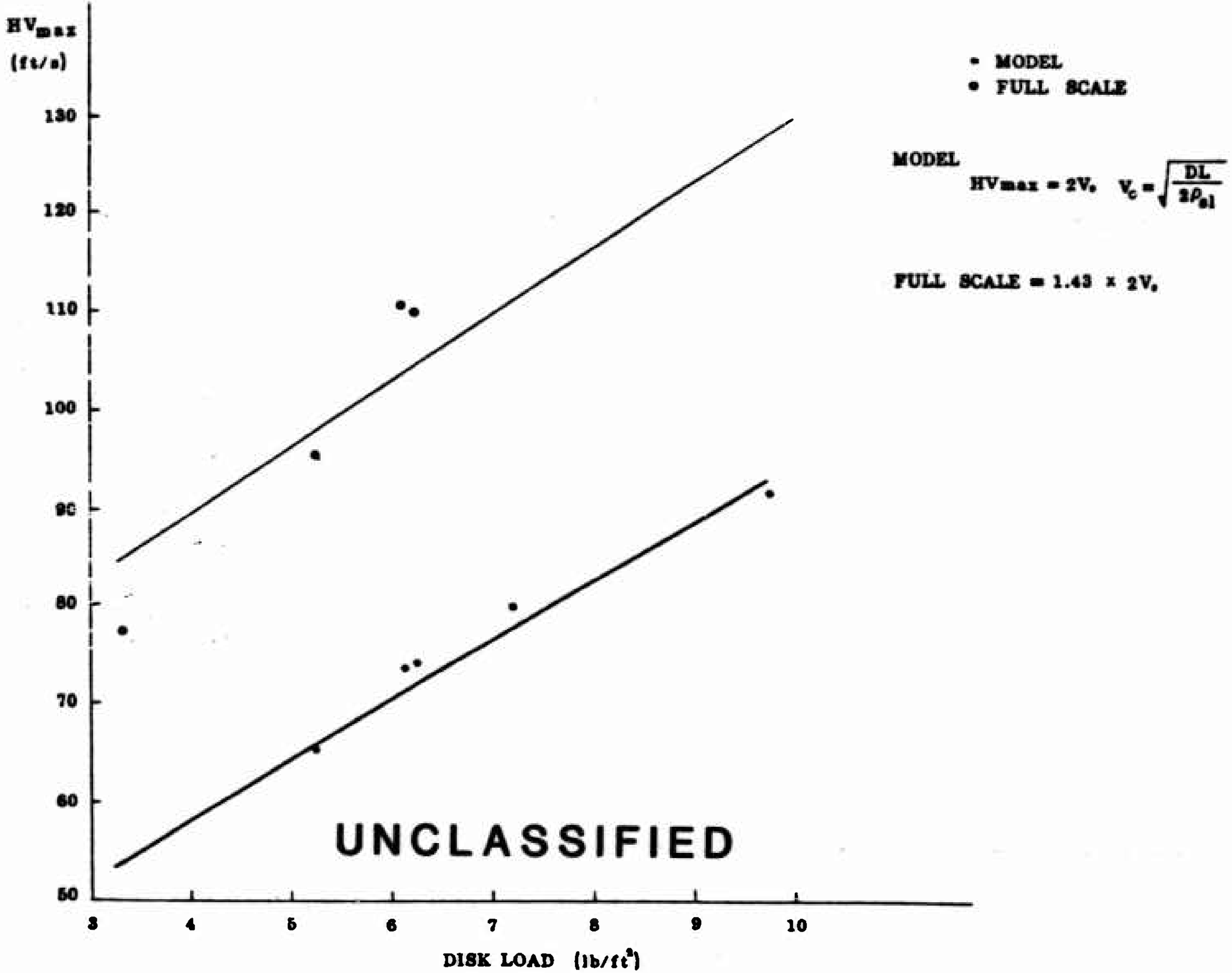

Figure Z-3. (U) Maximum horizontal velocity as a function of disk load.

	Rotor Diameter Feet	Aircraft Weight Pounds	Diskload Pounds Sq. Ft.	Max. Hor. Velocity fps	Max. Down Wash Force lb/sq ft	Personnel Maximum Force lb	Max. Force Velocity Radial Ft From Center
Helicopter							
SCAT	40.68	9,097	7	109	14	70	30.51
Utility	40.68	9,747	7.5	112	15	75	30.51
Helicopter Compound							
SCAT	39.7	10,438	8.43	119	17	84	29.78
Utility	39.7	10,961	8.85	122	18	88	29.78
ABC							
SCAT	37.14	10,292	9.5	126	19	94	27.86
Utility	37.14	10,954	10.11	130	20	100	27.86
ABC-Compound							
SCAT	36.82	11,181.8	10.5	133	21	104	27.62
Utility	36.82	11,837.6	11.12	137	22	110	27.62
T/R*							
SCAT	26.28	10,850	10	130	20	99	19.71
Utility	26.28	11,370.6	10.5	133	21	104	19.71
AH-1S	44	9,975	6.56	105	13	65	33
AH-64A	48	14,694	8.12	117	16	81	36
AH-64 (Max)	48	17,650	9.76	129	19	97	36
UH-60A	53.66	16,260	7.19	110	14	71	40.25
UH-60A (Max)	53.66	20,250	8.95	123	18	89	40.25
UH-60D (Max)	53.66	22,000	9.73	128	19	97	40.25
XV-15 (T/R)	25.00	12,475	12.71	116[1]	16	80	31.7[2]

*Two rotors, predicted by model for helicopters actual distribution differs as test data from XV-15 T/R shows.

1. Actual experimental value.
2. From aircraft center at 0°.

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Figure Z-4. (U) LHX downwash maximums comparison.

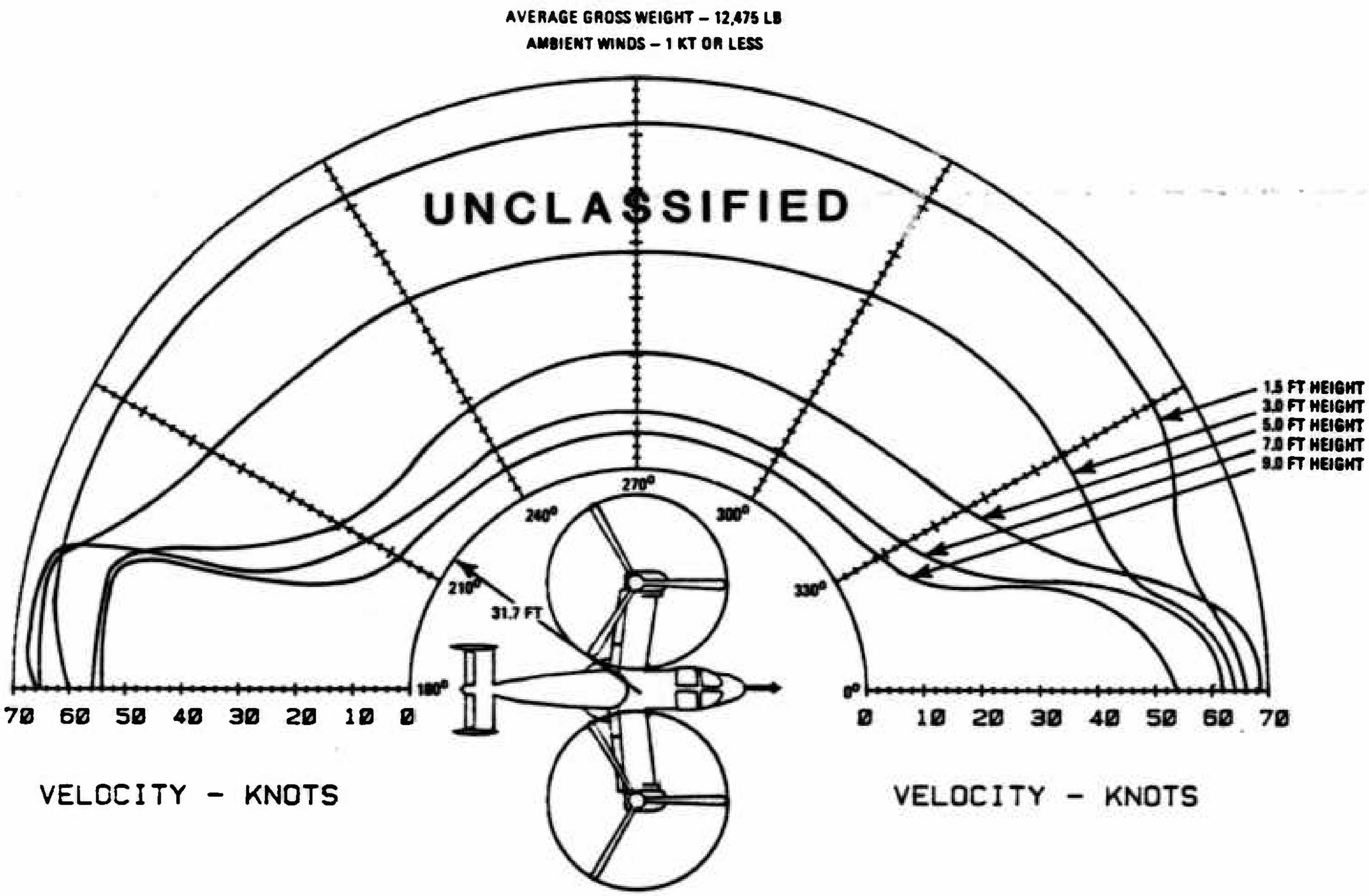

Figure Z-5. (U) Variation of downwash peak horizontal wind velocity around the XV-15 tilt rotor aircraft measured at five transducer heights at the 31.7-ft test position. Data from 0° to 330° and 270° were obtained at a 25-ft hover. Data from 210° to 180° were obtained during tests on the tie-down stand (6 ft wheel hover height). Data at 300° and 240° were extrapolated.

AVERAGE GROSS WEIGHT – 12,475 LB
AMBIENT WINDS – 1 KT OR LESS

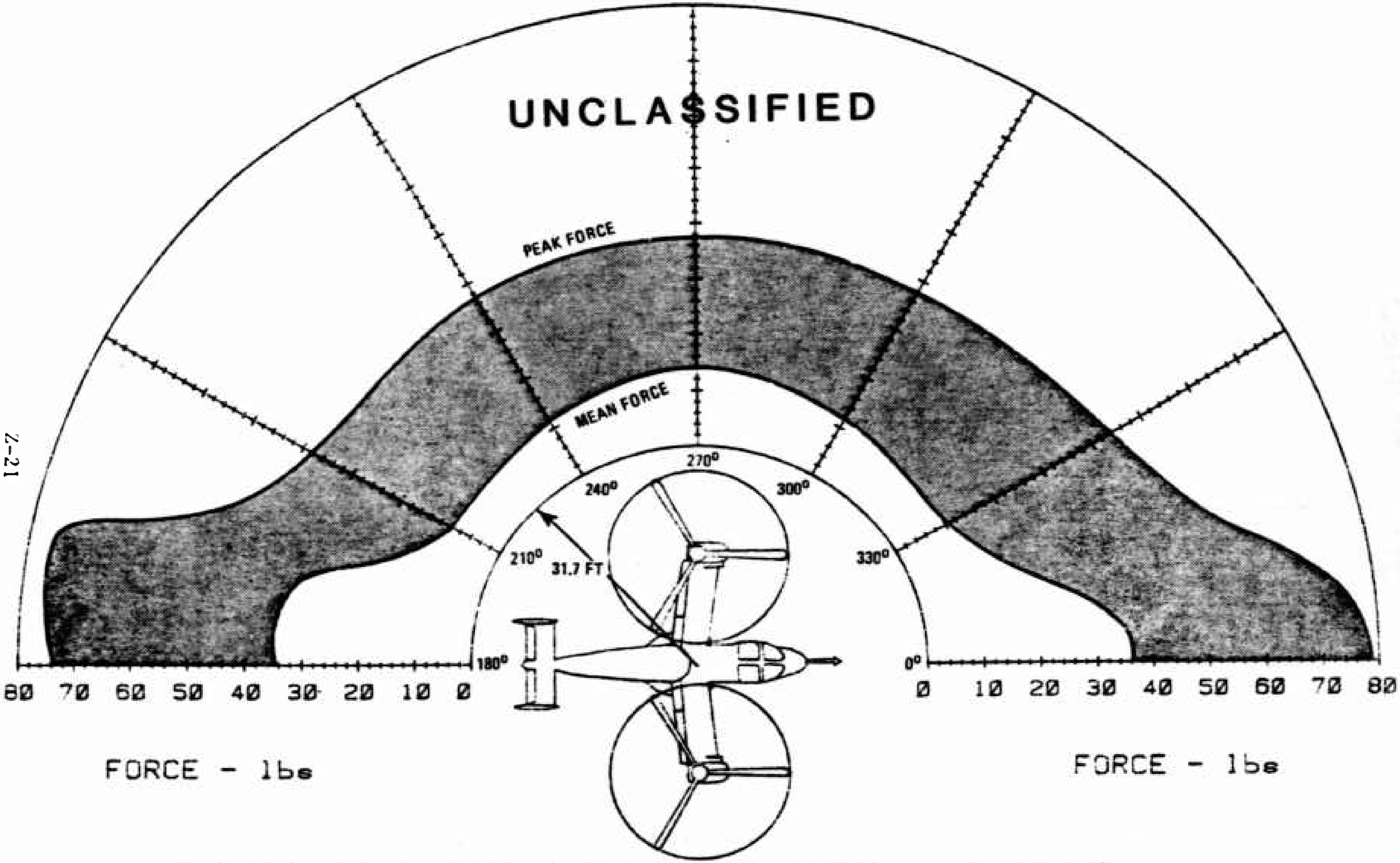

Figure Z-6. (U) Horizontal downwash wind forces on personnel as computed from measurements at the 31.7-ft position during a 25-ft hover and plotted as a function of relative bearing.

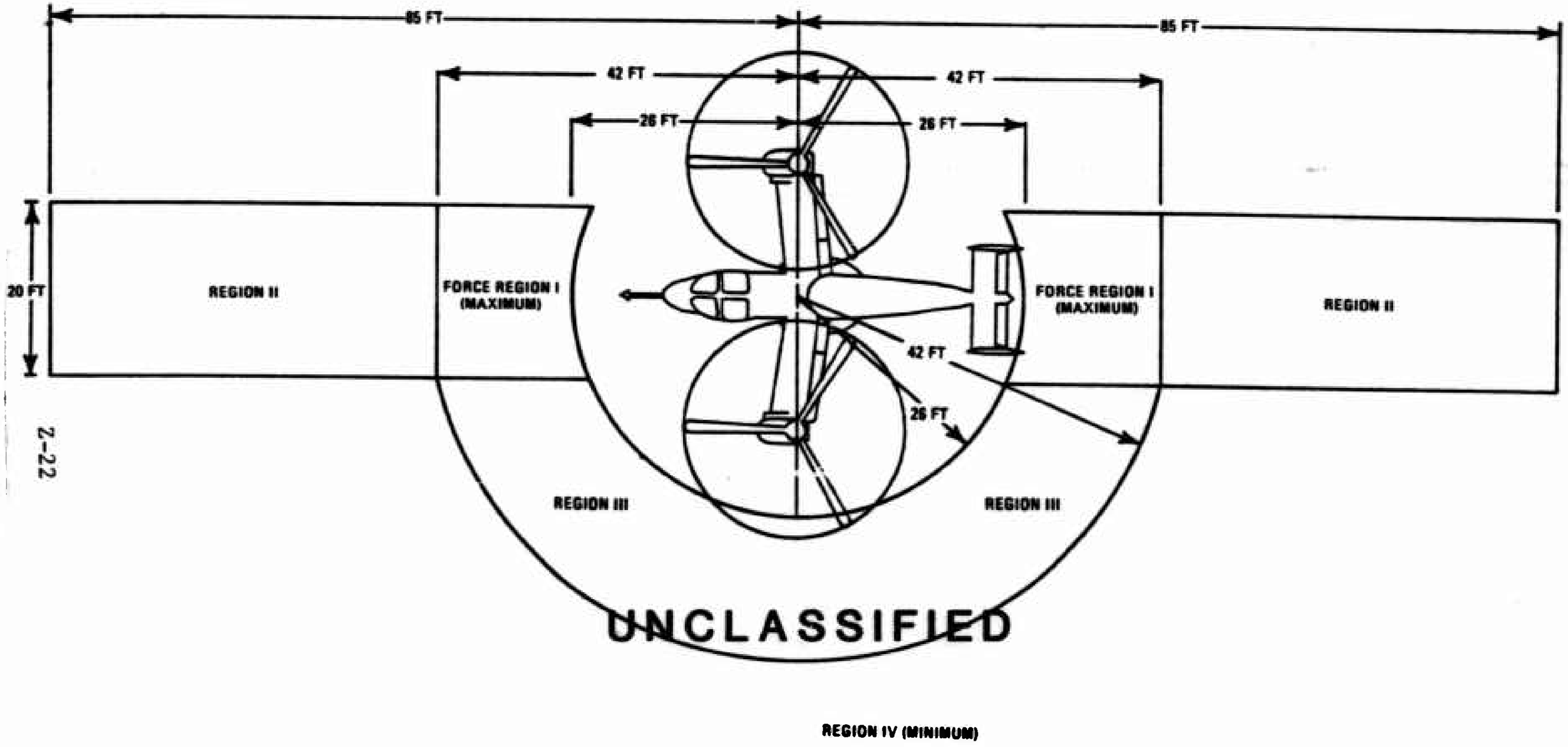

Figure Z-7. (U) Regions of different levels of wind force on personnel. Description of level of force in each region is contained in figure Z-8.

Regions[1]	Weight (Percentile) - lb		
	150 (25th)	171 (75th)	220 (99th)
I[2]	Exceed stability limit. Hazardous.	Difficult to walk through.	Slightly difficult to walk through.
II	Very difficult to walk through.	Slightly difficult to walk through.	No difficulty to walk through.
III	Moderately difficult to walk through.	No difficulty to walk through.	No difficulty to walk through.
IV	No difficulty to walk through.	No difficulty to walk through.	No difficulty to walk through.

NOTES:

1. Regions are defined in figure Z-7.
2. Maximum force region.

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Figure Z-8. (U) Personnel limitation in flow field regions.

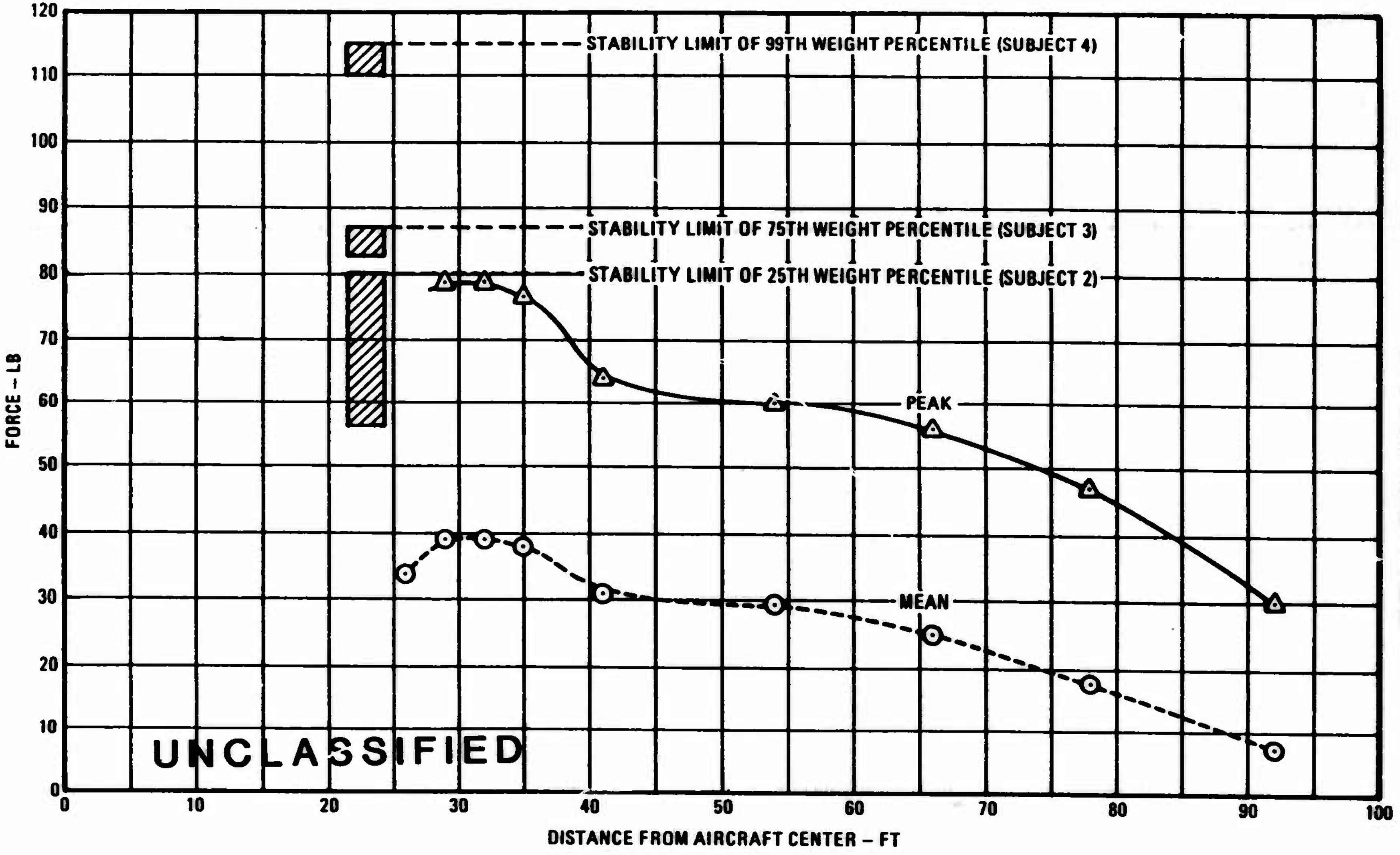

Figure Z-9. (U) Horizontal downwash wind forces on personnel at a relative bearing of 0° during hover at 25 ft AGL and an average gross weight of 12,475 lb.

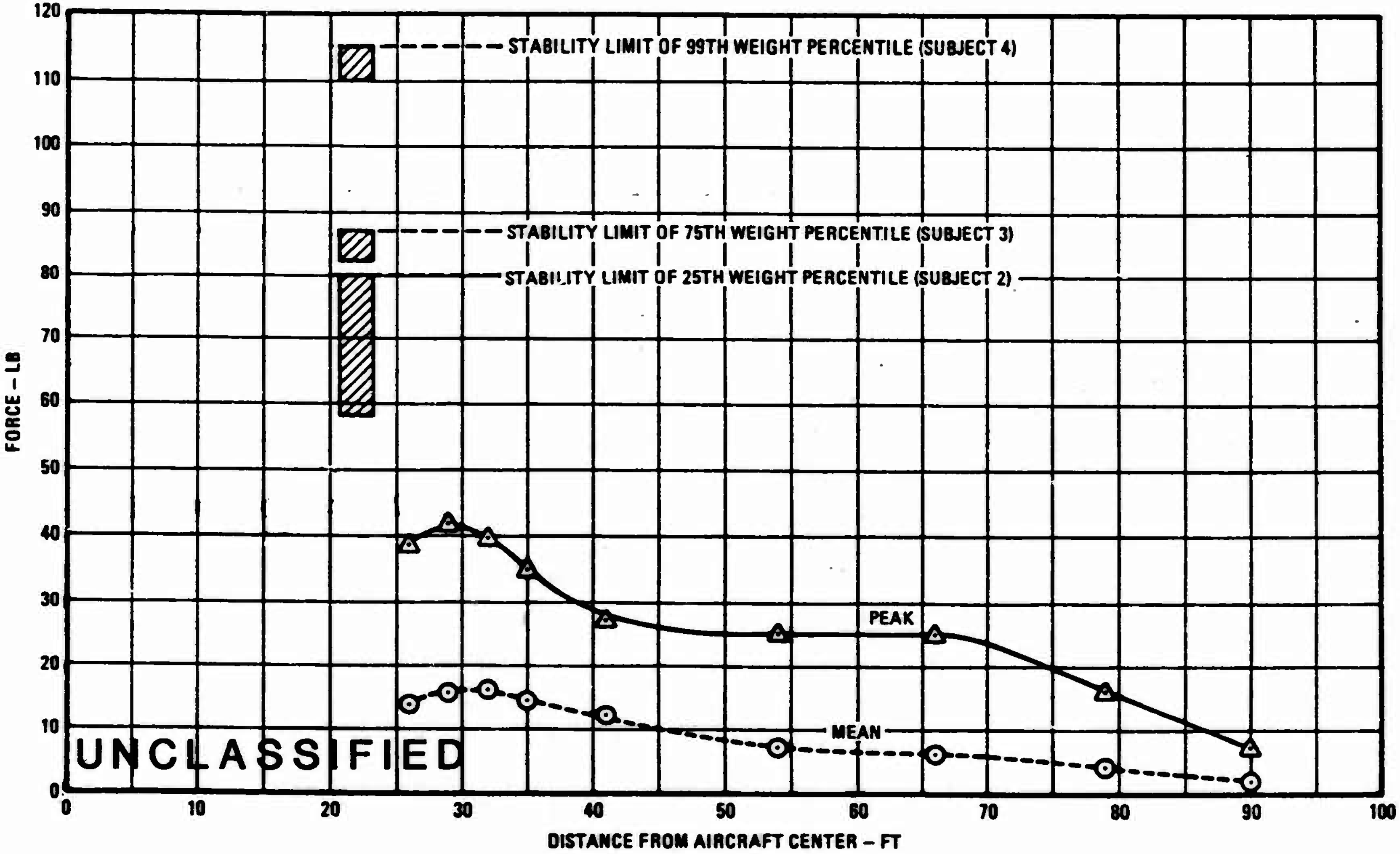

Figure Z-10. (U) Horizontal downwash wind forces on personnel at a relative bearing of 270° during hover at 25 ft AGL and an average gross weight of 12,475 lb.

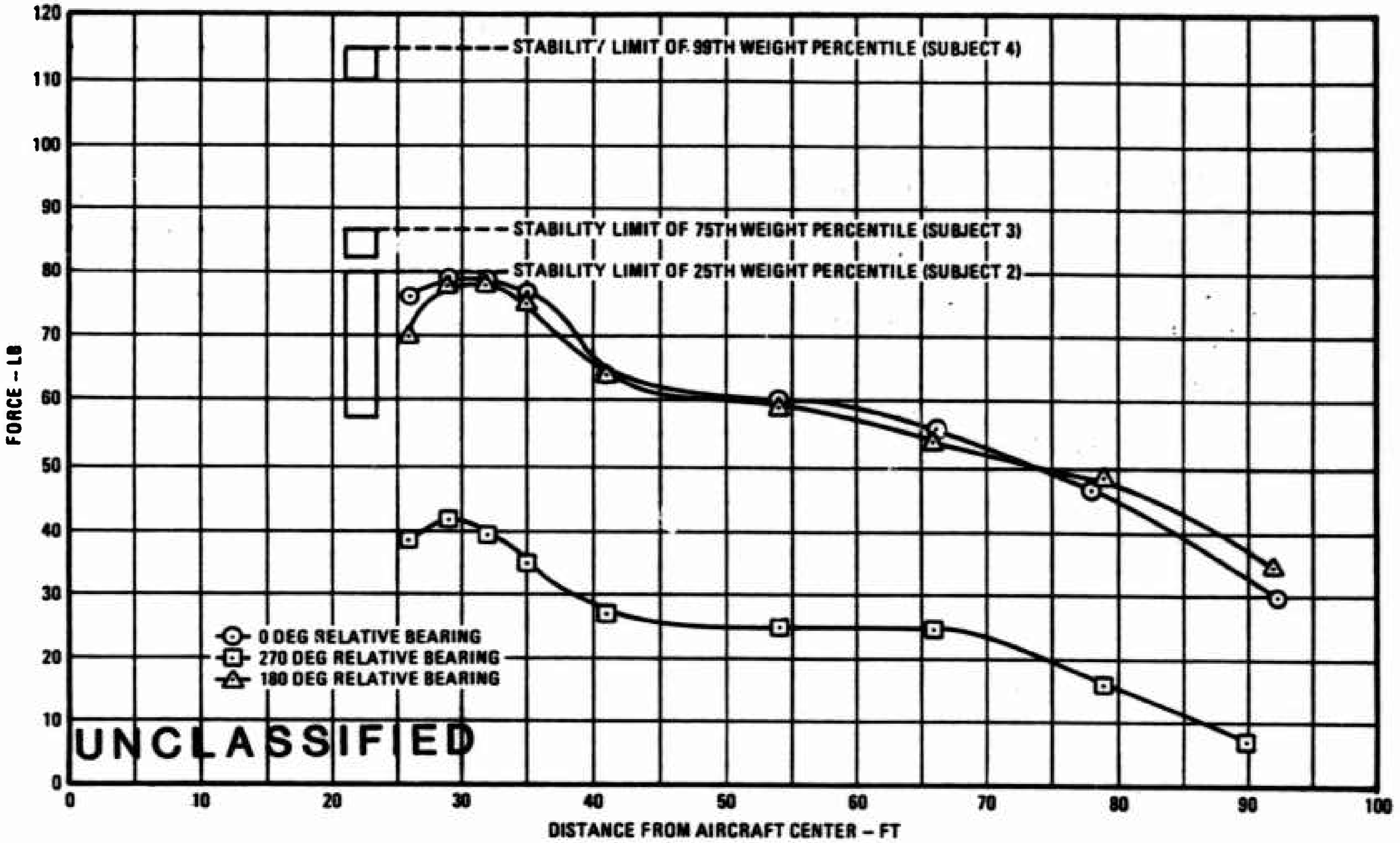

Figure Z-11. (U) Horizontal downwash wind forces on personnel at a relative bearing of 180° during hover at 25 ft AGL and an average gross weight of 12,475 lb.

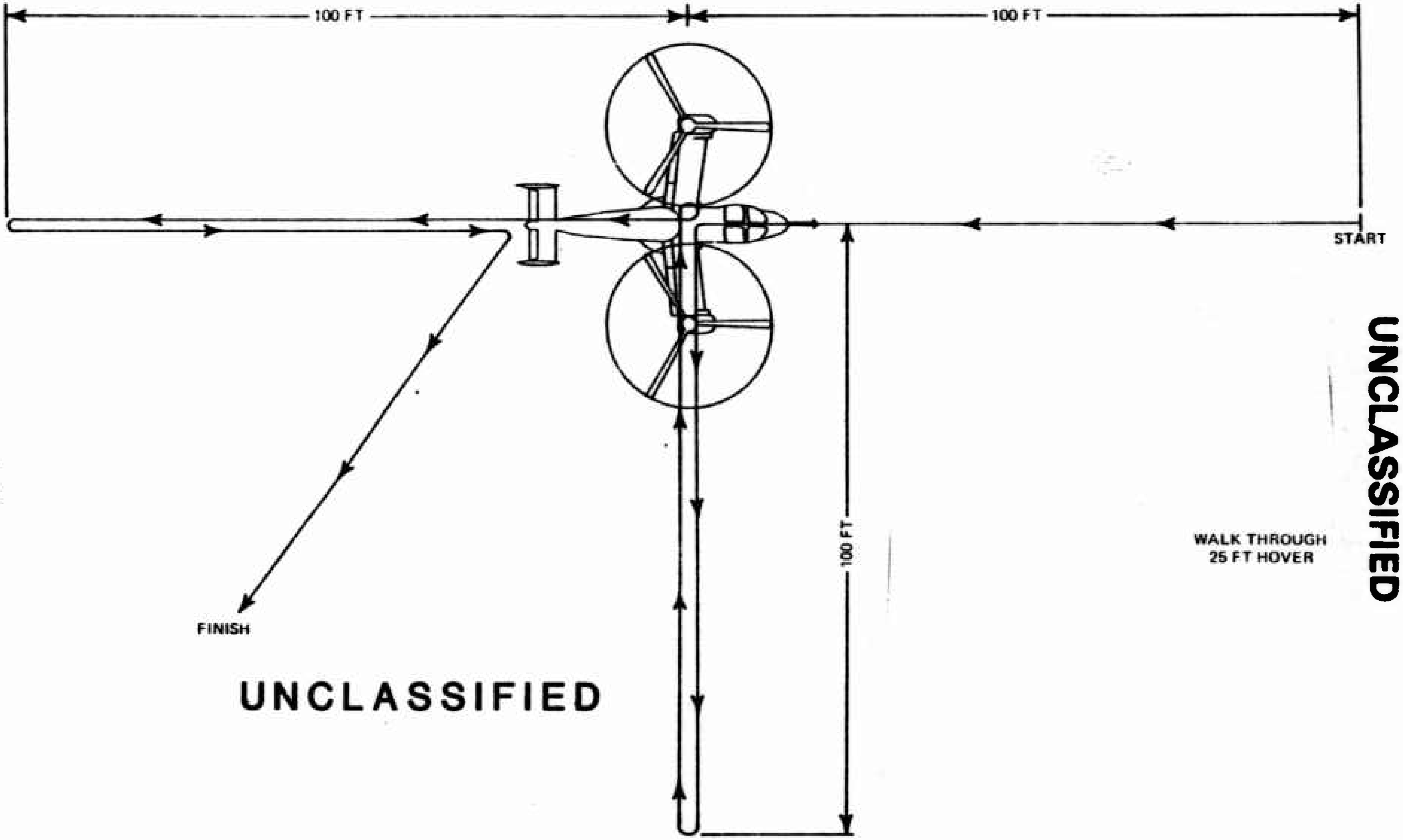

Figure Z-12. (U) Path of locations of test subject while conducting qualitative walk-around test under the XV-15 tilt rotor aircraft hovering at 25 and 50 feet.

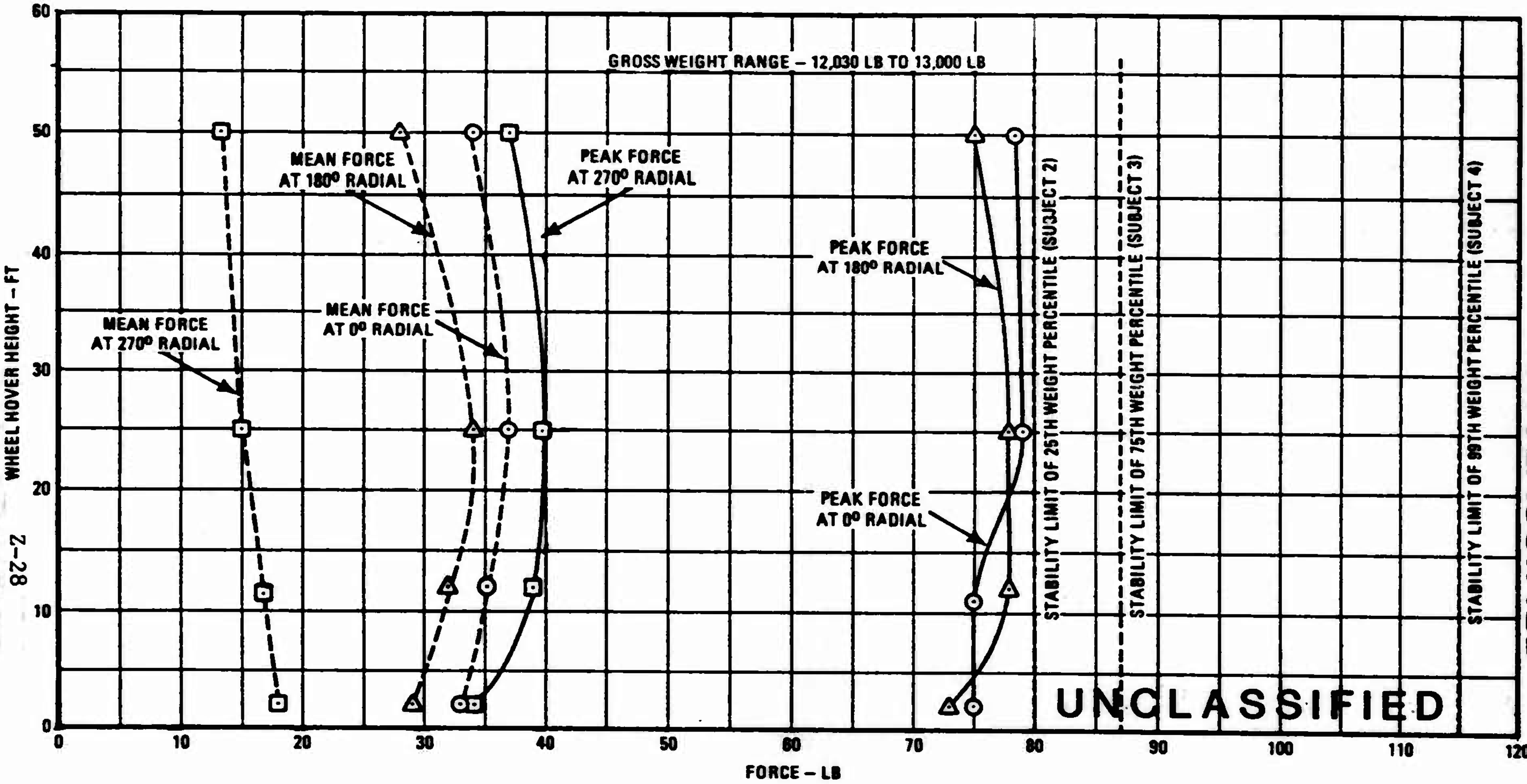

Figure Z-13. (U) Horizontal downwash wind forces on personnel as computed from measurements at the 31.7-ft test position and plotted as a function of hover height.

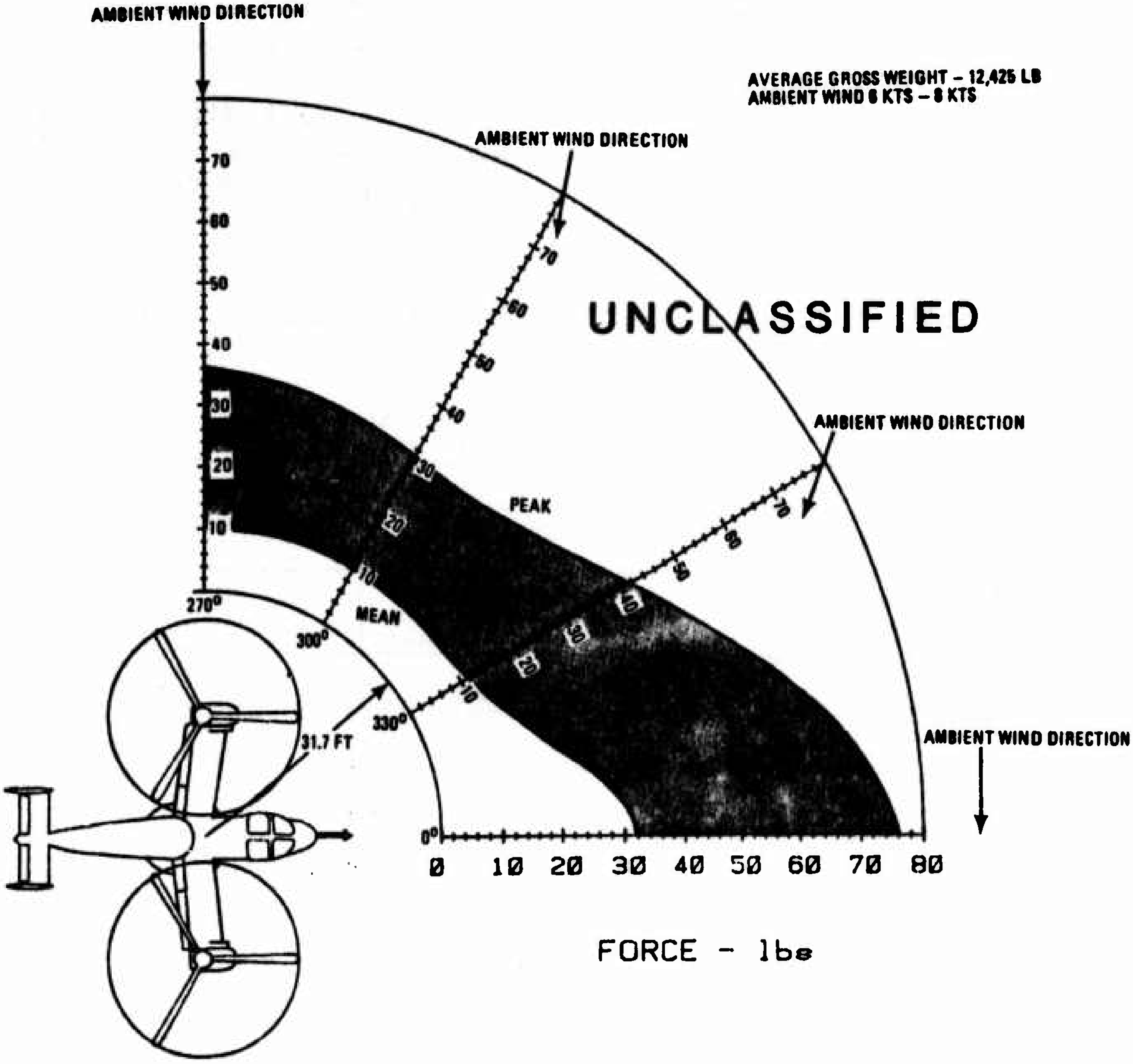

Figure Z-14. (U) Horizontal downwash wind forces on personnel as computed from measurements at the 31.7-ft test position during hover at 12 ft in an ambient crosswind.

a. Terrain with a large number of particles per unit ground area.

Terrain	Specific Gravity	Particle Size (Average), Inches	(S.G.) (Size)
Water	1.00	0.10 (estimated)	0.10
Sand	1.45	0.08 (measured)	0.12
Snow	0.27	0.15 (estimated)	0.04

b. Terrain with few particles per unit ground ara.

Terrain	Specific Gravity	Particle Size (Average), Inches	(S.G.) (Size)
Gravel and stone	2.5	1/2 to 3 (measured)	1.2
Debris	0.3	23 (measured)	6.9
Earth	1.6	1 (estimated)	1.6

c. Terrain with no significant particles.

Terrain
Sod Clay

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Figure Z-15. (U) Terrain particle parameters.

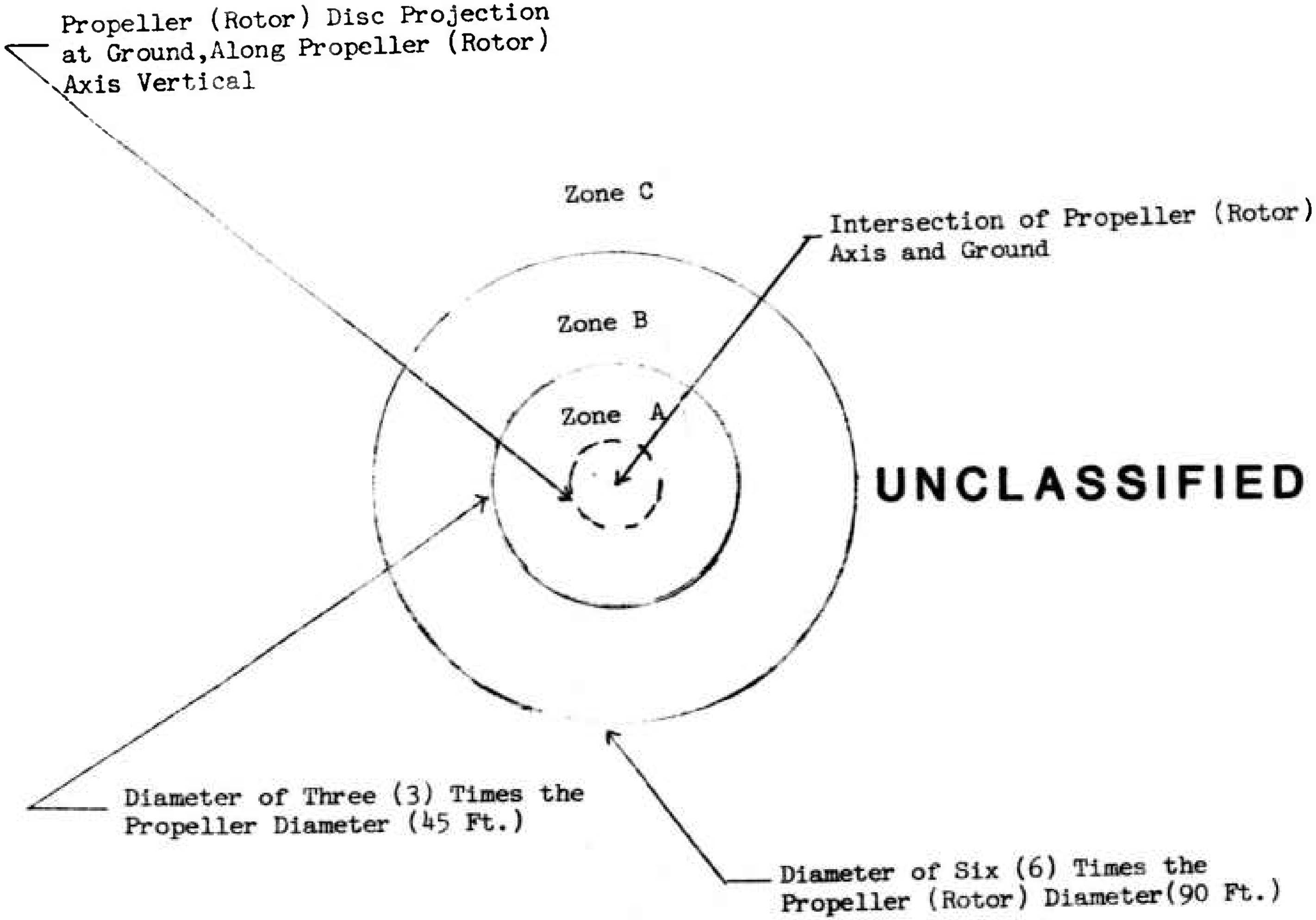


Figure Z-16. (U) Zones of operational limitations for personnel and equipment.

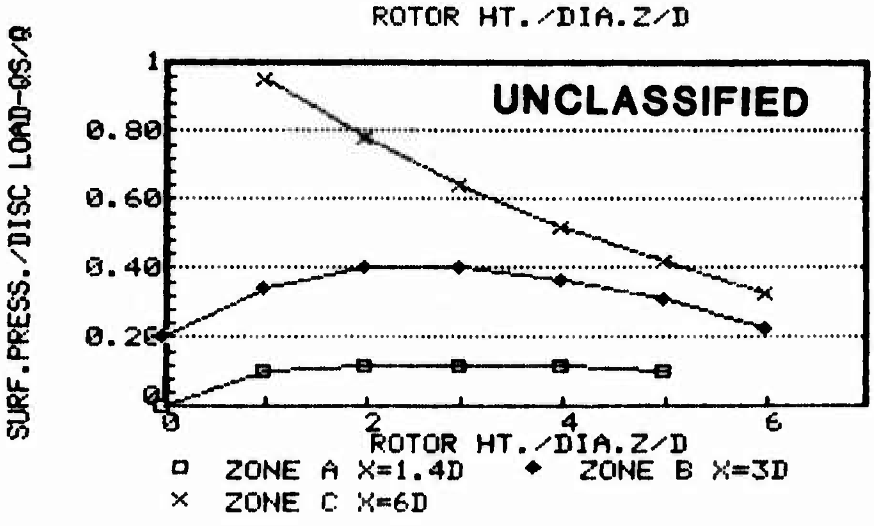


Figure Z-17. (U) Effect of rotor height on surface dynamic pressure for ground area zones considered in the test program.

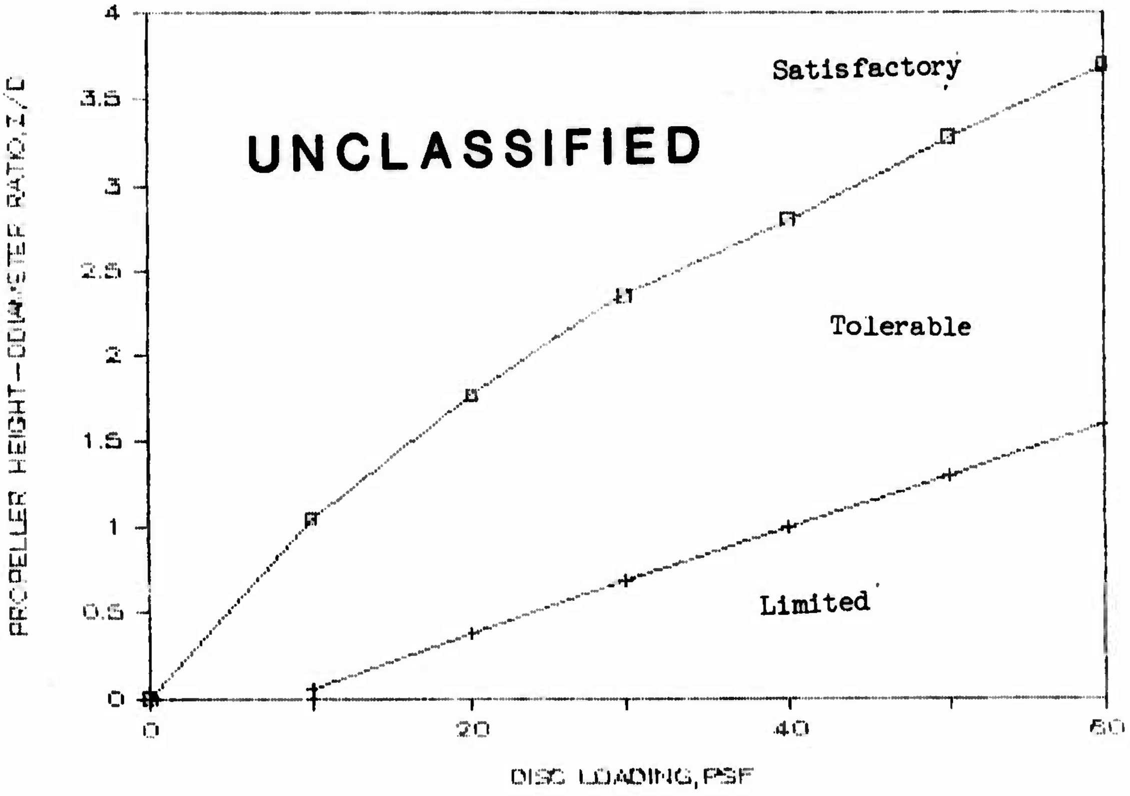


Figure Z-18. (U) Restriction of personnel motion by downwash aerodynamic forces in zone A.

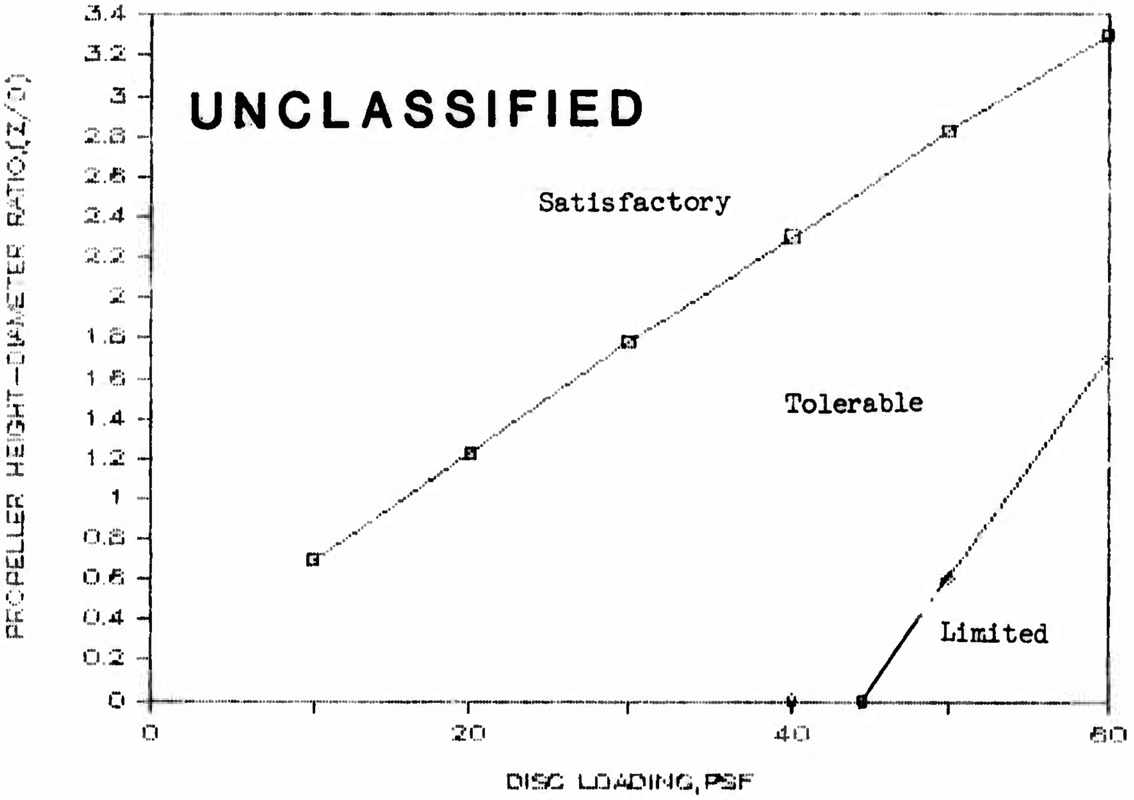


Figure Z-19. (U) Restriction of personnel motion by downwash aerodynamic forces in zone B.

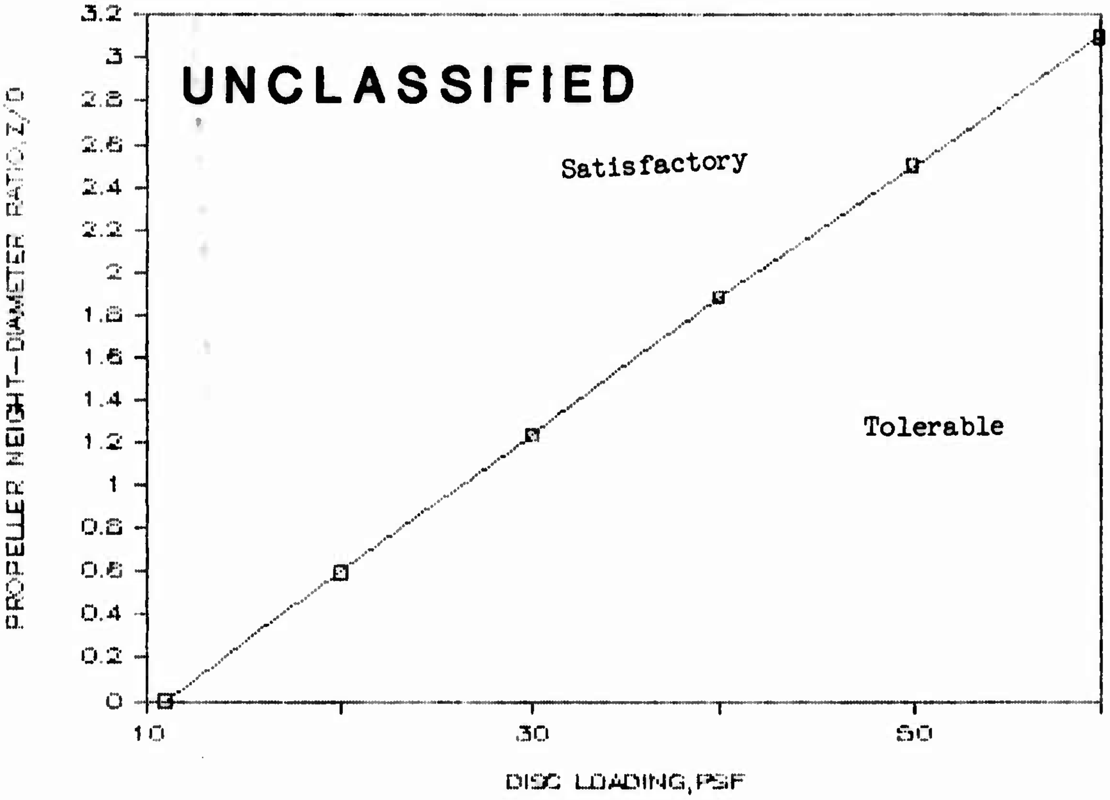


Figure Z-20. (U) Restriction of personnel motion by downwash aerodynamic forces in zone C.

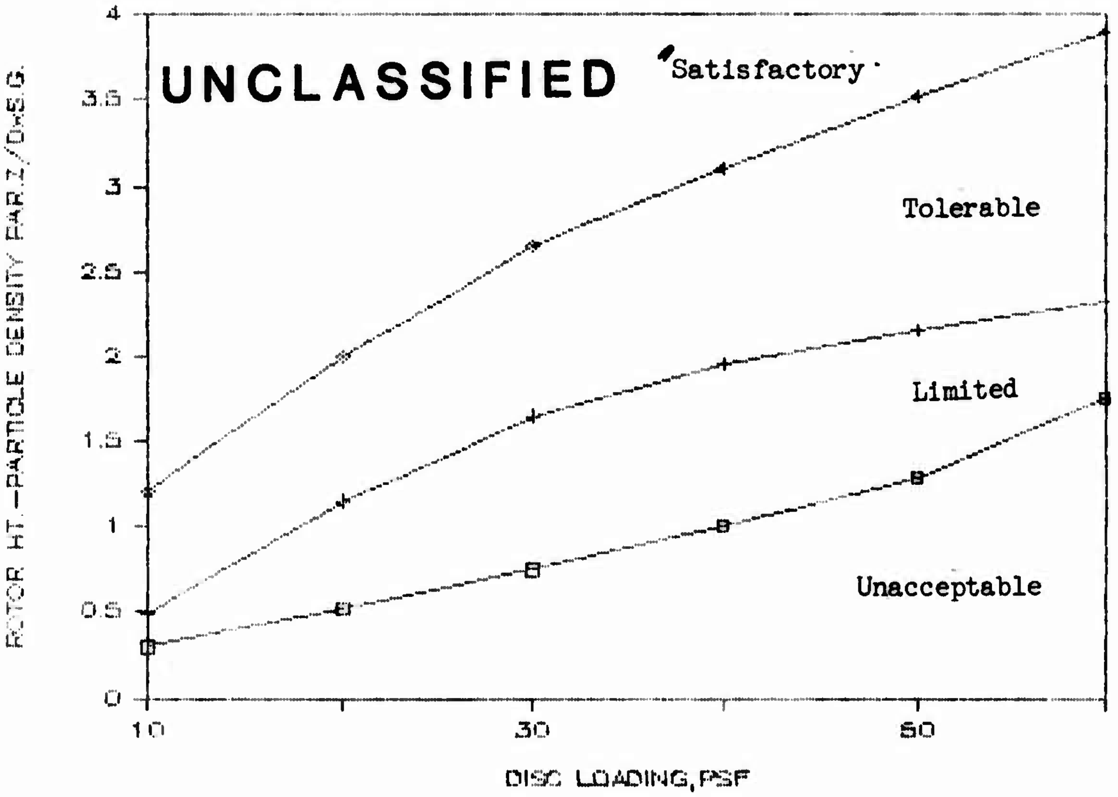


Figure Z-21. (U) Pilot's vision obstruction due to downwash.

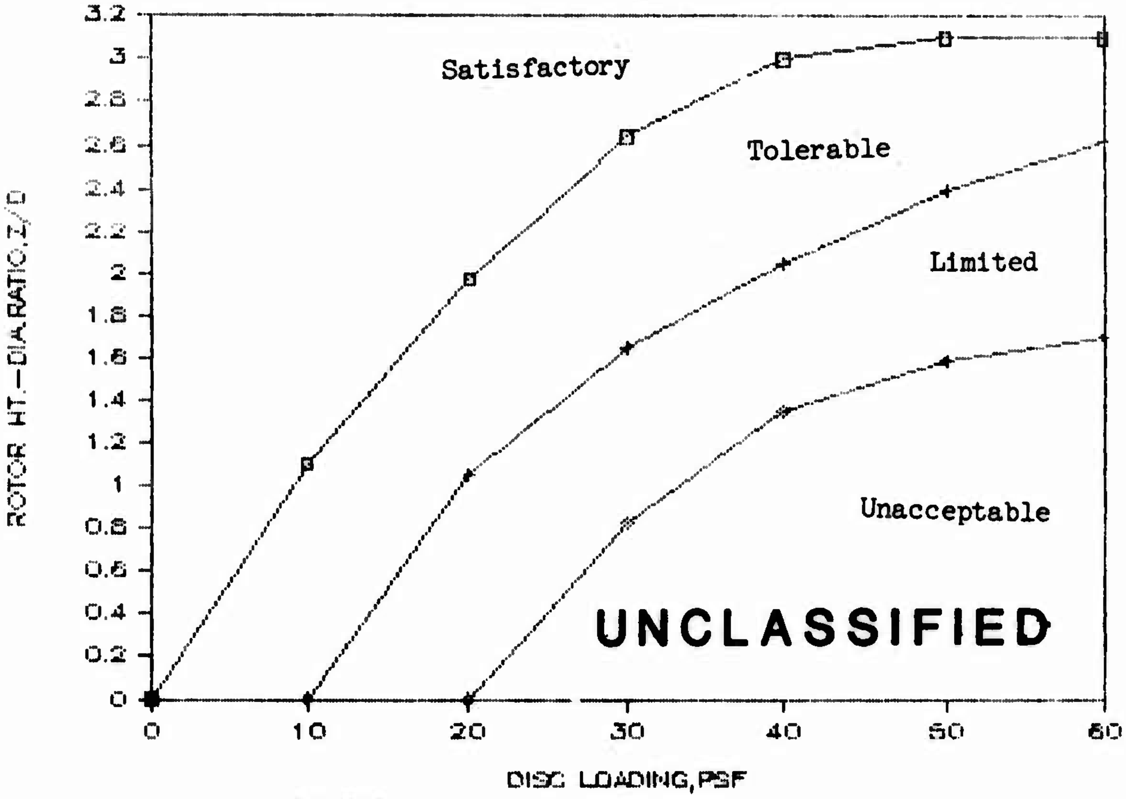


Figure Z-22. (U) Personnel vision problems in zone A.

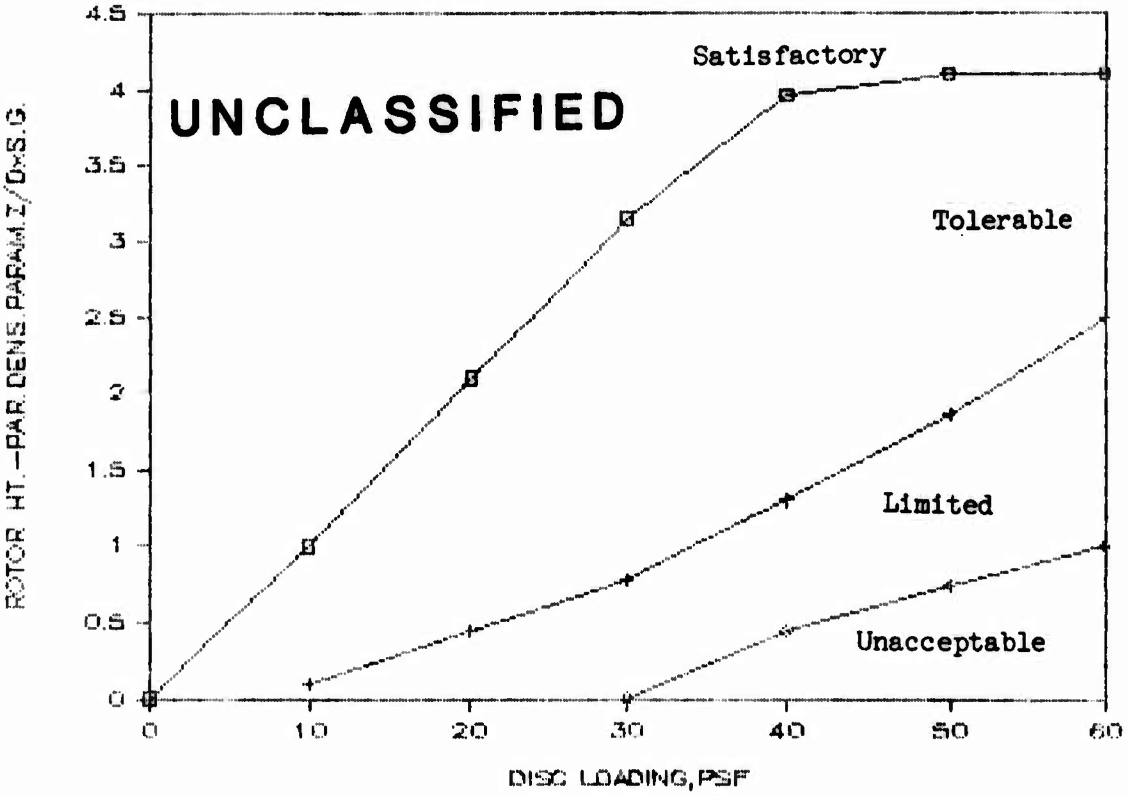


Figure Z-23. (U) Personnel vision problems in zone B.

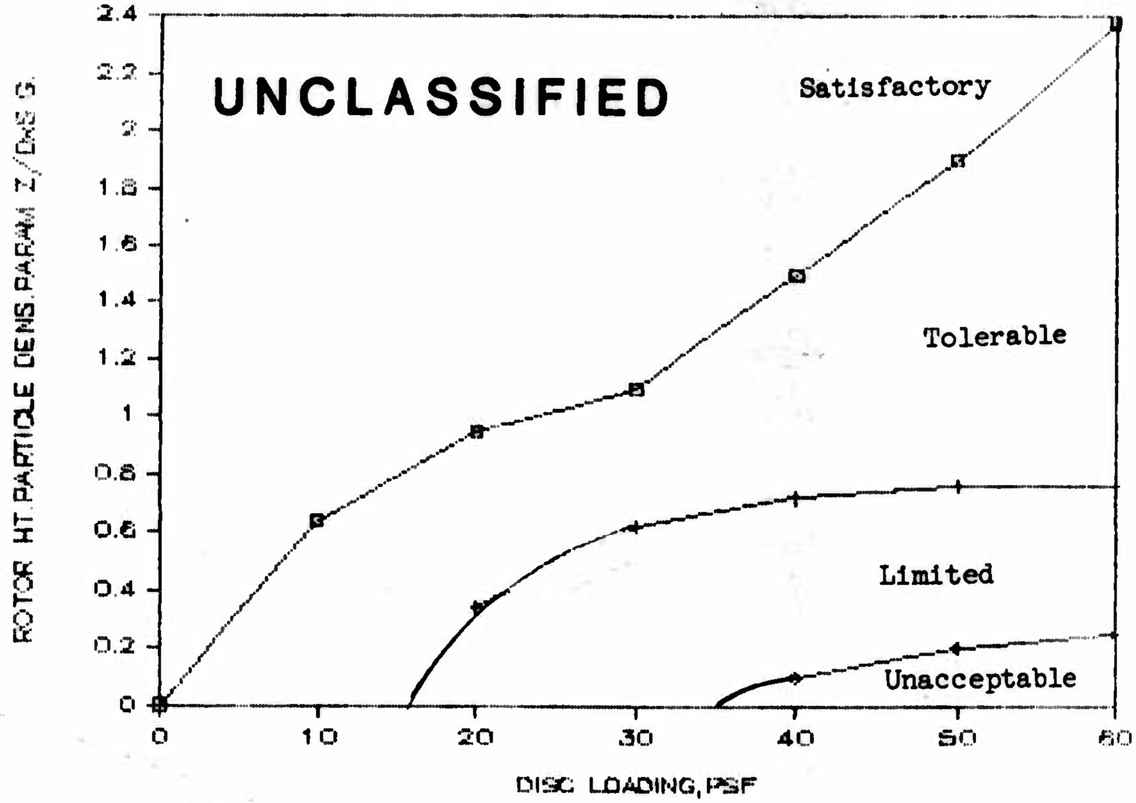


Figure Z-24. (U) Personnel vision problems in zone C.

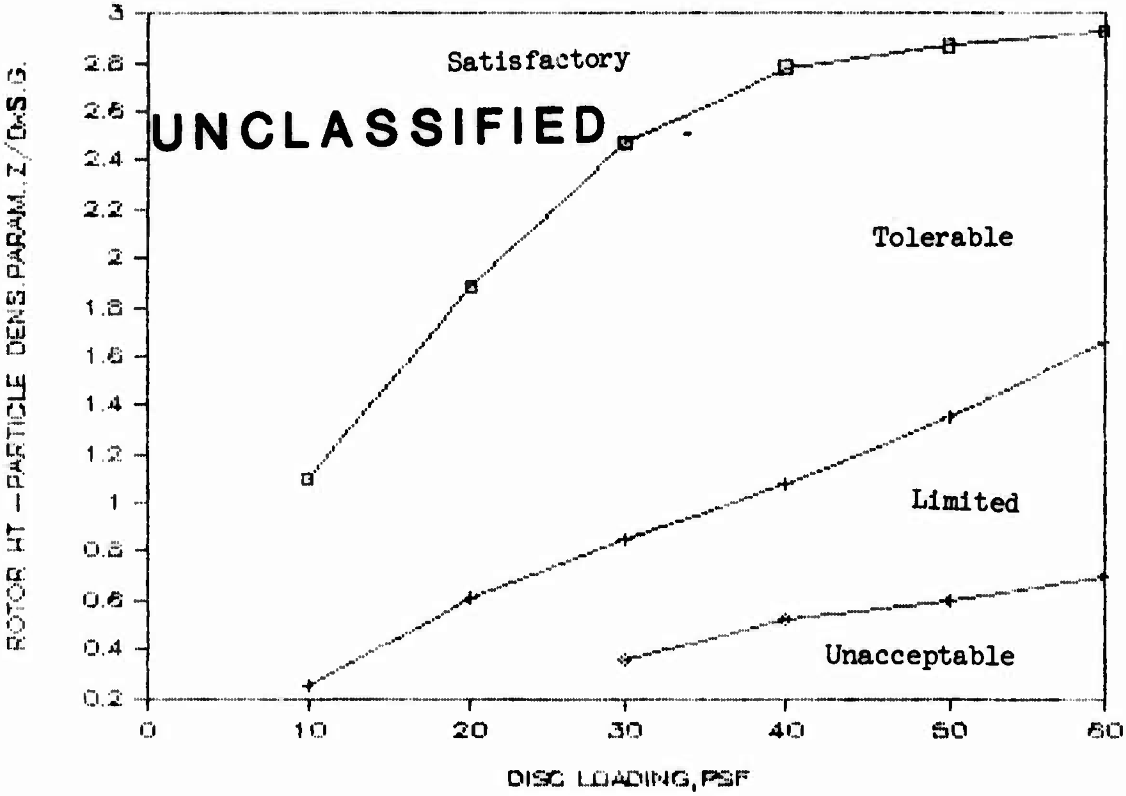
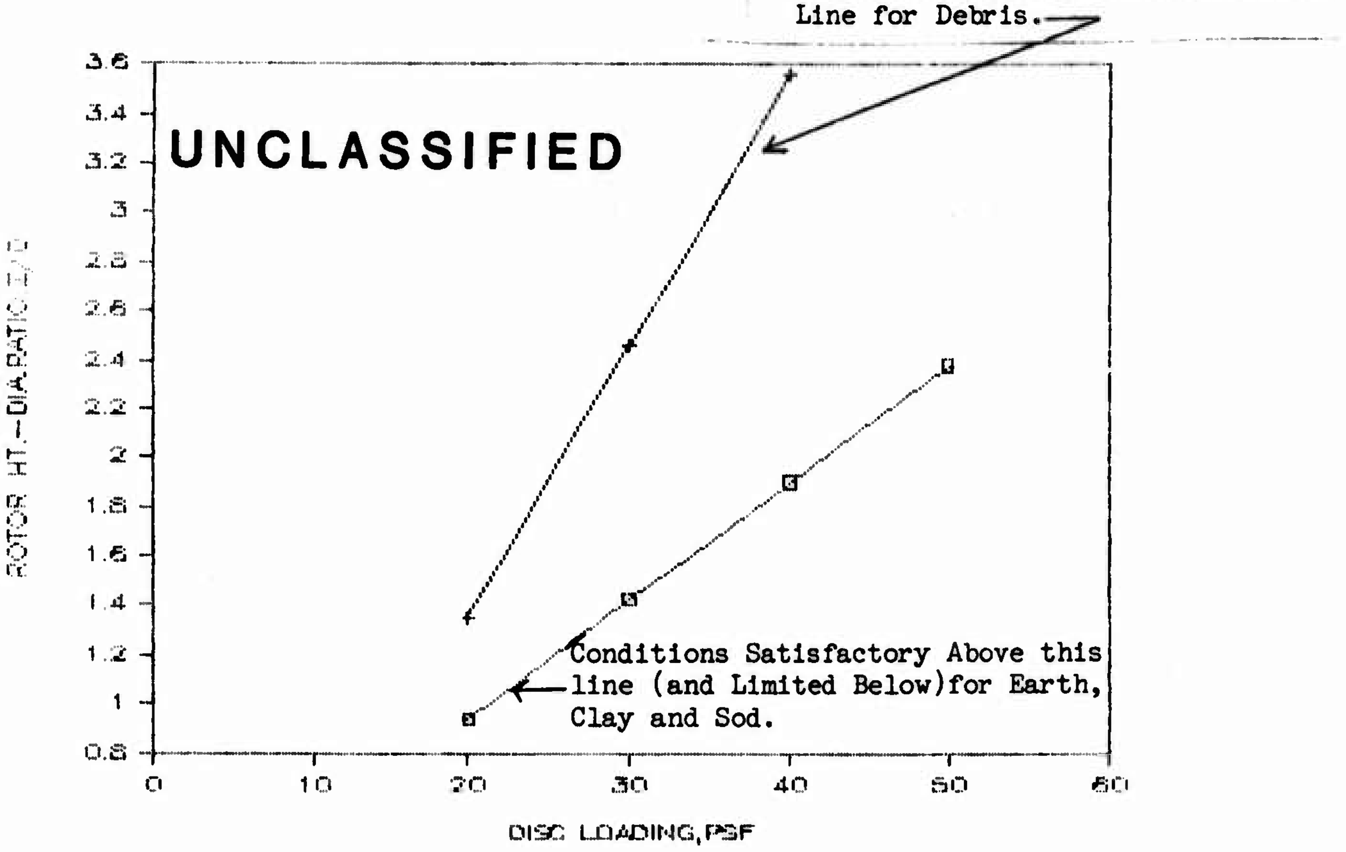


Figure Z-25. (U) Severity of concealment problem.



Conditions Unacceptable Below this Line for Debris.

Conditions Satisfactory Above this line (and Limited Below)for Earth, Clay and Sod.

Figure Z-26. (U) Personnel risk of injury in zone A.

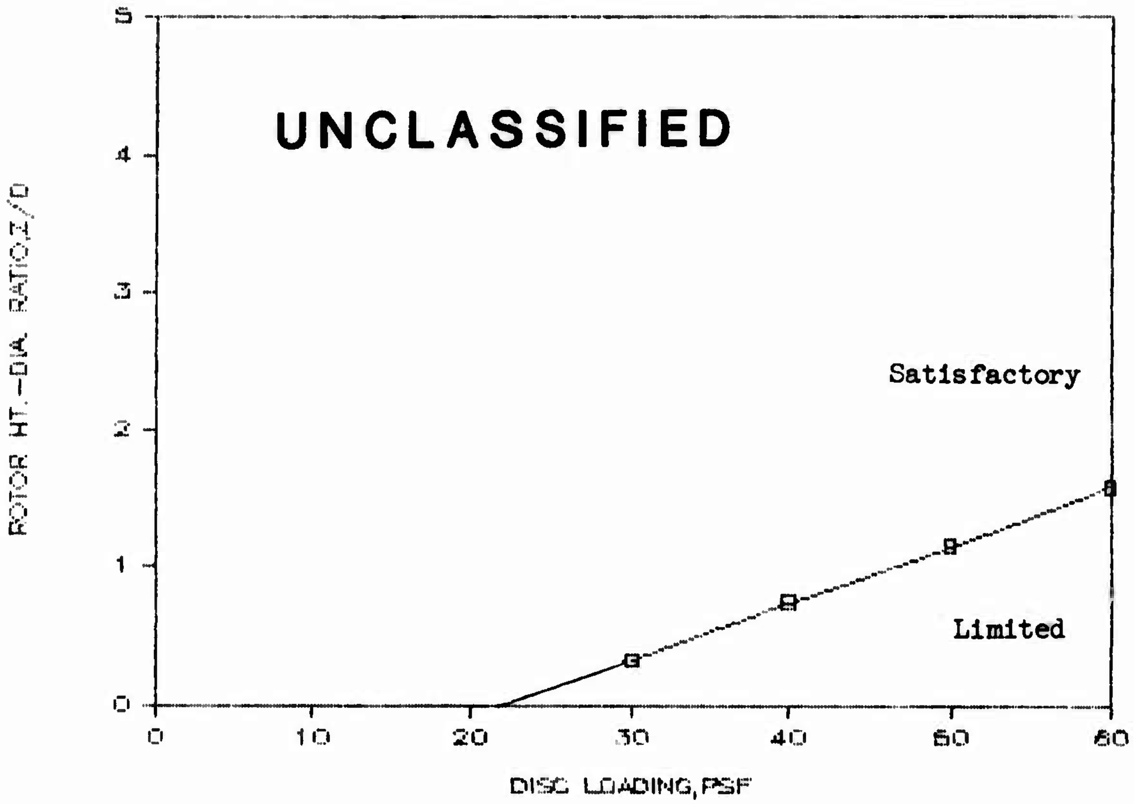


Figure Z-27. (U) Evaluation of possible damage to airframe.

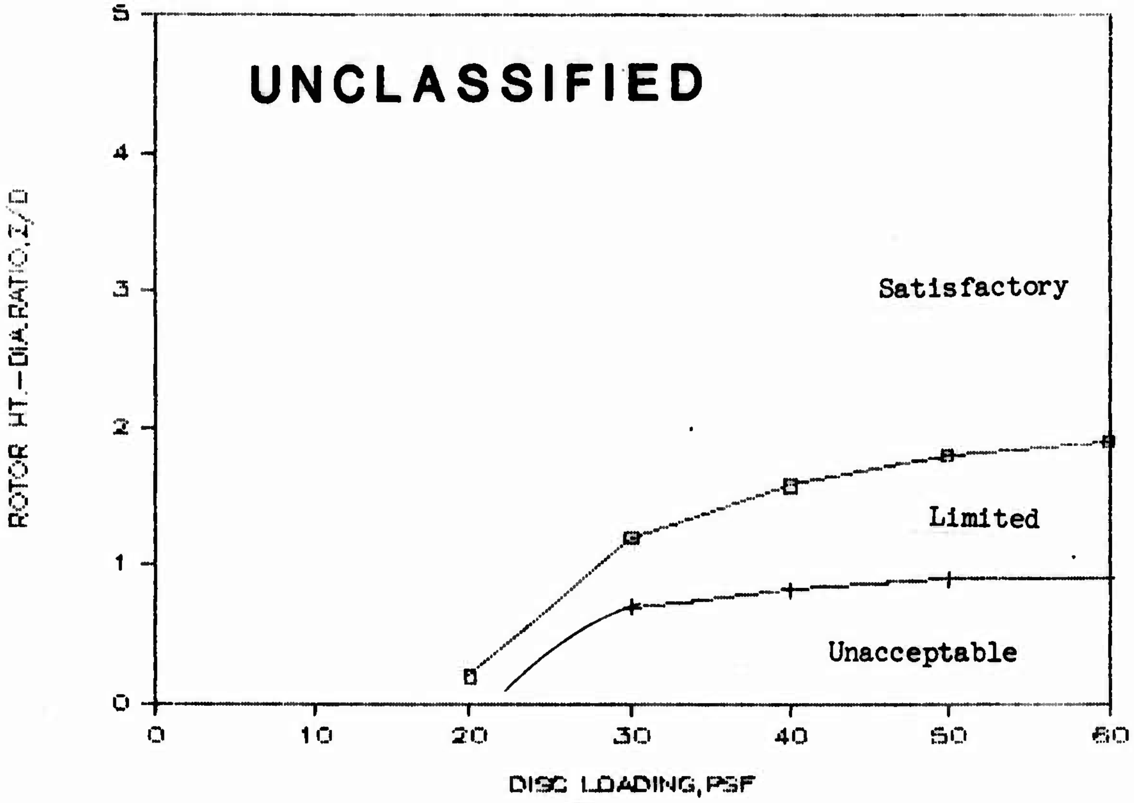


Figure Z-28. (U) Evaluation of possible damage to rotor.

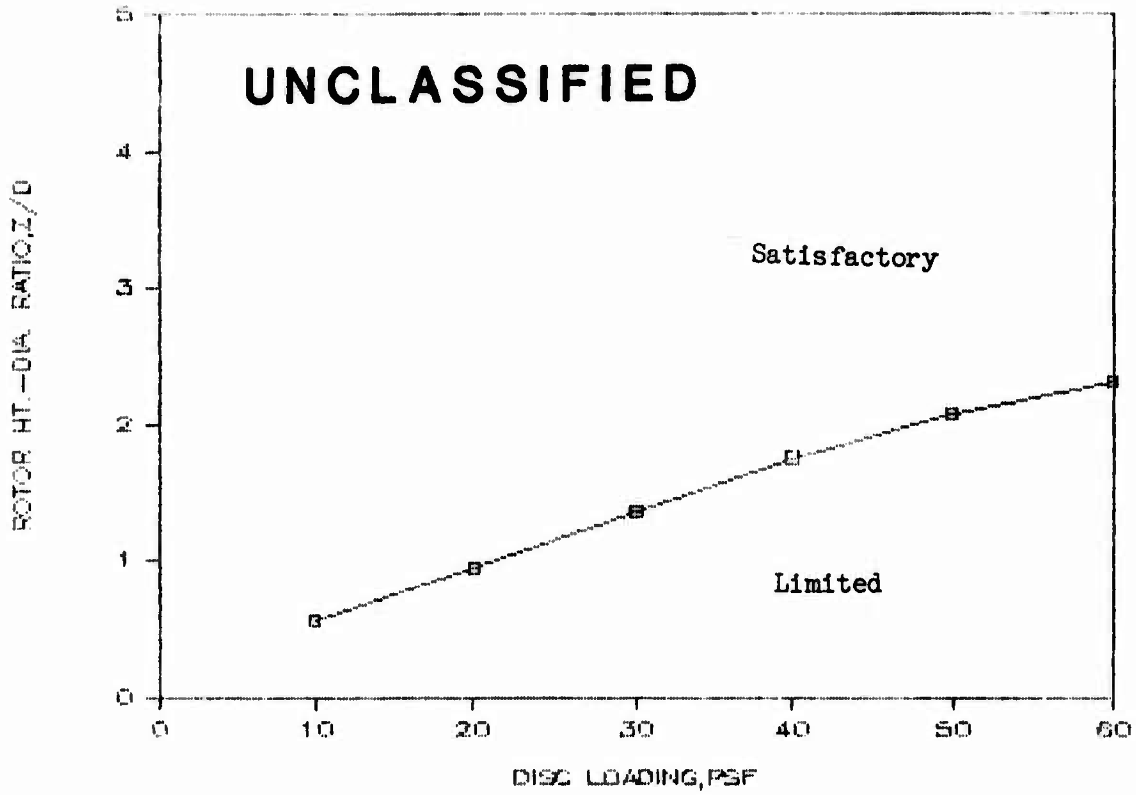


Figure Z-29. (U) Evaluation of damage to engine by terrain ingestion.

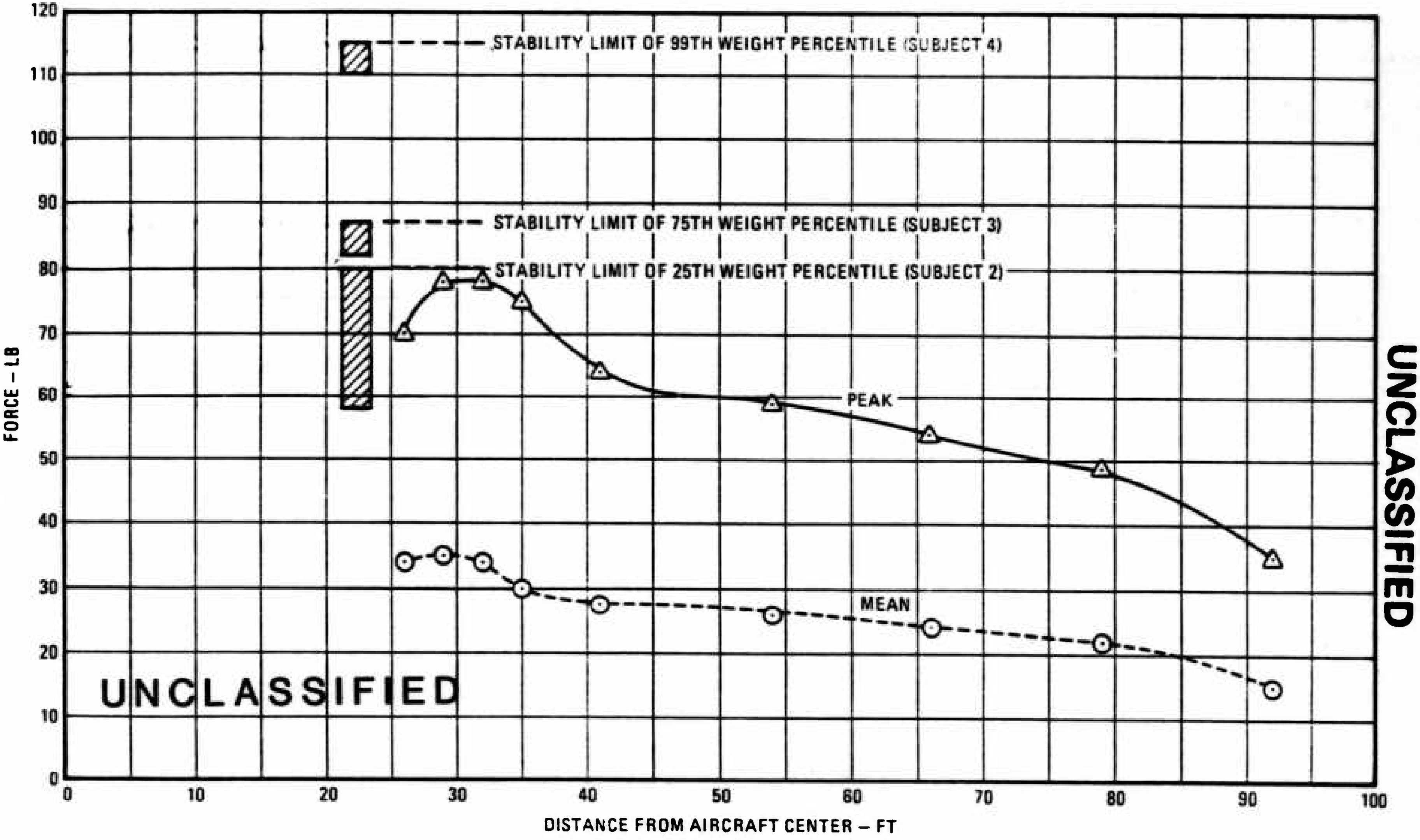


Figure Z-30. (U) Horizontal downwash peak wind forces on personnel plotted as a function of distance from the aircraft center during hover at 25 ft AGL and an average gross weight of 12,475 lb.

Z-9. (U) FINDINGS. Available tools and methods do not allow a confident comparison of the downwash effects among the proposed LHX variants. Comparisons extrapolated from disc loadings show roughly the same degree of operational effect as for existing Army rotorcraft. Characteristics peculiar to each variant will produce downwash flow differences that are not readily predictable without actual testing.

a. (U) In order of maximum downwash horizontal velocity (extrapolated from disc loadings), the variants are:

(1) (U) ABC-compound utility.

(2) (U) ABC-compound SCAT and T/R utility (tie).

(3) (U) ABC utility.

(4) (U) T/R SCAT.

(5) (U) ABC SCAT.

(6) (U) Helicopter compound utility.

(7) (U) Helicopter compound SCAT.

(8) (U) Helicopter utility.

(9) (U) Helicopter SCAT.

b. (U) In literature the question concerning the adequacy of design tools to assess the interactional aerodynamics in ground effect of compact rotorcraft of high disk loading is repeatedly raised. This and the consequences of inadequate determinations require that an aggressive test program be used to probe the needed design parameters.

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