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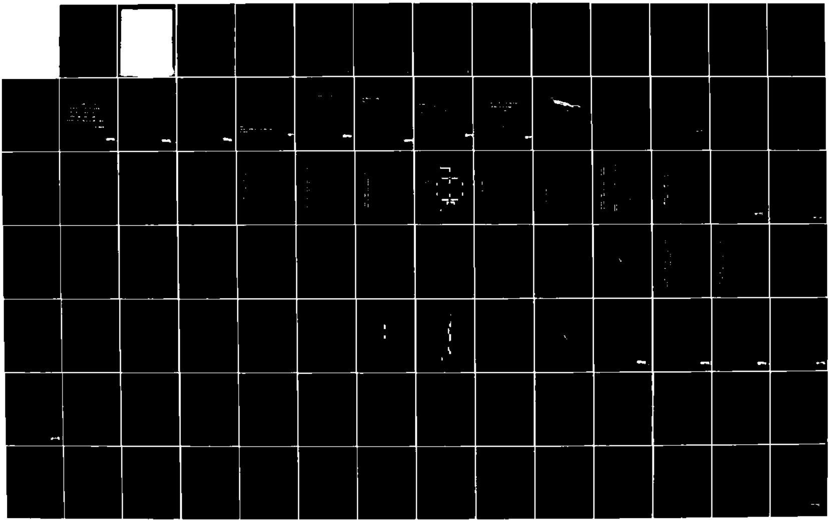

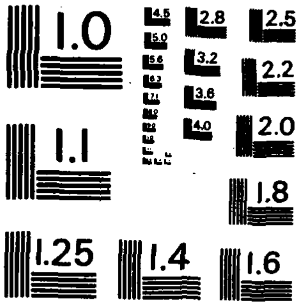

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AIRCREW AUTOMATED ESCAPE SYSTEMS
(AAES)

IN-SERVICE USAGE
DATA ANALYSES

(VOL I)

PAPERS

PRESENTED AT THE 21st ANNUAL SAFE SYMPOSIUM
SAN ANTONIO, TEXAS

5, 6, 7, 8 NOVEMBER 1983

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CHARLES W. STOKES III, G. RONALD HERD (APPLIED SCIENCES GROUP, INC.) FREDERICK G. GUILL (NAVAL AIR SYSTEMS COMMAND), LCDR. JAMES F. PALMER, MSC, (PACIFIC MISSILE TEST CENTER, PT. MUGU)

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

COMPILATION OF PAPERS CONCERNING EJECTION SEAT TYPE AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE AND EXPERIENCE. SUBJECTS INCLUDE: PROBLEMS IN USING SUCCESS RATES TO QUANTIFY ESCAPE SYSTEM RELIABILITY; THE EFFECTS OF FAMILY TIES AMONG EJECTION SEATS; A CRITIQUE OF U.S. NAVY EJECTION SEAT DESIGN; TEST AND R&M SPECIFICATIONS; DISCUSSIONS OF PLANS FOR CONTINUING TO ANALYZE ESCAPE SYSTEM USAGE DATA; IN-SERVICE SAFETY ASPECTS OF EJECTION SEAT TYPE ESCAPE SYSTEMS; QUALITY ASSURANCE PLANNING OF ESCAPE SYSTEMS TESTING AND TEST DATA ACQUISITION; ANALYSIS OF WINDBLAST, FLAIL AND TUMBLE; FACTORS INFLUENCING FREQUENCY AND SEVERITY OF NECK INJURIES SUSTAINED BY EJECTEES; MISHAP AIRCREW ANTHROPOMETRY ANALYSIS AND SCREENING TECHNIQUES; DISCUSSION OF MAINTENANCE INDUCED FATALITIES AND INJURIES; EXPERIENCE WITH SIDE-BY-SIDE UNSEQUENCED EJECTION

SEATS: PILOT STUDY TO ASCERTAIN MEANS FOR ENHANCING KNOWLEDGE CONCERNING USAGE OF LIFE SUPPORT SYSTEMS DURING EJECTIONS; INJURY AND EQUIPMENT DAMAGE PATTERNS: THE FLIGHT SURGEON'S REPORT (FSR) USEFULLNESS; AND PROPOSED FIELD INVESTIGATOR'S GUIDES FOR INVESTIGATING THE EMERGENCY USE OF ESCAPE AND LIFE SUPPORT SYSTEMS.

PREFACE

PREFACE

This collection of papers represents in part a report of the considerable progress made during the past year, in part a report of changes made from the prior published plans, and in part a report of plans for this next year for the effort to analyze U.S. Navy in-service usage data for ejection seat type aircrew automated escape systems (AAES) and for other aircrew life support systems (ALSS) equipments. This work is being performed by the Analytical Systems Division (ESA-31), Naval Weapons Engineering Support Activity under tasking assigned by the Crew Systems Division (AIR-531), Naval Air Systems Command.

These papers, however, could not have been prepared without the generous assistance provided by personnel of the Naval Safety Center, Norfolk, who created the necessary data tapes and provided guidance and counseling to the program team concerning the many nuances and pitfalls in the data. Especially helpful among the many have been Mr. Hardy Purefoy and Mrs. Betty Weinstein (Aviation Mishap Records Branch), Mrs. Sharone Thornton (Life Support Equipment Branch), and Capt. Trostle, Lcdr. Robert Bason, and Mrs. Jean Connery (Aeromedical Division). Major support also was provided by the Life Support Engineering Division, Aircraft and Crew Systems Technology Directorate, Naval Air Development Center, Warminster; the Aircrew Systems Branch, Naval Air Test Center, Patuxent River; and the Crew Systems Branch, Pacific Missile Test Center, Pt. Mugu.

One task, which early on became obvious as being extremely necessary, was to develop means for enhancing the quality of the average post-mishap investigation into and reportage of AAES/ALSS emergency usage and performance. To that end, the team has enlisted the services of Lcdr. James Palmer, Crew Systems Branch (1131), Pacific Missile Test Center, Pt. Mugu, to draft experimental "in-field investigative guides"; the full collection of those written to date being included in this volume.

Considerable assistance and guidance has been furnished to the team by Dr. Ronald Herd, now president of Applied Sciences Group, Incorporated, who, even if he has not simplified statistical analyses, has succeeded through great patience in explaining to the team the techniques, results, dangers, and the benefits of statistical analyses in a comprehendable manner. Dr. Herd's review, critique and advice concerning findings and, especially proposed findings and proposed analytical approaches, have been especially invaluable and the team is grateful for the resulting improvements in product quality. In addition, Dr. Herd has contributed one special analysis paper and one of the progress report papers presented in this volume.

As discussed in *U.S. Navy Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) In-service Usage Data Analyses Program: A Progress Report and Future Plans,* a major effort is currently underway at the Departmentof Energy's Oak Ridge National Laboratory with technical guidance being furnished by Mr. L. d'Aulerio of the Naval Air Development Center, Warminster, to develop escape system simulation models tailored to the characteristics of each AAES included in these data to permit enhanced analysis of each escape attempt and also of the collective series of escape attempts with the attendant identification and definition of problem areas as well as aspects that appear successful.

Acknowledgement also is due to the Graphics Section, Publications Department of ManTech International Corporation, responsible for creating the majority of the illustrations employed in the volume and for its on-time publication and delivery despite all of the problems caused by authors and the sponsor. Programming to develop the data used and presented in this volume was generated by Messrs. Robert Cox of the Institute of Modern Procedures and Tom Henke of Evaluation Research Corporation. These individuals must be commended for their willingness on often extremely short notice to rapidly develop new programs and program modifications to permit those analyzing the data to pursue and examine multitudinous interrelationships among the data.

The Naval Weapons Engineering Support Activity personnel contributing to these papers were Mr. Charles Geiberger (ESA-31C, team leader), Mr. Charles Stokes, Mrs. Myrtice Roberson, and Mr. John Vetter (ESA-31 Division Head). As has most unfortunately, despite the best of intentions of the team members to, for once, present the drafts early and to require fewer of them, this work, as so often is the case in human endeavors, has been delayed and subject to interminable changes, especially to satisfy the program sponsor. So once again without the multitudes of drafts quietly, quickly and efficiently readied on short notice by the Division Secretary, Miss Sandi Dorwart, much of this collection of papers would not be.

The Crew Systems Division Sponsor for this program is Mr. Frederick C. Guill (AIR-531C).

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PREFACE

INTRODUCTION

ANALYSES OF TESTING AND R&M REQUIREMENTS OF U.S. NAVY AAES/ALSS SPECIFICATIONS

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"ILITIES" ASPECTS OF AAES

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BIOGRAPHICAL SKETCHES OF AUTHORS AND RESEARCHERS

AIRTASK/WORK UNIT ASSIGNMENT
NAVAIR FORM 3930/1 (REV. 2-77)

DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
WASHINGTON, D.C. 20361

See NAVAIR 3900.8 or supersedure for applicable details on completing this form.

CLASSIFICATION UNCLASSIFIED		OCT 29 1982	PAGE 1 OF 3
ADDRESSEE Director, Naval Weapons Engineering Support Activity Systems Analysis Dept. (ESA-31) Washington Navy Yard, Wash, DC 20374		AIRTASK NO. A511-5111/184-4/3511-000-055 WORK UNIT NO. A531C-04 EFFORT LEVEL Normal	AMEND. NO. AMEND. NO.
NAVAIR PROJECT ENGINEER Mr. Frederick C. Guill AV 222-7486	CODE AIR-531C	CLASSIFICATION OF AT/WU UNCLASSIFIED	

1. The [redacted]/WORK UNIT ASSIGNMENT described below is assigned in accordance with the indicated effort level and schedule. Funding authorization [redacted] will be provided in separate correspondence. If this [redacted]/WORK UNIT ASSIGNMENT cannot be accomplished as assigned, advise the NAVAIR HQ cognizant code. No work beyond the planning phase will be accomplished unless the addressee has funds in hand or written assurance thereof.

2. Cancellation, References and/or Enclosures:

Work Unit Assignment A5312B-04 of 8 Oct 1981 with amendments, AIRTASK A511-511C/1844/2511-000-055 is cancelled.

Reference: (a) In-Service Engineering Aircraft Systems Support Report dtd 29 Sept 1982

Encl: (1) NAVAIR Consolidated Priority List - Aircraft Systems Fleet Support Projects dtd 29 Sep 1982

3. Technical Instructions:

a. TITLE. IDENTIFICATION AND REVIEW OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) AND AIRCREW LIFE SUPPORT SYSTEMS (ALSS) EQUIPMENTS IN-SERVICE RELIABILITY AND MAINTAINABILITY PROBLEMS

b. Purpose. To assign the responsibility to continue a systematic investigation of in-service AAES and ALSS data to identify problems for potential corrective action.

c. Background: (1) A multitude of pervasive, non-spectacular, low-grade AAES and ALSS in-service problems are continuously reported which lower AAES/ALSS reliability and maintainability and adversely affect aircrew and/or groundcrew safety and/or effectiveness. These problems left unmonitored and uncorrected occasionally manifest themselves in fatalities, serious injuries and/or very great difficulties to aircrews. Some problems, by degrading aircrew capability of operating/functioning effectively and efficiently can reduce total weapons system capability. Some manifest themselves in increased maintenance costs and/or increased hazards to maintenance personnel. (2) NAVAIR Headquarters established this effort in order to provide management with a valid basis for allocating resources based on predictions of need

SIGNATURE (By Direction COMNAVAIR) R E Malatino	DATE 10/29/82
CLASSIFICATION AND GROUP MARKING UNCLASSIFIED By direction	

Previous issues of this form are obsolete.

Work Unit No. A531C-04
AIRTASK A511-5111/184-4/3511-000-055

(3) Sponsor/convene symposia for disseminating the data, analyses and findings within the AAES and ALSS technical communities after NAVAIRHQ (AIR-531, AIR-00D and AIR-960) approval. Provide copies of released reports to AIR-531 and AIR-6103B.

(4) A semi-annual program review shall be held at NAVAIRHQ in February and August with NAVAIRHQ publishing a report of findings in March and September.

(5) Report to the Commander, Naval Air Systems Command (AIR-5111C & 531E) the man years and associated cost, cost of materials, travel and cost of contracts awarded for this project. This report shall be submitted 1 May 1983 and 1 November 1983 for final status.

b. Requirements for Future Planning Information.

In preparation for investigations to be undertaken duri[illegible]he forthcoming and ensuing fiscal years submit work unit plans prepared [illegible] accordance with the format and guidelines in NAVAIR INST 3900.8A by 15 Feb[illegible] and 1 August of each year. A work unit plan is required for each exi[illegible]or proposed WUA under the AIRTASK. The original of each work unit pla[illegible]all be submitted to the originator of the WUA with a copy to AIR-531E.

6. Contractual Authority. Contracts to perform all or portions of this WUA are hereby authorized within the funding indicated by the cost estimate.

7. Source and Disposition of Equipment. N/A

8. Aircraft Requirements None.

9. Status of Applicable Funds. Funds will be provided separately.

10. Security Classification Requirements. All work under this WUA is unclassified. In performing the prescribed work, access to information which is classified and/or to areas containing classified equipment may be required. Any reference to such classified material shall be in accordance with the applicable materials security classification. Information concerning survivability/vulnerability shall be classified in accordance with OPNAVINST. C5513.2A, Encl. (63), and OPNAVINST. S5513.8, Encl. (7). Data employed in this project are sensitive in the context of the Privacy Act. Precautions shall be exercised to guard against unauthorized disclosures and disclosures inconsistent with the Privacy Act.

Copy to:
Addressee (3)
NAVMATDATASYSGRU, Morgantown, W. Va. 26505
NAVAIRDEVCEN (603) WARMINSTER
NAVAIRTESTCEN (SY-70) PAXRIV
NAVWPNCEN (64) CHINA LAKE
NAVORDSTA (51) INDIAN HEAD
NAVSAFECEN NORFOLK
AFISC/SEL NORTON AFB, CA
PACMISTESTCEN 1131
U.S. Dept. Energy Oak Ridge TENN

predicated upon a continuous analysis of the total AAES and ALSS in-service experience.

d. Detailed Requirements/Cost Estimates: (1) The primary effort shall be for establishment of baseline data to aid in subsequent identification of trends and specific problems. Subsequent tasks for extending previous analytical techniques and data sources investigating efforts to identify specific AAES and ALSS inservice reliability and maintainability problems shall be assigned by AIR-531. (2) Continue to refine a system for the continuous systematic review of AAES and ALSS in-service data in a manner designed to identify and assess the significance of the many commonly occurring in-service problems affecting AAES in-service reliability and maintainability, aircrew and/or groundcrew safety, and aircrew mission performance and/or effectiveness. Utilize 3-M Systems, Unsatisfactory Reports (URs), Medical Officer's Reports (MORs)/Flight Surgeon's Reports (FSRs), Aircraft Accident Reports (AARs)/ Mishap Investigation Reports (MIRs), Subsystem Capability Impact Reports (SCIR), and Naval Air Rework Facility data systems. (3) Systems outputs shall be structured to provide data of assistance to NAVAIRHQ in the management of the scarce AAES/ALSS resources. Identify types of problems experienced, frequency of occurrence,experience severity, potential severity, causal factors, range of activities and/or types of AAES/ALSS experiencing the problems, etc. Integrate outputs into existing reporting systems to assure regular, early notification of NAVAIRHQ concerning in-service problems being experienced. (4) Perform specific, specialized, nonroutine analytical tasks of high priority as assigned. (5) The cost estimate is $119.0K for FY-83. Obligate quarterly as follows: first quarter $58.0K, second quarter $21.0K, third quarter $20.0K, fourth quarter $20.0K. (P.E. 78012N (O&MN), Subhead 47BS, Engineering Services Program).

e. Detailed Program Plan. N/A

f. Field Activity Contact. Mr. John Vetter, NAVWESA (ESA-31), (202)433-3621.

g. Headquarters Technical Support. NAVAIRHQ (AIR-531C) will provide technical guidance and assistance concerning AAES and ALSS throughout the project.

4. Schedule. A program schedule of major milestones for each task is outlined in reference (a).

5. Reports and Documentation:

a. Reports:

(1) Upon completion of each task outlined in reference (a), present data and findings in letter-type reports to NAVAIRHQ (AIR-531) and (AIR-6103B).

(2) Provide NAVAIRHQ approved (AIR-531, AIR-00D and AIR-960) for release summaries of findings to AAES and ALSS meetings such as the annual FAILSAFE and ILS/AMP meetings, and other appropriate technical forums for assuring the maximum dissemination of the data, analyses and findings throughout the AAES and ALSS technical communities. Provide copies of released reports and papers to AIR-531 and AIR-6103B.

PERTINENT QUOTATIONS

This section presents several quotations that, even though they were not written to describe the problems faced by individuals investigating a mishap to determine the AAES/ALSS usage and problems or the problems encountered later in using those records to create or compile a history of AAES/ALSS usage/non-usage and problems/successes, nonetheless seem quite appropriate for describing those problems encountered in these phases of attempting to put together the information and analyses necessary to define the AAES/ALSS usage problems for subsequent remedial action. It is hoped that this selection will be both enjoyable and at the same time, perhaps, provide the reader with new insights and perspectives concerning problems that are not peculiar to this effort to investigate and analyze AAES/ALSS usage but, rather, are shared by many in other endeavors.

"FOOL YOU ARE...TO SAY YOU
LEARN BY YOUR EXPERIENCE...
I PREFER TO PROFIT BY
OTHERS' MISTAKES, AND
AVOID THE PRICE OF MY OWN."

BISMARCK

> . . . if we know anything at all, it is about the past. The future is unknown and dark; the present does not exist except as a moving point in time. Only when we look backward is there any light of understanding, and when we look ahead it is only the reflected light from over our shoulder, from the past, that penetrates at all into the obscurity.

THE GERMAN WARS
D. J. GOODSPEED

Houghton Mifflin Company
Boston 1977

Archaeology offers a passage back into the past although archaeologists know very well that the bits of a smashed pot can tell us very little about the thoughts of the potter. But as all we have left are the very few, broken fragments of things that the Avebury people used we must manage with them. It is, after all, a rigorous but not uninteresting method, this gathering up of all the evidence, omitting nothing, looking for patterns amongst an antique jigsaw from which nine-tenths of the pieces are missing.

PREHISTORIC AVEBURY
AUBREY BURL

FIGURES HAVE TWO IMPORTANT PROPERTIES; THEY SAY A LOT AND THEY APPEAR TO BE ACCURATE. IN BOTH RESPECTS THERE IS A REAL DISADVANTAGE CONNECTED WITH THE APPARENT ADVANTAGE. FIGURES SAY SO MUCH THAT WITHOUT A DETAILED DISCUSSION IT IS IMPOSSIBLE TO UNDERSTAND THEM. WHEN THE DISCUSSION IS FURNISHED, THE SUBSTANCE IS IN THE WORDS RATHER THAN THE FIGURES AND THE LATTER ARE ONLY A DEVICE BY WHICH TO REMEMBER THE DISCUSSION.

FIGURES ARE ALSO MUCH TOO ACCURATE. THE TROUBLE IS THAT WITH REGARD TO THE FUTURE THIS ACCURACY CAN NEVER BE ATTAINED.

FROM
ENERGY FROM HEAVEN AND EARTH
DR. EDWARD TELLER
PAGE 294

GALBRAITH'S LAW

THINGS GO WRONG WHEN REMEDY IS ALLOWED TO PRESCRIBE DIAGNOSIS.

J. K. GALBRAITH

THE ROCKET TEAM, PAGE 33

FREDERICK ORDWAY III

"AS THINGS BECAME ORGANIZED AT PEENEMUNDE, IT WAS NATURAL THAT CONFLICTS BETWEEN ITS PERSONNEL IN VARIOUS OFFICES WOULD ARISE. AUDITORS, ACCOUNTANTS, AND CLERKS, WHO GENERALLY FEEL OUTSIDE THE MAINSTREAM IN ANY LARGE RESEARCH ORGANIZATION, BEGAN TO FLEX THEIR MUSCLES AT THE EXPENSE OF THE SCIENTISTS AND ENGINEERS. THEY FOUND ENDLESS INTERPRETATIONS FOR REGULATIONS. BUT DORNBERGER BROUGHT THIS PRACTICE TO A QUICK HALT, ONCE HE SAW WHAT WAS HAPPENING. HE SET FORTH POLICY FOR HVP IN CLEAR TERMS. 'THE ENGINEERS IN PEENEMUNDE HAVE TOP PRIORITY. ALL THEIR WISHES ARE TO BE FULFILLED TO THE EXTENT YOU CAN ASSIST. DON'T LOOK FOR REGULATIONS THAT PREVENT THINGS GETTING DONE. LOOK FOR ALL MEANS POSSIBLE FOR GETTING THE JOB DONE. REGULATIONS ARE MADE BY MEN; THEY CAN BE CHANGED BY MEN.' CRESTFALLEN, THE BOOKKEEPERS WITHDREW TO PONDER THEIR CODES IN THIS NEW LIGHT."

. . . CONTRAST BETWEEN TWO KINDS OF HISTORY — *REMEMBERED* HISTORY PRESENT IN THE MINDS OF PARTICIPANTS LONG AFTER THE EVENT, AND *ACTUAL* HISTORY, THE DAY-TO-DAY EVENTS AND PRACTICES, OFTEN FORGOTTEN WHEN THEY HAVE LITTLE GLAMOUR.

—Sovereignty for Sale
Rodney Carlisle
Page 217

**FOR EVERY PROBLEM
THERE IS A SIMPLE
SOLUTION . . .**

WHICH IS USUALLY WRONG. ATTRIBUTED TO H.L. MENCKEN

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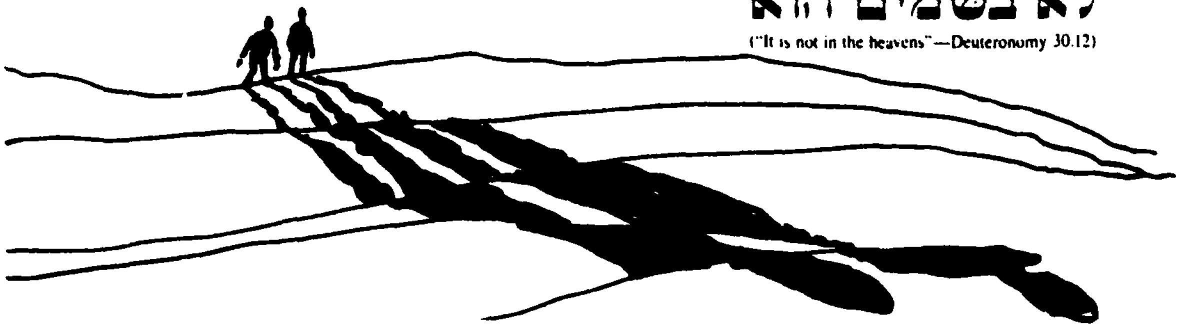
לא בשמים הוא

("It is not in the heavens"—Deuteronomy 30.12)



FOR EVERY PROBLEM THERE IS A SIMPLE SOLUTION . . .

WHICH IS USUALLY WRONG. ATTRIBUTED TO H.L. MENCKEN

TWO MEN ARE CROSSING A DESERT. THEY ARE THREE DAYS FROM THE NEAREST WATER HOLE.

ONE OF THE MEN IS CARRYING A CANTEEN. THE CANTEEN HOLDS THREE DAYS' SUPPLY OF WATER—FOR ONE MAN.

SHOULD THEY DIVIDE IT? THEN BOTH WILL DIE.

THEN WHAT IS THE OBLIGATION OF THE OWNER OF THE CANTEEN? ONE OPINION SAYS—A MAN MUST NOT STAND BY AND WATCH HIS FELLOW MAN DIE. HE SHOULD SHARE THE WATER WITH HIS COMPANION. ANOTHER SAYS—PRESERVATION OF ONE'S OWN LIFE TAKES PRECEDENCE. THE OWNER OF THE WATER MUST DRINK IT AND LIVE.

NOT SO SIMPLE, IS IT? IF YOU DON'T SEE A SIMPLE, OBVIOUS SOLUTION, YOU'RE IN GOOD COMPANY, BECAUSE THE DISCUSSION IS NEARLY 1900 YEARS OLD.

IT IS RECORDED IN THE TALMUD, AND HERE IS THE INTERESTING THING:

BOTH OPINIONS ARE PRESENTED IN THE TALMUD, THE PREVAILING AND THE DISSENT.

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INCIDENTALLY, IT WILL HELP TO EXPLAIN WHY THIS CAREFUL LABORATORY WORK WAS NECESSARY.

IN THE FIRST PLACE, IT MUST BE CLEARLY UNDERSTOOD THAT THERE IS NEVER ANY QUESTION OF HAVING BASKETFULS OF OBJECTS BROUGHT TO THE EXCAVATOR FOR HIM TO LOOK AT; THE FIRST AND MOST IMPORTANT RULE IN EXCAVATING IS THAT THE ARCHAEOLOGIST MUST REMOVE EVERY ANTIQUITY FROM THE GROUND WITH HIS OWN HANDS. SO MUCH DEPENDS UPON IT. QUITE APART FROM THE QUESTION OF POSSIBLE DAMAGE THAT MIGHT BE CAUSED BY CLUMSY FINGERS, IT IS VERY ESSENTIAL THAT YOU SEE THE OBJECT *IN SITU,* TO GAIN ANY EVIDENCE YOU CAN FROM THE POSITION IN WHICH IT LIES, AND THE RELATIONSHIP IT BEARS TO OBJECTS NEAR IT. . . .THERE WILL, AGAIN, BE EVIDENCE OF ARRANGEMENT TO BE SECURED, EVIDENCE THAT MAY SHOW THE USE FOR WHICH SOME PARTICULAR OBJECT WAS MADE, OR GIVE THE DETAILS FOR ITS ULTIMATE RECONSTRUCTION.

THE TOMB OF TUTANKHAMEN
HOWARD CARTER
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Figure 1

AN EXCAVATOR, THEN, MUST SEE EVERY OBJECT IN POSITION, MUST MAKE CAREFUL NOTES BEFORE IT IS MOVED, AND, IF NECESSARY, MUST APPLY PRESERVATIVE TREATMENT ON THE SPOT. OBVIOUSLY, UNDER THESE CONDITIONS IT IS ALL-IMPORTANT FOR YOU TO KEEP IN CLOSE TOUCH WITH YOUR EXCAVATIONS. . . . WHILE THE WORK IS ACTUALLY RUNNING YOU MUST BE ON THE SPOT ALL DAY, AND AVAILABLE AT ALL HOURS OF THE DAY. YOUR WORKMEN MUST KNOW WHERE TO FIND YOU AT ANY GIVEN MOMENT, AND MUST HAVE A PERFECTLY CLEAR UNDERSTANDING THAT THE NEWS OF A DISCOVERY MUST BE PASSED ON TO YOU WITHOUT ANY DELAY.

THE TOMB OF TUTANKHAMEN
HOWARD CARTER
CHAPTER 10
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Figure 2

THEN THERE IS PHOTOGRAPHY. EVERY OBJECT OF ANY ARCHAEOLOGICAL VALUE MUST BE PHOTOGRAPHED BEFORE IT IS MOVED, AND IN MANY CASES A SERIES OF EXPOSURES MUST BE MADE TO MARK THE VARIOUS STAGES IN THE CLEARING. MANY OF THESE PHOTOGRAPHS WILL NEVER BE USED, BUT YOU CAN NEVER TELL BUT THAT SOME QUESTION MAY ARISE, WHEREBY A SEEMINGLY USELESS NEGATIVE MAY BECOME A RECORD OF THE UTMOST VALUE. PHOTOGRAPHY IS ABSOLUTELY ESSENTIAL ON EVERY SIDE, AND IT IS PERHAPS THE MOST EXACTING OF ALL THE DUTIES THAT AN EXCAVATOR HAS TO FACE. ON A PARTICULAR PIECE OF WORK I HAVE TAKEN AND DEVELOPED AS MANY AS FIFTY NEGATIVES IN A SINGLE DAY.

WHENEVER POSSIBLE, THESE PARTICULAR BRANCHES OF WORK — SURVEYING AND PHOTOGRAPHY — SHOULD BE IN THE HANDS OF SEPARATE EXPERTS. THE MAN IN CHARGE WILL THEN HAVE TIME TO DEVOTE HIMSELF TO WHAT WE MAY CALL THE FINER POINTS OF EXCAVATION. HE WILL BE ABLE TO PLAY WITH HIS WORK, AS A BROTHER DIGGER EXPRESSED IT. IN EVERY EXCAVATION PUZZLES AND PROBLEMS CONSTANTLY PRESENT THEMSELVES, AND IT IS ONLY BY GOING CONSTANTLY OVER THE GROUND, LOOKING AT IT FROM EVERY POINT OF VIEW, AND SCRUTINIZING IT IN EVERY KIND OF LIGHT, THAT YOU WILL BE ABLE TO ARRIVE AT A SOLUTION OF SOME OF THESE PROBLEMS. THE PURPORT OF SOME PECULIARITY. . . THESE AND A SCORE OF OTHERS ARE THE QUESTIONS THAT AN EXCAVATOR HAS TO FACE, AND IT IS UPON HIS ABILITY TO ANSWER THEM THAT HE WILL STAND OR FALL AS AN ARCHAEOLOGIST.

THE TOMB OF TUTANKHAMEN
HOWARD CARTER
CHAPTER 10
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Figure 3

DETAILED AND COPIOUS NOTES SHOULD BE TAKEN AT EVERY STAGE OF THIS PRELIMINARY WORK. IT IS DIFFICULT TO TAKE TOO MANY, FOR, THOUGH A THING MAY BE PERFECTLY CLEAR TO YOU AT THE MOMENT, IT BY NO MEANS FOLLOWS THAT IT WILL BE WHEN THE TIME COMES FOR YOU TO WORK OVER YOUR MATERIAL. IN TOMB-WORK AS MANY NOTES AS POSSIBLE SHOULD BE MADE WHILE EVERYTHING IS STILL IN POSITION. THEN, WHEN YOU BEGIN CLEARING, CARD AND PENCIL SHOULD BE KEPT HANDY, AND EVERY FRESH ITEM OF EVIDENCE SHOULD BE NOTED IMMEDIATELY YOU RUN ACROSS IT. YOU ARE TEMPTED SO OFTEN TO PUT OFF MAKING THE NOTE UNTIL YOU HAVE FINISHED THE ACTUAL PIECE OF WORK ON WHICH YOU ARE ENGAGED, BUT IT IS DANGEROUS. SOMETHING WILL INTERVENE, AND AS LIKELY AS NOT THAT PARTICULAR NOTE WILL NEVER BE MADE AT ALL.

THE TOMB OF TUTANKHAMEN
HOWARD CARTER
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Figure 4

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE DATA ANALYSIS PROGRAM

(Presented at 19th Annual SAFE Symposium, December 1981)

Frederick C. Guill
Charles W. Stokes III

ABSTRACT

The Crew Systems Division, Naval Air Systems Command, realizing its requirement for specialized and in-depth analyses of all in-service data concerning aircrew automated escape systems (AAES) and, more recently, aircrew life support systems (ALSS) equipments, tasked the Naval Weapons Engineering Support Activity, Washington, D.C., to develop a system for providing such analyses. The background and objectives of this tasking are discussed.

U.S. Navy
Aircrew Automated Escape Systems (AAES) In-Service Data Analysis Program

Frederick C. Guill and Charles W. Stokes

INTRODUCTION

The purpose of this session is both to acquaint the audience with the Naval Air Systems Command's on-going Aircrew Automated Escape System (AAES) In-service Usage Data Analysis Program and to disseminate initial data summaries and preliminary analyses, especially as concerns U.S. Navy success rates, comparison of through-the-canopy and jettisoned-canopy ejections, and ejection associated flail and flail injury experience.

This program is being developed to "establish a systematic investigation of in-service AAES data, such as contained in the 3-M System, Unsatisfactory Reports, Medical Officer Reports of Aircraft Accidents, and Naval Air Rework Facility Data Systems, to identify for potential corrective action the many daily low-grade problems which contribute to the general lowering of AAES in-service reliability and cause the general worsening of AAES in-service maintainability." (Figure 1). Until this program was established the only arrangements for investigating AAES problems were created especially "for investigating and correcting spectacular AAES in-service problems, particularly those which cause fatalities. This effort is intended for reviewing the prevasive non-spectacular low-grade AAES in-service reliability (problem) and/or a general degradation of AAES in-service maintainability. These problems, vastly overshadowed by the spectacular ones, nonetheless are important, and if left unmonitored and uncorrected, occasionally manifest themselves in fatalities, serious injuries and/or very great difficulties experienced by the ejectee, which under slightly different conditions could have caused serious injuries. Some problems also manifest themselves in increased maintenance efforts and costs and/or increased hazards to maintenance personnel."

The program has been operational for two years and, as depicted in Figure 2, remains in its formative stages. In October 1981 a two day symposium was convened during which preliminary data presentation formats and analyses were furnished to attending representatives of the escape systems community.

THE PROBLEM

The basic problem confronting the Crew Systems Division (AIR-531), Naval Air Systems Command, is the effective management of limited resources to enhance aircrew safety and performance thereby contributing to the Navy's ability to perform its assigned missions. A major element of the problem has been identifying and selecting problems for resolution. This element has been especially difficult due to the nature of the information available to AIR-531, the dynamic nature of the Navy's escape systems inventory and the time lags between introduction of equipment or fixes and the availability of information suitable for determining how well it is performing and, if improvement is necessary, the availability of material for effecting improvement (Figure 3). It has not been uncommon for problems to be defined in terms of newly developed concepts and hardware irrespective of the actual needs of the Fleet. Nor has it been uncommon for identified needs to change dramatically as the escape systems inventory mix changes. Thus, for example, major efforts were directed in the early 1960's to developing means for making survivable aircraft impact with water during ditching, following cold cat shots, following aircraft falling off carrier decks and similar carrier vicinity type water impact situations. In the late 1950s through early 1960s a large number of aviators were lost following such accidents and action was initiated to ameliorate the impact effect upon the crew. By the latter half of the 1960s, however, the problem magnitude had declined to virtual insignificance as the escape system inventory mix shifted to seats which provided sufficient capability for pre-impact ejection. Today a major problem is the post-low level ejection in-water survival, particularly when near the powerful and large wake of the carrier.

Thus the system being developed under this project involves review and analyses of today's systems' problems coupled with review and analyses of the probable impact that expected inventory changes (including engineering changes already underway) and potential aircraft operational changes might have on the identified problems in the future (Figure 4). It is expected that marriage of these analyses with schedule and cost estimates for accomplishing resolution of identified problems will enhance AIR-531's ability to prioritize problems and to project and justify its needs for resources.

Figure 5 illustrates a typical data chain, that for FSRs (Flight Surgeons' Reports), developing the data to be employed in the analyses conducted under this program. Figure 6 depicts some of the expected potential uses of the analyses in attempting to resolve AAES problems and to reduce the risks associated with AAES usage, maintenance and ownership. Much of the data examined is acquired, maintained and furnished by the Naval Safety Center, Norfolk. The Naval Safety Center, as depicted in Figure 7, in addition to providing the data for analyses, has an active and important role in defining the program's investigation taskings.

FUTURE PLANS

During 1982 the major thrust of this program will be to develop data presentation formats and analyses which, as the data base is updated, will automatically reflect the added data. As a result of resource limitations only a limited effort can be mounted towards actually defining the in-service problems and their causal factors. This relative priority between enhancing program capability and identifying Fleet problems is necessary to reduce the excessive manual labor involved in developing problem analyses today and also to ensure achieving reproducible results. This project, again, is aimed primarily at developing a management tool for Crew Systems Division use in optimally managing its AAES resources. Secondarily this program will result in greater knowledge for the entire AAES community concerning all components of the AAES (Figure 8) and ultimately in reduced risks of usage, maintenance and ownership.

REFERENCES

1. Naval Air Systems Command AIRTASK No A512-512C/184-4/1512-000-055, Work Unit No. A5312B-04 dtd 5 Nov 80 to Naval Weapons Engineering Support Activity, entitled: *Identification and Review of Aircrew* Automated Escape Systems (AAES) In-Service Reliability and Maintainability Problems.

2. Ibid.

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE DATA ANALYSIS PROGRAM

PURPOSE

- ESTABLISH A SYSTEMATIC INVESTIGATION OF IN-SERVICE AAES DATA
  - —MOR/FSR (MEDICAL OFFICER'S REPORTS/FLIGHT SURGEON'S REPORTS)
  - —3M- (MAINTENANCE & MATERIAL MANAGEMENT SYSTEM)
  - —UR (UNSATISFACTORY REPORTS)
  - —AAR/MIR (AIRCRAFT ACCIDENT REPORT/MISHAP INVESTIGATIVE REPORT)

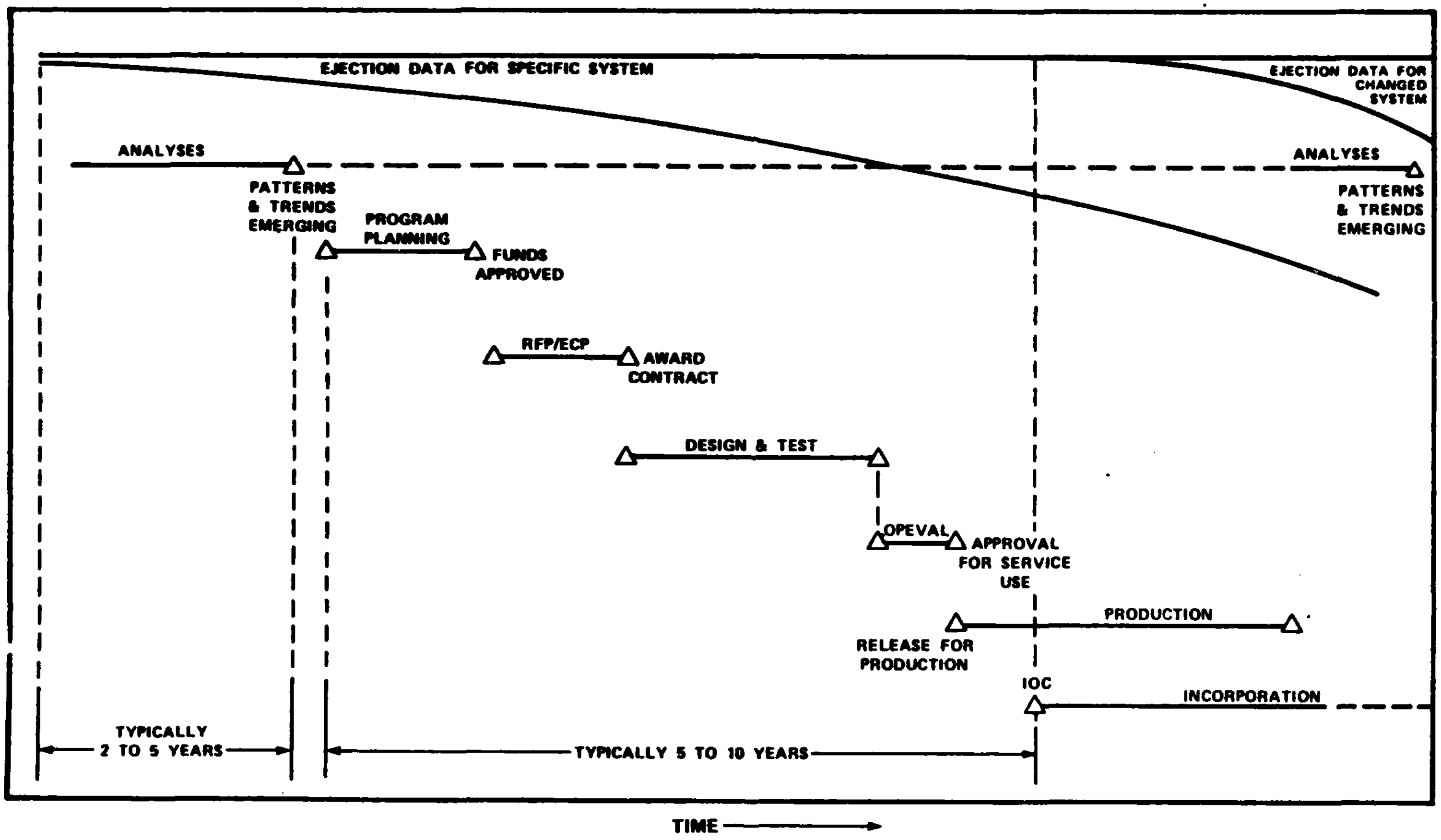
- INDENTIFY PERVASIVE LOW-GRADE, NON-SPECTACULAR PROBLEMS WHICH:
  - —LOWER AAES IN-SERVICE RELIABILITY
  - —WORSEN AAES IN-SERVICE MAINTAINABILITY
  - —MAY RESULT IN FATALITIES, SERIOUS INJURIES OR DIFFICULTIES

- EXAMINE EFFECTS OF DESIGN AND DESIGN CONCEPT CHANGES UPON
  - —AIRCREW SAFETY
  - —SYSTEM MAINTAINABILITY
  - —SYSTEM RELIABILITY
  - —GROUND CREW SAFETY

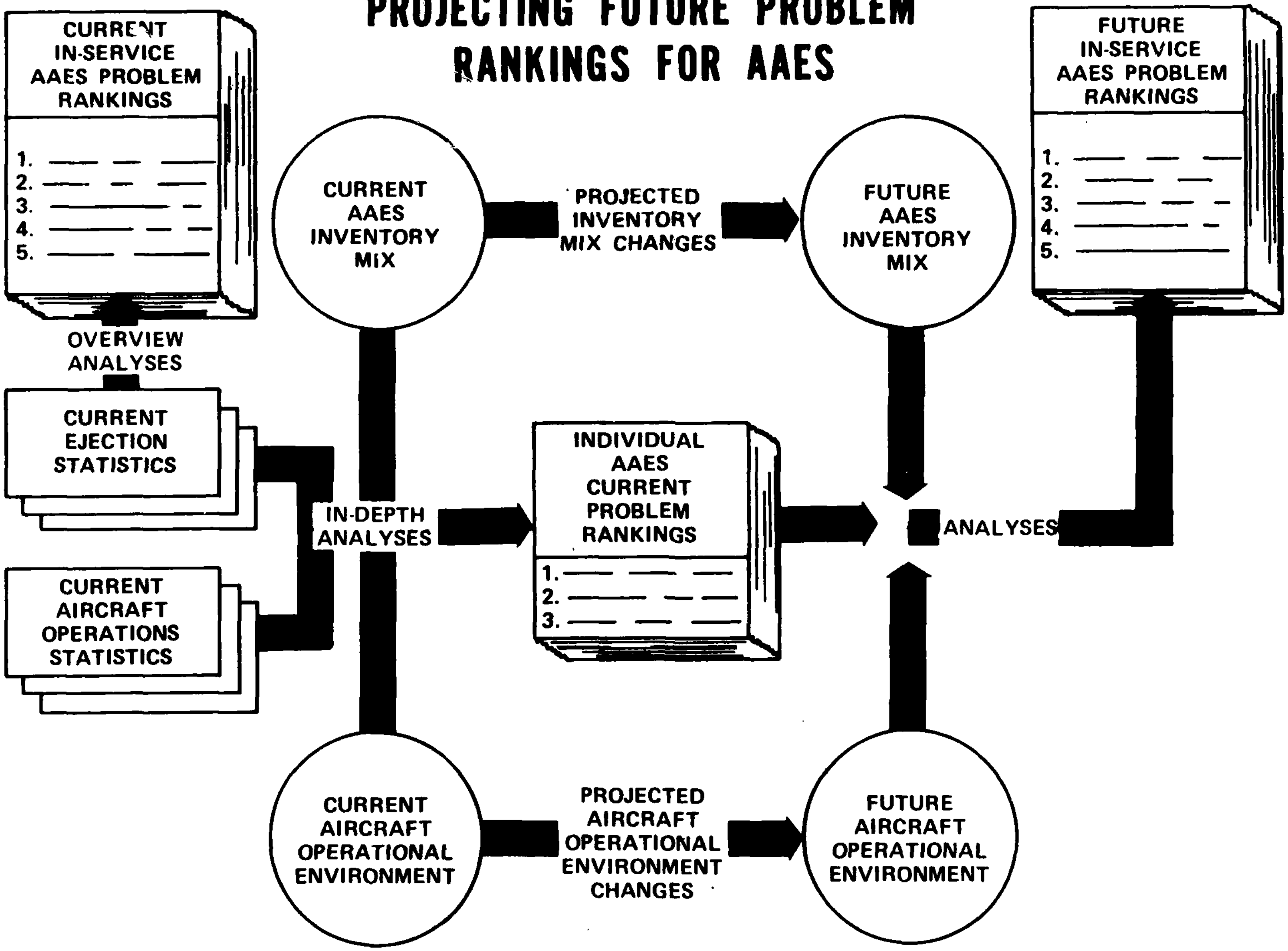
AAES IN-SERVICE USAGE DATA ANALYSES PROGRAM IS IN EARLY STAGES:

- INITIAL ACQUAINTANCE WITH AAES EQUIPMENTS/TECHNIQUES
- INITIAL ACQUISITION OF DATA
- ⇨ INITIAL ACQUAINTANCE WITH DATA
- ⇨ FORMULATE DATA ANALYSES TECHNIQUES AND PRESENTATION FORMATS
- ACQUIRE PRE-1969 DATA
- UPDATE DATA
- DEVELOP ROUTINE, PERIODIC AUTOMATIC ANALYSES TECHNIQUES AND PRESENTATION FORMATS
- CONDUCT SPECIAL ANALYSES

AIRCREW AUTOMATED ESCAPE SYSTEM DATA ANALYSES AND PROCUREMENT CYCLES



DATA INPUTS AND FLOW FOR PROJECTING FUTURE PROBLEM RANKINGS FOR AAES



AAES DATA CHAIN

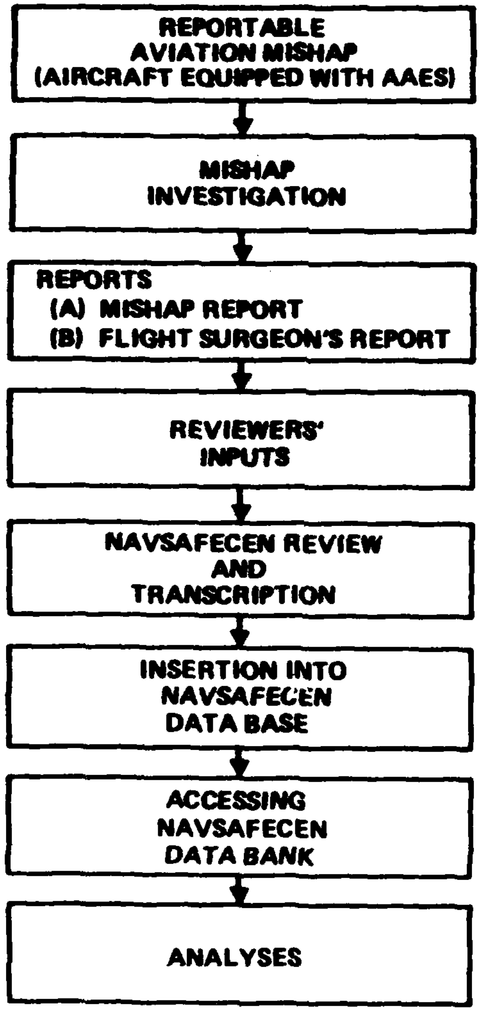


Figure 5

AAES DATA ANALYSES USAGES

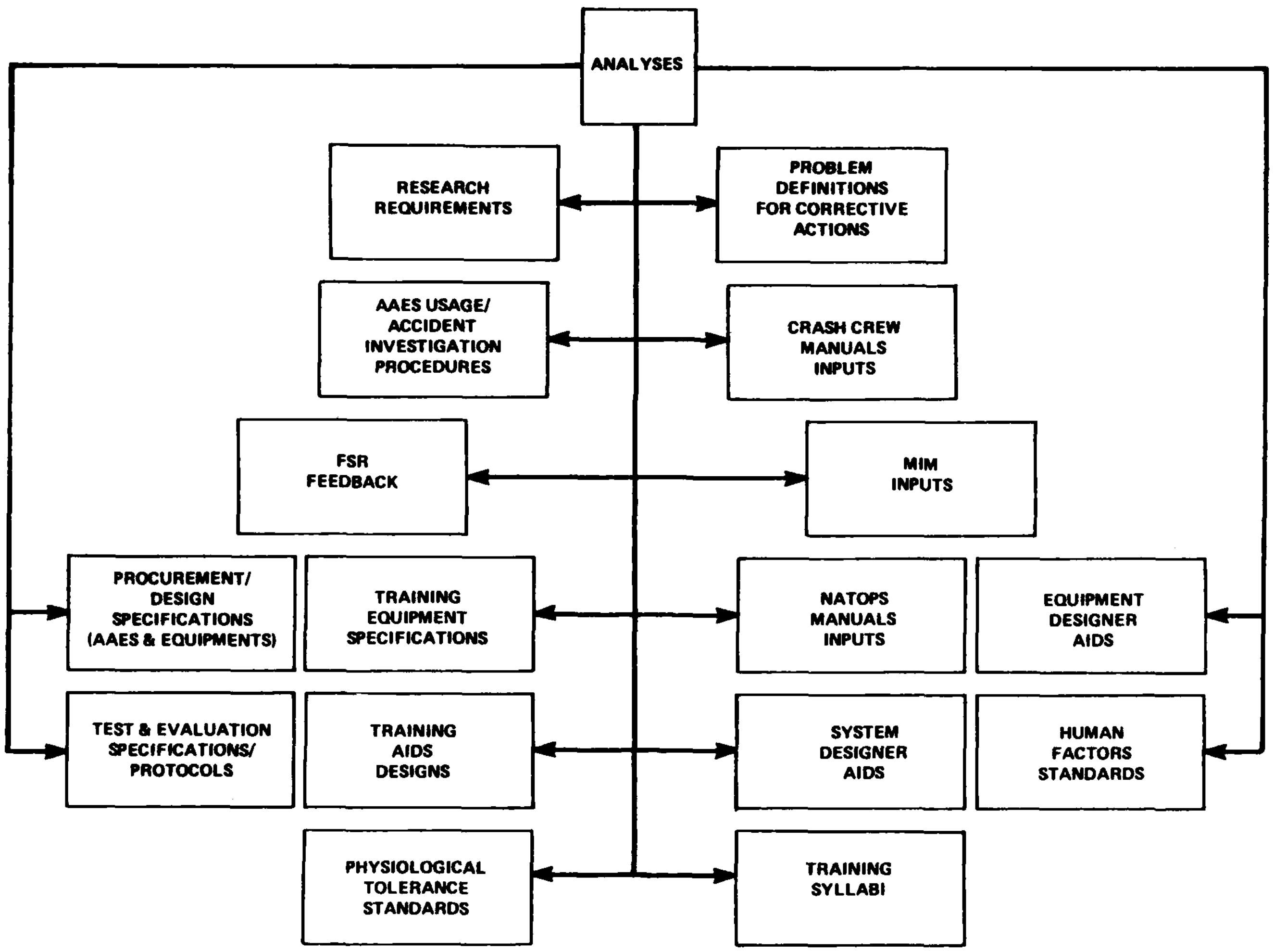
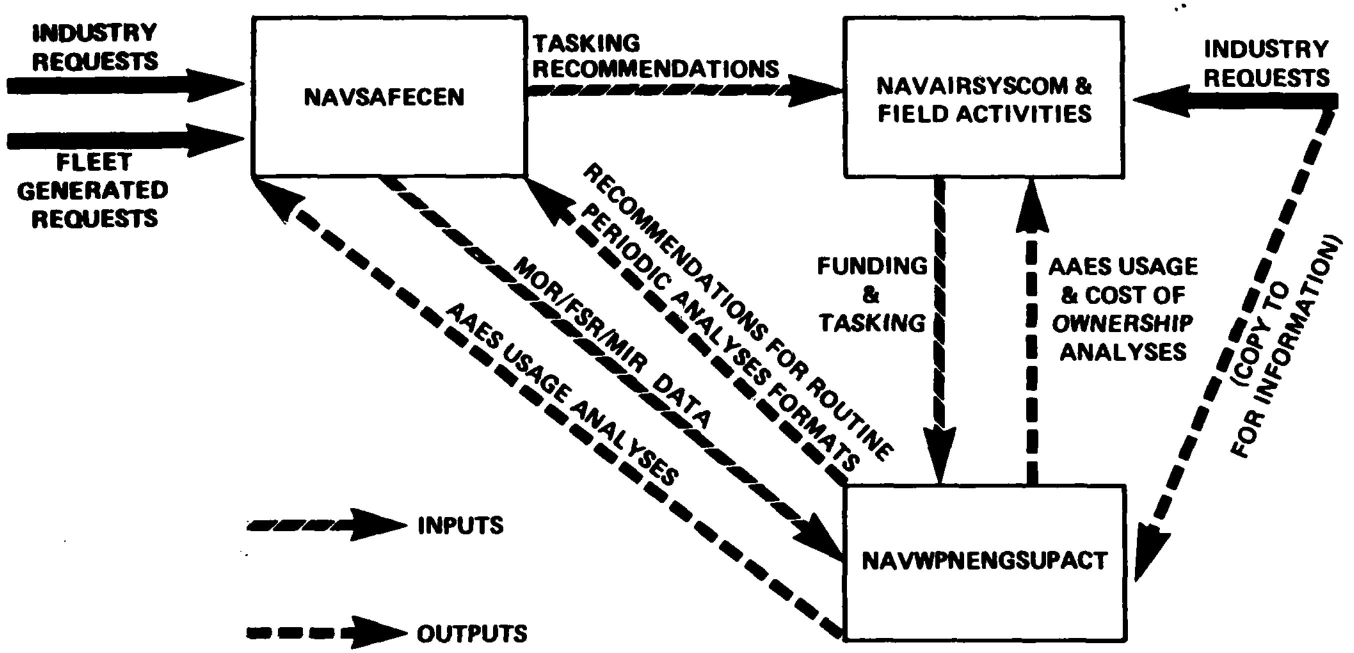


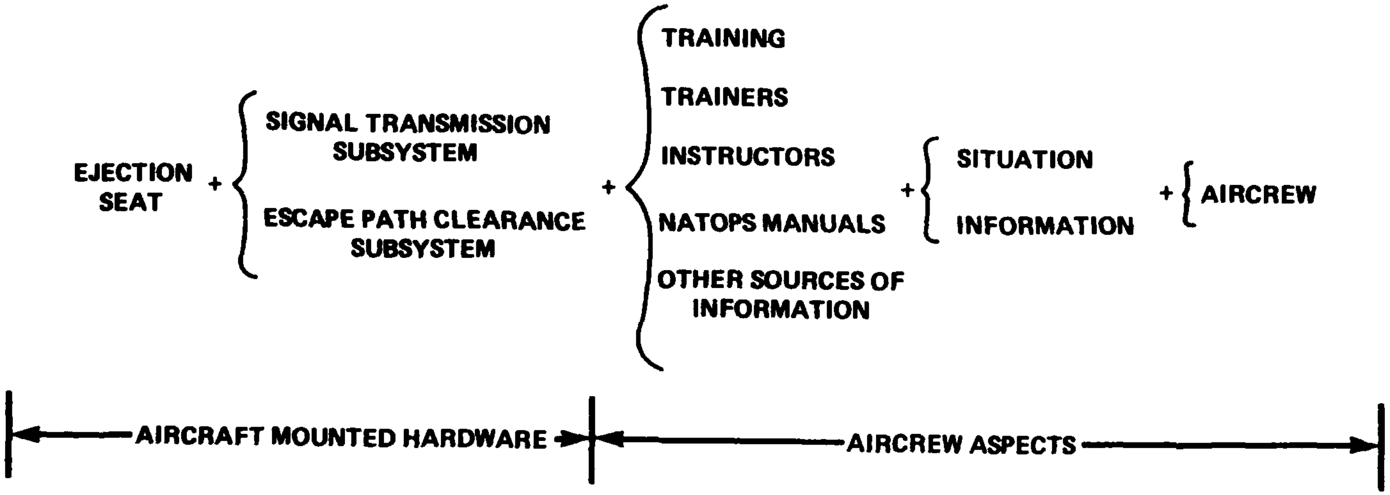
Figure 6

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE DATA ANALYSES PROGRAM

INTERRELATIONSHIPS BETWEEN
NAVAL SAFETY CENTER, NAVAL AIR SYSTEMS COMMAND, NAVAL WEAPONS ENGINEERING SUPPORT ACTIVITY
SHOWING TYPICAL FLEET AND INDUSTRY
ANALYSES REQUEST ROUTES



COMPONENTS OF COMPLETE AIRCREW AUTOMATED ESCAPE SYSTEM



EJECTION SEAT + { SIGNAL TRANSMISSION SUBSYSTEM, ESCAPE PATH CLEARANCE SUBSYSTEM } + { TRAINING, TRAINERS, INSTRUCTORS, NATOPS MANUALS, OTHER SOURCES OF INFORMATION } + { SITUATION, INFORMATION } + { AIRCREW }

AIRCRAFT MOUNTED HARDWARE

AIRCREW ASPECTS

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) AND AIRCREW LIFE SUPPORT SYSTEMS (ALSS) IN-SERVICE USAGE DATA ANALYSIS PROGRAM: A PROGRESS REPORT AND REPORT OF LONGER TERM PLANS

Frederick C. Guill

ABSTRACT

This report discusses the progress made during FY 1983, the insights obtained from those efforts, and the current long range plans resulting from those insights, for establishing a more useful AAES/ALSS in-service usage data analysis system to satisy the AAES/ALSS resources managerial decision needs of the Crew Systems Division, Naval Air Systems Command.

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) AND AIRCREW LIFE SUPPORT SYSTEMS (ALSS) IN-SERVICE USAGE DATA ANALYSIS PROGRAM: A PROGRESS REPORT AND REPORT OF LONGER TERM PLANS

Frederick C. Guill

INTRODUCTION

This paper presents in part a report on the progress and non-progress of the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis project, in part a listing of current efforts now underway and the hopes associated with them, as well as long range plans and thoughts concerning the how, where and why of the future development of this project. The purpose of this project is delineated in the project tasking[1] from the Crew Systems Division, Naval Air Systems Command and in a paper presented at the 19th Annual SAFE Symposium.[2] A paper[3] presented at the 20th Annual SAFE Symposium briefly discussed the program plans.

Considerable progress, much of it in program aspects either not previously anticipated or anticipated to occur much later in the development of this program, has been realized, especially in acquiring data for entry into the computers and in developing some of the special tools believed from the beginning to be necessary if the program were eventually to achieve many of its stated highly specialized objectives necessary to assure provision of the needed data and analyses to the Crew Systems Division.[1,2] On the other hand, major problems have continuously hampered the efforts to achieve several of these objectives and have limited the actual amount of progress achieved. Some of these problems, inherent in a new and as yet unproven value program such as this one, will remain for the foreseeable future, causing delays and limiting program abilities to undertake needed tasks.

RECENT PROGRESS

When this program was initiated, virtually its only source of data was the MOR/FSR (Medical Officer's Report/Flight Surgeon's Report) data extract computer tapes generated and maintained by the Naval Safety Center, Norfolk, and graciously furnished to the Naval Weapons Engineering Support Activity, Washington, D.C., in support of the program. A very large amount

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[1] AIRTASK No. A511-5111/184-4/3511-00-055 Work Unit No. A531C-04 dtd 29 Oct 1982

[2] U.S. Navy Aircrew Automated Escape Systems (AAES) In-service Usage Data Analysis Program by Frederick C. Guill and Charles W. Stokes presented at the 19th Annual SAFE Symposium December 1981

[3] U.S. Navy Aircrew Automated Escape Systems (AAES) In-service Usage Data Analysis Program Automation Plans-II by Charles W. Stokes and Frederick C. Guill

of the program team's efforts since receipt of those first data tapes and associated instruction manuals simply was consumed in gaining familiarity with the data, its capabilities and its limitations; a task which has proven to have been far greater than envisioned at the onset of the program and which, as a consequence of Naval Safety Center recent data format changes, is continuing.

During the past year, however, events have occurred which have permitted a significant proportion of the program's efforts to be devoted to other accomplishments such as:

- initiated development of a computer simulation model for an ejection seat.
- initiated development of a computerized log of all U.S. Navy ejections occurring prior to 1 January 1969.
- initiated development of a computerized log of all U.S. Navy manual bailouts occurring between 1950 and 1969.
- generation of detailed, supplementary case data from original MORs/FSRs for ejections in which severe and moderate neck injuries were reported to have been sustained by one or more of the ejectees.
- generation of detailed ALSS lists for each of 64 A-6 series aircraft mishap aircrewmen.
- development of standardized presentation formats for examining mishap aircrew anthropometric data and comparing the resultant populations of data to the standard U.S. Navy aircrew anthropometry references.[4,5]
- provided to the Johnson Space Center, Houston, in connection with the orbiter program, a review of U.S. Navy ditchings accompanied by a review of data obtained from the National Transportation Safety Board reports concerning commercial airline ditchings.
- obtained from the Naval Safety Center, Norfolk, additional MOR/FSR data extract computer tapes including data concerning all U.S. Navy helicopter mishaps and fixed wing non-AAES aircraft mishaps from 1 January 1969 through mid-1982 and updating the AAES equipped aircraft mishap data file to mid-1982 from its previous period of 1 January 1969 through 31 December 1979 (this update includes some non-ejection mishap data for AAES equipped crewmembers for that earlier period not contained in the earlier computer tapes).
- acquisition and storage in discrete monthly increments of 3-M (Maintenance and Material Management) System Data for all U.S. Navy AAES in inventory during the past year.
- initiation of development of what eventually is planned as a "user friendly" life cycle cost (LCC) and design-to-cost (DTC) model.
- development of several series of proposed field investigation guides for assisting the non-expert in performing a step-by-step examination of each retrieved article of mishap crewmember ALSS and recording the resultant data, and in acquiring and recording data concerning the on-site location and retrieved condition of that ALSS.

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[4] NAVAIRTESTCEN Report SY-121R-R2

[5] Naval Air Engineering Center (ACEL) Report ACEL-533

- o initiated the conceptualization of a computer model of the crewmember and that individual's articles of ALSS reported carried, used and/or worn to permit rapid identification of probable damage sites for each ALSS element when the crewmember has sustained injuries.

When the project with the Oak Ridge National Laboratory (Department of Energy) currently being undertaken with considerable assistance from the Naval Air Development Center, Warminster, is completed, the AAES/ALSS Equipment In-service Usage Data Analysis Program will be equipped with a series of ejection simulation models tailored to the characteristics of each individual system for which the program contains mishap ejection data. These simulation models will differ significantly in the functions performed, the totality of the AAES simulated, the nature of the input data, and their purpose from simulation models which now exist. It is anticipated that in their final versions these models will include a limited amount of appropriate aircraft flight and ejection response data peculiar to the specific mishap aircraft flight configuration (i.e., ordnance load, hung ordnance, wing failure, etc.) and manuever prior to and during the escape attempt. These models (Figure I) eventually will become, in one usage, an automatic part of the data analysis system being developed and will flag for special attention those escape attempts in which the reported escape conditions (i.e., ejection altitude, airspeed, attitude, descent rate, and/or maneuver) are not supported by (or do not support) the reported observed results (e.g., escape sequence interrupted by ground impact, parachute full deployment and opening, etc.). Another anticipated usage of these models will be the evaluation for all recorded escapes of the effects of potential changes in order to more precisely define the problems which require addressal by AAES and AAES element designers.

Progress in developing the first of these models has been slow but promising and the present indications are that the first model(s), sans aircraft flight and ejection response characteristics, will become operational during this next year. Prior to incorporating these models into the data analysis system it is planned to coordinate the proposed models with the ejection seat and airframe manufacturers to ensure their individual accuracy. As these models become operational, initially as ejection seat or escape system models, it is planned to seek assistance from sources such as the Naval Air Test Center, Patuxent River, and the individual aircraft manufacturers concerning how best to model the aircraft flight and ejection response characteristics which will ultimately enhance the capability of these models to assess the timeliness of ejection (i.e., initiated in or out of the system performance envelope) and the potential for anomalous escape system performance to have occurred.

A future step for each of these system tailored models will be the development of means for estimating total ejected weight and, perhaps, the static (pre-ejection) center of gravity for each ejectee-seat combination. This step would permit incorporation into a subroutine of a model, the ejectee's anthropometry as reported in the FSR, after having been screened for the presence of unlikely data or data combinations, and his ALSS equipment configuration as reported by the FSR, automatically entering the weight for each article noted as worn, carried or available to the mishap crewmember for the escape and subsequent descent and survival phases. Additional data available in most FSRs which might be incorporated include surface winds, terrain and, if applicable, sea state.

As envisioned, these models eventually will perform most of these data retrievals and combinings automatically in the process of developing the assessment of the timeliness of escape initiation, in assessing the likelihood that the system's performance might have been anomalous, and in estimating the ejectee's surface contact (impact) velocity.

Using data long collected by the project's sponsor, supplemented by the annual Naval Safety Center, Norfolk, publication Emergency Airborne Escape Summaries in conjunction with information airframe and ejection seat manufacturers have graciously furnished, the program has developed a computerized log of ejection attempts and another of bailout attempts for aviation mishaps occurring prior to 1 Janaury 1969, a cut-off imposed on Naval Safety Center furnished mishap data by Navy interpretations of the Privacy Act requirements and restrictions. These logs (which contain no crew names or other crew identification) start with the U.S. Navy's first ejection, 9 August 1949. They do not, unfortunately at this time contain truly significant amounts of information or sufficient indications concerning non-ejection and non-bailout type situations. At present these logs can only be described as rudimentary and the information contained in them is meager, generally constrained to type aircraft, sometimes type of seat (completeness of these data is improving), escape attempt altitude and speed, occasionally the attitudes and maneuver during the escape attempt, a limited description of any injuries sustained by the crewmember, the type of rescue vehicle and the duration between escape and rescue, and a terse description (especially terse for pre-1963 mishaps) describing the nature of the mishap or other significant aspects. At present the logs are useful primarily for identifying mishaps for which the Naval Safety Center, Norfolk, should be able to locate and furnish original MOR documents for examination in those instances in which certain mishap or escape characteristics appear potentially similar to those being investigated for mishaps or ejections occurring after 1968 and for which the examination of the earlier mishaps or ejections might assist in the analysis, understanding the problems and/or defining the problems currently occurring.

These logs were initiated for several reasons. One, to permit increasing populations of escape attempts with common (shared) attributes (i.e., type of seat, ejection airspeed and altitude, configuration of various ALSS equipments, etc.) in the hopes of achieving statistically significant, yet specialized populations to analyze and from which to draw conclusions concerning such aspects as trends, how some of today's current yet old equipment (e.g., in the case of Koch parachute quick release fittings, how they have been and are performing and what might be expected to occur if changes in bulk and mass or other characteristics were to occur). Another was to similarly increase populations experiencing apparently similar results and/or consequences. The 1 January 1969 cut-off date for the ready access to computerized summaries of data concerning earlier ejections and ejection attempts resulting from the Privacy Act interpretations imposes severe restrictions adversely affecting attempts to study topics such as neck injuries, vertebral fractures, flail injuries, landing injuries, the effects of parachute size or opening aids, the effects of changing escape performance capabilities as from Mk5 Series to Mk7 Series or from RAPEC I/ESCAPAC I to successive ESCAPAC versions. These, and similar analytical efforts aimed at enhancing the safety of present and future aircrew, can be, and are at present, severely handicapped without access to these earlier ejection attempts and could (as has been the case in several past efforts in earlier years) cause erroneous conclusions and/or definitions of problems or permit or cause popularization of erroneous beliefs among aircrew, AAES/ALSS requirements formulaters, AAES/ALSS project managers, AAES/ALSS designers, AAES/ALSS manufacturers, and AAES/ALSS maintainers. Such results can and have penalized present aircrew and maintenance personnel and could penalize many generations of aircrew and maintenance personnel yet to enter the service.

Efforts are planned to continue to enhance the data contained in these logs for it is not enough to merely count successes and failures or injuries, the data must be of such a quality, as well as quantity, to permit conducting in-depth, penetrating and detailed systems-knowledgeable examinations if we are to understand the many causal factors and mechanisms of current potential current problems, ejectee injuries and ALSS damage, and their interactions so as to be able to define clearly the problems requiring resolution in a manner permitting planning, funding, scheduling and, eventually, resolution of the problem.

Of necessity the data contained in the Naval Safety Center computerized MOR/FSR data extract tapes are limited in quantity and detail, being only a portion of the total mishap data extracted and stored, to permit its economic storage, retrieval and management level analyses. All data suffers to some degree these same problems and that data in the Naval Safety Center's data banks is, without question, extremely valuable. However, that data often fails to provide adequate answers to in-depth, very detailed probings. One such example has involved the incidence of "ejection associated" neck injuries reported sustained by ejectees. Another concerns the usage exposure of ALSS to various emergency conditions; information necessary when attempting to make managerial decisions concerning either allocating very scarce AAES/ALSS resources (funds, knowledgeable and skilled personnel, and facilities) among known and suspected problems to achieve an optimal and timely improvement in aircrew safety, or, even more difficult and often more important, seeking to justify significant additions to available resources to permit efforts to resolve problems which are more complex than initially anticipated or which were unknown at the time the budgets were submitted. Obviously, failure to achieve additional resources, which under current political realities are increasingly difficult to justify to the extent of actually acquiring them, means that some serious problems must remain unaddressed, therefore unresolved, and that aircrew safety to some degree must suffer. But a system, such as being developed under this project, should ensure that the Crew Systems Division will be able to consciously and with relatively full knowledge decide which risks require actions which are of lesser importance and therefore are less damaging to naval aircrew safety if total funds and other resources do not permit the addressal of all identified problems.

Thus, as reported in another paper[6] a considerable effort was undertaken late in 1982 to identify those mishaps in which one or more ejectees sustained a severe or moderate neck injury (the classifications "severe" and "moderate" are arbitrary, are described in the paper, and served to control the scope of the effort -- a major necessity in terms of time available, personnel available, funding available, and that all important and very frustrating computer storage capacity). During this effort the original MORs/FSRs for the reported 21 severe and 114 moderate "ejection associated" neck injuries occurring during the period 1 January 1969 through 31 December 1979 were identified. In addition, using the initial draft of the ejection logs, 12 earlier severe ejection associated neck injuries were identified (although identified, the earlier 109 moderate "ejection associated" neck injuries were not subsequently examined due simply to lack of resources). With the extensive cooperation of the Naval Safety Center, Norfolk, the original MORs/FSRs for these identified mishaps were located and thoroughly examined and an extensive body of supplementary information extracted concerning the nature and violence of the mishap leading to the ejection, events and factors inducing forces on the aircrew/ejectee, events and factors influencing the magnitude of those forces, and events and factors influencing the ability of the aircrew/ejectee to withstand those forces without injury. Just recently, the effort to enter into this program's computer this new body of data, to proof it and make it manageable and amenable to analyses has been completed and preliminary results are now being obtained. From the inception of the effort to the present has been just shy of one year and has involved in excess of two man-years effort -- a significant portion of which was donated to the program without charge. Nonetheless, this effort severely impacted many other previsously planned efforts, but the never ceasing politico-technical demands for action to resolve this problem perceived by the Fleet and others to be extremely serious and the frequent, costly proposals for action being advanced and gaining advocates have necessitated a more rapid addressal of this problem than initially planned.

An opportunity arose and was taken in April of this year, while examining A-6 series (non EA-6B) mishaps' original MORs/FSRs to extract information[7] concerning the ALSS equipments listed in these documents as having been initially present and available to the mishap crewmembers. Since, as reported at the 20th Annual SAFE Symposium,[8] the ALSS equipment data presented in the Naval Safety Center MOR/FSR data extract computer tapes for mishap crewmen was extremely limited, being generally reported

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[6] Factors Influencing the Incidence and Severity of "Ejection Associated" Neck Injuries Sustained by U.S. Navy Ejectees: 1 January 1969 through 31 December 1979 by Frederick C. Guill

[7] Reported in Aircrew Life Support Systems (ALSS) Equipment Presence, Usage and Damage During U.S. Navy A-6 Series Aircraft Ejection; A Preliminary Study (1 January 1969 through 31 December 1972) by Frederick C. Guill

[8] Aircrew Life Support Systems (ALSS) Equipment Aspects of U.S. Navy Ejections, 1 January 1969 through 31 December 1979 by Frederick C. Guill, presented at the 20th Annual SAFE Symposium 5,6,7,8 December 1982

only when a noteworthy factor had occurred, that data could not satisfy the Crew Systems Division needs to ascertain the frequency and severity of ALSS equipment problems versus their total exposure to emergency conditions and versus their total attempted usage (e.g., if five failures of a type of ALSS were reported in the data, were those five the result of five exposures/usages or 100 per cent, the result of 25 exposures/usages or 20 per cent, or the result of 100 exposures/usages or 5 per cent, or some other rate and associated statistical confidence in that rate?). When problems result in the same severity of consequences and available resources will not admit addressing all problems, then some problem ranking mechanism is required and the tape data simply could not, and can not, satisfy that critical resources management need.

Recently the ALSS equipment data extracted during this effort (limited by personnel resources and time to 64 crewmembers involved in mishaps during the period from 1 January 1969 through 31 December 1972) was codified using Naval Safety Center equipment codes, entered into the computer, proofed, and determined to be suitable for usage. As reported,[9] the results greatly exceeded the team's hopes and expectations in terms of reducing the magnitude of ALSS equipment exposures/usages unknowns (i.e., the extracted data appear potentially capable of providing reasonable to high accuracy rates of exposures/usages for each type/model of equipment with relatively tight, identifiable "worst case" limits due to the small quantities of "unknown types" or "not mentioned at all" types of ALSS equipments). An interesting result of this effort was the identification of a probable significant underreportage of ALSS garment damage. This result is based upon the comparison of reported injuries, garments worn, and the reported damage thereto for each of the 64 crewmembers. A letter has been prepared and sent to the Naval Safety Center, requesting their permission for the Naval Weapons Engineering Support Activity to examine all post-1968 MORs/FSRs to extract the available ALSS equipment data and also the reporting Medical Officer's description of the injuries sustained and their severity.

As reported last year[10] a review of the ejectee anthropometry revealed potentially significant differences for each morphological feature between the ejectee population values and the "representative" population values reported in the two earlier referenced U.S. Navy aircrew anthropometry standard references. In developing and examining these data and then comparing them to standard, accepted values, several data presentation formats were developed and are used in a paper[11] examining these data for

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[9] Aircrew Life Support Systems (ALSS) Equipment Presence, Usage and Damage During U.S. Navy A-6 Series Aircraft Ejections: A Preliminary Study (1 January 1969 through 31 December 1979) by Frederick C. Guill

[10] U.S. Navy Ejectee Anthropometry, 1 January 1969 through 31 December 1979 by Frederick C. Guill, presented at the 20th Annual SAFE Symposium 5,6,7,8 December 1982

[11] U.S. Navy Aviation Mishap Aircrew Anthropometry; 1 January 1969 through 31 December 1979 by Frederick C. Guill

all U.S. Navy mishap aircrew (i.e., those in AAES and in non-AAES fixed wing aircraft and in helicopters, exclusive of non-aviation personnel passengers). The problem in the earlier examination of these data for AAES equipped aircraft mishap crewmembers was that there was no way to definitively determine the reasons for the differences in values and value distributions occuring between the ejectee and "representative" populations. It was possible that the differences resulted from errors in measuring the ejectees or in transcribing that data into the MORs/FSRs (examination by the author of the paper found no transcriptional errors occurring at the Naval Safety Center when comparing original MOR/FSR data to the computer tape data). Another possibility which might account for the differences is that the developed "representative" populations studied were created to represent the entire spectrum of Naval aviators while the ejectee population might be a population constrained by cockpit dimensions or other aircraft type peculiar factors thus forming a unique AAES subpopulation of Naval aviation. Yet another explanation conceivably could be that the techniques in creating the "representative" populations were in some manner biased, creating errors. These and other potential explanations are being examined using the three aircrew subsets' (AAES, helicopter and non-AAES fixed wing aircraft) and, in addition, the total mishap aircrew populations' anthropometry. The issues at hand could influence among other things cockpit design, garment design and stocking plans, escape system designs, and aviator personnel assignments/utilization. It is conceivable that the results could influence the assumptions and methodologies employed in future anthropometric studies of U.S. Navy aviation personnel.

The National Aeronautics and Space Administration recently has re-examined the issue of orbiter vehicle crew escape for certain, very specific scenarios. One set of scenarios envisioned ditching the orbiter which would entail a water touchdown at speeds of 200 knots or greater. A limited study of Naval Safety Center data and National Transportation Safety Board data suggested that for normal and reasonably safe aircraft ditching, speeds needed to be well below 150 knots to avoid extreme structural damage and consequent high mortality rates. Considering the orbiter's pressure hull within an outer fuselage construction in which the two are interconnected by mechanical means rated for 9G's, the flight deck structural strength, and the single ingress/egress hatch in the vehicle's side which passes through both the pressure hull and fuselage (and hence might jam as a result of ditching forces), an informal note and a briefing were provided to the Johnson Space Center orbiter management personnel suggesting orbiter ditching could be expected to be very hazardous. Similar questions were posed earlier this year with respect to the experience with manual bailouts from aircraft with a view of possibly considering manual bailout from the orbiter under specialized scenarios. Unfortunately, due to the priorities of Crew Systems Divisions' needs, the temporary loss of several key personnel and the current incompleteness of the program's bailout log, no answers have been furnished. However, perusal of the bailout log in its current state suggests that many well accepted "facts" concerning manual bailout and especially concerning the safety of the crewmember while in the vicinity of the aircraft during bailout may require significant revision.

Early this year, the Naval Safety Center, Norfolk, furnished to the Naval Weapons Engineering Support Activity computer tape extracts of data from MORs/FSRs and other mishap report forms for all aviation mishaps from 1 January 1969 through mid-1982. Due to changes in OPNAVINST 3750.6 there were numerous, significant and, to some degree, troublesome changes in the data format on those new tapes such that the data are not precisely compatible with the earlier AAES mishap tapes. A major portion of the program's personnel resources has been engaged in developing the means to employ the tapes interchangeably and to identify changes (e.g., significantly revised narrative synopses of some cases, etc.) wherein Naval Safety Center assistance will be required. This effort is nearing completion and, as mentioned earlier, the first steps to employ these new data have been taken in developing the mishap aircrew anthropometrics.

As the program team began acquiring and learning the nuances associated with the 3-M System data, warnings were received concerning the differences in speed at which the flight hours, the maintenance actions, and the maintenance man-hours data were entered into the system. As reported last year[12] sources of this information alleged that these differences in the speed of reportage and recordage could produce significant errors. As was also reported in that paper, the pilot sample examined did not appear subject to major problems, but that the issue would be further studied. The data is now being acquired and, unlike the normal manner for its retention, being held in discrete monthly increments for all AAES equipped aircraft escape system elements. Unfortunately limited personnel resources have precluded conducting the necessary examination. One other factor discovered and reported in that paper concerning 3-M System data for AAES, was that the 3-M System does not include a significant amount of Naval Aircraft Rework Facility (NARF) data and, even if it did, a superficial survey of the AAES induction and processing procedures employed by several NARFs revealed a wide variance between the NARFs with respect to the manner in which similar seats were treated. The nature of these differences would result in highly different levels of activity and costs reported even for identical seats. Hence, at the moment, since maintenance efforts removed from Fleet level activities might not be eliminated totally but, rather, shifted in part or totally to NARF level, there exists at present no reliable means for comparing the true cost of AAES ownership and the maintenance action and expenditures data available may therfore in fact distort that cost (Figure 2) signficantly, creating erroneous impressions of superior/inferior maintainability relationships among competing AAES. Figure 2 illustrates, using hypothetical examples, how the quantity of effort planned or actually expended at NARF level might impact the Navy's cost of AAES ownership. The figure also illustrates how the 3-M System data, when not supplemented with the NARF level data, could result in misleading maintenance/maintainability estimates and comparisons and, possibly thereby, lead to poor decisions concerning AAES competition,

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[12] Precautions Required in Using U.S. Navy 3-M (Maintenance and Material Management) System Data for Analyzing or Comparing Aircrew Automated Escape Systems by Frederick C. Guill, presented at the 20th Annual SAFE Symposium, 5,6,7,8 December 1982.

proposed AAES design features and approaches, or proposed AAES changes. Action is planned to solicit NARF AAES maintenance procedures and data with hopes of developing a rational, standard approach for evaluating AAES cost of ownership following its acquisition.

In this connection, an opportunity arose, and action has been initiated to acquire a "user friendly" life cycle cost (LCC) and design-to-cost (DTC) model for U.S. Navy AAES/ALSS directly usable by Navy AAES/ALSS engineers and managers at any facility. It has been interesting and extremely disturbing in past Crew Systems Division exercises to expend considerable scarce resources to enhance AAES corrosion resistance and AAES/ALSS maintainability (i.e., reducing frequency of maintenance, time to maintain, numbers and cost of spares, etc.) only to find that the new AAES or ALSS which has been saddled with a large development cost and now often costs more than earlier models is penalized by present U.S. Navy LCC approaches. The LCC approach for small equipments, which include AAES and ALSS, has been to take a fixed precentage of the acquisition and development costs, multiply that fixed percentage by the expected life of the article and add the resultant to the acquisition and development costs to determine the AAES or ALSS article LCC. Naturally under this approach, the expenditures and increased initial acquisition costs associated with enhancing the design in the expectation of reducing the costs of ownership during the article's service life not only are not recognized as beneficial, but actually serve to penalize the article (a very strong disincentive for using improved technological know-how for producing equipments to better survive and function in the very hostile marine environment in which the U.S. Navy operates and in which many of the emergencies occur requiring use of these equipments).

One major problem evident early on in this program concerning MOR/FSR recorded data was the need to ensure that (1) the data were accurately, carefully and thoroughly generated and recorded concerning the retrieved conditions of AAES and ALSS, (2) the data were accurately, and thoroughly generated and recorded concerning which AAES and ALSS equipments were involved in mishaps, and (3) the quality of the data being generated be enhanced. Since it was impractical to establish a team, or several teams of experts solely dedicated to investigate AAES/ALSS emergency usage and since the personnel assigned to perform the AAES/ALSS retrieval and examination process normally were on a temporary detail and were not fully expert with respect to the configuration, usage, functioning, and normal/abnormal post-use condition of these equipments, a low level, barely funded effort has been underway to create field investigator guides to assist the personnel assigned to that often unpleasant duty perform the duties reasonably well. Those guides drafted and now ready for trial use and comments are published in this document.

Finally, as noted earlier, comparison of ejectee injuries and reports of ALSS garment damage has suggested that the damage is being seriously under reported, a condition that can lead to complacency within responsible Navy and corporate managements and serious problems and/or fatalities among aircrew. The program team is formulating a concept for attempting to identify among present ALSS equipment, areas of high probability of having sustained damage. The concept is briefly reported and illustrated in a separate paper (footnote 7). If successful, this tool will be offered to the Naval Safety Center, the Air Force Inspection and Safety Center and other interested government agencies.

COMPARATIVE PROGRESS

Figure 3 illustrates the stages of program progress which had been achieved when the previous report (footnote 3) was issued and the stages which have been achieved during this past year.

PROGRAM PROBLEMS

The primary problem facing this program, as any of the very dedicated team members will inform you if asked, is there is so much that urgently needs to be done and so few resources with which to accomplish that work.

Already, the computer facility seems to have been filled and still the penurious program sponsor wishes to incorporate additional vast amounts of data and then immediately have it spewed out in multiple analytical approaches in zero time.

The program has been fortunate that, in addition to its meager official funding, it has received funds from several activities, including the Naval Weapons Engineering Support Activity itself, that equal or exceed the official budget and which have permitted more technical experimentation and earlier achievement and/or initiation of planned milestones. In addition, the program team has received considerable valuable assistance, so far at no cost to the program, of several personnel having special knowledge and skills needed to ensure the timely achievement of the programs' many intermediate and final objectives.

CONCLUSION

Those of us working on the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis Program believe strongly in the program and in its potential to soon begin to visibily benefit the U.S. Navy and are striving to make that happen at the earliest date possible.

AIRCREW AUTOMATED ESCAPE SYSTEM (AAES)

IN-SERVICE DATA USAGE ANALYSIS PROGRAM TRAJECTORY SIMULATION MODEL FOR DETERMINING WHETHER EJECTION
OCCURRED IN OR OUT OF SYSTEM PERFORMANCE ALTITUDE

STANDARD ESCAPE TRAJECTORY PLOT

KEY NO	EVENTS	NOMINAL EVENT TIME FOR SYSTEM	REPORTED EVENT COMPLETED (YES/NO)
1.	CANOPY FIRST MOTION		
2.	AIRCRAFT CANOPY CLEAR OF SEAT PATH (XX°)		
3.	SEAT FIRST MOTION		
4.	ROCKET BURN OUT		
5.	DART RELEASE/STA		
6.	SEAT/MAN SEPARATION		
7.	PARACHUTE PACK OPEN		
8.	PARACHUTE LINE STRETCH		
9.	PARACHUTE FIRST FULL OPEN		
10.	PARACHUTE FIRST VERTICAL		

AIRCRAFT PARAMETERS AT ESCAPE

AIRCRAFT MODEL
- SPEED ________
- ALTITUDE ________
- ATTITUDE
  - — BANK ________
  - — PITCH ________
- SINKRATE ________
- MANEUVER ________
- TYPE SEAT ________
- CREW POSITION ________

TOTAL EJECTED WEIGHT

TYPE SEAT ________ ________
TYPE COVERALLS ________ ________
TYPE HELMET ________ ________
TYPE BOOTS ________ ________
TYPE RESTRAINT HARNESS ________ ________
TYPE PERSONNEL FLOTATION ________ ________
TYPE SURVIVAL VEST ________ ________
ADDITIONAL EQUIPMENT
________ ________ ________
________ ________ ________
________ ________ ________
CREW HEIGHT ________
CREW WEIGHT ________
CREW SITTING HEIGHT ________
CREW TRUNK HEIGHT ________
CREW BUTTOCK KNEE ! ENGTH ________
CREW LEG LENGTH ________
CREW SHOULDER WIDTH ________
CREW FUNCTIONAL REACH ________
CREW AGE ________

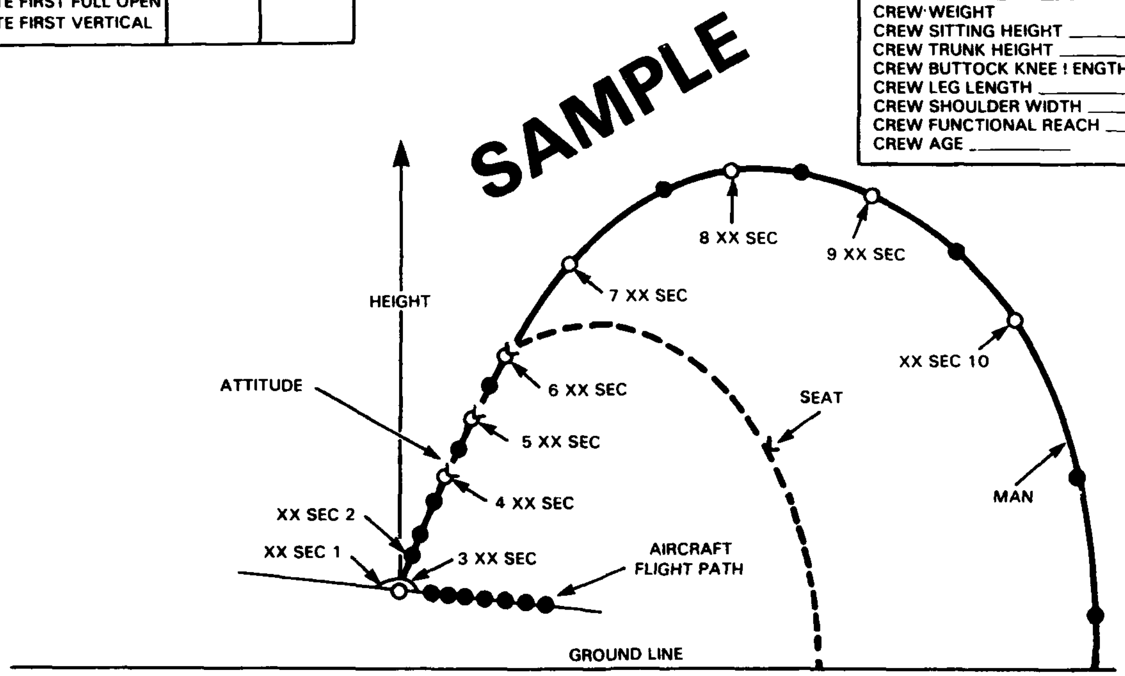

Figure 1

SAMPLE COMPARATIVE MAINTENANCE MAN-HOUR TOTALS DEPICTING POTENTIAL EFFECT OF NARF MAN-HOURS

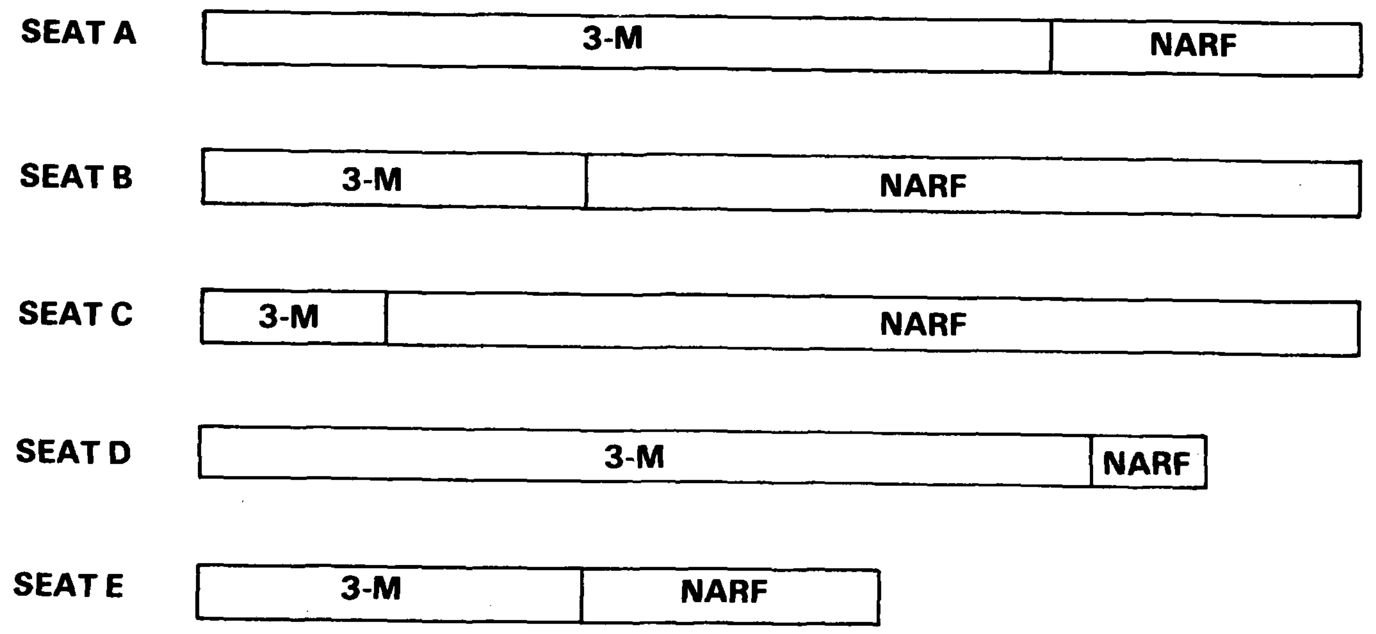

Figure 2

AAES IN-SERVICE USAGE DATA ANALYSIS PROGRAM IS IN EARLY STAGES:

- INITIAL ACQUAINTANCE WITH AAES EQUIPMENTS/ TECHNIQUES
- INITIAL ACQUISITION OF DATA
- 1982 INITIAL ACQUAINTANCE WITH DATA
- 1982 FORMULATE DATA ANALYSES TECHNIQUES AND PRESENTATION FORMATS
- 1983 ACQUIRE PRE-1969 DATA
- 1983 UPDATE DATA
- (INITIATED) 1983 DEVELOP ROUTINE, PERIODIC AUTOMATIC ANALYSES TECHNIQUES AND PRESENTATION FORMATS
- CONDUCT SPECIAL ANALYSES

Figure 3

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
AND
AIRCREW LIFE SUPPORT SYSTEMS (ALSS)
IN-SERVICE USAGE DATA ANALYSIS PROGRAM

AUTOMATED ANALYTIC TOOLS AND PROCEDURES: A REPORT OF PROGRESS AND LONG-TERM PLANS

Charles W. Stokes III

ABSTRACT

The Analytical Systems Division (ESA-31), Naval Weapons Engineering Support Activity, Washington, D.C., under tasking from the Crew Systems Division, Naval Air Systems Command, Washington, D.C., has been developing systems for analyzing in-service usage data concerning aircrew automated escape systems (AAES) and aircrew life support systems (ALSS). Initial efforts, devoted to gaining familiarity with the data and data sources, have essentially been completed. As a consequence of the earlier efforts, ESA-31 has become cognizant of many problems with the data as regards its use to satisfy the Crew Systems Division's needs for information to aid in their decision-making processes. As discussed in this paper, these earlier efforts have (1) permitted refinement of estimates concerning data needs, the associated effort required to acquire the additional data and the related expansion in computer capacity to store, access and analyze the additional data, and (2) resulted in the formulation and initial development of several conceptual tools for analyzing the data. Additionally, as a consequence of working with the available data, concepts are being considered and formulated with a view towards enhancing the quantity and quality of the raw data provided to the Naval Safety Center, Norfolk, without increasing the report preparer's effort. Also being considered are means for providing Crew Systems Division and perhaps its field activities user-friendly, controlled direct access to the developed data base.

INTRODUCTION

This paper presents a brief report of the progress of the Analytical Systems Division (ESA-31) of the Naval Weapons Engineering Support Activity, Washington, D.C., in the development of a system of computer-based procedures, techniques and tools in support of the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis Program. Successful implementation of such a system will result in a unique AAES/ALSS information resource based upon an integrated repository of data from such sources as Medical Officer's Reports (MOR), Flight Surgeon's Reports (FSR), Mishap Investigation Reports (MIR), Search and Rescue Reports (SAR), the Maintenance and Material Management (3-M) System, Naval Air Rework Facility (NARF) Data Systems, Subsystem Capability Impact Reports (SCIR), Unsatisfactory Reports (UR), Quality Deficiency Reports (QDR), Configuration Control Systems, and various reports on equipment testing, cost, inventory and operation.

A companion paper[1] by the program sponsor presents a report of overall program progress.

RECENT PROGRESS

The long-term automation objective remains the same (i.e., to utilize state-of-the-art information technology and analytical techniques to support the Crew Systems Division (AIR-531) of the Naval Air Systems Command, Washington, D.C., in its decision-making process by developing techniques useful for performing periodic, routine analyses and for performing unique, highly specialized studies). However, lessons learned from the program's recent experience with MOR/FSR data indicate that original estimates of equipment resources required to meet the long-term automation objective were far too low. Figure 1 depicts the initial acquisition and analysis process for Medical Officer's Report and Flight Surgeon's Report data.

Of greatest impact was the discovery that the computerized MOR/FSR data is of insufficient detail to permit meaningful analysis of ALSS equipment usage in the detail required by the Crew Systems Division in its decision making processes. There is, however, a large body of additional, detailed data available in the original hardcopies of MORs and FSRs. The Naval Safety Center has recently granted ESA-31 access to these originals. The extracted data will be entered into ESA-31 computers thus providing a more nearly complete picture of actual ALSS equipment usage histories. Adding to this the possibility of developing MOR/FSR format records from the recently developed logs of manual bailouts and pre-1969 ejections; the sooner-than-planned processing of helicopter and other non-AAES aircraft; the annotations and comments added by the project sponsor, AIR-531C; and the other unforeseen or earlier than originally planned additions resulting from the evolutionary process of defining data, data sources, data limitations, Crew Systems Division needs, and specific computer functions; it has become obvious that our initial estimates of computer capacity requirements are no longer adequate.

Current project plans, therefore are (1) to conduct an exhaustive study of current computer technology and trends and (2) to develop estimates of the quantity of data, the response times and the data and analytical presentation format parameters which will strongly influence the types of technology required if the program is to perform in the manner intended. It is also planned to develop a 5-year, step-by-step plan to meet the

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[1] U.S. Navy Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) In-service Usage Data Analysis Program: A Progress Report and Report of Longer Term Plans by Frederick C. Guill

long-term objective of a user-friendly analytical tool with an integrated data base including data from the MOR, FSR and other sources which are required for the conduct of special in-depth analytical studies as well as the on-line, quick response to queries. (NOTE: It is intended that those techniques which prove useful to Crew Systems Division and would be desired on a routine, periodic base will be made available to the Naval Safety Center, Norfolk, so as to avoid any duplication of mission or efforts.)

CURRENT SYSTEM - September 1983

In the past year significant improvements have been made to components of the AAES/ALSS data system at the Naval Weapons Engineering Support Activity (ESA-31), Washington, D.C. (Figure 2). The project previously shared a minicomputer with all of the other projects and administrative functions of the Analytical Systems Division (ESA-31). But, since June of this year, a new Wang 2200 MVP minicomputer has been acquired and is now dedicated solely to the AAES/ALSS program. This doubled the available memory and storage capacities and greatly decreased processing time. However with the addition of MOR/FSR records through mid-1982 for mishaps involving AAES-equipped aircraft, and records since 1 January 1969 for helicopter and other non-AAES aircraft mishaps, the limits of the current on-line storage have been reached. To alleviate this condition the project team is developing procedures which will store the less-used data off-line on magnetic tape to relieve some of the capacity pressure, but will keep these data quickly and easily accessible for processing. This preliminary capability to process non-AAES mishap data coupled with the evaluation of AAES/ALSS data in the U.S. Navy 3-M (Maintenance and Material Management) System marks the beginning of the development of an integrated AAES/ALSS data base.

A major software improvement has been the development of a user-friendly computer program for searching MOR/FSR narrative synopses or supplemental narrative data for specific words or phrases; and for each of the mishap records thereby selected, to display the narratives on a computer terminal screen or to combine narratives and associated codified data and print a report. This capability has made it possible to easily expand the set of records selected by searching not only the codified data but also the narrative data to include records which have indications of a specific problem of interest in the narrative synopsis section but not in the codified data. The additional information provided by these records, which otherwise would not have been selected, has often proven to be extremely important for proper definition of the extent and seriousness of problems and for aiding in identifying, or limiting the quantity of, their probable causal factors and mechanisms.

Due to the limits of ESA-31's current computer configuration, development of the simulation model and of the computer procedures for analysis of U.S. Navy 3-M (Maintenance and Material Management) System data must be accomplished on outside computers. As a preliminary step in the development of a prototype escape system simulation model, the project is examining for possible applicability an existing model which was developed by the Naval Air Development Center (NADC), Warminster, Pa. The present ESA-31 computer configuration does not support this model's computer language (Control Data Corporation FORTRAN) or its internal memory requirements, consequently as a temporary measure this project is sponsoring the conversion of the model to a large IBM computer at the Department of Energy's Oak Ridge National Laboratory, Oak Ridge, Tennessee, preparatory to modifying the program for use in analyzing escape attempts. When fully modified, the model which currently is used in testing and test data analysis using pre-determined values such as weight, center of gravity, etc., will include subroutines to develop ejected weight and center of gravity based upon ejectee anthropometry and ALSS configuration. In addition, the modified model will accommodate aircraft flight and ejection response characteristics versus the current model's applications to fixed track sleds. Similarly, the volume of 3-M data to be processed exceeds in-house capabilities at this time and the processing required to ascertain Crew Systems Division needs is currently being done at the U.S.A.F. San Antonio Data Service Center, San Antonio, Texas.

INITIAL CONCEPTS FOR LONG-TERM SYSTEM

Toward the long-term goal to provide user-friendly analytical and decision support tools, there are several general concepts which may prove to be viable: automatic computer input of raw data, automated data validation, completely integrated data base, user-friendly analytical procedures and decision support, and a properly protected, limited and controlled-access telecommunication network providing access for the Crew Systems Division and its participating field activities (Figure 3).

At present FSR data is recorded on paper forms prescribed by OPNAV Instruction 3750.6. To be processed by computer the FSR data must be transcribed, including summarization of narrative and other textual data, for entry into the Naval Safety Center's computer data base. Our experience has shown that the transcription process is remarkably accurate; most errors and omissions, upon checking, were found to have been on the original documents. However, summarization of the narrative information, which is necessary given the constraints on computer capacity, can often result in the omission of information which may be extremely important in some unforeseeable in-depth analytical study. And, the valuable information found in sketches and photographs is not available for study except by manual means. It is possible to make the data collection and recordation process more effective and efficient both for the investigators and data recorders in the field and for the later users of that data, by having mishap investigators use portable computers to develop and store data at the accident scene and to prepare the accident reports. Such a computer approach would contain error-checking routines and step-by-step procedures for searching for and evaluating evidence and should dramatically reduce error rates while ensuring the collection of some potentially valuable data which at present is often not collected. At such time as resources permit, such equipments and procedures will be developed and initial trials conducted "in the field" during AAES testing which in essence represents a controlled, manufactured mishap scene with which to experiment. If successful, such procedures would not only enhance the quantity and quality of mishap data available for analyses, but would (1) enhance that data with appropriate controlled test data (2) enhance and expedite the collection of AAES test data including the effects on the associated ALSS, thereby improving the knowledge acquired from each test and test series and probably reducing the cost, risk and time to conduct the test series and analyze the data. Meanwhile, while paper forms remain in use, optical character readers or similar technology might be used to directly input to a computer data which is not presently entered and even some that currently is entered. Advances in graphics and image processing could make even computer analysis of sketchs and photographs practicable. These and other innovations for entering the data will be explored under this project to develop techniques for more rapidly and accurately analyzing the FSR data and for performing these analyses in the detail required to support the AIR-531 decision-making process.

Once raw data is presented to the system in a computer-readable format, it is planned that automatic validation procedures will check interrelationships among the data (see example Figure 4). These would flag the types of errors which are not often detected in routine editing procedures (e.g., wrong seat/aircraft combination, conflicting anthropometric measurements, erroneously attributed operating characteristics, etc.) Upon detection, in many instances automatic remedies could be effected and reported or, in others, the problem identified for resolution by team personnel. This facet of the problem is being examined to ascertain means for ensuring that the data used in the required analyses are valid data, for otherwise the resulting analyses could be worthless or, worse, misleading and deleterious to the safety of aircrew, groundcrew, ships, and facilities.

At the core of an effective, efficient system is an integrated on-line data base containing all pertinent data. It should provide a complete history of AAES/ALSS in-service (peacetime and combat) experience as well as equipment specifications, quality assurance and test data, and current and projected aircraft/AAES inventories and operations. Such a system would permit identification of present problems and assessment of their potential for causing harm in the future (i.e., if a problem plagued system is scheduled to be removed before a fix could be developed, proven, manufactured, and installed, the scarce AAES/ALSS resources might more profitably be applied to other problems). These data would be structured so that information could be quickly and accurately obtained via a computer terminal without new programming but this would not preclude new programming required by special, extended analytical studies.

It is expected that the day-to-day operations of the system will be that of an intense, interactive environment with three basic user types: (1) computer specialists who maintain the system and create new programs, (2) analysts who conduct studies, and (3) AAES/ALSS managers who use the system to formulate questions for detailed analyses with which to develop information for, and supporting, decisions and plans.

Accordingly, the primary automated tools needed by each type of user will be different. Computer specialists' needs will include a Data Base Management System, an extensive repertoire of programming language and utility programs, automatic documentation of programs, and other programming aids. Analysts will be the prime users of detailed simulation models featuring, among other aspects, two-dimensional and three-dimensional graphics of aircraft and AAES behavior during a mishap (see example Figure 5), standard statistical analyses techniques and specially developed AAES/ALSS life-cycle cost models, on-screen body-injury vs. ALSS damage comparisons, on-screen escape event sequence "what if" analyses and other similarly complex analytical tools and techniques. The managers will also use simulation and life-cycle cost models but normally at the highest level of detail. Management's primary tools under this project will be very user-friendly programs with capabilities for rapid indexing and cross-referencing to retrieve information from data bases of summary statistics, published studies, reports, as well as appropriate regulations and other documents.

Management level users may also require that a telecommunication network be established or, optionally, that stand-alone desk top computers be provided for their needs. Each option presents a different set of problems. Because of the sensitivity of the MOR/FSR data due to the Privacy Act concerns and the extensive efforts which have been and will be expended in developing the uniquely expanded data bases, a telecommunication network would have to be proven reasonably secure from unauthorized access both to preclude unauthorized use of this privileged data and to prevent damage to the unique, one-of-a kind data bases and programs. A stand-alone desk top computer would contain a copy of appropriate portions of the central computer data base necessitating strict synchronization of the growth and enhancement of the central data and all copies.

CONCLUSION

The preliminary concepts presented here are only estimates of what the final system might contain. The development of formal plans for a step-by-step evolutionary process to reach system goals is in progress. As each step is taken, our goals will be re-evaluated, taking into account changing technology, changing user needs and the lessons learned at each step of the process. There is no fixed priority of implementation of these concepts, but generally the analyst's needs will be addressed first, even if it means using outside computer sites, the computer specialist's needs second, and finally the needs of management level users until a basic, working system has been developed and proven.

As a program requirement imposed upon the Naval Weapons Engineering Support Activity by the Naval Air Systems Command sponsor, any automated tools developed and any routine, periodic analytic techniques and formats developed will be made available to the Navy, Air Force and Army Safety Centers and other interested government agencies.

INITIAL
MEDICAL OFFICER'S REPORT/FLIGHT SURGEON'S REPORT
DATA ACQUISITION AND ANALYSIS

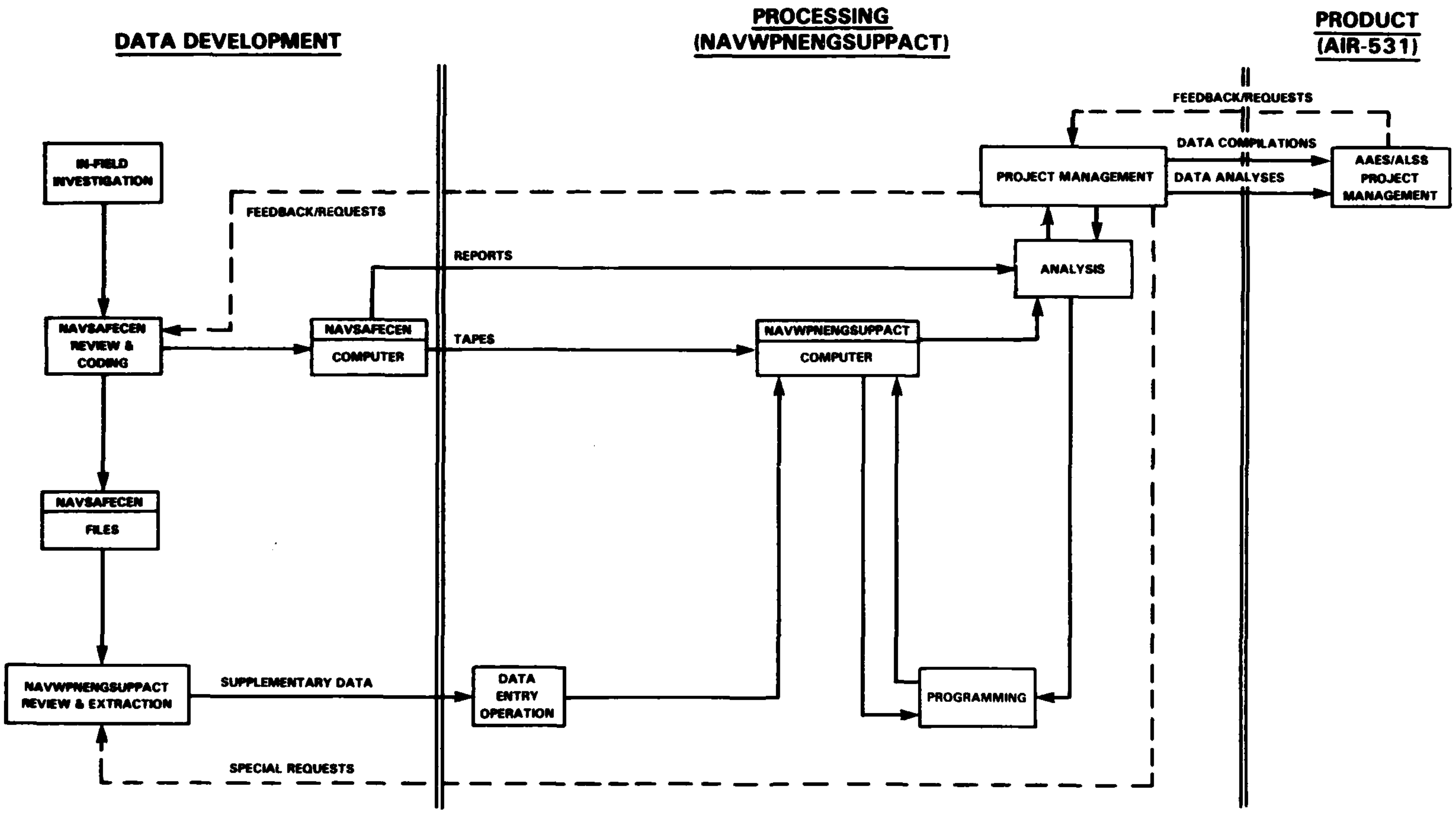

Figure 1

CURRENT
MEDICAL OFFICER'S REPORT/FLIGHT SURGEON'S REPORT
DATA ACQUISITION AND ANALYSIS

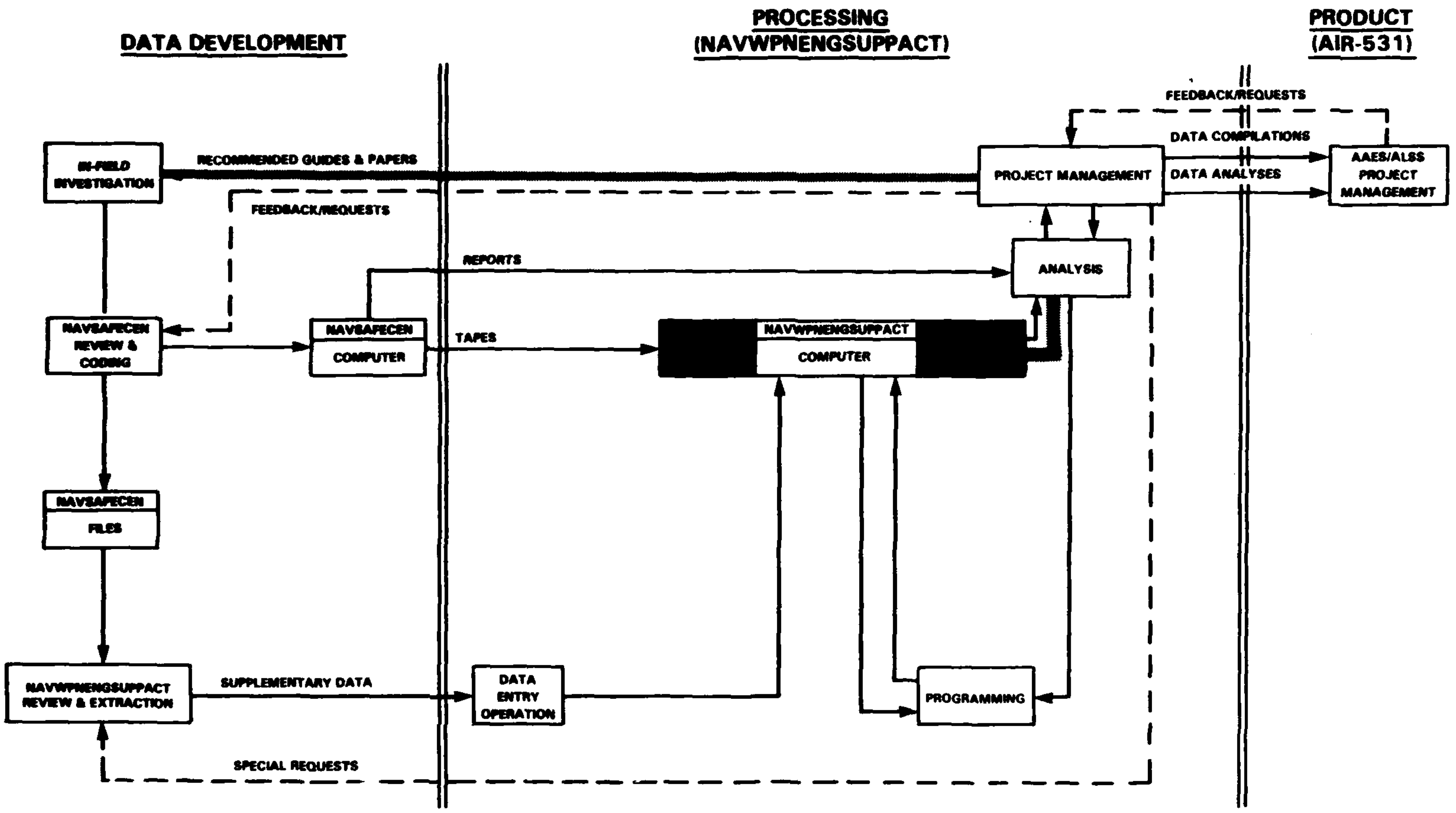

Figure 2

LONG-TERM
MEDICAL OFFICER'S REPORT/FLIGHTSURGEON'S REPORT
DATA ACQUISITION AND ANALYSIS

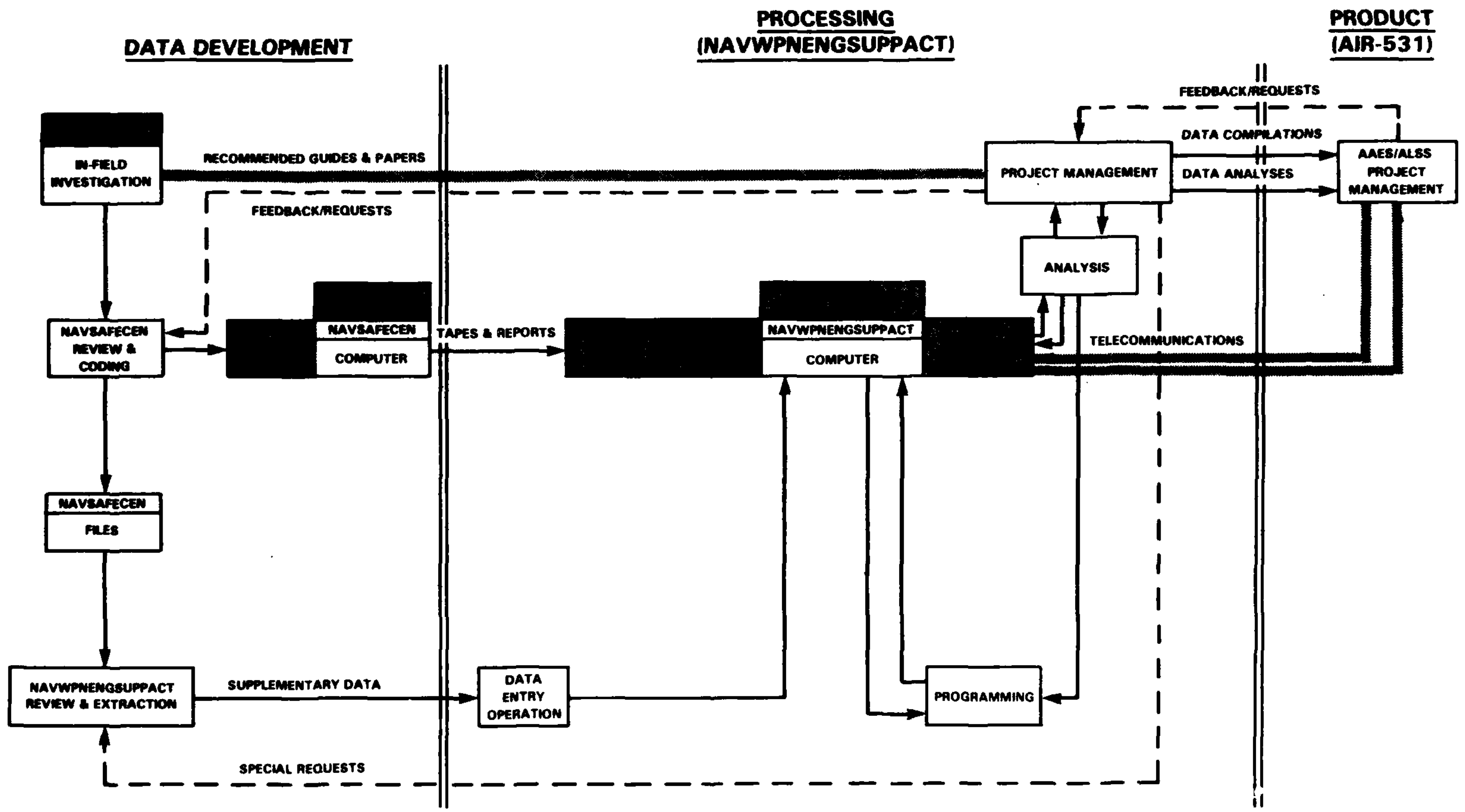

Figure 3

U.S. NAVY MISHAP AIRCREW
ANTHROPOMETRIC DATA SCREENING FLOW
(FOR VALIDATING EACH INDIVIDUAL ANTHROPOMETRIC DATA VALUE)

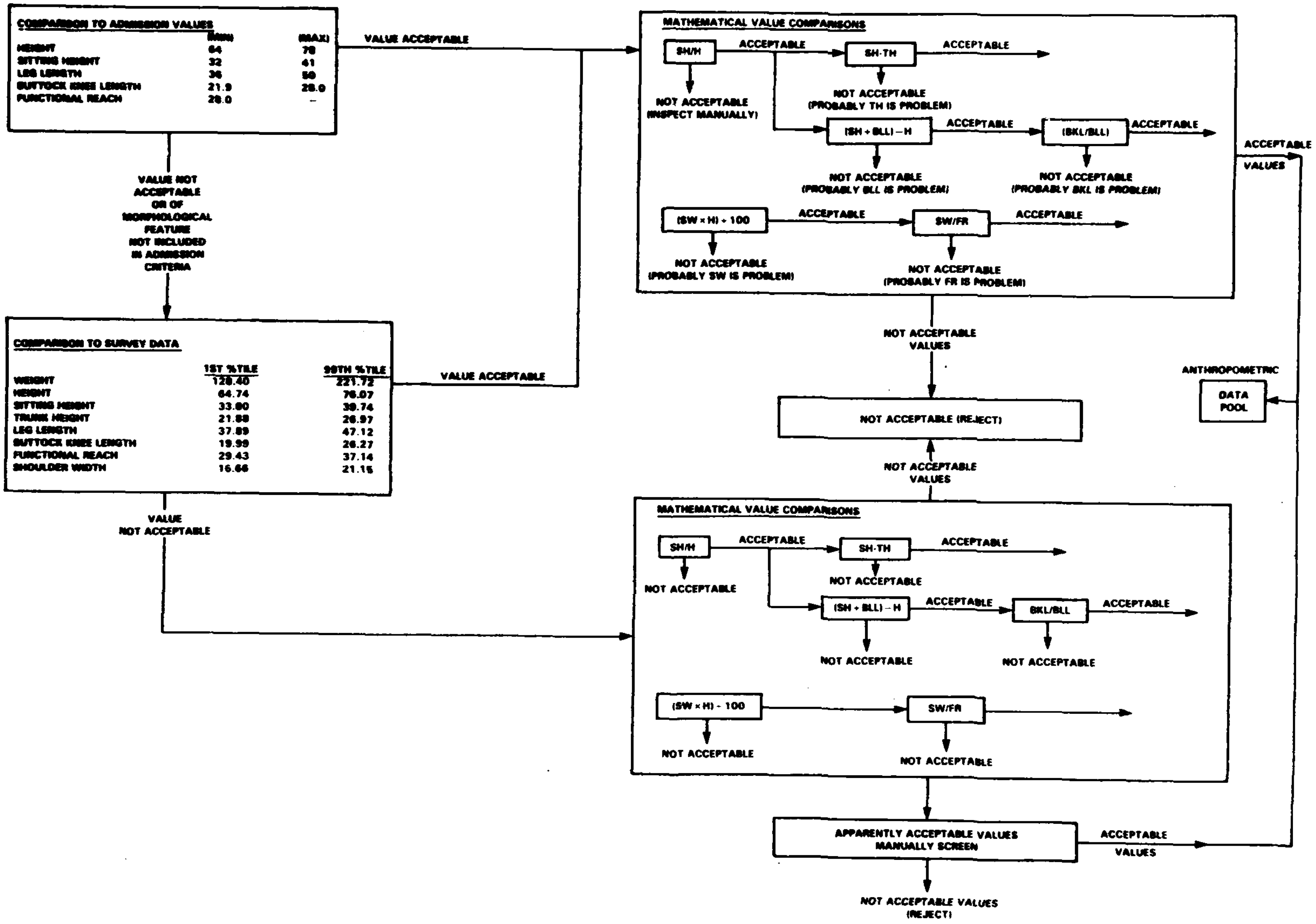

Figure 4.

AIRCREW AUTOMATED ESCAPE SYSTEM (AAES)

IN-SERVICE DATA USAGE ANALYSIS PROGRAM TRAJECTORY SIMULATION MODEL FOR DETERMINING WHETHER EJECTION OCCURRED IN OR OUT OF SYSTEM PERFORMANCE ALTITUDE

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6.	SEAT/MAN SEPARATION		
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8.	PARACHUTE LINE STRETCH		
9.	PARACHUTE FIRST FULL OPEN		
10.	PARACHUTE FIRST VERTICAL		

AIRCRAFT PARAMETERS AT ESCAPE

AIRCRAFT MODEL
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- ALTITUDE ____
- ATTITUDE
  - – BANK ____
  - – PITCH ____
- SINKRATE ____
- MANEUVER ____
- TYPE SEAT ____
- CREW POSITION ____

TOTAL EJECTED WEIGHT

TYPE SEAT ____ ____
TYPE COVERALLS ____ ____
TYPE HELMET ____ ____
TYPE BOOTS ____ ____
TYPE RESTRAINT HARNESS ____ ____
TYPE PERSONNEL FLOTATION ____ ____
TYPE SURVIVAL VEST ____ ____
ADDITIONAL EQUIPMENT
____ ____ ____
____ ____ ____
____ ____ ____
CREW HEIGHT ____
CREW WEIGHT ____
CREW SITTING HEIGHT ____
CREW TRUNK HEIGHT ____
CREW BUTTOCK KNEE LENGTH ____
CREW LEG LENGTH ____
CREW SHOULDER WIDTH ____
CREW FUNCTIONAL REACH ____
CREW AGE ____

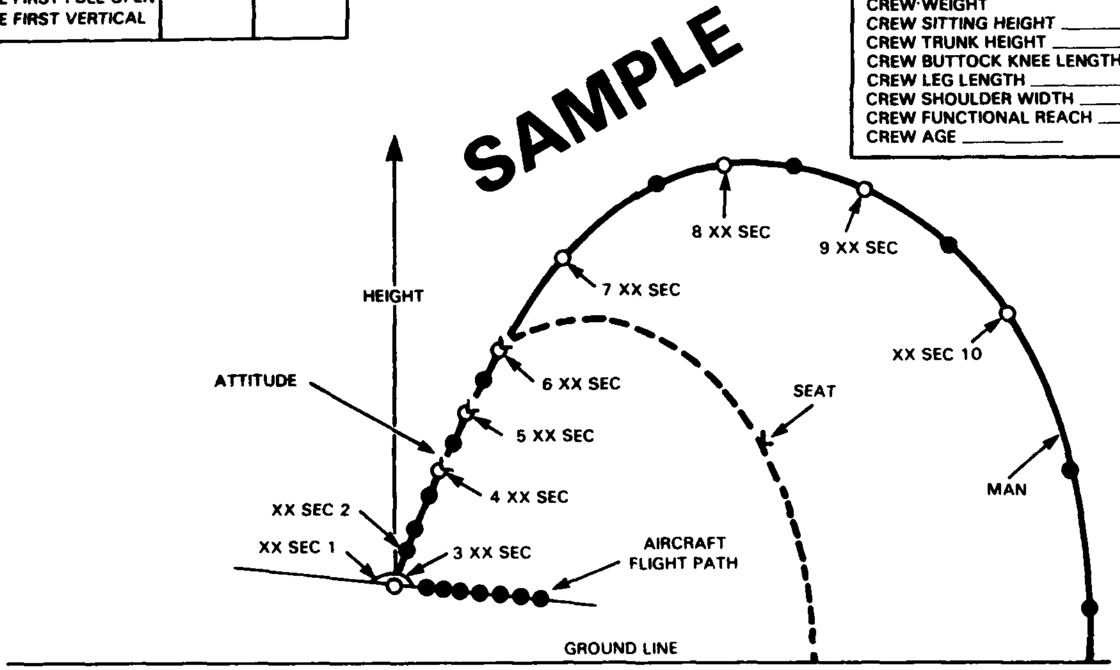

Figure 5

INTRODUCTORY NOTES

ANALYSES OF TEST AND R&M REQUIREMENTS OF U.S. NAVY AAES/ALSS SPECIFICATIONS

The requirements imposed by the U.S. Navy upon the designer, developer and manufacturer of aircrew automated escape systems (AAES) and aircrew life support systems (ALSS) equipments are established in the primary specifications for each type of equipment. The problems faced in establishing these requirements are manifold, among of them being impact on costs (development and procurement), impact upon Navy staffing (particularly maintenance personnel and skills), impact on facilities (type and frequency of maintenance), immpact on availability schedules, and incremental gains in performance and reliability vs. incremental increase in development and procurement costs.

Specification requirements typically cover such mundane topics as quantities and conditions of tests to be conducted, the type (production or production design but not production tooling and procedures built) articles to be tested, the type of data to be acquired, general description of data recordation equipment needed (cameras, frame speeds, telemetry, umbilical, etc.) etc. The issues then, and difficult ones to resolve satisfactorily since often the technical aspects are not the predominant aspect, are: do the specification requirements (1) assure achievement of stated test objectives such as demonstrating performance capability or permitting assessment of system reliability, and (2) are the resources sufficient for achieving those objectives and optimally employed to assure their achievement.

The three primary specifications governinng at present AAES test article configuration and type, quantity and type results as well as type of data and of test instrumentation, and of R&M (reliability and maintainability) are, respectively, MIL-S-18471F, MIL-E-9426F and MIL-STD-2067. The following paper analyzes these three documents in terms of test resources utilization vs. stated testing objectives and identifies strenghts and weaknesses in the approaches employed and recommends areas requiring in-depth evaluation to ascertain appropriate actions for enhancing the requirements' capability of achieving those stated objectives.

A Review and Critique of the Specifications governing Design, Performance, R&M Evaluation and Test for U.S. Navy Ejection Seat Type Aircrew Automated Escape System.

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ABSTRACT

The U. S. Navy has established test requirements for aircrew automated escape systems (AAES) in three basic documents: MIL-S-18471F; MIL-E-9426F(AS); and MIL-STD-2067(AS). This paper reviews those AAES test program requirements from a statistical point-of-view and makes recommendations for improvements in test planning and data analyses.

The statistical technique of "analysis of variance" is applied to specific Navy-furnished sled test data for peak Gz, pitch, roll, and yaw rates to illustrate the potential applications of statistical procedures to the analysis of test data. Several recommendations for improving the collection of data and the analysis of the data are presented for consideration at the conclusion of the paper.

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SUMMARY

The U.S. Navy has established test requirements for aircrew automated escape systems (AAES) in three basic documents, MIL-S-18471F, MIL-E-9426F(AS) and MIL-STD-2067(AS). The purpose of this effort was to review the AAES test program requirements from a statistical point-of-view and that review included the above referenced documents and test results of selected sled tests provided by the U.S. Navy. The infomation obtained from these sources form the basis for these comments.

The systems tests identified as the Service Release Test program, although not so specified, constitutes part of a test-analyze-and-fix (TAAF) program. Any "problem" that is identified during the testing either from the marginality of success analysis or performance evaluation is investigated, defined, and its consequence(s) evaluated and the results are reported to the U.S. Navy Program Manager for a decision as to whether to initiate action. If corrective action is deemed appropriate then the system test is rerun after the corrective action is taken and proven in subsystem tests. If a corrective action is taken as a result of a system test and that action entails design changes, then qualification testing must be accomplished at the component or subsystem level before the system test is rerun. The objective of this test program is to use lower, less costly, indenture level tests to qualify the design at that level of indenture and to use the system level tests (SRT) to assess the interfaces or interactions among the system elements.

This approach does not readily lend itself to the classical reliability demonstration tests of MIL-STD-781; however, there are statistical techniques such as the analysis of variance which can be employed effectively to aid the Navy in arriving at a decision to continue development efforts or to release the seat for service use. Futhermore, the techniques for allocation of test resources among levels of system indenture, developed for NASA, should be considered for use by the Navy in their AAES programs.

The sled test program is a critical test series in the service release test program to determine the "man-rating" of escape systems and especially of the component ejection seats. Recent efforts to employ statistical techniques for evaluating the performance of seat systems is encouraging and one such possible application has been illustrated in this report.

It is our belief that more emphasis should be placed on the analysis of the data by statistical methods such as the analysis of variance techniques illustrated herein. More comparisons with data from other sled tests should be conducted to detect similarities and dissimilarities, weaknesses and strengths, and marginality of success and safety problems.

The statistical technique of "analysis of variance" was applied to specific Navy-furnished sled test data for peak Gz, pitch, roll and yaw rates. The results from that analysis indicate that for those systems:

- There was a difference in response between dummy sizes.
- There was no difference in response between trainer and nontrainer seat configurations.
- The was a difference in response among generic seat configurations but the differences do not impact on safety.
- There was no evidence of speed effect in these specific response data.

The requirements for test plans should be expanded to include a section on the statistical analysis of the test data. The statistical test plan should identify the plan(s) by which the data will be analyzed, the risk of wrong decision levels, and the least detectable differences based upon the number of tests and the test design.

AAES TEST PROGRAM

The U.S. Navy has established procedures for demonstrating the compliance of new aircrew automated escape systems (AAES) with the design and performance requirements stipulated for ejection seat type AAES in MIL-S-18471F. Determination of the conformance to requirements is established, in part, through demonstrations and/or tests. The test requirements are established in two basic documents, MIL-S-18471F and MIL-STD-2067(AS) and the details of the testing required are given in MIL-E-9426F(AS).

The purpose of this report is to review the test program from a statistical point-of-view. An attempt has been made to identify where statistical concepts and techniques might be added or improved to strengthen the analyses and results derived from the tests. Such results should enhance the safety of Navy aircrew.

The AAES test program consists of two major categories of tests - design verification and service release tests. The design verification tests (DVT) are an integral part of the system development program and are used by the contractor to demonstrate to the Navy the capability of the system and its components to achieve the design and performance requirements and, therefore, the readiness of components, subsystems and system to commence the more expensive and rigorously controlled service release tests. The Service Release Test (SRT) program commences after the DVT program, after the full definition of the production baseline configuration, and after the reliability and maintainability and other analyses have been completed to the satisfaction of the government procuring agency. The SRT program is composed of component and system tests which are used by the developing agency to determine if the system is ready for service use. Decision criteria have been established for the purpose of determining if the individual tests and subsequently the SRT program is successful.

THE SERVICE RELEASE TEST PROGRAM.

The service release test (SRT) program consists of five major types of tests of which the design compliance tests are the most extensive and the most likely to be assisted by statistical techniques. The types of tests in the SRT program are:

- -Aircrew station fit and capability tests (Engineering proofing model)
- -Environmental conditioning & windblast tests (production article)
- -Component/Subsystem Qualification Tests (Full production components)
- -Design Compliance Tests (production units)
- -Maintainability & Reliability Tests (production unit)

The data collected on each type of test is used for that particular evaluation and contributes to the evaluation of system reliability.

Design Compliance Tests.(Ejection Seat Type AAES)

Design compliance tests are conducted to ascertain the compliance of the escape system with specified design requirements, crash load strength, and escape performance requirements. The design compliance tests encompass five primary categories of demonstration or performance and those categories are:

- -Crash loads strength demonstration
- -Seat-man restraint physiological acceptability demonstration
- -Ground, track, and flight performance demonstrations
  - .Impulse noise level demonstrations
  - .Cabin air contamination tests (Capsules)
  - .Flotation tests (Capsules)
- -Underwater performance demonstrations (Components only)
- -Field Maintainability verification demonstration

Performance tests on the escape system consist of the ground, track, flight, and maintainability tests. An escape system must, at least, complete the track and flight tests satisfactorily to be released for service use. The purpose of the performance tests is to provide data for assessing system performance, to detect and identify existing or incipient problems which might degrade system performance and/or safety, to assess the system reliability and maintainability, and to obtain data for consideration for use in the NATOPS manual to inform aircrew of system operation and capabilities.

Although it is not clear from the requirements, the flow diagram in MIL-E-9426F suggests that the acquisition agency relies upon component testing to form the foundation of their test program. Then, selected subsystems, such as ballistic signal subsystem tests (BSTS) and system design compliance tests are employed to confirm the lower level testing and to identify any harmful component or subsystem interactions within the full system during the system tests.

Track (Sled) Tests.

Track tests are tests conducted on the escape system mounted in a cockpit section of the aircraft mounted on a sled and loaded with a fully ALSS-equiped dummy ballasted or altered to statically represent the appropriate weight and dynamic center of gravity to demonstrate the functioning of the ejection, separation, stabilization, and recovery subsystems and components at velocities representing the complete dynamic pressure range of aircraft or vehicle. The tests may be conducted from a jet-propelled sled or from a rocket-propelled sled representing the aerodynamic and structural configuration of the aircraft structure adjacent to the escape system and containing the escape system and associated structures.

The number of ejection seats to be furnished to the Navy for the SRT track tests are identified in AR-72 as 22 shipsets (ejection seats, canopy systems, and escape sequencing systems each), a cockpit section sled, and two ejection seats with inert ballistic elements and working firing mechanisms. The components are required by MIL-S-18471F and MIL-E-9426F to be actual production articles, representing not only the actual design, but also the production, procurement, inspection and assembly procedures, and actual tooling and jigs.

Data acquisition for the track tests requires instrumentation of the escape system structure and the dummy, telemetry equipmemt to collect the instrumented data at a central data control, photographic coverage of the test events, and a master timing system to provide a single time source to all the recording systems. For each performance test, the data required to be recorded includes the following:

- -Site information
  (location, altitude, heading, height above ground)
- -Meteorological data (measured at block house)
  (wind, temperature, humidity, barometric pressure)
- -Master times of events within the test
- -Height, down range, and lateral offset from track of the events
- -Structure-mounted instrumented data vs time
  (6 performance characteristics)

-Dummy-mounted instrumented data vs time
  (8 performance characteristics)
-Photographic coverage vs time
  (11 performance characteristics)

The 25 performance characteristics listed above are not necessarily independent; in fact, several are strongly interdependent such as the acceleration measured on the structure and on the dummy.

The number of track tests that are required for a single crew station system is given in MIL-E-9426(AS) and is presented in Table 1.

Table 1. The Track Test Program for a Single Crew Station System.

Speed (knots)	Percentile anthropometric dummy	Number of tests
0	3 98	2 2
50	3 98	2 2
100	3 98	1 1
265	3 98	1 1
360	3 98	1 1
435	3 98	1 1
500	3 98	1 1
600	3 98	2 2
Total		22

The major emphasis in the specifications is on data acquisition and the requirements imply that measurements are continually recorded throughout each escape system test.

The number of different speed levels that are required for the test program seems to be excessive. If speed is considered important and it is necessary to determine the effect of speed and if funding limits the number of trials, then the concentration of tests at two or three selected levels (say, high, low, and intermediate levels) is more effective in that determination than spreading them uniformly over the range of speed. It might be appropriate to conduct the low speed tests at 50 knots (representing landing mishap speed) and 100 knots (representing cold catapult launch speed) and these two speeds might satisfy the information needs on the specific "high-risk" operational conditions in the low speed range. If demonstrations are desired at the higher speed risk conditions, then tests at the 500 knots or 600 knots might satisfy that need.

Example of Track (Sled) Test Data

Data provided by the Navy from some past sled tests are presented in Table 2. These data consist of four measurements (maximum values) taken during each test on three different generic ejection seat systems. These data are measurements on similar events in each of several tests. Each generic ejection seat system was adapted to two aircraft - usually a trainer as well as the combat system. The four measurements (independent point measurements) that were recorded during each test were the maximum 20 msec duration peak measurements on vertical acceleration (Gz) on the dummy during the booster phase and the maximum 20 msec duration peak measurements of yaw, pitch, and roll rates (deg/sec) on the dummy during the flight phase. Each test was conducted at a selected ejection speed between zero to 600 knots. The basic data on similar event types within the test sequence for ejection seat models designed for the A-7, TA-7C, AV-8A, AV-8B, F-18 and TF-18 are presented in Table 2 for each of two dummy sizes, a 3-percentile size and a 98-percentile size. A P-percentile anthropometric dummy size is that dummy size which corresponds to an aviator size that divides the population of aviators into two groups with P percent of the aviators smaller in size and (1-P) percent of the aviators larger in size.

There are a series of different events within a test that are related through time thus forming a time series such as the acceleration measured continuously during a test. The time series events form a different set of interrelated measurements that should be studied at some future date.

Table 2(a). The maximum 20 msec peak measurements on vertical acceleration (Gz) on the dummy during the boost phase for various speeds, dummy sizes, and aircraft.

Speed	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
0	15.0	15.2	12.2	14.6	13.8	13.0	14.0	13.1	12.3	13.4	10.2	8.6
0	14.6	14.3		16.4			12.6	14.1	11.3			
0		14.9						11.1				
0		13.4						13.7				
0		14.5						14.6				
50			15.4						11.2			
50									14.2			
75				15.4								
100			16.4			10.3						11.9
130												
150						12.5						10.5
180			15.6	15.0								
195		12.0					11.7	12.3				
195							13.2					
225					12.0						10.4	12.0
225												10.5
230									13.6			
240										10.3		
250	15.0								13.3			
250	13.7											
350		11.1					10.9	11.7	13.6			
360												
430			15.6						12.4			
430									12.6			
435					13.7						9.4	
450	13.3	13.9		14.1		10.0		12.6		10.6		14.2
450	13.0	15.1						11.6				
450	13.6											
475			17.0									
500									10.8			
600	12.1	12.2	18.6	14.0	14.0	12.6		10.6	13.5	10.8	9.0	9.9
600		12.9						9.2				
Total	111.1	149.5	110.8	89.5	53.5	58.4	62.4	134.6	138.8	45.1	39.0	77.6
n	8	11	7	6	4	5	5	11	11	4	4	7
$\bar{x}$	13.9	13.6	15.8	14.9	13.4	11.7	12.5	12.2	12.6	11.3	9.8	11.1

Table 2(b). The maximum 20 msec peak measurements of Pitch rates (deg/sec) on the dummy during the flight phase for various speeds, dummy sizes, and aircraft.

Speed	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
0	410		764	315			475		369	632		304
0				1194					260			
0												
0												
0		650				367		300				
50			1050		220				180		520	
50									250			
75				774								
100			1300			371						753
130					260						600	
150						673						398
180			350	474								
195		1200					325					
195							350	350				
225												914
225												368
230									450			
240										485		
250	750								350			
250	450											
350		1500					1250	515	400			
360					580						420	
430			345						300			
430									475			
435												
450	520	900		550	440	716		700		1212	650	1500
450	850	350						450				
450	1150											
475			640									
500									245			
600	500	450	1100	611	680	487		700	728	1100	730	831
600		550						750				
Total	4630	5600	5549	3918	2180	2614	2400	3765	4007	3429	2920	5068
n	7	7	7	6	5	5	4	7	11	4	5	7
$\bar{x}$	661.43	800.0	792.71	653.0	436.0	522.8	600.0	537.86	364.27	857.25	584.0	724.0

Table 2(d) The maximum 20 msec peak measurements of roll rates (deg/sec) on the dummy during the flight phase for various speeds, dummy sizes, and aircraft.

Speed	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
0	75	200	331	435		299	115	225	162	200		175
0				280					70			
0												
0												
0												
50			425		480				75		180	
50									90			
75				790								
100			450			403						375
130					520						260	
150						777						493
180			441	1340								
195		750					630	600				
195							630					
225												413
225												850
230									1000			
240										1034		
250	1415								675			
250	1050											
350		385					565	955	725			
360					1040						380	
430			622						475			
430									350			
435												
450	955	400		820	870	559		650		470	720	1320
450	455	1150						800				
450	825											
475			780									
500									260			
600	1150	425	825	1415		671		600	550	580	710	455
600		400						375				
635					950							
Total	5925	3710	3874	5080	3860	2709	1940	4205	4432	2284	2250	4081
n	7	7	7	6	5	5	4	7	11	4	5	7
$\bar{x}$	846.43	530.0	553.43	846.67	772.0	541.8	485.0	600.71	402.91	571.0	450.0	583.0

Table 2(c). The maximum 20 msec peak measurements of Yaw rates (deg/sec) on the dummy during the flight phase for various speeds, dummy sizes, and aircraft.

Speed	3% Dummy						98% Dummy					
	A-7	TA-7C	AV8A	AV8B	F-183	TF-18	A-7	TA-7C	AV8A	AV8B	F-18	TF-18
0	228	250	597	345		389	360	250	179	255		258
0				405					105			
0												
0												
0												
50			310		460				90		360	
50									220			
75				510								
100			550			494						538
130					500						460	
150												576
180			873	855		549						
195		600					730	700				
195							755					
225												723
225												1070
230									425			
240										790		
250	1270								450			
250	570											
350		510					575	715	625			
360					1160						860	
430			495						139			
430									700			
435												
450	720	900		680	1440	741		750		415	1320	1092
450	570	1000						650				
450	1025											
475			550									
500									190			
600	940	500	1350	675		1550		950	340	940	1310	1092
600		350						750				
635					1480							
Total	5323	4110	4725	3470	5040	3723	2420	4765	3463	2400	4310	5349
n	7	7	7	6	5	5	4	7	11	4	5	7
$\bar{x}$	760.43	587.14	675.0	578.33	1008.0	744.6	605.0	680.71	314.82	600.0	862.0	764.14

Test Plans

A test plan is required from the contractor for approval prior to the commencement of any tests. The plan requirements include:

- -Test objectives
- -Description of each planned test
  - .equipment & facilities
  - .performance characteristics
  - .accuracy of test instrumentation and recording devices
  - .data to be recorded
  - .marginality of success plan
  - .analysis plan
- -Safety procedures
- -Schedule

The major emphasis in the plan is on the acquisition of the data. The analysis plan is directed toward the organization and display of the data such as trajectory plots and data matrices but little or no emphasis on the statistical analysis of the data acquired. There is no requirement for a statistical data analysis section to the test plan but such a requirement should be established.

RELIABILITY AND MAINTAINABILITY PROGRAM

The reliability and maintainability (R&M) program required by MIL-S-18471F is defined and the quantitative requirements are specified in MIL-STD-2067(AS).

MIL-S-18471F establishes an overall system effectiveness analyses program of which the reliability and maintainability (R&M) program is a part. The system effectiveness analyses consist of vulnerability, R&M, human factors, system safety, and electromagnetic interference/radiation control. The author of the specification stated that combining these analytical specialities in this manner was done to assure program management attention. It was assured that each problem and proposed resolution was reviewed from all these viewpoints before presentation to management for action; thus, either obtaining a consensus among these specialists, or, more importantly, exposing the areas of disagreement and anticipated problems associated with each proposed resolution to program management. This "completed staff work" approach was informally invoked in the SIIIS-3 program before being made a formal requirement. There is a hazard, recognized by the author, that such an approach could lead to interminable argument and no information flow from these areas to the program manager. Without this positive reporting on problems from the specialities there is a danger of differing views being expressed too late in the program to be considered without expensive and time-delaying recycling through a design effort.

The R&M program requires a program plan to be submitted for Government procuring activity approval and, following that approval, for the contractor to implement the program plan under Government guidance and review. The R&M plan must be implemented in accordance with MIL-STD-2067(AS), MIL-STD-785, AND MIL-STD-470. A reliability model must be developed and it must be capable of handling the effect(s) of degraded performance. Allocations and predictions must be employed. Failure mode effect and maintenance action rate analyses must be conducted. Single failure point(s) must be investigated and resolved and, during testing, marginality of success analysis must be performed to identify any actual or potential anomalous behavior(s); which if found, must then be reported by the contractor to the Government Program Manager, whether or not corrective actions can at that time be proposed. Another critical aspect, required in MIL-S-18471F, is that after the engineering proofing article has been approved,a complete history of configuration changes must be maintained, detailing each design change, alternative actions considered, rationale for the recommendations and the cause.

The service release performance tests (a part of the design compliance tests) are used to assess the attainment of the specified reliability requirements for the AAES while maintainability demonstrations are conducted by Government personnel in accordance with MIL-S-18471F (providing the test article), MIL-E-9426F and MIL-STD-471.

The quantitative requirements for AAES reliabilities are specified in MIL-STD-2067(AS) for each mode of AAES functioning. The reliability requirement for the AAES conditional upon crew actuation of a firing control handle is "expressed as the probability that the AAES shall perform successfully and automatically all escape capabilities following initiation, shall be equal to or better than 0.98 at the 90 percent lower confidence level". This statement is interpreted to mean that the design reliability requirement for the AAES shall be greater than 0.98 and that it must be demonstrated to be equal to or greater than 0.98 with the risk of rejecting a good product of 10 percent, i.e. a type I error of 10 percent.

System reliability demonstration is achieved by analysis employing component reliabilities at their lower 90% confidence level based upon historical component and SRT data, and by the successful completion of the SRT program.

This approach to reliability demonstration does not lend itself to the classical reliability demonstration tests of MIL-STD-781. That feature is not a demerit in our view; however, more effective use of the reliability analysis should be achieved. When the reliability analysis is based upon historical data and the uncertainties associated with the quantitative values can be established as implied by the 90% confidence level phrase, then the uncertainties can be used to allocate test resources among the component and system tests to achieve the greatest reduction in total uncertainty. It is obvious that this is the objective of the Navy, but implementation techniques are not identified or required. We suggest the reliability variation analysis technique developed for NASA be considered as one possible technique. This technique is presented in two reports "Reliability Variation Analysis", Booz-Allen & Hamilton, Contract NASw-643, 1963, and "An Evaluation of a Test Allocation Procedure" Kaman Sciences Corporation, Contract N00140-66-C-0517, 1967 (AD 845875/6)

System maintainability requirements for the AAES are that the direct maintenance manhours (DMMH) shall be less than 1.75 hours per aircraft-month and that no single ejection seat system shall have DMMH of more than 0.05 hours per 35-flight hour month. The mean time to repair (MTTR) for the AAES shall not exceed 0.85 hours and the maximum corrective maintenance time, at the 95th percentile, shall not exceed 2.5 hours

SATISFACTORY TEST PROGRAM CRITERIA.

Under MIL-E-9426F, results from individual system tests can be classified as acceptable, failure, or "no test". A "no test" occurs when a failure of the test fixtures, set up, maintenance, etc. does not allow information to be obtained or affects the validity of the information on the escape system performance. A failure occurs when the escape system does not perform adequately during the test. An acceptable test occurs when (1) the escape system has performed adequately, i.e. the ejection seat has been ejected from the test vehicle along a trajectory insuring a safe margin for clearing the aircraft structure and a sufficiently clear drop following the blossoming of the parachute, (2) there have been no escape system malfunctions, (3) there have been no test bed/instrumentation or photographic coverage failures causing "no test" conditions, and (4) there are no maintenance induced "no test" conditions.

For a test program involving 10 or more individual tests, it is considered a satisfactory test program when (1) at least eighty (80) percent of the tests in the SRT program are satisfactory, (2) at least eight (8) consecutive successes occur in the track tests, and (3) the remaining twenty (20) percent of the tests are classified as "no test", i.e. no failures have occurred in the escape system during these tests. Upon completion of the SRT program, the successive successful tests requirements are as defined in Table 3.

Table 3. The number of consecutive successful tests that are required for the various numbers of tests in the SRT program.

Number of tests in program	Minimum number of consecutive successful tests
6	6
7	6
8	7
9	8
10 or more	8

The criteria for a successful AAES test program are: (1) there are no failures during the program, (2) a run of successful tests as given in Table 3 occurs, and (3) all other trials are "no-test". The test program's and the individual test's success then will depend upon the reliability of the AAES and the reliability of the test bed set-up, i.e. instrumentation, telemetry, and photographic equipments. The old adage that the test equipment must be as accurate or as reliable as the equipment being tested is appropriate here. This feature can be seen most easily by looking at the probability of a successful test program. If the probability of passing a single test is R_A for the AAES and the probability that the test facilities function properly during a single test is R_F, then the probability models for a successful program are given below. The probabilities have been calculated for six combinations of R_A and R_F, namely, for R_A equal to 0.98 and 0.99 and for R_F equal to 0.95, 0.99 and 1.0, and are presented in Table 4.

Table 4. The Probability of a successful program for a given reliability of the AAES and various reliability levels for the test set-up.

Run* Criteria	Reliability of AAES					
	0.98			0.99		
	Reliability of Test Bed			Reliability of Test Bed		
	R = 0.95	R = 0.99	R = 1.0	R = 0.95	R = 0.99	R = 1.0
6/6	0.65	0.83	0.89	0.69	0.87	0.94
6/7	0.67	0.83	0.87	0.72	0.87	0.93
7/8	0.63	0.80	0.85	0.68	0.87	0.92
8/9	0.58	0.78	0.83	0.64	0.85	0.91
8/10	0.60	0.77	0.82	0.66	0.88	0.90

* Run criteria is given as the number of consecutive successful tests preceeding the slash (x) and the number of tests conducted following the slash (y), i. e. x/y.

Run/Tests	Model
6/6	$(R_A R_F)^6$
6/7	$(R_A R_F)^7 + 2(R_A R_F)^6 (1-R_F)$
7/8	$(R_A R_F)^8 + 2(R_A R_F)^7 (1-R_F)$
8/9	$(R_A R_F)^9 + 2(R_A R_F)^8 (1-R_F)$
8/10	$(R_A R_F)^{10} + 4(R_A R_F)^9 (1-R_F) + 3(R_A R_F)^8 (1-R_F)^2$

Although it is not clear from the requirements in the specifications, in our discussions with the author it became clear that the system tests called for in the Service Release Test program constitute, in actuality, part of a test-analyze-and-fix program. Any "problem" that is identified during the testing either from the marginality of success analysis or performance evaluation is investigated, defined and its consequence evaluated. If corrective action is deemed appropriate by the government procuring agency, then the system test is rerun after the corrective action is taken and proven through analyses, and tests conducted at component or subsystem levels to remedy the problem (without introducing additional, new, serious problems). If a corrective action is taken as a result of a system test and that action entails design changes, then qualification testing must be accomplished at the component level and/or subsystem level, as appropriate, before the system test is rerun. The objective of this test program is to use lower indenture level (components and subsystem) tests which are far less expensive and time consuming than full system testing to qualify the design at that level of indenture and to use the system level tests (SRT) to assess the interfaces and/or interactions among the system conponents.

There are techniques, developed for NASA and its manned space program, that could be used to assist in the allocation of test resources among system and component testing prior to the commencement of any testing. The technique is presented in two reports entitled "Reliability Variation Analysis" and "An Evaluation of a Test Allocation Procedure" referenced earlier. The basic principle in the NASA technique is to allocate test effort to minimize the uncertainties associated with reliability of the system elements. In a sense, this is what the specification author is attempting to do on an ad hoc basis during the testing program, however, success in reducing the uncertainties will depend upon the program manager's ability and experience. A formal technique, as described in the two referenced reports, for planning the allocation of test effort among a system and its components will yield more optimal and consistent test resource allocation, and will result in better test utilization for achieving the stipulated reliability objectives.

STATISTICAL ANALYSIS OF SLED TEST DATA.

Much of the data on ejection seat testing consists of response measurements and these measurements are recorded along with the fixed speed at which the specific test actually occurred, the particular aircraft/seat employed, and the particular size and weight of the dummy. If the speed has an impact upon the measured response, such as Gz, yaw rate (deg./sec.), pitch rate (deg./sec.) or roll rate (deg./sec.), then to make a comparison between two measured responses, say peak Gz, for a particular seat and dummy size, it is necessary to recognize when differences in speed exist and to make adjustments for that speed difference.

Suppose, as a hypothetical example, two measurements of peak Gz, one for an A-7 seat and the other for an F-18, are available for the same dummy size, but for different speeds as shown in Figure 1.

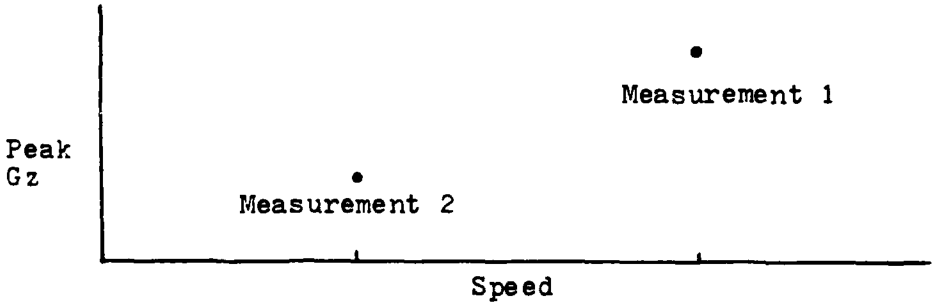

Figure 1.

One can ask the question, is the difference in peak Gz measurements due to the difference in the seat designs? To answer that question, one must recognize that the speed was different between the two seats for these measurements. Suppose the relation of peak Gz to speed was as shown by the solid line in Figure 2 below.

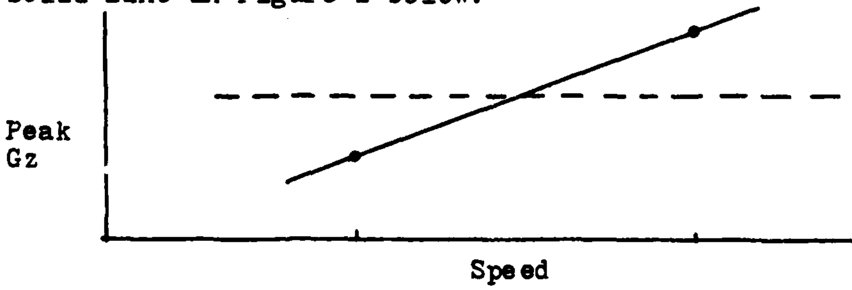

Figure 2.

It is clear that all the differences between the two peak Gz measurements in this hypothetical example can be associated with the differences in speed and not with differences between seats. If there were no relationship between speed and peak Gz, the dotted line in Figure 2 would be appropriate and it is clear under these circumstances that all the difference would be attributable to seat differences. The above illustration is an idealized picture since the variation inherent in measurement data, test conditions, and random deviations have been ignored.

Regardless, if it is thought that speed has an impact on responses, then adjustments can be made to all measurements to "standardize" the speed for comparison purposes. Thus, these data can be partitioned into groups (seat and dummy size) and the variation among the total observations after adjustment for speed can be partitioned for comparisons. One might think of each response measurement as being composed of contributions from speed and from each of the groups plus a random element that reflects the sampling differences. Thus, each measurement can be represented by the following relation:

$$y - bx = a + d + c + e$$

where: y is the measured response
x is the known and fixed speed at which the test was conducted
b is the effect of speed
a is the overall mean response after speed adjustment
d is the effect of dummy size
c is the effect of seat design/configuration within size
e is the random sampling element

Analysis of Variance.

Implementing the analysis of variance is the process of partitioning the sum of squares defined by

$$SS = \sum_{ijk}(y_{ijk} - bx_{ijk} - a - d_i - c_{ij})^2 ,$$

so that the contribution of each group can be measured and compared to random or chance variation. Tables summarizing the analyses of the data are given in Appendix A of this paper and the general conclusions are summarized in Table 5. The conclusions, drawn from the statistical analysis conducted on the test data, are based upon the quantitative data and are dependent only indirectly (through the test results) upon the specifics of seat configurations.

Table 5. Summary of the Analyses for the Various Measures

Measure		Aircraft Included	Differences that are statistically significant (i.e. too large to be due to chance)				
			Table	Dummy Size	Aircraft Model	Seat Model	Trainer
Peak Gz	No Adjustmt for Speed	All	1	Yes	Yes		
			2	Yes		Yes	
		A-7 & F-18	3	Yes	Yes		
			4	Yes		Yes	No
		A-7 & AV-8	5	Yes	No		
			6	Yes		No	
		AV-8 & F-18	7	Yes	Yes		
			8	Yes		Yes	
	Adjusted for Speed	All	9	Yes	Yes		
			10	Yes		Yes	
Pitch (Deg/Sec)	No Speed Adjustmt	All	11	No	No		
			12	No		No	
	Adjusted for Speed	All	13	No	No		
Roll (Deg/Sec)	No Speed Adjustmt	All	14	Yes	No		
			15	Yes		No	
	Adjusted for Speed	All	16	Yes	No		
			17	Yes		No	
Yaw (Deg/Sec)	No Adjustmt for Speed	All	18	No	Yes		
			19	No		Yes	
		A-7 & F-18	20	No		No	
		A-7 & AV-8	21	No		No	
		AV-8 & F-18	22	No		Yes	
	Adjusted for Speed	All	23	No	Yes		
			24	No		Yes	
		A-7 & F-18	25	No		No	
		A-7 & AV-8	26	No		No	
		AV-8 & F-18	27	No		Yes	

There are significant differences (too great to be due to chance variation) among these seats with respect to peak Gz. Table 10 in Appendix A of this paper shows the results of the analysis of variance for the three primary seat types (A-7, F-18, AV-8 aircraft) after considering dummy size differences. The F-statistic, which measures the difference among aircraft/seats, shows a value of 6.03. Attaining that high an F-value is a very rare event if the peak Gz's were the same. Only 5 times in 100 would one expect to obtain an F-statistic value of 6.03 or higher if the peak Gz's were alike. Thus, it is very likely that this F-value is not due to chance, but due to differences among aircraft/seats.

To determine how the differences are distributed, a comparison of the three aircraft seats pairwise is helpful. The pairwise differences of peak Gz for these seats are:

A-7(ER) vs AV-8	Difference is not significant
A-7(ER) vs F-18	Significant difference
AV-8 vs F-18	Significant difference

The implications of these results are that the AV-8 and A-7 seats responded similarly with respect to peak Gz and that they differed from the F-18 response. Considering that the A-7(ER) and the AV-8 ejection seats are from the SIIIS-3 family and the F-18 seat is from a different family with a different design concept, this result is not surprising, but could be and probably should be expected. A look at the overall mean values for the peak Gz forces are as follows:

AV-8	13.7
A-7(ER)	13.1
F-18	11.4

The 98th percentile dummy in these seats experienced consistently lower peak Gz forces than did the 3rd percentile dummy, both within the same seat type and between seat types. Tables 1 thru 10 in Appendix A of this paper show that there were significantly different peak Gz forces for the two dummy sizes. In every case the larger dummy experienced lower forces than the smaller dummy, as one might expect as a consequence of the basic laws of physics.

The differences in peak Gz between trainers and non-trainers for seats in the same series aircraft are not significantly different for the given ejection airspeeds and dummy sizes. These seats are essentially the same and the results confirm our expections. Table 4 in Appendix A of this paper indicates virtually identical results between a trainer and non-trainer, given the aircraft series.

The impact of speed upon the peak Gz for these systems is not significant and this is consistent over all seats. A comparison of the numbers in Tables 1, 2 with Tables 9, 10 in Appendix A of this paper indicates very little change in any of the quantities when adjusted for speed differences. Had there been a significant impact of speed upon peak Gz, the numerical quantities for similar items would have appeared quite different between the two tables. This result does not agree with our intuition, i.e., the data does not support the contention that higher speed causes higher peak Gz forces.

The differences among these seats are significant for yaw rate, but not for pitch and roll rates. Tables 18 and 23 in Appendix A indicate yaw rate differences among the three seat types or among the six aircraft types, while Tables 12 and 13 indicate no such difference among seat or aircraft types for pitch rate. Tables 14 and 15 indicate no significant difference among aircraft or seat types for roll rate.

Pairwise comparisons for yaw were made since there were significant differences among the seats with respect to yaw rate.

A-7 vs AV-8 exhibits no significant difference
A-7 vs F-18 exhibits no significant difference
AV-8 vs F-18 exhibits significant difference.

The overall yaw rates were ranked as follows:

F-18	-	837.4 deg./sec.
A-7(ER)	-	664.7 deg./sec.
AV-8	-	492.0 deg./sec.

The difference in these seats between the 3rd percentile and the 98th percentile dummy is not significant for yaw and pitch rates, but it is significant for roll rate. Tables 14 thru 17 in Appendix A of this paper show the difference between dummy sizes in relationship to roll rate with the 3rd percentile dummy (lighter dummy) exhibiting significantly more roll, on the average, than the 98th percentile dummy. Tables 11-13 and 18-27 exhibit no such difference for pitch and yaw rates.

The overall roll rates were ranked as follows:

3rd Percentile dummy	-	679.95 deg/sec
98th Percentile dummy	-	505.05 deg/sec

Sample Size.

The number of tests conducted on a system design during the SRT program determines the assurance with which decisions can be made concerning the safety associated with the system design under test. There are methods to determine the number of tests that should be run which are based upon (1) the risk of wrong decisions, (2) the repeatability of test results, and (3) the magnitude of the deviations that have engineering significance.

The number of tests that should be conducted on each seat-aircraft configuration if selected differences are to be detected can be determined from the measured experimental error present in the past test programs and the risk of wrong decisions that are acceptable to the project manager. The number of trials are shown in Table 6 for the various levels of risk, number of aircraft models and the detectable differences for the four characteristics.

CONCLUSIONS AND RECOMMENDATIONS.

The AAES test program is the basis for decisions regarding the "man-rating" of the ejection seats, and detailed data is collected on a few specimens in order to allow decisions to be made. Unfortunately, no objective guidelines are given or required in the analysis of these data and, as a result, all decisions are made on the basis of engineering judgement. Engineering judgement based upon extensive testing experience over several seat programs can be a valid way of arriving at a decision, but it is dependent upon the subjective criteria of the individuals involved. There is little assurance that the same decision would be arrived at by another set of individuals equally experienced and there is even less assurance that a lesser experienced set would arrive at the same or better decision. Therefore, it is our belief that more emphasis should be placed on the analysis of the data by statistical methods such as the analysis of variance techniques illustrated herein. More comparisons with data from other sled tests should be conducted to detect similarities and dissimilarities, weaknesses and strengths, and marginality and safety problems.

The statistical technique of "analysis of variance" was applied to the specific sled test data furnished by the Navy and described earlier for peak Gz, pitch, roll and yaw rates. The results, as discussed earlier, from that analysis indicates that:

- There was a difference in response between dummy sizes.
- There was no difference in response between trainer and nontrainer seat configurations.

Table 6. The number of trials (tests) per aircraft model required for various detectable differences, number of aircraft models, and risk of wrong decisions for each characteristic.

Characteristic	Risk	Number of Aircraft Models	Detectable Differences			
			2g	3g	4g	5g
Peak Gz	0.25	2	7	4	3	3
		6	11	6	4	3
		12	13	6	4	3
	0.10	2	8	5	4	3
		6	12	6	4	3
		12	14	7	5	4
	0.025	2	9	6	4	3
		6	14	7	5	4
		12	16	8	5	4
			400 d/s	500 d/s	600 d/s	700 d/s
Pitch	0.25	2	8	6	5	4
		6	12	9	6	5
		12	15	10	8	6
	0.10	2	9	7	5	5
		6	14	10	7	6
		12	17	12	9	7
	0.025	2	11	8	6	5
		6	17	11	8	7
		12	19	13	10	8
Roll	0.25	2	8	6	5	4
		6	14	9	7	5
		12	17	11	8	6
	0.10	2	10	7	6	5
		6	16	11	8	6
		12	18	13	9	7
	0.025	2	11	8	7	6
		6	18	12	9	7
		12	21	15	11	8
Yaw	0.25	2	8	6	5	4
		6	13	9	7	5
		12	16	11	8	6
	0.10	2	10	7	6	5
		6	16	10	8	6
		12	18	13	9	7
	0.025	2	11	8	7	6
		6	18	12	9	7
		12	20	14	11	8

- There was a difference in response among generic seat configurations but based upon Navy furnished criteria concerning risk of injury the differences do not impact on safety.
- There was no evidence of speed effect in these specific response data.

The number of speed levels called forth in the specification should be reviewed, given the limitations on the amount of resources for testing. If it is desirable to measure the effect of speed and if there is a continuous speed response regime, then, from a statistical point of view, it is preferable to select specific levels of speed, and conduct several tests at each of the levels rather than to spread the tests uniformly over the range of speed. The number of levels selected should be established on the basis of the expected relationship between speed and the response measured. If the relationship is linear then only the two extreme speed levels could be used, whereas more speed levels would be required if the relationship is more complex. Replication of the tests at each speed level (for each dummy size) is essential to be able to establish the repeatability of the tests.

Data analysis is currently limited to data compilations and organized data displays. Specific types of statistical analyses should be planned, adapted to the test plan, and implemented to aid the Program Manager in decision making. It is recommended that statistical techniques be required in the analyses of all test data and that a statistical section be added to the test plan requirements. The statistical test plan should identify the plan(s) by which the data will be analyzed, the risk of wrong decision levels, and the least detectable differences based upon the number of individual tests and the test plan design.

The illustration of the application of statistical techniques to sled test data employs a single response measure for each test and that analysis does not show evidence of a speed effect among the response measurements. Our intuition suggests that there should be a relationship between speed and test stress on the AAES and, therefore, one is not quite comfortable with limiting the analysis to a single response measure representing the whole test sequence. Most characteristics that are measured during each test have time histories covering the AAES test sequence from initiation to vertical descent. Only single point data such as maximums or minimums have historically been used for consideration due to the inability to acquire reliable, readable time histories running from initiation through vertical descent or the inability to organize and handle the complex time history. Consideration should now be given to employing time series analyses as part of the statistical analyses program. Also new techniques of statistical analysis should be reviewed, applicable methods of analysis should be identified for the various kinds of data, and a review of the repeatability of scaling procedures should be conducted.

The allocation of test resources can be changed during the SRT program and this re-allocation is currently being done on an ad hoc basis. The capability to shift resources among tests is important; however, a prior plan of allocation should be established to assure that all test aspects are covered and optimum testing among the various levels are established. Decision points should then be established where re-allocation procedures can be employed to optimize the process.

The R&M program does not utilize past histories on parts, components or mechanisms since there has been no concerted effort at acquisition and organizing test data histories. The histories of the corrective actions should also be developed, reviewed and summarized for use in future reliability analysis.

There is a need for a review of the pyramid of component and subsystem specifications to assure that the R&M requirements are consistent with system requirements and to assure that testing satisfies economic and timely accomplishments of AAES test needs.

It is important to require an in-depth review of the reliabilities of the test site equipment since a successful program is very dependent upon the test site equipments as well as the AAES.

An in-depth review should be made of the maintainability assessments and requirements in order to derive more realistic requirements and to identify techniques that are more applicable to the unique features of the AAES system.

It is also recommended that the word "probability interval" replace the terms "confidence limits" throughout the Appendix A of MIL-STD-2067(AS) so the descriptions therein are more appropriate.

APPENDIX A

Analysis of Variance Tables

APPENDIX A

ANALYSIS OF VARIANCE OF TEST DATA ON AIRCRAFT-SEAT CONFIGURATIONS

Two models were employed in the analysis. One model ignored the differences in speed among the test observations and the other model made an adjustment for the speed differences. The two models representing the contributions of the various factors to each measured observation. The same models were used for each response characteristic, i.e., peak G_z, pitch rate, yaw rate and roll rate.

Model 1 without an adjustment for speed would be:

$$Y_{ijk} = a + d_i + c_{ij} + e_{ijk}$$

where

Y_{ijk} = the measured response on the ijk-th observation
a = an overall mean
d = an effect due to dummy size
c = an effect due to seat design
e = a random sampling element
i = identifies the dummy size ($i = 1, 2, \ldots L$)
j = identifies the seat design ($j = 1, 2, \ldots M$)
k = identifies the individual observations
($k = 1, 2, \ldots N_{ij}$)
$N = \sum_{ij} N_{ij}$

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* significant at the 5 percent level

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AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE
USAGE DATA ANALYSES VO..(U) NAVAL WEAPONS ENGINEERING
SUPPORT ACTIVITY WASHINGTON DC C W STOKES ET AL.
UNCLASSIFIED 05 NOV 83 NAVWESA-1-83-VOL-1 F/G 1/3 NL

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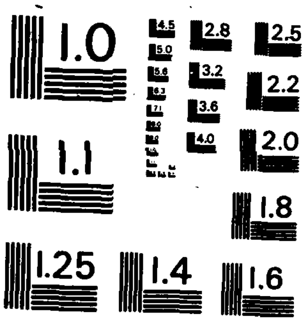

1.0
4.5
5.0
5.6
6.3
7.1
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Model 2 with an adjustment for speed would be:

$$Y_{ijk} - bX_{ijk} = a + d_i + c_{ij} + e_{ijk}$$

where

X_{ijk} = the speed associated with the ijk-th observation,

b = the effect of speed on the response,

a,d,c,e = elements are the same as defined in Model 1.

The only difference in the analysis between the use of Model 1 and 2 is that when Model 2 is employed, Y - bX is used instead of Y. The regression coefficient b is determined by simple linear regression between X and Y using all the observations. Then, a new value Y' = Y - bX is calculated and these new y-values are employed in exactly the same analytical procedures as used for Model 1 and shown below.

The pattern of observations for these data represent an unbalanced twofold nested classification data set as illustrated in the following table.

Pattern of Observations for an Unbalanced
Twofold Nested Classification Data Set

D_1				D_2				...	D_L			
C_{11}	C_{12}	...	C_{1M}	C_{21}	C_{22}	...	C_{2M}	...	C_{L1}	C_{L2}	...	C_{LM}
e_{111}	e_{121}	...	e_{1M1}	e_{211}	e_{221}	...	e_{2M1}	...				
e_{112}	e_{122}	...	e_{1M2}	e_{212}	e_{222}	...		...				
⋮	⋮		⋮	⋮	⋮			... ...				
e_{11N11}	e_{12N12}	...	e_{1MN1M}	e_{21N21}	e_{22N22}							

The analysis is based upon the assumption that the effects of dummy size and seat design are systematic components in the model and not random variables. In other words, the dummy sizes and seat designs were not randomly selected to represent a broader population of sizes or seats.

The analysis of variation that was employed is shown in the following table.

Source of Variation	Degrees of Freedom (D.F.)	Sum of Squares (SS)	Mean of the Sum of Squares (MSS)
Between Dummy Size	L - 1	$SS_D = \sum_i \sum_j \sum_k (\overline{Y}_{i..} - \overline{Y}_{...})^2$	$SS_D/(L - 1) = S_3^2$
Between Seats Within Dummy Size	L(M - 1)	$SS_S = \sum_i \sum_j \sum_k (\overline{Y}_{ij.} - \overline{Y}_{i..})^2$	$SS_S/(M - 1)L = S_2^2$
Within Seats	N - ML	$\sum_i \sum_j \sum_k (Y_{ijk} - \overline{Y}_{ij.})^2 = SS_W$	$SS_W/(N - ML) = S_1^2$
Total	N - 1	$\sum_i \sum_j \sum_k (Y_{ijk} - \overline{Y}_{...})^2$	

The mean square, S_1^2, characterizes the variation within seats, is the average of the LM "within seat" variances, and is independent of any hypothesis concerning the means. The mean square, S_2^2, characterizes the variation between seats within dummy size and is an average of L "within dummy size" variances which are computed for each dummy size group. If the M seat group means within dummy size are equal, then S_2^2 is just another estimate of the same variance that is estimated by S_1^2. Thus, if the value of S_2^2/S_1^2 is not significant, all observations within the dummy group may be considered as drawn from the same population and the equality of the means of the dummy size groups is tested by S_3^2/S_1^2. However, if the value of S_2^2/S_2^1 is significant, then the seats are considered to be different and S_3^2/S_2^2 is used to test for differences between dummy sizes.

Table 1. Analysis of Variance: Peak Gz

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	94.51	94.51	*
Aircraft	10	92.57	9.26	4.68*
Error	71	140.43	1.98	
Total	82	327.51		

Table 2. Analysis of Variance: Peak Gz

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy size	1	94.51	94.51	*
Seat	4	73.54	18.39	8.88*
Error	77	159.46	2.07	
Total	82	327.51		

Table 3. Analysis of Variance: Peak Gz
(Without AV-8 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	39.04	39.04	6.43*
Aircraft	6	36.40	6.07	2.95*
Error	47	96.74	2.06	
Total	54	172.18		

Table 4. Analysis of Variance: Peak Gz
(Without AV-8 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy size	1	39.04	39.04	*
Trainer	2	1.28	0.64	
Seat	4	34.62	8.66	4.20*
Error	47	97.24	2.06	
Total	54	172.18		

Table 5. Analysis of Variance: Peak Gz
(Without F-18 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	70.10	70.10	29.96*
Aircraft	6	9.22	1.54	0.66
Error	55	128.75	2.34	
Total	62	208.07		

Table 6. Analysis of Variance: Peak Gz
(Without F-18 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	70.10	70.10	31.43*
Seat	2	6.60	3.30	1.48
Error	59	131.37	2.23	
Total	62	208.07		

Table 7. Analysis of Variance: Peak Gz
(without A-7 Aircraft-seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	82.57	82.57	7.14*
Aircraft	6	69.41	11.57	5.03*
Error	40	91.86	2.30	
Total	47	243.84		

Table 8. Analysis of Variance: Peak Gz
(without A-7 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	82.57	82.57	*
Seat	2	61.52	30.76	13.55*
Error	44	99.75	2.27	
Total	47	243.84		

Table 9. Analysis of Variance: Peak Gz
(Adjusted for Speed Differences)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy size	1	95.02	95.02	*
Aircraft	10	89.35	8.94	4.86*
Error	71	130.77	1.84	
Total	82	315.14		

Table 10. Analysis of Variance: Peak Gz (Adjusted for Speed Differences)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	95.02	95.90	7.30 *
Seat	4	52.57	13.14	6.03*
Error	77	167.55	2.18	
Total	82	315.14		

Table 11. Analysis of Variance: Pitch

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	164,906.25	164,906.25	
Aircraft	10	1,578,976.38	157,897.64	1.37
Error	63	5,901,389.88	93,672.86	
Total	74	7,315,460.00		

Table 12. Analysis of Variance: Pitch

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	164,906.25	164,906.25	
Seat	4	649,983.21	162,495.80	1.72
Error	69	6,500,570.53	94,211.17	
Total	74	7,315,460.00		

Table 13. Analysis of Variance: Pitch
(Adjusted for Speed)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	148,358.95	148,358.95	
Aircraft	10	1,554,546.34	155,454.63	1.89
Error	63	5,183,299.30	82,274.59	
Total	74	6,886,204.59		

Table 14. Analysis of Variance: Roll

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistics
Dummy Size	1	573,460.72	573,460.72	5.55*
Aircraft	10	1,023,523.08	102,352.31	0.99
Error	63	6,515,362.87	103,418.46	
Total	74	8,112,346.67		

Table 15. Analysis of Variance: Roll

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	573,460.72	573,460.72	5.32*
Seat	4	94,245.24	23,561.31	0.22
Error	69	7,444,640.71	107,893.34	
Total	74	8,112,346.67		

Table 16. Analysis of Variance: Roll
(Adjusted for Speed)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	510,996.83	510,996.83	6.70*
Aircraft	10	1,076,503.29	107,650.33	1.41
Error	63	4,808,064.55	76,318.48	
Total	74	6,395,564.67		

Table 17. Analysis of Variance: Roll
(Adjusted for Speed)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	510,996.83	510,996.83	6.11*
Seat	4	117,623.67	29,405.92	0.35
Error	69	5,766,944.16	83,578.90	
Total	74	6,395,564.67		

Table 18. Analysis of Variance: Yaw

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	251,038.84	251,038.84	
Aircraft	10	2,157,560.27	215,756.03	2.08*
Error	63	6,517,000.69	103,444.46	
Total	74	8,925,599.28		

Table 19. Analysis of Variance: Yaw

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistics
Dummy Size	1	251,038.84	251,038.84	
Seat	4	1,567,748.87	391,937.22	3.81*
Error	69	7,106,811.57	102,997.27	
Total	74	8,925,599.28		

Table 20. Analysis of Variance: Yaw
(Without the AV-8 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	7,829.86	7,829.86	0.06
Seat	2	348,776.88	174,388.44	1.43
Error	43	5,228,418.96	121,591.14	
Total	46	5,585,025.70		

Table 21. Analysis of Variance: Yaw
(Without the F-18 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	302,155.72	302,155.72	
Seat	2	449,359.31	224,679.65	3.15
Error	50	3,561,381.50	71,227.63	
Total	53	4,312,896.72		

Table 22. Analysis of Variance: Yaw
(Without the A7 Aircraft-Seat)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	327,602.44	327,602.44	
Seat	2	1,385,006.82	692,503.41	5.73*
Error	46	5,563,171.48	120,938.51	
Total	49	7,275,780.74		

Table 23. Analysis of Variance: Yaw
(Adjusted for Speed)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	96,643.60	96,643.60	
Aircraft	10	1,570,578.49	157,057.85	2.19*
Error	63	4,514,644.12	71,661.02	
Total	74	5,746,808.35		

Table 24. Analysis of Variance: Yaw
(Adjusted for Speed)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	96,643.60	96,643.60	
Seat	4	890,079.92	222,519.98	3.23*
Error	69	4,760,084.83	68,986.74	
Total	74	5,746,808.35		

Table 25. Analysis of Variance: (Yaw Adjusted for Speed)
(A-7 and F-18 Only; Excluding AV-8)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	28,199.00	28,199.00	
Seat	2	389,888.14	194,944.07	3.08
Error	43	2,721,088.28	63,281.13	
Total	46	3,139,177.18		

Table 26. Analysis of Variance: (Yaw Adjusted f[illegible] Speed)
(A-7 and AV-8 Only; Excluding F-18)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	213,330.50	213,330.50	3.17
Seat	2	332,713.09	166,356.55	2.68
Error	49	3,046,270.42	62,168.78	
Total	52	3,592,314.01		

Table 27. Analysis of Variance: (Yaw Adjusted for Speed)
(F-18 and AV-8 Only; Excluding A-7)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic
Dummy Size	1	210,740.44	210,740.44	
Seat	2	865,759.77	432,879.89	6.11*
Error	46	3,260,167.31	70,873.20	
Total	49	4,336,667.52		

THE DATA ADJUSTED FOR SPEED

PART II

The adjustment for speed was made on the basis of the effect of speed as measured in the sample data. Those calculations for each variable are given below:

Peak G_z:			
$\Sigma xy =$	269,406.9		$n = 83$
$\Sigma x^2 =$	9,611,824.0		$\hat{b} = -0.0015$
$\Sigma y =$	1,070.3	Adjusted	$y = y + 0.0015x$
$\Sigma x =$	21,394		
Pitch:			
$\Sigma xy =$	14,743,635		$n = 75$
$\Sigma x^2 =$	9,835,112		$\hat{b} = +0.3578$
$\Sigma y =$	46,080	Adjusted	$y = y - 0.3578x$
$\Sigma x =$	22,042		
Yaw:			
$\Sigma xy =$	17,679,651		$n = 75$
$\Sigma x^2 =$	9,888,237		$\hat{b} = +0.9562$
$\Sigma y =$	49,098	Adjusted	$y = y - 0.9562x$
$\Sigma x =$	21,927		
Roll:			
$\Sigma xy =$	15,334,442		$n = 75$
$\Sigma x^2 =$	9,878,337		$b = +0.6745$
$\Sigma y =$	44,350	Adjusted	$y = y - 0.6745x$
$\Sigma x =$	22,077		

Peak G_z, Adjusted for Speed

$y'' = y + 0.0015x$

	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
	15.0	15.2	12.2	14.6	13.8	13.0	14.2	13.1	12.3	13.4	10.2	8.6
	14.6	14.3	15.5	16.4	12.3	10.5	12.6	14.1	11.3	10.7	10.7	12.1
	16.2	14.9	16.6	15.5	14.4	12.7	12.0	11.1	11.3	11.3	10.1	10.7
	14.1	13.4	15.9	15.3	14.9	10.7	13.5	13.7	14.3	11.7	9.9	12.3
	14.0	14.5	16.3	14.8		13.5	11.4	14.6	14.0			10.8
	13.7	12.3	17.7	14.9				12.6	13.7			14.9
	14.3	11.6	19.5					12.2	14.1			10.8
	13.0	14.6						13.3	13.1			
		15.8						12.3	13.3			
		13.1						11.5	11.6			
		13.8						10.1	14.4			
n	8	11	7	6	4	5	5	11	11	4	4	7
y	14.36	13.95	16.24	15.25	13.85	12.08	12.74	12.60	13.04	11.78	10.23	11.46
n						41						42
y						14.38						12.24

Pitch, Adjusted for Speed
$y' = y - 0.3578x$

	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
	410	650	764	315	202	367	475	300	369	632	502	304
	661	1130	1032	1194	213	335	255	280	260	399	553	717
	361	1375	1264	747	451	619	280	390	162	1051	291	344
	359	739	286	410	279	555	1125	539	232	885	489	833
	689	189	191	389	465	272		289	368		515	287
	989	235	470	396				485	261			1339
	285	335	885					535	275			616
									146			
									321			
									66			
									513			
n	7	7	7	6	5	5	4	7	11	4	5	7
$\bar{y}$	536.3	664.7	698.9	575.2	322.0	429.6	533.8	402.6	270.3	741.8	470.0	634.3
n						37						38
$\bar{y}$						554.3						465.34

Yaw, Adjusted for Speed

$y' = y - 0.9562x$

	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
	228	250	597	345	412	389	360	250	179	255	312	258
	1031	414	262	405	376	398	544	514	105	561	336	442
	331	175	454	438	816	377	569	380	42	-15	516	433
	290	470	701	683	1010	311	240	320	172	366	890	508
	140	570	84	250	65	976		220	205		736	855
	595	-74	96	101				376	211			662
	366	-224	776					176	290			518
									-272			
									567			
									-288			
									-234			
n	7	7	7	6	5	5	4	7	11	4	5	7
Y	425.9	225.9	424.3	370.3	535.8	490.2	428.3	319.4	88.8	291.8	558.0	525.1
n						37						38
Y						402.3						330.5

Roll, Adjusted for Speed

$y' = y - 0.06745x$

	3% Dummy						98% Dummy					
	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18	A-7	TA-7C	AV-8A	AV-8B	F-18	TF-18
	75	200	331	435	446	299	115	225	162	200	146	175
	1246	618	391	280	432	336	498	468	70	872	172	308
	881	149	383	739	797	676	498	719	41	166	137	392
	651	96	320	1219	566	255	329	346	56	175	416	261
	151	846	332	516	522	266		496	845		305	698
	521	20	460	1010				195	506			1016
	745	-5	420					-30	489			50
									185			
									60			
									-77			
									145			
n $\bar{y}$	7 610.0	7 274.9	7 376.7	6 699.8	5 552.6	5 366.4	4 360.0	7 345.6	11 225.6	4 353.3	5 235.2	7 414.3
n $\bar{y}$						37 476.4						38 311.3

Mean Peak G_zs for Various Aircraft and Dummy Size Combinations

	Ignoring Speed		Adjusted for Speed	
Aircraft	3% Dummy	98% Dummy	3% Dummy	98% Dummy
A-7	13.9	12.5	14.4	12.7
TA-7C	13.6	12.2	14.0	12.6
Both	13.7	12.31	14.1	12.6
AV-8A	15.8	12.6	16.2	13.0
AV-8B	14.9	11.3	15.3	11.8
Both	15.4	12.26	15.8	12.7
F-18	13.4	9.8	13.9	10.2
TF-18	11.7	11.1	12.1	11.5
Both	12.4	10.6	12.9	11.0
Total	14.0	11.8	14.4	12.2

APPENDIX B

SOME STATISTICAL CONSIDERATIONS IN TEST PLANNING.

Design compliance tests are conducted on the final design at the end of engineering development and are used to determine if the design will perform satisfactorily when tested under conditions consistant with the design specifications, along with boundary values for these conditions. These conditions are usually "design to" values, and since they can occur in combinations of levels, it is conceptually important to assess the effect, if any, of these combinations. Thus, the application of statistical experimental designs would appear to be very appropriate for these situations, and factorial-type designs would allow combinations of boundary conditions to be used effectively and efficiently. The fundamental purpose of experimental design is to isolate or separate sources of variation so that technical information can be obtained on a basic process or equipment. However, the application of statistical experimental designs in engineering studies which involve complex man-machine operations with vector-state performance characteristics is not simple nor straightforward.

An engineer does a lot of experimental testing for engineering investigative analysis. In many cases, data aquisition and storage are achieved automatically through instrumentation and computer storage, which encourages the engineers to adopt the philosophy that "a lot of data" is better than "too little data," and since it is available "we might need it anyway." In other cases, the engineer may be interested in only one outcome or measurement and thus overlook the opportunity to record more data than he needs, but which could be used for analyses of related critical interaction-type failures of which he is not yet aware. Thus, the complex engineering problem analysis and the many uncertainties in a system design evaluation encourage the engineer to establish very broad test objectives with many conditional alternatives. From a research point of view, such investigative studies are valuable but this approach may weaken the ability of a statistical test to detect differences if the approach does not allow control of the sample size in the experimental design, or does not define precisely the specific objectives of the experiments for decision-making.

Because of the multidimensional aspects of a hardware system and the facilities used for testing the system, it is very difficult for the project manager to know of the evolutionary changes that take place (or should take place) as the test engineers, the operational personnel, and the maintenance people resolve the interdependence of their responsibilities in preparation for an operational test of the system. The operational scenario is usually modified to accommodate instrumentation for engineering data acquisition and environmental simulation.

To determine the size of the experiment, replications and number of factors, it is necessary to review the existing information on system or operational characteristics. Summary data may hide critical variability particularly if the basic data is of the analog type. You can anticipate differences resulting from key factors in engineering hardware tests, e.g., equipment-to-equipment variation in performance characteristics, test installation to test installation variation in test conditions and instrumentations, and operator-to-operator variation in satisfactory performance or failure definition.

The planning objective is to assure that differences in responses observed among test specimens will depend only upon the particular configuration and model of the specimen. We increase the accuracy of our experiments by careful selection and application of the specimens or by skillful grouping of specimens in such a way that all specimens of one configuration are closely comparable with those of another configuration. In this way we exercise sufficient control over external influences so that every configuration produces its effect under comparable and desired conditions.

The results of a recent test conducted on an electronic system disclosed that greater differences (variation) existed between test facilities than between test cells (cells within a facility) and greater differences were observed between test cells than between systems within cells. The observed variances for facilities, cells, and systems were consistent with the ratios 100:10:1 in that order. This experience is consistent with our experience with other types of systems. The greatest differences have been associated more with differences in the engineering-operations-maintenance team than with any other single factor.

One problem always encountered is establishing a consistent, non-contradictory definition of satisfactory performance. The performance of a system can be described by the values of the "n" characteristics; however, in many situations this vector state cannot be converted into an ordered single-valued performance variable. Generally, when bounds are established for satisfactory performance for each characteristic individually, the set of boundary values will not be compatible with the overall system criteria. Unless there is a one-to-one correspondence between system criterion and the criterion for subsystem, or subsystem indenture, you can expect this to be an area of disagreement in reconciling failure analyses. It becomes very important to make the criteria applicable to the system characteristics only. Judge the system as it is used and on the same basis it is judged during use.

Engineering objectives are almost always stated in the broadest, most general terms and it can sometimes be difficult to convert these generalities into specific objectives. Considerable interrogation exchanges may be necessary before specific objectives can be established that will be acceptable to both the statistician and the engineering group. It is important during these exchanges that the scope of inference desired from the experiment is explored and the engineering group has a realistic understanding of what can and what cannot be done. For example, the demonstration of a system capability may be the most important result of a test. On many occasions reliability demonstration (qualification) testing is conducted on a single pre-production "prototype" model and then engineering management may wish to make inferences about the future production model. Such tests on a single pre-production model are demonstrations of capability and after completion of the test with an accept decision, the inference about the reliability to be expected from a production run of such systems is limited. Everyone can cite examples of mean time between failures (MTBFs) for production units that are one third to one tenth the MTBF observed on the qualification test.

There is a general lack of appreciation of randomization as a means of controlling the effects of unknown or uncontrollable factors as well as a lack of appreciation of the separation of variance into their causes or sources, for better conclusions. It will be desirable to control some of those factors that affect reliability while control of others will not be possible because we are not cognizant of them, because of economic reasons, or because of other pertinent reasons. Those factors not controlled experimentally will have to be controlled by randomization, a device for insuring that an item under study will not be continually favored or handicapped in successive observations by some extraneous factors. The effect of randomization is to transform unknown and/or systematic variations into independent and chance (random) variations. The need for randomization procedures has to be emphasized throughout the planning phase and must be monitored during the experiments so the rules are not ignored. We have found it helpful to always prepare a description of the randomization process and to present the rationale for the requirement in a write-up for the participants. The need for experimental design to separate or isolate variences is easier to convey since it is analogus to the noise problem in electronic signals and once the concept is understood, the engineer is likely to grasp its importance.

The lack of independence among factors is usually important in hardware design evaluation. One of the first important considerations is to be able to detect, at least, first order interactions. In many cases, lack of independence is known but the effect is not known. For example, temperature and vibration are known to affect system reliability but, for a given design, the effect of combinatorial levels of temperature and vibration at, near, or outside the design specification limits is critical in appraising the prospects of the system in operational use. We have conducted several experiemnts where a primary consideration was estimating the interaction effect and there was no interest in main effects.

INTRODUCTORY NOTES

ANALYTIC ASPECTS

A major problem confronting and, in many instances confounding, those responsible for, and potential users of, aircrew automated escape systems (AAES) and aircrew life support systems (ALSS) is attempting to ascertain how well or how poorly a particular piece of equipment, a pariticular conceptual approach or technique, or a particular system is performing. Typically simple measures of a non too simple problem are created and employed, such as percentage rates, to measure success (e.g., percentage of ejectees surviving) or to measure problems (e.g., percentage of ejectees incurring major injuries, etc.). These yardsticks of performance are extremely important, yet, at the same time, as a consequence of their virtue of being simple and seemingly easily understood by many people, they may become extremely dangerous since few people in truth really understand them.

Frequently these performance yardsticks after being computed are plotted to display for everyone their trends, sometimes delineated carefully by imposing techniques which many of us vaguely recall as being the proper approach without recalling the proper conditions for usage of the techniques nor the caveats concerning the technique's use. As a consequence, impressions can be generated and emotional battles fought to enhance aircrew safety; but the proposed actions in fact may be inappropriate as a consequence of the oft-forgotton limitations of percentage-type data arrays and/or of the other analytic techniques and tools, including grouping decisions, employed to examine these data.

An important task assigned to the Naval Weapons Engineering Support Activity, Washington, D.C., as a part of the program to analyze in-service usage data for aircrew automated escape systems (AAES) and aircrew life support systems (ALSS) is to develop and demonstrate appropriate analytic techniques for routine, standardized, repeated analyses of AAES and ALSS performance which could be implemented on a routine basis and which avoid many of the perils of current approaches. As an initial step in accomplishing this part of the tasking, problems with some of the current approaches were discussed in the paper Problems With the Use of Percentages In the Analysis of AAES Data by John Vetter presented at the 19th Annual SAFE Symposium, December 1981.

Another typical simple approach frequently employed by those analyzing performance of AAES and ALSS equipments is grouping; grouping by generic types of equipments, by families of equipment (i.e., families of ejection seats, families of survival kits, families of helmets, etc.), or by other perceived common (shared) aspects. All too frequently those who perform such grouping analyses lack adequate knowledge concerning the actual similarities between the equipments, those aspects which in fact are identical and those aspects which in fact differ significantly. Nor, often, do those performing such grouping analyses understand sufficiently the functioning of the equipments and the likely magnitude of the effects of those differences. Thus one can find many statistics purporting, for example, to analyze the performance of "The ESCAPAC Seat" or "The Martin-Baker Seat", when in fact such singular seats do not exist. Instead these terms describe two very different families of seat types each of which is comprised of many individual and often distinctly different seats possessing some shared attributes, including the designer/manufacturer. For some purposes these may be carefully grouped, while for other purposes their differences in design and functioning make inappropriate such broad groupings. This aspect of analysis of AAES is discussed in detail in the paper Significance and Limitations of Family Ties Among Ejection Seat Type Aircrew Automated Escape Systems.

SIGNIFICANCE AND LIMITATIONS OF FAMILY TIES AMONG EJECTION SEAT TYPE AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

Frederick C. Guill

ABSTRACT

A common practice within the escape systems community is to group seats into families and to then discuss them as though they were single seats not multiple seats with often significant differences. This practice is examined and the benefits derivable from and the hazards associated with it are discussed and illustrated.

SIGNIFICANCE AND LIMITATIONS OF FAMILY TIES AMONG EJECTION SEAT TYPE AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

Frederick C. Guill

INTRODUCTION

Commonly ejection seats are thought of and discussed in familial terms as opposed to individual seat terms. Thus one frequently hears or sees references to "the ESCAPAC seat" or to "the Martin-Baker seat" even though there are in service at present and have been in service over the years in many different aircraft models, many different varieties of ESCAPAC and Martin-Baker ejection seats. Recognized families during the past two decades have been differentiated on the basis of their designer/manufacturers although throughout the 1960's there remained in active inventory some seats using the NAMC Type I (later the Type II) ballistic catapult which, despite their non-shared designer/manufacturer heritage, became known as "the NAMC Type I (later the Type II) seats". Thus today one will hear or see references to the following ejection seat families as though there were but a single seat rather than a grouping of related seats:

ESCAPAC	(Douglas Aircraft Company)
Martin-Baker	(Martin-Baker Aircraft Company, Ltd.)
North American	(Rockwell International, Columbus Division)
Stencel	(Stencel Aero Engineering Corporation)

Within these broad groupings or families there exist several significant, easily identified subgroupings, such as in:

Martin-Baker	Mk5 Series, Mk7 Series, Type9, Mk10 Series
ESCAPAC	1, IA-1, IC-2, IC-3; and IF-3, IG-2, IG-3, IG-4; and IE-1
North American	LS-1, LS-1A, HS-1, HS-1A, LW-3B

and many less apparent subgroupings representing evolutionary changes, as well as changes necessitated by crew station, life support equipment peculiarities, and anticipated or planned aircraft mission needs, occurring over many years of design and manufacture by specific companies.

These various familial groupings and major subgroupings are important and provide considerable assistance in investigating seat usage and analyzing ejection statistics since they highlight very major design and conceptual similarities and differences. Nonetheless, useful as these familial distinctions are, they can, and often do, become impediments to communications concerning specific seats, to the accurate and complete investigation of specific ejections, and to the accurate assessment of how well or how poorly specific seats are doing in service. This familial view of ejection seats leads to an over-acceptance of these seat-to-seat similarities within a family (and to some degree an over-acceptance of seat-to-seat differences between seats of differing families) and, thereby, to a strong tendancy to overlook the often very critical design differences existing between individual seats of the same family (and similarly a failure to recognize often very critical similarities between seats of different families). Figures 1 and 2 list the individual seats comprising the ESCAPAC and the Martin-Baker ejection seat families as employed within U.S. Navy aircraft, respectively, betweem 1 Janaury 1969 and the present.

As shown in Figures 1 and 3, amongst the seats comprising a family, in this instance ESCAPAC, there frequently are many differences in design, sometimes even when, as in the case of ESCAPAC IC-2, the designator would seem to indicate one seat in multiple applications. As shown in Figure 3, U.S. Air Force and U.S. Navy versions of the ESCAPAC IC-2 installed in A-7 series aircraft differed in several very important respects.

To further illustrate the differences between, as well as the similarities among, ejection seats often grouped together and discussed as one type, e.g., "ESCAPAC", Figures 4 through 9, in addition to Figure 1, highlight important characteristics of several of the ESCAPAC series of ejection seats. Figure 4 depicts the design evolution of ESCAPAC ejection seats in A-4, A-7 and S-3 aircraft. Figure 5 depicts for each ESCAPAC configuration named in the preceding figure the major design features (these, for the purposes of illustration, are simplistically labelled, e.g., "rocket separator" which includes not only the man-seat separation rocket but also the timing changes and other changes affecting the man-seat separation subsystem). The evolutionary changes that occurred within these A-4, A-7 and S-3 ESCAPAC ejection seats are highlighted in Figures 6 through 9. A similar series of evolutionary design changes and specific application differences occurred within the Mk5 and Mk7 series of ejection seats. Some of these differences are shown in Figure 2.

SIGNIFICANCE OF FAMILY-TO-FAMILY DIFFERENCES IN EJECTION SEAT DESIGNS, BEHAVIOR AND USAGE STATISTICS

For many years the vast majority of U.S. Navy ejection seats have been either ESCAPAC or Martin-Baker (initially Mk5 Series, later superseded by the Mk7 Series) type ejection seats. Initially, and for a long period thereafter, the success rates and other "bottom line" or "overview" statistical data for these two families of ejection seats were very similar (Figures 10 and 11) indicating that the "paper performance" similiarities of these seats probably were real. However, by 1978 these statistical performance measures had diverged significantly (Figures 12 through 14), creating considerable concern since the divergence appeared to be a result of worsening performance of ESCAPAC type ejection seats. (The success rate for Martin-Baker seats, primarily Mk7 Series then essentially replacing the older Mk5 Series, appeared to have remained largely unchanged as the worsening ESCAPAC trend developed (Figures 15 and 16).) Of particular concern to users and the Naval Air Systems Command was the apparently worsening trend for ESCAPAC "in envelope" ejections occurring over water (Figure 17).

Further examination of the accumulated ejection statistics from these two families of ejection seats revealed a number of potentially significant, recently developed differences in their ejection records. Several of these patternistic differences appeared important in terms of their potential for producing injuries and fatalities. In each of these recently developed differences it appeared that the changeover from older to newer, upgraded versions of ESCAPAC type ejection seats were resulting in increasingly undesirable performance characteristics, while the performance of the Martin-Baker ejection seats remained essentially unchanged during the changeover from Mk5 Series to Mk7 Series. These performance differences between the two families developed even though the evolutionary "paper performance" of contemporary ESCAPAC and Martin-Baker ejection seats remained very similar. These differences in "in-service performance", although not accurately defined, were becoming apparent to the Fleet and were helping to cause a worsening trend in the morale of U.S. Navy aviation personnel. (Although one can accept the expected consequences of an out-of-envelope ejection, it is extremely difficult to accept high fatality rates and major injury rates for ejections appearing to have been well within the advertised safe envelope, particularly so when one is a potential user.)

Thus the immediate problem was to identify just what had changed in each family of ejection seats and which of those changes might be related to the divergence between their familial statistical performance measures. It was recognized that there were a number of potentially important conceptual differences between these two families; the most important of these were suspected to be:

o Differences in stability

Those ESCAPAC ejection seats for which most usage data has been acquired do not have continuously operating stabilization systems, whereas all versions of Martin-Baker seats, shortly after clearing the disabled aircraft, are drogue stablized until personnel parachute deployment starts (during personnel parachute deployment in Mk 5 and Mk 7 series ejection seats the seat and man experience a short period without active stabilization and, in fact, the parachute deployment forces may slightly destabilize the combination).

o Man-seat separation

The ejectee in ESCAPAC ejection seats has to be separated from the seat before deployment of the backpack type personnel parachute can occur. Separation of the ejectee from the first (early model) ESCAPAC (and RAPEC) seats was achieved by first inflating a bladder on the seat back followed by the inflation of one in the seat bucket. This bladder inflation sequence caused the ejectee to lean forward in the seat so that the subsequent upward push from the inflation of the seat bucket bladder would not jam the parachute pack up against the headrest and prevent or impair man-seat separation. During the evolution of the ESCAPAC family, the separation system was changed to a snubber system (ESCAPAC IA-1) which slowed the seat and released all personal restraints causing the ejectee's inertia to separate him from the seat. Subsequently, the latest ESCAPAC seats (installed in A-4, A-7 and S-3 series aircraft) used a small man-seat separator rocket motor to propel the seat down and aft away from the ejectee. Occasionally, at least with the bladder separation system, man-seat separation distances would develop so slowly as to permit or cause post-separation collisions between man and seat and/or seat interference with the deploying parachute, often with severe consequences for the ejectee. Throughout the evolution of U.S. Navy Martin-Baker ejection seats, the ejectee's personal restraints were released from the seat when parachute deployment began but the ejectee remained loosely attached within the seat by "sticker clips" during parachute deployment so that when the parachute opened and abruptly slowed the ejectee, the inertia of the seat caused it to separate from the ejectee on a non-interference path.

o Parachute deployment

The ESCAPAC parachute was packed in a standard U.S. Navy backpack. In the first ESCAPAC (and the RAPEC) seats, the pack flaps were opened either through automatic or manual actuation of the ripcord, thereby releasing a small pilot chute. Some pilot chutes opened umbrella fashion and some were coiled spring types that tended to pop out of the parachute pack a short distance. This pilot chute was attached to the apex of the personnel parachute canopy and once it managed to clear the wake effects of the ejectee would retard the parachute causing it to emerge apex first from the pack. The blanking effects of the ejectee's wake made the duration of this process highly variable. Therefore, to make it more consistent and thereby predictable,

> the later versions of ESCAPAC employed an externally mounted pilot chute which would enter the windstream essentially clear of the ejectee's wake effects during his separation from the seat. This EPC (external pilot chute) was effective for low speed ejections, q-force during ejections much greater than 120 knots would shred the EPC thereby avoiding a too-quick deployment and the subsequent too-high speed opening of the personnel parachute. Inasmuch as body orientation of the ejectee was random, i.e., neither body nor seat being stabilized immediately prior to, during or following man-seat separation, at the time of parachute pack opening the parachute could be deploying into the wind and around the ejectee with a chance of wrapping around the ejectee and never opening or, if deploying crosswind, sustaining damage while "spooning" (taking on the shape of the bowl of a spoon). In Martin-Baker seats the personnel parachute is forcibly extracted from a Martin-Baker designed top-opening parachute pack by the duplex drogues which are used initially to stabilize and decelerate the seat and ejectee. The fact that the drogues are deployed and working when they are transferred from seat structure to the parachute apex assures the rapid, controlled, downstream deployment of the personnel parachute and, accordingly, avoids deployments into the wind or crosswind.

As is easily observed, these differences in these three aspects of the competing designs are highly interrelated. What is not obvious at first is the cause for these differences and, even more important, whether these conceptual design differences had any relationship to the diveregence between the statistical performance measures of the two families of seats.

The ESCAPAC approach of separating man from seat and then deploying the personnel parachute is a natural outgrowth of early ejection seat design evolution in which the concern was effecting in-flight escape from a disabled aircraft (the escape process was then commonly known as in-flight emergency egress, i.e., signifying that design attention was focused upon the means for getting the crew out of the disabled aircraft). Thus the early concepts of ejection seats really represented means for effecting the transfer of the bailout point from within the disabled aircraft to some point outside of that airplane, requiring the ejectee to then only push clear of the ejected seat as opposed to climbing out of the aircraft. In performing the latter, one sometimes had to overcome high acceleration and/or windblast loads, and then avoid injurious contact with various aircraft surfaces. It was only later that automation of the pre- and post-ejection sequences began and that concern eventually was focused in turn over time from simply egressing an inflight aircraft to escape from low level flight, groundlevel, zero/zero and, most recently, low-level, adverse-attitude escape conditions. Early in these initial years of ejection seats Martin-Baker introduced their basic concept of stabilizing man and seat and subsequently forcibly deploying the personnel parachute while the ejectee was in the seat. This represented a major, innovative and extremely controversial departure from the main stream of ejection seat evolution and was not readily accepted by the escape systems community, the military services or industry.

The role of these conceptual design differences, if any, in the recently developed divergence between the families' statistical performance measures is not readily apparent. After all, the central difference, that of the need in ESCAPAC seats for the man to separate a considerable distance from the seat before pack opening and pilot chute deployment of the personnel parachute versus the forcible withdrawal of the personnel parachute by already working dorgues and the subsequent separation of man from seat by personnel parachute opening forces in Martin-Baker seats, had not appeared to result in significant "in-service performance" differences. So if these differences now were significant, the obvious question was why now? Why had they not been significant earlier?

SIGNIFICANCE OF SEAT-TO-SEAT DESIGN DIFFERENCES WITHIN AN EJECTION SEAT FAMILY

With the latest evolution in ESCAPAC ejection seat design, the ESCAPAC IF-3, ESCAPAC IG-3, (both in A-4 series aircraft, with the latter replacing both the former and the ESCAPAC IC-3 before the former had totally replaced the ESCAPAC IC-3 as initially planned) and ESCAPAC IG-2 (in A-7 series aircraft), the ESCAPAC ejection records quickly began to reflect several disturbing trends and patterns not previously evident:

- An increased reportage by survivors and observers of tumbling (violent tumbling and multiple tumbles) and flailing (especially flailing during low speed escapes).
- Reportage of an increased incidence of low-speed flailing injuries.
- Severe damage to the survival kit causing either:
  - the kit to open in mid-air spewing its contents into the deploying personnel parachute, or
  - breakage of the survival kit handles precluding the ejectee from opening the kit once on the surface.

Statistical analyses of the accumulated in-service usage data in late 1978 strongly suggested the existence of a correlation between these new ESCAPAC usage phenomena and the introduction of the collective changes comprising the rocket motor type man-seat separation subsystems in ESCAPAC IF-3, ESCAPAC IG-3 and ESCAPAC IG-2.

If, as these early data suggested, these most recent man-seat separation subsystem changes were the cause of the recent degradation of "in-service performance" and if the previous man-seat separation subsystems had not caused major problems, then why were these changes necessary and how had these changes produced the degraded "in-service performance"?

The evolution which occurred in ESCAPAC man-seat separation subsystems is understandable in the context of the general ejection seat/escape system evolution and in the context of competitive pressures -- i.e., the need to offer and provide ejection seats at least equal to, or better than, those of competitors and/or at least meeting or bettering customer specification requirements. In first providing take-off and landing speed groundlevel escape capability and then later zero/zero (0/0) escape capability, ESCAPAC ejection seat designers (like the designers of many other types of contemporaneous ejection seats) did not have to surmount any major difficulties caused by the then current slow bladder man-seat separation subsystem (bladders were at that time used in many other manufacturer's ejection seats) or the slow, uncertain personnel parachute deployment subsystem (again identical to, or similar to, the personnel parachute deployment systems used in many other manufacturer's ejection seats). Adequate time to assure succesful completion of man-seat separation and the generally interference free deployment of the parachute was obtainable by increasing the height of the trajectory apogee since, for the free fall condition, $t=\sqrt{2S}/a$ where t represents time from apogee to impact with the surface, s represents the apogee height (hence the distance to be travelled during the free fall), and a represents the earth's gravitational constant (32.2 fps) (see Figures 18 and 19). In addition, as a consequence of the trajectory height and, therefore, the extended time available in which to complete all sequenced functions and events, man and seat remained together for a relatively long time during which time the combination benefitted from larger mass moments of inertia than either man or seat possessed separately (1.1 seconds vs. the more recent 0.52 seconds) tending to show the tumble rate while ensuring a significantly greater velocity decay between ejection and man-seat separation, especially during high speed escapes. Thus, even though the sequenced, relatively long duration low-force pushes from the separation bladders in older ESCAPAC may have caused the ejectee to tumble during and following separation from the seat, the tumble rate was low and, due to the longer deceleration time period, windblast (q force) imposed upon the tumbling ejectee was lower for a given initial ejection airspeed than for the newest ESCAPACs. Thus although there were problems associated with the older man-seat separation systems (e.g.: seat hanging up in parachute, flailing, etc.), on the surface the problems normally appeared no worse than those common to other ejection seats in the U.S. Navy inventory. (It should be remembered that when the early RAPEC I ejection seat, the predecessor to the ESCAPAC series of ejection seats appeared, the Navy's inventory of aircraft and therefore of seats was heavily weighted to those designed and manufactured in the late 1940's and early 1950's and that a groundlevel escape capability at any speed was unknown until the introduction of the RAPEC I, LS-1, HS-1, and the Mk5 Series ejection seats.) Therefore the ESCAPAC family appeared to be performing as well as other ejection seats.

However, all of this changed rapidly when the U.S. Navy began requiring escape capabilities which included both the zero-zero (0/0) condition and the low-level adverse-attitude condition as well. Achieving the latter requirement meant reducing propulsive thrust and resulted in lower trajectory heights and an associated significant reduction in the time available for accomplishing the full separation of the man from the seat and the safe, complete deployment and opening of the personnel parachute. This latter effect was extremely critical when attempts were made to upgrade to the new requirements many existing seat designs, among them those in the ESCAPAC series.

As a consequence of the dramatically reduced time available for effecting man-seat separation and then parachute deployment and opening in order to meet the new U.S. Navy requirements, it was necessary in the most recent ESCAPACs to:

- o Initiate man-seat separation sooner (0.52 second vs. 1.1 second)
- o Employ a more positive, faster means of separating man and seat (rocket thruster vs. separation bladders).
- o Use a seat pouch mounted EPC (external pilot chute) deployed clear of ejectee wake effects during man-seat separation to effect rapid, consistent deployment of the parachute following low speed ejections.
- o Employ a ballistic spreader gun to control the parachute throat, preventing premature and asymmetric filling which poses many hazards, and assuring prompt opening of the parachute just prior to full line stretch thereby reducing the randomness of parachute filling times (including, occasionally very slow, as well as normal -- nominal -- times) during low airspeed openings.

These changes soon were reflected in the changes in fatality and injury rates and patterns since:

- o There was less time for velocity decay, resulting in man-seat separations occurring at higher airspeeds (and, therefore greater windblast (q force) at separation for given ejection airspeeds.

- o The ejectee was tumbled more and also more violently. With the separation force greater, more rapid and skewed, forces were introduced which induced the greater, and possibly epicyclic, tumbling (as opposed to the essentially pure pitch, lower speed tumbling associated with separation bladders). The more violent tumbling occurring in a greater windblast field appears to have increased the incidence of flail injuries associated with low speed ejections and to have probably contributed to the reported apparent helplessness of many low level ejection survivors in the water and to the increase in drownings among low level overwater ejectees.

- The survival kit on at least two occasions was wrenched open during man-seat separation, a problem not previously experienced, necessitating the temporary addition of a closure strap until kit lid locks were redesigned to preclude this inadvertent, premature opening and the consequent spewing forth of the contents into the parachute (this problem occurred twice, once with fatal consequences, before introduction of the strap). (The strap upon occasion made the survival kit contents inaccessible to survivors, exacerbating their plight.)

- The survival kit handles for manual opening of the kit for access to the liferaft and other survival equipments were often broken off apparently during man-seat separation precluding opening of the kit and the use of the kit equipment by the survivor once on the surface.

SUMMARY

Analyses have been conducted of ejection data for ESCAPAC series ejection seats and Martin-Baker series ejection seats and other types of ejection seats. Analyses of the data for the other systems involved far smaller quantities with reduced statistical significance. Thus the primary emphasis and illustrative examples used have of necessity been those among the ESCAPAC and Martin-Baker ejection seat families. The important point of this discussion has not been the problems of the ESCAPAC series ejection seats but, rather, the potential that design changes or differences in design can, and generally do, produce distinct, detectable changes or differences in the ejection data (changes in fatality rates, causes and patterns; changes in injury rates, causes and patterns; and changes in equipment damage rates, causes and patterns; etc.). These potentials need to be considered during design and should be watched for with every in-service usage of a system. (With care, however, the first glimmers of such potential problems sometimes can be detected during system testing, especially when a thorough, pre-planned post-test analysis and teardown is conducted for each test and the resultant data is continually compared within the growing data collection. However, the likelihood of such detection declines markedly as the numbers of systems tests is reduced, which is often agreed to by both parties, Government and contractor, to effect "up-front" program economies -- economies that often appear politically mandatory if a new, upgraded system offerring improved capability is to be acquired and incorporated in Fleet aircraft.)

It should also be noted that different applications of the same or essentially identical seats can produce differences in these ejection data. Thus, for example, a 1963 examination of early Martin-Baker Mk5 Series ejection seat ejection data suggested that a major, if not the most significant, cause for the then alarmingly increased vertebral fracture rate associated with the introduction of the Mk5 Series seats was the frequently simultaneous change in many of the modified aircraft from jettisoning canopies before ejecting to ejecting through the canopies. The cause appeared statistically not to be, as was then the common assumption, characteristics of the newly introduced Mk5 Series ejection seats themselves. Providing support for this theory was the wide variation in the incidence of vertebral injuries for individual model seats, e.g., Mk A5, Mk F5, Mk H5, etc., and the apparent very large differences in vertebral injury incidence rates between those Mk5 Series seats ejecting through the canopy and those ejecting after jettisoning of the canopy. Interestingly, this division (jettisoning vs. through-the-canopy) when applied to the data for the older NAMC Type I and Type II ballistic catapult seats replaced by the Mk5 Series seats, demonstrated vertebral injury incidence rates similar to those then being experienced with the new Mk5 Series seats for similar canopy modes. This, to a degree, demonstrates the significance of (1) differences within a family of seats, (2) similarities between seats of different families of seats, and (3) the need to consider and examine the potential impact(s) of all changes in the total aircrew automated escape system (AAES) and not just the patently obvious ones such as the introduction of a new ejection seat.

Examination of design differences both within and between families of aircrew automated escape systems (AAES) appears likely to reveal many design causes for specific injury or equipment damage rates and patterns and thereby permit focusing resources on correcting these causal factors to improve the safety of aircrews using existing escape systems and, also, on developing appropriate specification design, analyses, test, and evaluation requirements to reduce or eliminate these and similar causal factors from escape systems yet to be designed. These examinations also may reveal design approaches which reduce or eliminate the incidence of specific injuries and/or equipment damage. It is these aspects, among others, that underlay the creation of the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis project by the Crew Systems Division, Naval Air Systems Command, and its placement in the care of systems analysis experts having no AAES/ALSS ties or commitments; the Analytical Systems Division, Naval Weapons Engineering Support Activity, Washington, D.C.

U.S. NAVY ESCAPAC CONFIGURATIONS
1 JANUARY 1969 THROUGH 31 DECEMBER 1979
CONFIGURATION DETAILS

	AIRCRAFT	PARACHUTE	SURVIVAL KIT (SEAT PAN)	ROCKET CATAPULT	MAN/SEAT SEPARATION	STABILIZATION	CANOPY BREAKERS AND CANOPY MATERIAL	INERTIA REEL	WEIGHT (LB)
I	A-4A, B, C D E	NB-8 W/2 SEC DELAY MK 5 WITH ZERO DELAY LANYARD	PK 2 W/28 IN.³ OF O₂ (SEAT PAN DAC 5811063)	RAPEC-1 1140 LB/SEC SUSTAINER 47.5 DEG THRUST ANGLE	BLADDER INSTL DAC 5870701 503 @T = 1.1 SEC MK 80 CART	NONE	NO BREAKERS	REEL HARDMAN 3015-37 11 IN. TRAVEL	SEAT ASSY [illegible] EJECTABLE 138.10 SEAT SYS 148.[illegible]
IA-1	A-4A, B, C D E	USN NB-11 & NES 10 W/0.75 SEC DELAY MK 4	PK 2 W/28 IN.³ OF O₂	RAPEC 1 1140 LB/SEC SUSTAINER 47.5 DEG THRUST ANGLE	BLADDER INSTL DAC 5870701 503 @T = 1.1 SEC MK 80 CART	SNUBBER DART	NO BREAKERS	REEL HARDMAN 3015-37 11 IN. TRAVEL	SEAT ASSY 67.20 EJECTABLE 141.[illegible] SEAT SYS 180.30
IC-2	A-7	USN NB-10 USAF NB-10A W/2 SEC DELAY MK 6 WITH ZERO DELAY LANYARD	USN/RSSK 8A USAF/ROCH 140000 W/[illegible] IN.³ OF O₂	USN/TALLEY 2174-520 MK 7 2000 LB/SEC 53.4 DEG THRUST ANGLE	BLADDER INSTL DAC 5870701 507 @T = 1.1 SEC MK 80 CART	DART STENCEL 40 001 001	FOLDING BREAKER DAC 5810082 1/4 STRETCHED ACRYLIC	REEL HARDMAN 3015-37 11 IN. TRAVEL	SEAT ASSY 80.5 EJECTABLE 141.[illegible] (1) SEAT SYS 182.30 (1)
IC-3	A-4 F TA-4F & SUBS	USN NB 10 W/2 SEC DELAY MK 6 WITH ZERO DELAY LANYARD	RSSK-8A W/50 IN.³ OF O₂	USN/TALLEY 2174-522 MK 13 2000 LB/SEC 53.4 DEG THRUST ANGLE	BLADDER INSTL DAC 5823075 503 @T = 1.1 SEC MK 80 CART	DART STENCEL 46 001 001	NO BREAKERS	POWER REEL HARDMAN 100501-1 11 IN. TRAVEL	SEAT ASSY 60.00 EJECTABLE 141.00 (1) SEAT SYS 101.20 (1)
IE-1	S-3A	USN NES-12C WITH BALLISTIC SPREADER AND EXTERNAL PILOT CHUTE. W/0.85 SEC DELAY MK 30	RSSK 8A-1 W/50 IN.³ OF O₂	DAC A1151301 TALLEY 10407 3 1050 LB/SEC 65 DEG OR NAVY/UPCO MK 10 1100 LB/SEC 57 DEG THRUST ANGLE	ROCKET TYPE DAC A115130 100 LB/SEC (MK 82, MK 90) @T = 0.62 SEC OEA 2240100	STAPAC DAC J115140 505 DAC A115131 235 LB/SEC VERNIER ROCKET	LONG FIXED BREAKER DAC 5675282 1/4 STRETCHED ACRYLIC	POWER REEL PAC SCI MK D 01514 18 IN. TRAVEL	SEAT ASS 80.8 EJECTABLE 148.7 (1) SEAT SYS 108.1 (1)(2)
IF-3	A-4F TA-4	USN NES-12C WITH BALLISTIC SPREADER AND EXTERNAL PILOT CHUTE. W/0.75 SEC DELAY MK4	RSSK-8A-1 W/50 IN.³ OF O₂	USN/TALLEY 2174-522 MK 13 2000 LB/SEC 53.4 DEG THRUST ANGLE	ROCKET TYPE DAC A115130 100 LB/SEC (MK 82) @T = 0.77 SEC MK 12	DART STENCEL 40 001 001	NO BREAKERS	POWER REEL HARDMAN 100501 1 11 IN. TRAVEL	SEAT ASSY 67.7 EJECTABLE 140.7 (1) SEAT SYS 108.2 (1)
IG-2	A-7	USN NES-12C WITH BALLISTIC SPREADER AND EXTERNAL PILOT CHUTE. W/0.75 SEC DELAY MK 4	RSSK 8A-1 W/50 IN.³ OF O₂	USN/UPCO MK 10 1100 LB/SEC 57 DEG THRUST ANGLE	ROCKET TYPE DAC A115130 100 LB/SEC (MK 82) @T = 0.62 SEC OEA 2240100	DART MODIFIED PER DAC 5675204	FOLDING BREAKER DAC 5810082 1/4 STRETCHED ACRYLIC	REEL HARDMAN 3015-37 11 IN. TRAVEL	SEAT ASSY 57.8 EJECTABLE 140.8 (1) SEAT SYS 140.6 (1)(3)
IG-3	A-4F TA-4F & SUBS	USN NES-12C WITH BALLISTIC SPREADER AND EXTERNAL PILOT CHUTE. W/0.75 SEC DELAY MK 4	RSSK-8A-1 W/50 IN.³ OF O₂	USN/UPCO MK 10 1100 LB/SEC 57 DEG THRUST ANGLE	ROCKET TYPE DAC A115130 100 LB/SEC (MK 82) @T = 0.57 SEC MK 11	DART MODIFIED PER DAC 5675204	NO BREAKERS	POWER REEL HARDMAN 100501 1 11 IN. TRAVEL	SEAT ASSY 57.8 (1) EJECTABLE 140.8 (1) SEAT SYS 140.8 (1)(3)

NOTES: (1) INCLUDES 18 LB OF SURVIVAL EQUIPMENT.
(2) AIRCRAFT UPRIGHT LEVEL ATTITUDE.
(3) WEIGHT OF SEAT RAILS AND CATAPULT SUPPORT NOT INCLUDED

Figure 1

U.S. NAVY MARTIN-BAKER EJECTION SEAT CONFIGURATIONS
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

SEAT MODEL	AIRCRAFT[1]	PARACHUTE	PRIMARY CANOPY MODE
MK5 SERIES			
MK A5	TF-9J (F9F-8T)	I-24	THROUGH
MK F5	F-8 SERIES (F8U)	I-24	JETTISON[3]
MK GRU5	A-6 SERIES (A2F)	I-24	JETTISON[4]
MK GRUEA5	EA-6B	I-24	JETTISON[4]
MK H5	F-4 SERIES (F-4H)	I-24	JETTISON
MK L5	T-1A (T2V-1)	I-24	THROUGH
MK M5	F-3 SERIES (F3H)	I-24	THROUGH
MK N5	AF-1E (FJ-4B)	I-24	THROUGH
MK P5	F-6A (F4D-1)	I-24	JETTISON
MK X5	F-11A (F11F-1)[2]	I-24	THROUGH
MK Z5	AF-9J (F9F-8B)	I-24	THROUGH
MK 7 SERIES			
MK A7	TF-9J	28 FT FLAT W/PDVL	THROUGH
MK F7	F-8 SERIES	28 FT FLAT W/PDVL	JETTISON[3]
MK GRU7	A-6 SERIES	28 FT FLAT W/PDVL	THROUGH
MK GRU7A	F-14 SERIES	28 FT FLAT W/PDVL	JETTISON
MK GRUEA7	EA-6B	28 FT FLAT W/PDVL	THROUGH
MK H7	F-4 SERIES	29.8 RING-SLOT SKYSAIL 28 FT FLAT W/PDVL	JETTISON
TYPE 9, MK 1	AV-8A		FRAGMENTATION[5]
MK 10 SERIES			
MK US105	A/F-18 SERIES	GQ AEROCONICAL	

[1] INASMUCH AS REFERENCES TO MK5 SERIES EJECTION SEATS OFTEN EMPLOY THE ORIGINAL U.S. NAVY DESIGNATION, THESE ARE SHOWN IN PARENTHESES AFTER THE CURRENT AIRCRAFT DESIGNATORS.

[2] *FEW MK X5 EJECTION SEATS ACTUALLY WERE INSTALLED IN F11F-1 AIRCRAFT, ALTHOUGH PURCHASED AND AVAILABLE. THE SEATS, WITH THE EXCEPTION OF* NAME PLATES, WERE IDENTICAL TO MK Z5 EJECTION SEATS AND THEREFORE, DURING THE CUBAN MISSILE CRISIS OF 1962, A NUMBER OF THESE SEATS WERE UNCRATED AND INSTALLED IN F9F-8P AIRCRAFT REPLACING THE STANDARD, ZERO DELAY LANYARD SEATS NORMALLY IN THESE AIRCRAFT.

[3] MK F5 AND MK F7 EJECTION SEATS WERE EQUIPPED WITH AN INTERRUPTOR MECHANISM WHICH ALLOWED THE PULLING OF A FIRING CONTROL TO INITIATE CANOPY JETTISONING. AFTER THE CANOPY TRAVELLED A SPECIFIED DISTANCE, A LANYARD ATTACHED TO IT FREED THE INTERRUPTOR TO PERMIT CONTINUED PULLING OF THE FIRING CONTROL HANDLE TO INITIATE EJECTION – ESSENTIALLY A TWO-PULL ACTION TO EFFECT AN ESCAPE. IN THE EVENT THE CANOPY DID NOT JETTISON, AN INTERRUPTOR D-RING HANDLE LOCATED ON THE STARBOARD SIDE OF THE HEADBOX COULD BE PULLED AND EJECTION COULD BE ACCOMPLISHED THROUGH-THE-CANOPY. IF THE INTERRUPTOR HANDLE WERE PRE-PULLED, I.E., BEFORE FLIGHT, EJECTION COULD BE ACCOMPLISHED THROUGH-THE-CANOPY BY AN UNINTERRUPTED PULL OF EITHER FIRING CONTROL.

[4] LATER CONVERTED TO THROUGH-THE-CANOPY.

[5] *AV-8A CANOPY WAS EXPLOSIVELY FRAGMENTED BY A SYSTEM INITIATED BY THE INITIAL UPWARD TRAVEL OF THE SEAT.* IF THE FRAGMENTATION SYSTEM FAILED, THE EJECTION AUTOMATICALLY CONTINUED THROUGH-THE-CANOPY.

Figure 2

DISSIMILARITIES BETWEEN USN & USAF A-7 ESCAPAC EJECTION SEATS

	USN	USAF
SEAT TYPE:	IC-2 → IG-2	IC-2
PARACHUTE:	NB-10 → NES-12C (BAL. SPRDR. GUN)	NB-10A
RESTRAINT:	STD. NAVY TORSO[1]	STD. USAF TORSO[1]
SEAT-MAN SEP:	BLADDERS → "EAR BURNER" ROCKET	BLADDERS
PROPULSION:	MK7 (2000 LB/SEC) → MK16 (1100 LB/SEC)	MK7 (2000 LB/SEC)
SURVIVAL KIT:	RSSK-8A → RSSK-8A-1[1]	USAF/KOCH/140000[1]

NOTE: [1]DIFFER IN LAP BELT CONFIGURATION AND SURVIVAL KIT ATTACHMENT TO MAN.

Figure 3

EVOLUTION OF ESCAPAC WITHIN SPECIFIC AIRCRAFT

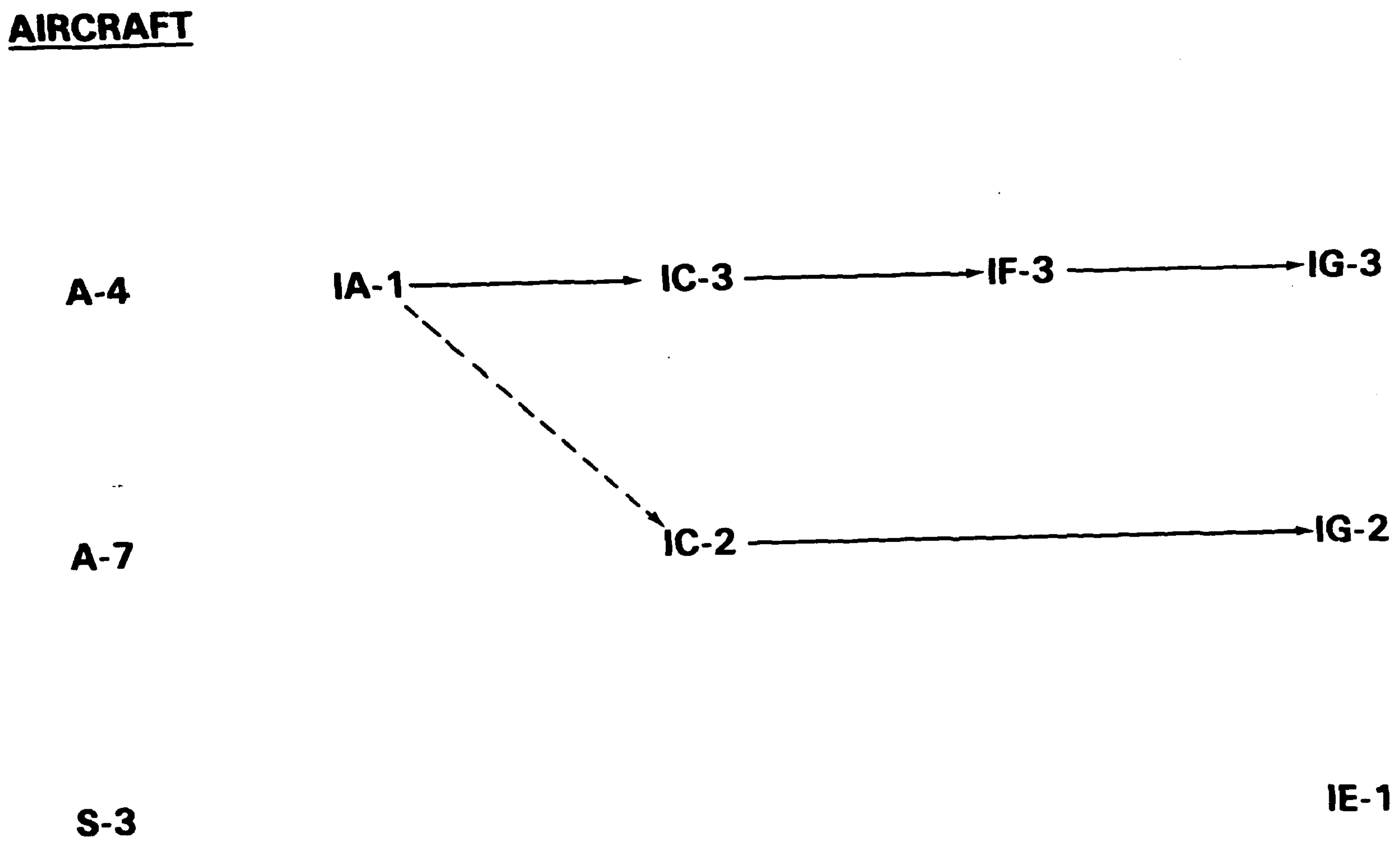
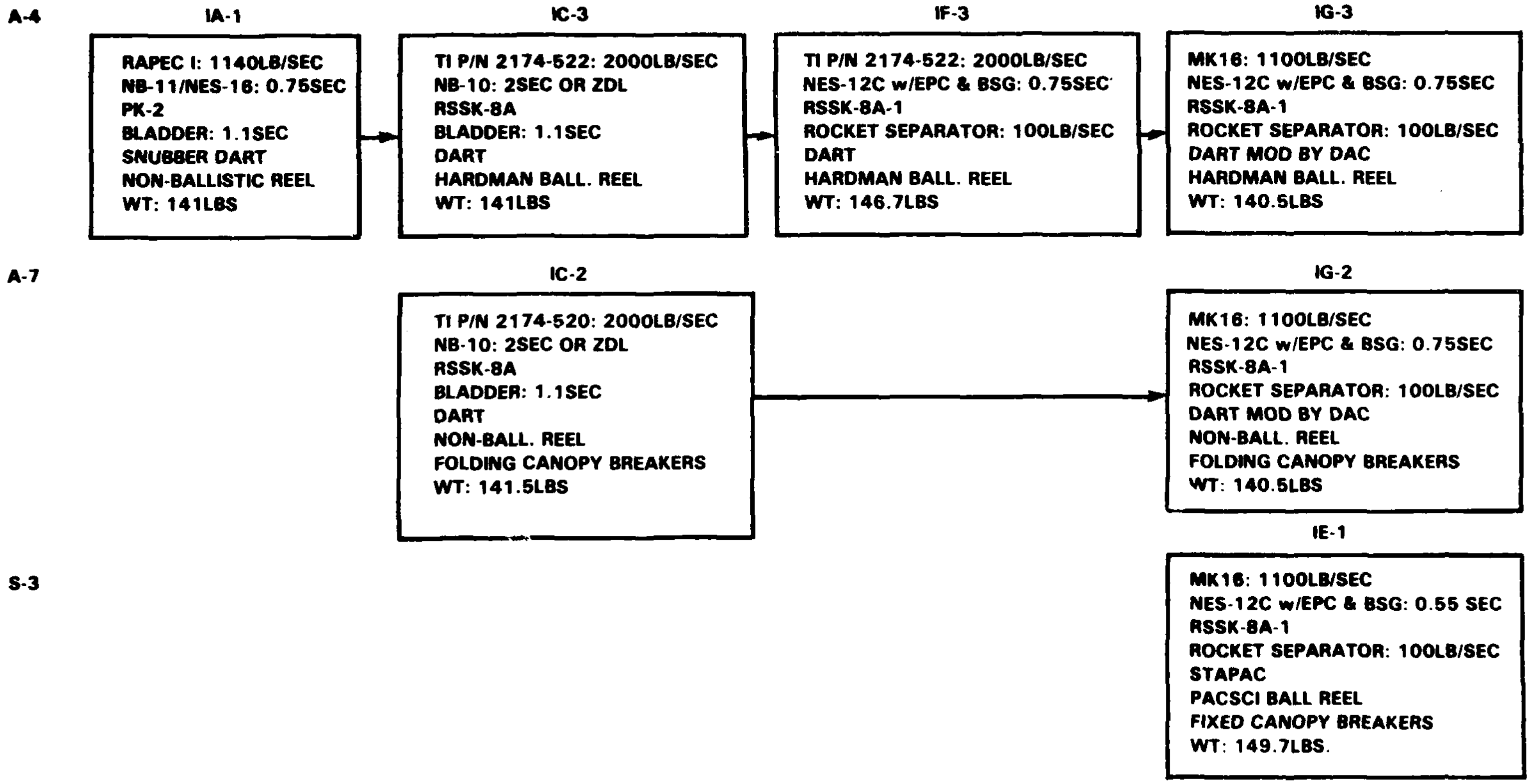


Figure 4

EVOLUTION OF ESCAPAC WITHIN SPECIFIC AIRCRAFT



A-4

IA-1

RAPEC I: 1140LB/SEC
NB-11/NES-16: 0.75SEC
PK-2
BLADDER: 1.1SEC
SNUBBER DART
NON-BALLISTIC REEL
WT: 141LBS

IC-3

TI P/N 2174-522: 2000LB/SEC
NB-10: 2SEC OR ZDL
RSSK-8A
BLADDER: 1.1SEC
DART
HARDMAN BALL. REEL
WT: 141LBS

IF-3

TI P/N 2174-522: 2000LB/SEC
NES-12C w/EPC & BSG: 0.75SEC
RSSK-8A-1
ROCKET SEPARATOR: 100LB/SEC
DART
HARDMAN BALL. REEL
WT: 146.7LBS

IG-3

MK16: 1100LB/SEC
NES-12C w/EPC & BSG: 0.75SEC
RSSK-8A-1
ROCKET SEPARATOR: 100LB/SEC
DART MOD BY DAC
HARDMAN BALL. REEL
WT: 140.5LBS

A-7

IC-2

TI P/N 2174-520: 2000LB/SEC
NB-10: 2SEC OR ZDL
RSSK-8A
BLADDER: 1.1SEC
DART
NON-BALL. REEL
FOLDING CANOPY BREAKERS
WT: 141.5LBS

IG-2

MK16: 1100LB/SEC
NES-12C w/EPC & BSG: 0.75SEC
RSSK-8A-1
ROCKET SEPARATOR: 100LB/SEC
DART MOD BY DAC
NON-BALL. REEL
FOLDING CANOPY BREAKERS
WT: 140.5LBS

S-3

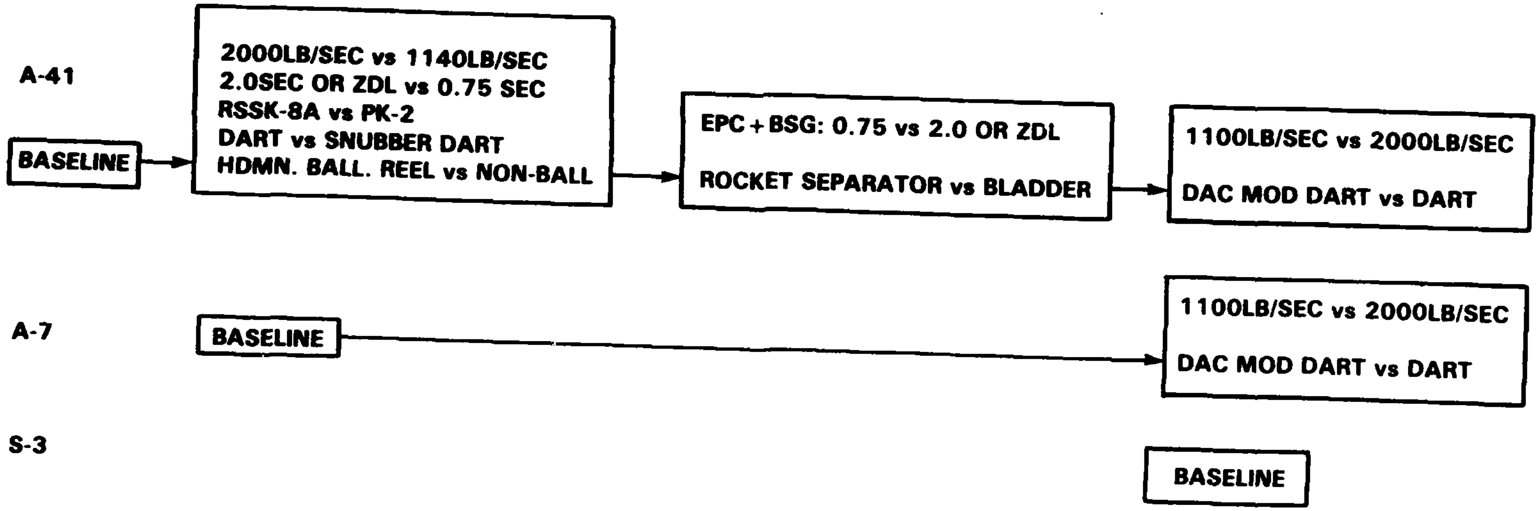
IE-1

MK16: 1100LB/SEC
NES-12C w/EPC & BSG: 0.55 SEC
RSSK-8A-1
ROCKET SEPARATOR: 100LB/SEC
STAPAC
PACSCI BALL REEL
FIXED CANOPY BREAKERS
WT: 149.7LBS.

Figure 5

]

EVOLUTION OF ESCAPAC WITHIN SPECIFIC AIRCRAFT CONFIGURATION CHANGES ALONG EVOLUTIONARY PATH



A-41

BASELINE

2000LB/SEC vs 1140LB/SEC
2.0SEC OR ZDL vs 0.75 SEC
RSSK-8A vs PK-2
DART vs SNUBBER DART
HDMN. BALL. REEL vs NON-BALL

EPC+BSG: 0.75 vs 2.0 OR ZDL
ROCKET SEPARATOR vs BLADDER

1100LB/SEC vs 2000LB/SEC
DAC MOD DART vs DART

A-7

BASELINE

1100LB/SEC vs 2000LB/SEC
DAC MOD DART vs DART

S-3

BASELINE

Figure 6

SIGNIFICANT ESCAPAC CONFIGURATION DIFFERENCES
A-4 vs A-7

A-4	**ESCAPAC IC-3** **BASELINE**	**ESCAPAC IG-3** **BASELINE**
A-7	**ESCAPAC IC-2** **NON-BALL. vs HDMN. BALL. REEL** **FOLDING CANOPY BREAKERS vs NONE**	**ESCAPAC IG-2** **NON-BALL. vs HDMN. BALL. REEL** **FOLDING CANOPY BREAKERS**

Figure 7

SIGNIFICANT ESCAPAC CONFIGURATION DIFFERENCES
A-4 vs S-3

A-4	ESCAPAC IG-3 BASELINE
S-3	ESCAPAC IE-1 0.55 SEC. vs 0.75 SEC. PARA. PACK OPEN STAPAC vs DAC DART PACSCI BALL. REEL vs HDMN. BALL. REEL FIXED CANOPY BREAKERS vs NONE

Figure 8

SIGNIFICANT ESCAPAC CONFIGURATION DIFFERENCES
A-7 vs S-3

A-7	ESCAPAC IG—2 BASELINE
S-3	ESCAPAC IE-1 0.55 SEC. vs 0.75 SEC. PARA. PACK OPEN STAPAC vs DAC MOD. DART PACSCI BALL. REEL vs NON-BALL. REEL FIXED CANOPY BRKRS. vs FOLDING CANOPY BRKRS.

Figure 9

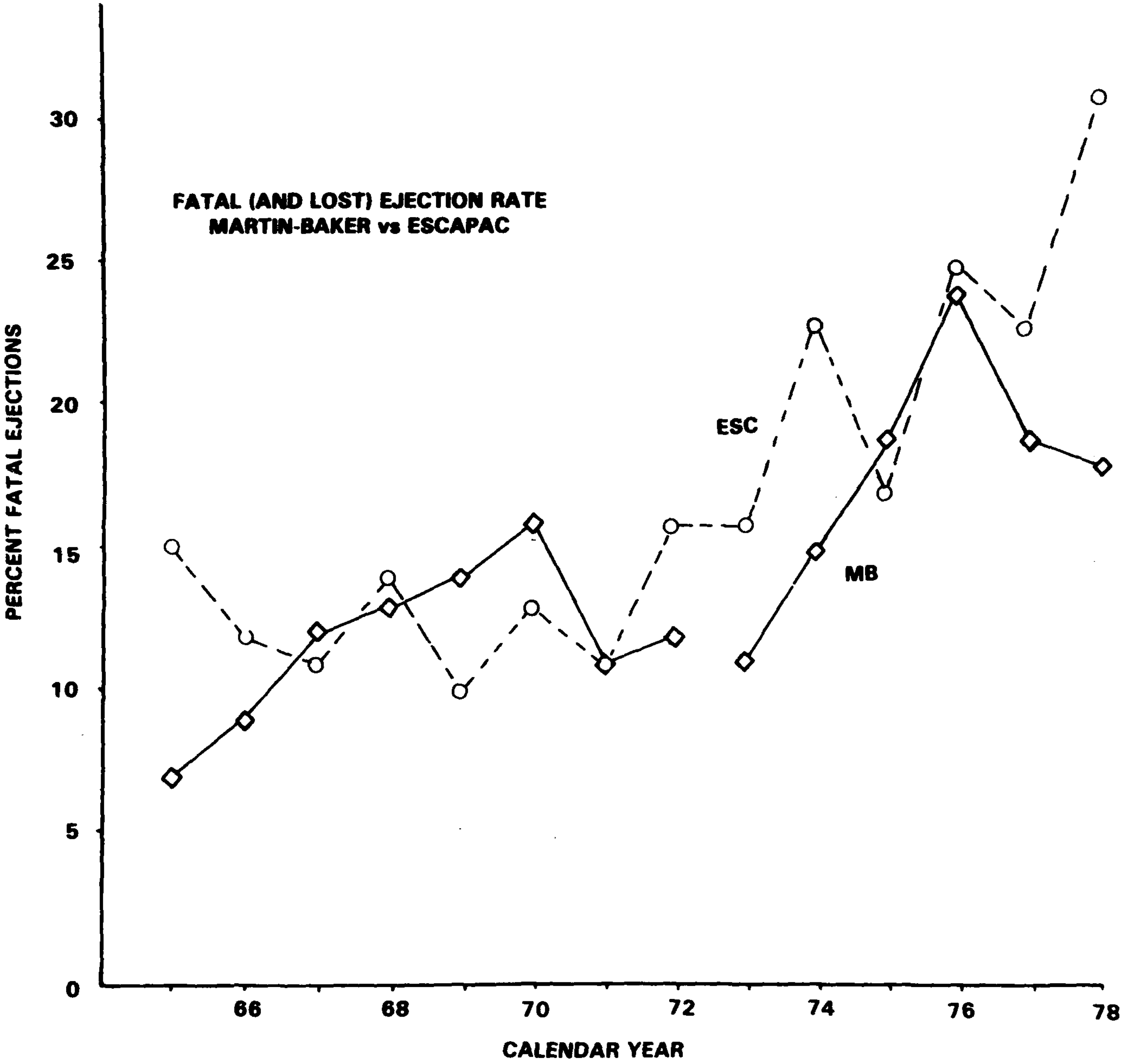

FATAL (AND LOST) EJECTION RATE
MARTIN-BAKER vs ESCAPAC
PERCENT FATAL EJECTIONS
30
25
20
15
10
5
0
ESC
MB
66
68
70
72
74
76
78
CALENDAR YEAR

Figure 10

(CY1974 THROUGH JUNE 30 1978)
(DAS TIME FRAME)

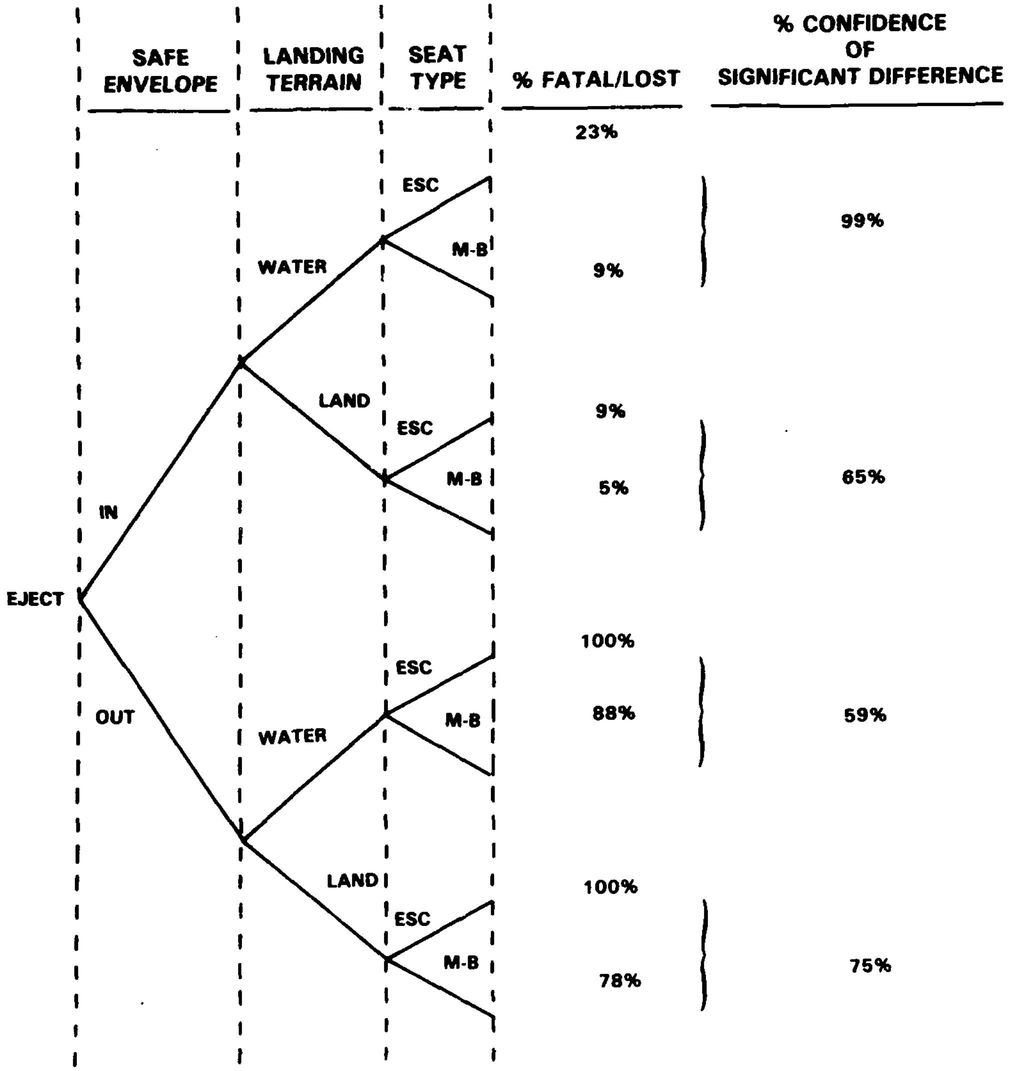
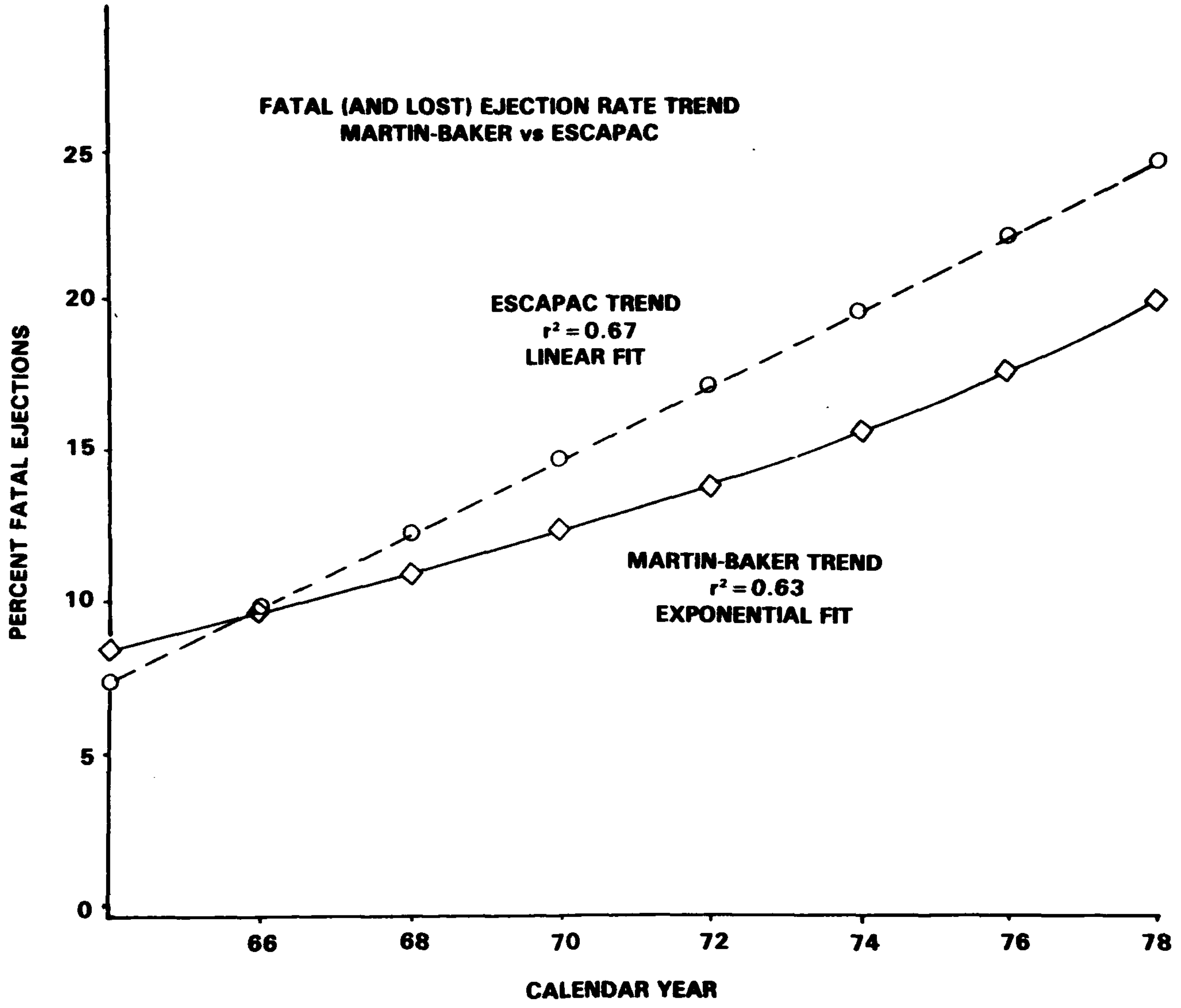


Figure 11



FATAL (AND LOST) EJECTION RATE TREND
MARTIN-BAKER vs ESCAPAC

Figure 12

ESCAPAC vs MARTIN-BAKER FATAL/LOST DIAGRAM

(CY1969 THROUGH CY1973)

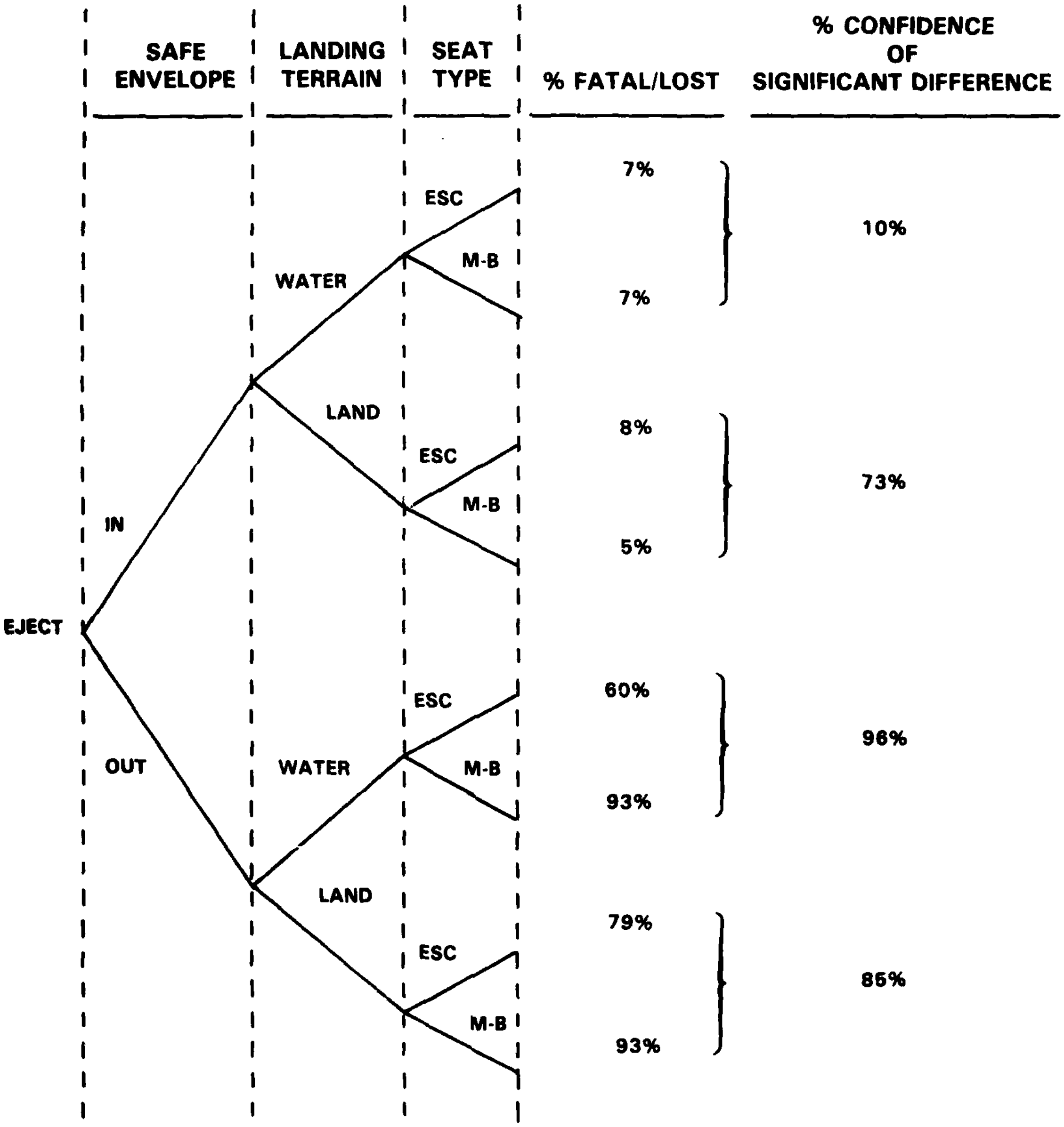


Figure 13

CHANGES IN ESCAPAC INJURY RATES OVER THE PAST DECADE

INJURY	1969 – 1973 (INCL.)	1974 – 1978 (INCL.)	△
FATAL/LOST	13%	23%	+10%
MAJOR	14%	17%	+ 3%
MINOR/MINIMAL/NONE	73%	60%	−13%
TOTAL # EJECTIONS	336	149	−187

% CONFIDENCE OF SIGNIFICANT DIFFERENCE 99%
(I.E., . . . AT A CONFIDENCE LEVEL OF 99%, THE INJURY CATEGORIES REFLECT TWO DISTINCT SAMPLE POPULATIONS RATHER THAN RANDOM OCCURRENCES DRAWN FROM THE SAME POPULATION).

Figure 14

DATA PERIOD: 1/169 THRU 12/31/73

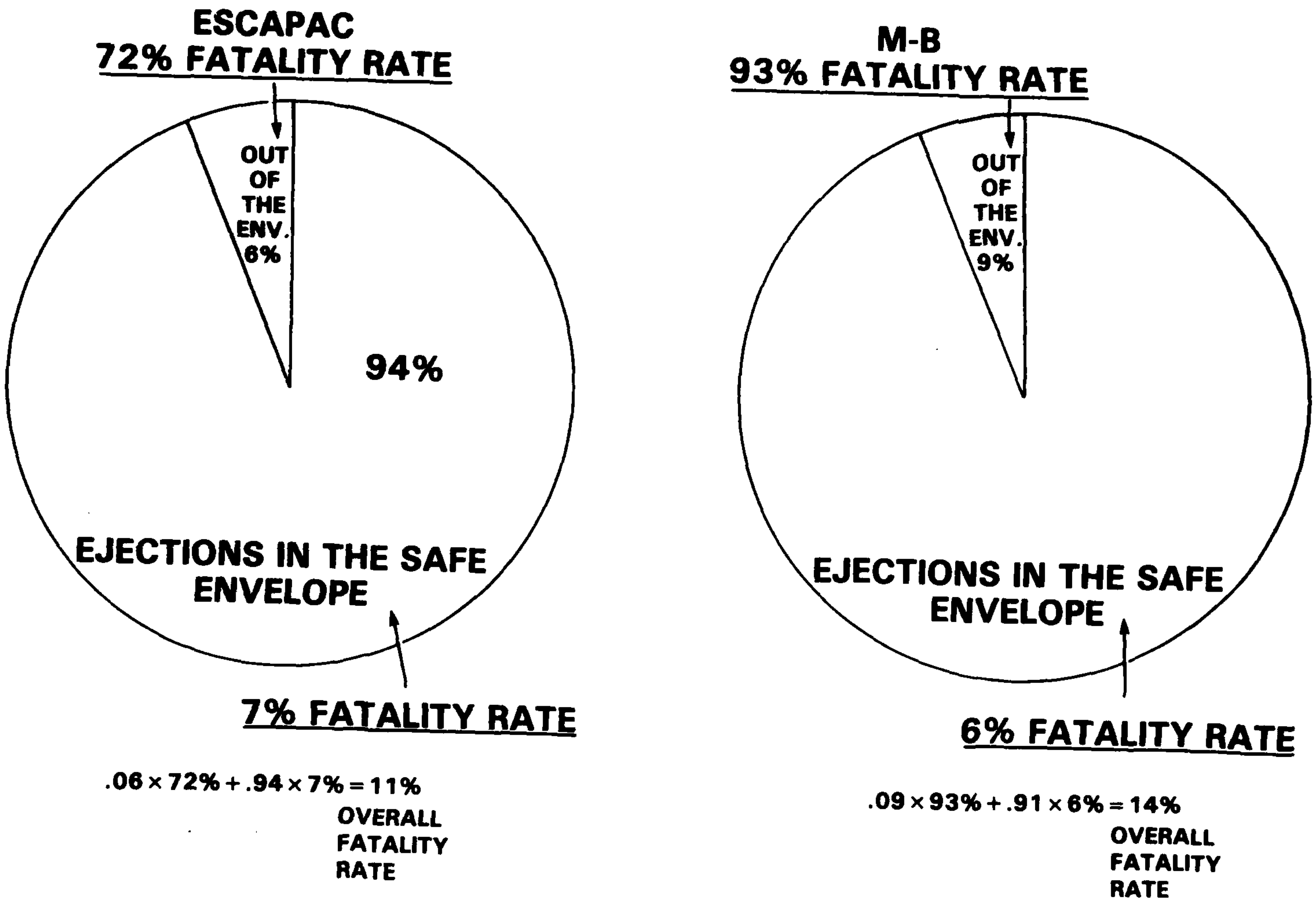


Figure 15

WHY ARE THE FATALITY RATES APPROXIMATELY EQUAL FOR ESCAPAC AND MARTIN-BAKER FOR THE PERIOD 1/1/74-6/30/78?

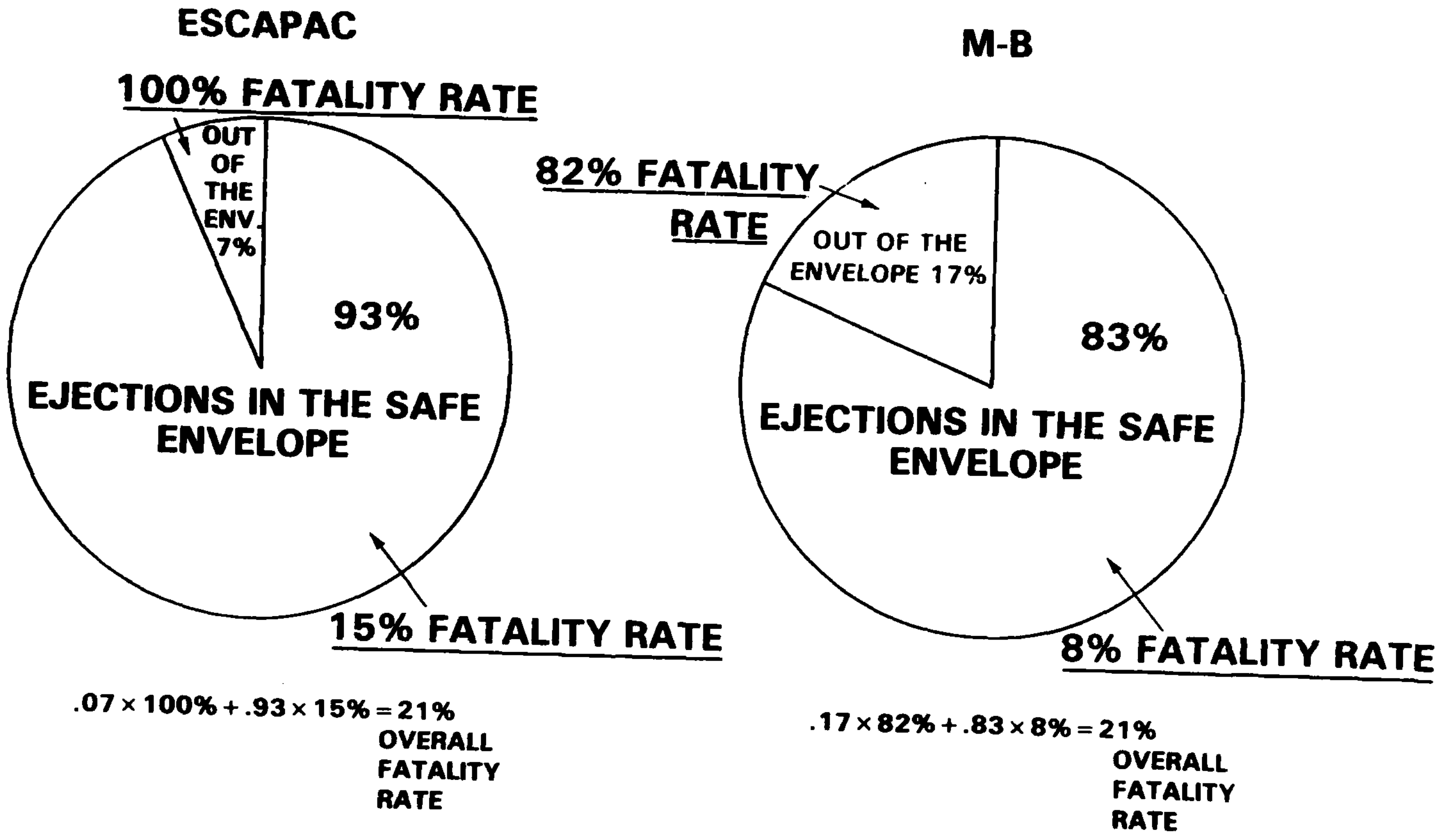


Figure 16

1/1/74 — 6/30/78

COMPARATIVE FATALITY RATES WHILE EJECTING IN THE SAFE ENVELOPE

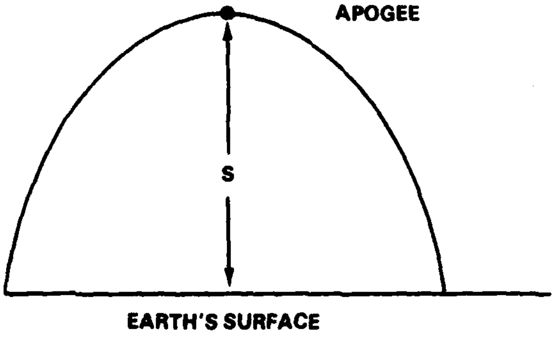
WATER ONLY

SEAT	# EJECTIONS	% TOTAL & LOST	% SURVIVORS
ESCAPAC	56	23%	77%
MARTIN-BAKER	117	9%	91%
% CONFIDENCE OF SIGNIFICANT DIFFERENCE	99%		

*ESCAPAC FATALITY RATE FOR ALL "IN ENVELOPE — WATER" EJECTION ATTEMPTS GREATER THAN 2X LARGER THAN MBA's.

Figure 17

FREE FALL AND TOTAL TRAJECTORY TIMES FOR GIVEN TRAJECTORY HEIGHTS ABOVE EARTH'S SURFACE



$s = \frac{1}{2} AT^2$

$\therefore t_{f.f.} = \sqrt{\frac{2S}{a}}$

WHERE $a = 32.2$fps

$t_{TRAJ.\ TOTAL} \geq 2t^{FREE\ FALL}$

s (FEET)	$t_{FREE\ FALL}$ (SECONDS)	$t_{TRAJ.\ TOTAL}$ (SECONDS)
0	0	0
25	1.25	2.49
50	1.76	3.52
75	2.16	4.32
100	2.49	4.98
125	2.79	5.57
150	3.05	6.10
175	3.30	6.59
200	3.52	7.05
225	3.74	7.48
250	3.94	7.88
275	4.13	8.27
300	4.32	8.63
325	4.49	8.99
350	4.66	9.33
375	4.83	9.65
400	4.98	9.97
425	5.14	10.28
450	5.29	10.57
475	5.43	10.86
500	5.57	11.15

Figure 18

EVOLUTION OF U.S. NAVY ESCAPAC ESCAPE CAPABILITY (COMPARATIVE 50TH PERCENTILE DATA)

TYPE ESCAPAC	TRAJECTORY APOGEE/PARACHUTE FIRST INFLATION/EJECTEE RECOVERY UPRIGHT WINGS LEVEL, NOSE LEVEL 100 KTS (FEET) [APOGEE/INFLATION/RECOVERY]	PARACHUTE FIRST INFLATION/ MINIMUM TERRAIN CLEARANCE ALTITUDE REQUIRED INVERTED, WINGS LEVEL, NOSE LEVEL 100 KTS (FEET BELOW AIRCRAFT) (INFLATION/RECOVERY)
IC-2	155/145/110	398/ 420
IC-3	155/145/110	398/ 420
IE-1	167/165/122	−293/−324
IF-3	131 KTS SLED 3RD% 246/246/197 98TH% 115/115/106	NO DATA
IG-2	139/136/94	−300/−336
IG-3	139/136/94	−300/−336

Figure 19

INTRODUCTORY NOTES

"ILITIES" ASPECTS OF AAES

Increasingly in all technological fields, there has developed an awareness that although designers are trained to consider all aspects of a design problem, there exist needs for design knowledgeable specialists capable of examining designs from highly specialized, analytical, worst case or "what if" viewponts. Thus an area of design analyses, often termed "ilities" has evolved to ensure full consideration of these worst case or "what if" aspects of design.

The term "ilities", itself derives from the ending of many of these specialties which began with reliability and now include:

- Reliability
- Maintainability
- Systems Safety
- Human Factors
- Systems Vulnerability
- Hazards of Electromagnetic Radiation

and other highly specialized fields.

Increasingly, as problems with shared characteristics have occurred and recurred, first ad hoc efforts would be made to solve the problems and, frequently, since the problems would persist in some manner with consequences deemed undesirable, resources would be deliberately planned within programs to address the prevention or, at the very least, the control of the problems and their consequences. Thus, slowly, a cadre of individuals would acquire a highly specialized and unique experience and body of knowledge and would evolve techniques for the optimal management of these types of problems. Frequently, from these beginnings, have evolved the design critical analyses specialties commonly grouped together as "ilities".

Acceptance of these "over-the-shoulder" onlookers and criticizers by designers (and in the case of newer "ilities", by the older, established "ilities") has generally been slow and with considerable reluctance; in part due to their education during which they were taught to consider and analyze all factors in developing a design, in short, to take and exercise full responsibility for achieving an optimal system design. Another important factor retarding the acceptance of "ilities" is that such specialties can be considered to represent a management expression of dissatisfaction with the designer's products. Yet another factor retarding the acceptance of "ilities" has been cost. The cost of performing an "ility", generally is visible, if not for various reasons, highly visible. The benefits derived from expenditures for "ilities" efforts seem all but, if not actually, invisible. If performed correctly, and the resulting advice heeded, then the problems of the past will not recur or their consequences will remain within acceptable limits in the newly issued systems, and the customer (Fleet) will have few, if any complaints. Then the production acquisition managers and designers will happily accept and probably claim full credit for the product's success.

"Ilities" specialists claims of having contributed in some significant manner to that success generally will be difficult to document and, even if well documented, they often will be strongly discounted by managers and designers.

The "ilities" have been especially important in AAES (as well as ALSS), even when in the early designs, not recognized by terms now familiar and not practised by the highly specialized personnel now involved in all programs, for a man's life was known to be at stake with each design and each article delivered. Today, looking back at those early attempts to assure reliability and quality, etc., they appear almost kindergartenish in comparison to today's techniques and technologies. (Probably the same will be said thirty years from now by our successors.) Increasingly, requirements have been defined and written into specifications to be invoked in future procurements. An examination of the ejection seat specifications, from those preceding the basic MIL-S-18471 (design) and MIL-E-9426 (test) to the latest revisions of these specification and their associated, AAES specialized AAES "ilities" specifications, will reveal a major growth in the importance of, and an associated major increase in an AAES program's resources devoted to, the application of the "ilities".

There nave been, and there remain, many problems as the attempt is made to benefit AAES and, thereby, aircrew safety, with "ilities". Many of the "ilities" required modification due to the "one shot" nature of AAES. Many of the "ilities" are extremely new and rapidly evolving and hence changing. Many of the "ilities" have become seemingly reports and other paperwork oriented as opposed to design impact oriented in their execution, i.e., many "ilities" practitioners have reached the stage of being more interested in receiving properly formatted reports than in ensuring that the critical information is inserted into the design process in a timely, and therefore cost effective, manner. These and other problems in the interfacing of AAES (and ALSS) and the "ilities" are being addressed and are not always unique to the AAES (and ALSS) "ilities" interfacings but occur in the "ilities" interfacings with other equipments and systems as well.

The following five papers briefly address a few of the AAES - "ilities" problems. The first paper addresses the problems which essentially rule out the use of in-service experience in estimating an AAES reliability. The second paper outlines broadly the dichotomy faced in AAES design concerning aircrew safety during emergencies and the safety of all personnel encountering AAES under other conditions. The paper briefly indicates a growing ability within the AAES/ALSS Equipments In-Service Usage Data Analysis program to examine this issue and the intent, as resources permit, to explore and define that ability. The third paper briefly outlines another "ilities" aspect requiring fuller design attention; that of ensuring through attentive design the in-service quality assurance, i.e., ensuring both correctness of maintenance and the ability to inspect and verify its correctness. The fourth paper discusses briefly the problems inherent in assuring acquisition and retention of the requisite quantity and quality of AAES test data and in assuring that delivered articles possess the required quality; both often extremely difficult tasks. The paper provides illustrations of two similar techniques, in their full detail, which, if employed in the early stages of a program, might provide assistance in ensuring achievement of these critical objectives and which, also, might serve as models for developing means for helping to ensure achievement of other critical objectives. The fifth and last paper in the section discussed the design problem of reducing AAES vulnerability to disablement; disablement resulting from localized aircraft damage as well as disablement resulting from actions associated with the removal or occurring after the removal of major AAES elements from crew stations (i.e., vulnerability to "friendly" actions).

PROBLEMS IN THE QUANTIFICATION OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE RELIABILITY

Frederick C. Guill

ABSTRACT

An often cited system reliability number for escape systems is that derivable for a given seat by examining its in-service record, often simply the ratio of survivors versus escape attempts. The fallacies and problems associated with this approach, including the frequent failure to recover major elements of the escape system for investigation, the varying quality of such post-ejection investigations that are conducted upon recovered elements, and the often conflicting views among would be assessors of system reliability of what consitutes a failure are discussed to explain why this approach is cited in MIL-STD-2067 as unacceptable.

PROBLEMS IN THE QUANTIFICATION OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE RELIABILITY

Frederick C. Guill

INTRODUCTION

When applied to the field of aircrew automated escape systems (AAES) many standard specialized disciplines such as Systems Reliability encounter major difficulties. In the specific case of applying the standard Systems Reliability techniques and procedures to AAES, the problems arise as a consequence of the "one-shot" nature of the majority of the elements of an AAES (i.e., once such an element of an AAES has been used it is an expended article which cannot be reused). A large portion of an AAES may be likened to a fire extinguisher sitting quietly on a wall ready for emergency use, never functioning or operating until an emergency requires its usage.

This longterm idle, "one-shot" nature of AAES differs markedly from the normal "multiple (frequent) use" and/or "continuous use" nature of devices with which reliability has long been associated and for which much of the Systems Reliability technology was developed. Therefore, no single escape critical component is able to acquire a usage history, as is the case for most other equipments, with which to make reliability estimates. Instead a collection of single performance, essentially "go no-go" performance, data are acquired during tests of large quantities of components and subsystems and, due to extremely high costs, a small number of complete AAES. Thus, then, are the data with which element and system reliabilites are estimated -- an estimate concerned with whether following an actuation attempt escape will be initiated and whether all subsequent sequenced events will occur in proper sequence, completely and properly.

In addition to the "one-shot" nature of AAES and their elements which prevents testing the functioning of elements retrieved after an escape attempt, there is another very critical problem affecting the ability of employing Systems Reliability technology in assessing AAES in their in-service environments. This problem is the high potential for non-recovery of many, if not all, elements of an AAES following its in-service usage. This latter aspect results in the loss of a very large proportion of U.S. Navy AAES following their use and, therefore, the loss of much evidence concerning how well or how poorly each individual AAES and each specific type AAES in fact performed. It is important to realize that survival of an ejectee does not mean that the system used did not experience one or more critical failures as the type landing terrain (e.g., snow, mud, water, etc.) may have been very forgiving, the ejectee may have overcome the problem(s) manually, or other mitigating circumstances may have operated in favor of the ejectee's survival. On the other hand, non-survival of an ejectee does not necessarily mean that there was in fact a critical failure of the system. Conditions of escape could have precluded safe escape (e.g., ejection outside of the system performance envelope), the ejectee could have manually induced a system failure (e.g., many "beat the system" efforts were only partially completed, totally disrupting the automatic operation of the post-boost phase functions of the escape sequence), the system could have been damaged during or as a consequence of the events resulting in disablement of the aircraft and the need for the escape attempt, or the terrain or environment (e.g., water, cold temperatures, hail, etc.) may have contributed to, or caused, the ejectee's death.

As a consequence, the U.S. Navy has expressed in MIL-STD-2067(AS), "Aircrew Automated Escape Systems, Reliability and Maintainability (R/M) Program, Requirements for," the following position concerning use of in-service ejection data, especially a system's succes rate, for assessing AAES reliability:

> "3.2.6 In-Service Success Rate. That percentage of ejecting aircrew who survived through separation from the escape system and surface contact. Includes many "lucky" or "fluke" saves from among the "out-of-envelope" ejections, unsuccessful (non-malfunction) "out-of-envelope" ejections, other non-malfunction fatalities, and system malfunction caused fatalities. Separation of these effects to correct the success rate to obtain a measure of in-service reliability is a matter of judgemental interpretation of accident data of varying veracity and as such is not an acceptable quantification of AAES reliability."

As a consequence of these cited and oft-experienced difficulties as well as other difficulties, the U.S. Navy assessment of AAES reliability is based upon an amalgamation of component and system testing conducted under specified, controlled conditions and followed by thorough, detailed, expert post-test retrieval of the test article remains, investigation of the test data and all of the hardware recovered from the test, and the systematic collection, test-to-test comparisons and test series group analyses of the resultant data. (This effort, especially the thorough examination of hardware recovered after a test, has been termed Marginality of Success, or MOS, and is directed towards the identification of potential and experienced problems and the assessment of the potential severity of their consequences on ejectee safety.) These data are factored with other test derived data to derive an estimate of system reliability, using the conservative approach delineated in Figures 1 through 3 to obtain a probabilistic estimate as opposed to the simple point estimate derivable by dividing the number of failures by the number of tests. The probabilistic estimate is lower than a point estimate, given the same data. The probabilistic estimate, derived using lower confidence limits (LCLs), results in an estimate with a limited probability that the true system reliability value, which cannot be measured directly, is less then the estimate, i.e., the true value of system reliability is therefore highly likely to be greater than the LCL estimate of system reliability. This information is presented to, and considered by, contractor and Navy team members in assessing system design and its readiness for introduction into the Fleet.

ASSESSING IN-SERVICE AAES RELIABILITY

Occasionally, despite the difficulties inherent in the task, it becomes necessary to assess or compare AAES in-service reliability. It is instructive to examine these attempts as they clearly illustrate many of the difficulties to be experienced. One recent such effort was that of two different groups separately assessing the in-service reliability of ESCAPAC series ejection seats (used by the Navy in A-4, TA-4, A-7, TA-7, and S-3 series aircraft).

One group in examining the record for ESCAPAC ejection seats as presented in the Naval Safety Center computerized MOR (Medical Officer's Report) and similar Air Force data extracts found that "... of the 179 ejections during the period January 1974 through June 1, 1978, only 4 (2 percent) involved equipment failures of the seat...98 percent reliability rate..." [1] The same group found "...7 (4 percent) of the 179 ejections during the 4 1/2 year period reviewed involved equipment failures that emanated from faulty maintenance work..." [2] Thus that group in examining the secondary records provided to them for 179 ESCAPAC ejections found evidence of 11 failures. The 179 ejections were reported by that group to have involved 40 U.S. Air Force and 139 Navy ESCAPAC series ejection seats.

A detailed, in-depth examination by a second group of the original records, Medical Officer's Reports (MORs), for 140 U.S. Navy ESCAPAC series ejections (the two groups inexplicably differ by 1 in their totals) occurring during the same period (1 January 1974 through 1 June 1978) revealed evidence of 21 failures during the 140 ejections (Figure 4). Several very important aspects contributing to the obviously different totals of failures are the differences between them concerning: (1) the definition of "failure" employed by those performing the reliability assessments, (2) understanding of the AAES design and designed functioning, (3) the sources of their data, (4) the depth of examination of that data and its sources, and (5) understanding of how that data is generated and the experience and expertise variance among those preparing that data. The U.S. Navy employs a very strict, rigorous definition of "failure"; presented in Figure 5. In addition, the second group examined the original source documents (MORs) in extreme detail thereby uncovering many descriptions of failures not specifically cited or designated as failures but which should have been so cited or designated in the appropriate locations in the original reports. These non-designations and non-citations resulted in the secondary source documentation used by the first group having no failure callouts in many of these escape cases.

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[1] Defense Audit Service (DAS) Report No. 79-130, page 4

[2] Ibid.

Another critical aspect governing assessment of AAES in-service ejections reliability is illustrated in Figures 6 through 9. During the period from 1 January 1969 through 1 June 1974 the U.S. Navy experienced 470 ejections using ESCAPAC series ejection seats. Of these 201 occurred overwater and 269 overland. With only a few unique exceptions none of the significant AAES elements involved in overwater ejections were recovered, whereas in most overland ejection cases most major elements of the AAES involved were recovered. Thus in most instances failures occurring during overwater escapes could not be detected or, if obvious to the ejectee or to observers, could not be investigated satisfactorily to a degree sufficient to permit identification without question of the causal factors and mechanisms.

For the specific period in which the one group discovered 11 failures and the other 21 failures, only 80 of the 140 ESCAPAC ejections were over land (and hence the seats were generally recovered) or over water with the seats later recovered. 17 of the 21 known failures occurred amongst the 80 recovered or recoverable seats (Figure 9). And only 4 were reported amongst the 60 over water ESCAPAC ejections in which the elements were lost. This difference in reported failure rates, when one examines the available records, appears clearly related to the frequent examination of hardware following overland ejections and the extremely infrequent hardware retrieval and examination following ejection over water. A statistical examination of these failure rates of highly similar, and in many instances identical, design ejection seats quickly reveals the failure rate among the overland and recovered seats (0.21) to be statistically significantly greater (indicating, therefore, that the difference is extremely unlikely to be due to chance) than that for the seats lost over water (0.07), suggesting that many seats containing evidence of significant failures remain hidden deep within Davy Jones' locker as it is unlikely that the seats used overwater would have experienced such an improvement in reliability over that experienced by essentialy the same seats when used overland.

Thus for the entire ESCAPAC family, the first group assessed ESCAPAC series ejection seats' in-service reliability by direct computation as 94 per cent [(179-11) ÷ 179] (this group divided failures into "reliability" and "maintainability" types of failures with a 2 percent and a 4 percent degradation, respectively). The second group using the same technique (direct computation) assessed in-service reliability either as 85 percent [(140-21) ÷ 140] (based on all ejection attempts) or as 79 percent [(80-17) ÷ 80] (based on overland recoverable and actually recovered overwater ejection attempts). These differences in computed reliability are a consequence of the use of different source documents, a consequence of differring assessments concerning what constitutes a failure, a consequence of differences in the investigators' knowledge of the detailed functioning of each of the ejection seats used, and, also, as a consequence of discounting or not discounting those seats not recovered.

However, two other critical factors are involved in assessing system reliability:

- o Using standard conservative statistical reliability estimation procedures, such as a lower confidence limit estimate (specified by MIL-STD-2067 as $R_{.90LCL}$), and
- o Effects of design differences between the individual seats comprising a family such as the ESCAPAC series seats.

The first factor occurs as a consequence of the nature of reliability which, although it is an inherent feature of a system's design, cannot be directly measured. Reliability, therefore, is a design attribute which must be estimated on the basis of observed results of a series of system trials. To provide an aid in assessing the probable accuracy of such estimates, a statistical estimation process is employed (Figure 2) which attempts to "bound" the true (or actual) system reliability between an upper bound (upper confidence limit: UCL) and lower bound (lower confidence limit: LCL), essentially thereby a confidence interval. What is created then is an estimate of the probability that the true reliability value of the system is greater than the upper estimate and/or lower than the lower estimate. This figure illustrates the derivation of the 90 per cent confidence interval for which the lower single sided confidence R_{LCL} of 95 per cent estimate forms the lower statistical estimate of the system reliability. The probability, by definition of a system's true reliability being less than this $R_{.95LCL}$ estimate is 5 percent (i.e. the probability that the true system reliability is equal to or greater than the $R_{.95LCL}$ estimate is 95 percent). In a similar manner, the probability that the true reliability value is greater than the 95 per cent upper confidence single sided limited ($R_{.95UCL}$) is only 5 per cent (i.e., the probability of the true value being less than the estimate is 95 per cent). The combination of these two 95 per cent single side confidence limits results in a 90 per cent confidence interval commonly expressed in reliability specifications as $R_{.90LCL}$, where LCL is defined as lower confidence level but in fact defines the confidence interval.

The effect of this statistical approach to estimating system reliablity results in a lower, more conservative estimated value than that obtained using the direct computational method (Figure 9), i.e. for 17 failures amongst 80 ejections $R_{.90LCL}$ value is 71 percent versus the direct computational value of 79 percent.

It must be acknowledged that even minor seeming differences in designs can produce differences, often very major, in reliability. Thus the presence of design differences between seat types comprising a seat family (e.g., ESCAPAC) requires that reliability be assessed seat-type-by-seat-type as shown in Figure 10. Largely as a consequence of extreme variations in population sizes (i.e., numbers of ejections for each type seat) and, to some degree as a consequence of the differences in numbers of failures for each type seat, these individual seat type $R_{.90LCL}$ estimates shown in Figure 10 vary considerably and for several of the seat types could change dramatically should future recovered ejected seats not reveal evidence of any failures.

OTHER AAES CHARACTERISTICS IMPACTING UPON ESTIMATING OF AAES IN-SERVICE RELIABILITY

AAES in-service reliability characteristics and impacts differ significantly in many ways from those of more common equipments used often and for long periods of time. As yet these have not been critically examined in depth, but it is important that these characteristics and impacts be recognized. Among these characteristics and impacts are:

- Age (calendar) sensitivity (i.e. as opposed to flight and/or flight hour sensitivity) of many AAES elements. Because of this age sensitivity, many elements must be maintained and replaced at regular calender intervals irrespective of the numbers of flights and/or flight hours accumulated by the element while installed.

- Post-usage investigation of AAES and their elements. As previously discussed, many Navy AAES and their elements are not recovered after usage thereby resulting in the loss of evidence concerning how well or how poorly the system and its elements functioned. Those which are recovered are subjected to varying degrees of post-usage investigation. Based upon the reports which have been submitted, usually MORs, many of these investigations appear superficial and there is apparent a wide variation in the expertise and the investigative skills, ability and interest of those conducting the post-usage investigations as well as of those preparing the reports of the investigative results.

- Actions resulting from discovery of a failure. As previously discussed, many elements of AAES are "one-shot" elements for which post-usage repair/refurbishment either is impractical or for aircrew safety reasons (e.g., stress imposed upon the item is unknown, hence if refurbished and reused it might fail) not permitted, thus dictating the consignment of these elements to the scrap heap once the post-usage investigation has been completed and documented. Unless the investigation for these types of AAES elements indicates that the failure probably is not an isolated incident (i.e., indicating that other escape attempts using that AAES element's design and its maintenance procedures are likely to experience similar failures), it is unlikely that any action will occur concerning those remaining in Navy AAES inventory since there is considerable concern regarding the potential that inspection to ascertain the presence of the potentially dangerous condition (especially when inspection requires some teardown or removal of the AAES or any of its elements) may introduce far more problems than will be detected and resolved.

- Limits on eliminating single point failures in AAES designs. Many of the "one-shot" AAES elements are especially critical since there are no effective, acceptable means for providing either redundant or back-up elements. Examples include personnel parachute, propulsion units and even critical portions of AAES initiation subsystems. (Space limitations and the need for aircrew mobility while performing as aircrew, for example, preclude the use of a manually actuated reserve parachute such as is common for parachutists.)

These types of AAES in-service reliability characteristics and their impacts can be expected to exert strong influences on in-service System Maintainability and on System Life Cycle Cost (LCC). Among common aspects of maintainability expected to be influenced are:

- In-service DMMH/FH (direct maintenance man-hours per flight hour)
- In-service MTTR (mean time to repair)
- In-service $M_{max_{ct}}$ (maximum corrective maintenance time)
- In-service MTBF (mean time between failures)

with attendant impacts upon spares policy and maintenance personnel staffing policy.

Among the aspects of LCC which can be expected to be strongly influenced by these AAES in-service reliability characteristics and impacts are the relationships between:

- R&D (research and development) costs

- Acquisition costs

- O&S (operation and servicing) costs

It can be expected that for many AAES elements, O&S costs will represent a significantly smaller proportion of the total LCC than for similar types of devices in applications experiencing the wear and tear associated with frequent and/or long usage. These aspects and impacts are discussed in greater detail in other reports.

CONCLUSION

The problem of assuring high in-service reliability is a critical one, and, although the in-service usage data cannot and should not be ignored (the data might reveal failure types not discovered or anticipated during design analyses, evaluation and test), system reliability should not be estimated strictly on the bases of these data but, rather on the bases of test programs testing to system design limits and allowing collection of performance data and the careful retrieval and expert post-usage examination of all elements of the AAES.

SYSTEM RELIABILITY

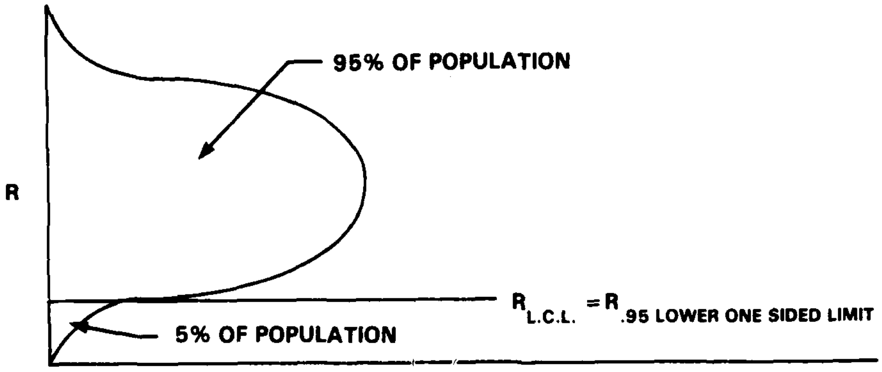
- TRUE VALUE OF NON-PHYSICAL ATTRIBUTES INCAPABLE OF BEING DIRECTLY MEASURED CAN ONLY BE ESTIMATED THROUGH OBSERVING RESULTS OF TRIALS OF SYSTEM POSSESSING THOSE ATTRIBUTES.

- ESTIMATION PROCESSES INVOLVE ATTEMPTING TO "BOUND" TRUE VALUE WITHIN AN UPPER BOUND AND A LOWER BOUND.

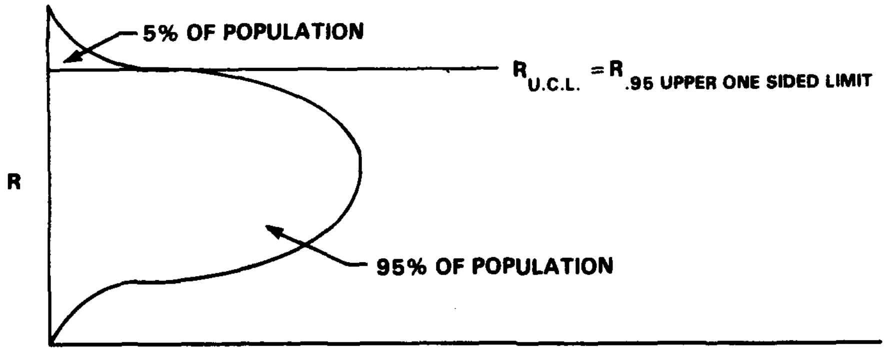
- BOUNDING TECHNIQUES INVOLVE STATISTICAL LIKELIHOOD THAT TRUE VALUE IS EITHER:
  - GREATER THAN UPPER BOUND, OR
  - LESS THAN LOWER BOUND.

- THIS "CONFIDENCE LEVEL" IS MEANS FOR EXPRESSING PROBABILITY THAT TRUE VALUE BEING ESTIMATED IS CONTAINED WITHIN THE ESTIMATED BOUNDS.

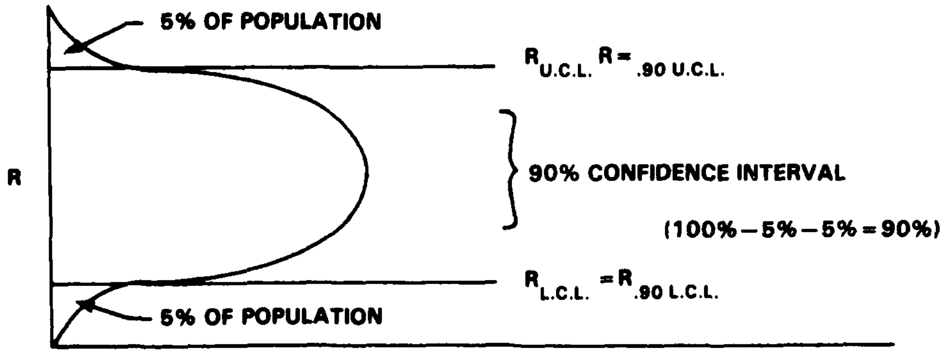
Figure 1



LOWER ONE SIDED LIMIT



UPPER ONE SIDED LIMIT



COMBINED LOWER AND UPPER ONE SIDED LIMITS
WITH LOWER AND UPPER CONFIDENCE INTERVAL LIMITS

Figure 2

SAMPLE CALCULATIONS FOR 90% CONFIDENCE INTERVAL

- PROBABILITY TRUE SYSTEM RELIABILITY GREATER THAN 90% UPPER CONFIDENCE LEVEL VALUE:

$$\frac{1 - \text{CONFIDENCE INTERVAL}}{2} = \frac{1 - .90}{2} = .05$$

- PROBABILITY TRUE SYSTEM RELIABILITY LESS THAN 90% LOWER CONFIDENCE LEVEL VALUE:

$$\frac{1 - \text{CONFIDENCE INTERVAL}}{2} = \frac{1 - .90}{2} = .05$$

- PROBABILITY TRUE SYSTEM RELIABILITY EQUAL TO, OR GREATER THAN 90% LOWER CONFIDENCE LEVEL VALUE:

$$\frac{1 + \text{CONFIDENCE INTERVAL}}{2} = \frac{1 + .90}{2} = .95$$

Figure 3

NAVY IDENTIFIED
ESCAPAC FAILURES DURING PERIOD
REVIEWED BY DAS 1/1/74-6/30/78

2 — RSSK — PREMATURE OPENING AT SEPARATION
4 — RSSK — OPENING PREVENTED BY DAMAGE AT SEPARATION
3 — LANYARD FAILURES
3 — SEAT MAN SEPARATION FAILURES
3 — SEAT FAILED TO FIRE
1 — WINDBLAST INDUCED EJECTION
2 — SUSTAINER ROCKET FAILURES
1 — LOWER HANDLE FAILED
1 — PARACHUTE DID NOT DEPLOY (ARMING CABLE RELEASE)
1 — CANOPY BREAKERS FAILED

21 FAILURES IN 140 NAVY ATTEMPTS

Figure 4

U.S. NAVY DEFINITION OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) RELIABILITY SYSTEM FAILURE

MIL-S-18471 DEFINES EJECTION SEATS AS BEING ELEMENTS OF:

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

- MIL-S-18471 REQUIRES THAT ALL ESCAPE SEQUENCE EVENTS OCCUR AUTOMATICALLY FOLLOWING ACTUATION OF A SYSTEM FIRING SINGLE CONTROL.
- FAILURE OF AN ACTUATED CONTROL TO INITIATE THE ESCAPE SEQUENCE, OR, FOLLOWING SEQUENCE INITIATION, INTERRUPTION OF THAT SEQUENCE, WHETHER OR NOT THE EJECTEE MANUALLY BY-PASSES THE FAILURE POINT, CONSTITUTES A SYSTEM FAILURE.

Figure 5

1/1/69 — 12/31/78

ESCAPAC TOTAL EJECTIONS

A-4	IA-1 88 DATES: 69-78	IC-3 129 DATES: 69-77	IF-3 20 DATES: 72-77	IG-3 35 DATES: 74-78
A-7		IC-2 159 DATES: 69-76		IG-2 34 DATES: 75-78
S-3				IE-1 5 DATES: 73-78

Figure 6

1/1/69 — 12/31/78

ESCAPAC OVER WATER EJECTIONS

A-4	IA-1 35 40% DATES: 69-78	IC-3 36 28% DATES: 69-77	IF-3 12 60% DATES: 72-77	IG-3 10 29% DATES: 74-78
A-7		IC-2 86 54% DATES: 69-76		IG-2 20 59% DATES: 75-78
S-3				IE-1 2 40% DATES: 73-78

N.B. THE PERCENTAGES REFLECT THE PROPORTION OF TOTAL EJECTIONS FOR THAT SYSTEM WHICH OCCURRED OVERWATER.

Figure 7

1/1/69 — 12/31/78

ESCAPAC OVER LAND EJECTIONS

A-4	IA-1 53 60% DATES: 69-78	IC-3 93 72% DATES: 69-77	IF-3 8 40% DATES: 72-77	IG-3 25 71% DATES: 74-78
A-7		IC-2 73 46% DATES: 69-76		IG-2 14 41% DATES: 75-78
S-3				IE-1 3 60% DATES: 73-78

N.B. THE PERCENTAGES REFLECT THE PROPORTION OF TOTAL EJECTIONS FOR THAT SYSTEM WHICH OCCURRED OVERLAND.

Figure 8

COUNTING IN-SERVICE FAILURES

- USN DETAILED REVIEW OF ESCAPAC USAGE RECORDS REVEALED THAT OUT OF 140 EJECTIONS DURING PERIOD COVERED BY DAS REVIEW:
    - ONLY 80 SEATS WERE RECOVERED OR RECOVERABLE (ALL OVERLAND EJECTIONS CONSIDERED RECOVERABLE— NOT KNOWN HOW MANY WERE).
    - 21 KNOWN FAILURES WERE IDENTIFIED (DETAILS FOLLOWING CHART).
    - 17 FAILURES WERE IDENTIFIED AMONG RECOVERED/ RECOVERABLE SEATS.

- GIVEN $F=21, N=140$
  $R_{.90LCL}=.81$

- HOWEVER, SINCE 60 SEATS WERE LOST IN OCEAN AND NOT RECOVERED, MORE REALISTIC ESTIMATE GIVEN BY
  $F=17, N=80$:
  $R_{.90LCL}=.71$

Figure 9

(1/1/74 — 6/30/78)

ESTIMATES OF ESCAPAC IN-SERVICE RELIABILITY

(FOR ILLUSTRATIVE PURPOSES ONLY, DEMONSTRATING SOME OF THE PROBLEMS INVOLVED IN DEVELOPING IN-SERVICE RELIABILITY ESTIMATES FOR AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) AND THEIR COMPONENTS)

	ESCAPAC SEAT TYPE							
	IA-1	IC-2	IC-3	IE-1	IF-3	IG-2	IG-3	TOTAL
NUMBER OF IDENTIFIED FAILURES	3	3	3	1	5	3	3	21
NUMBER OF IDENTIFIED FAILURES WITH RECOVERED SEATS	3	2	2	1	3	3	2	16
TOTAL NUMBER OF ESCAPE ATTEMPTS	17	25	19	5	15	32	27	140
NUMBER OF ESCAPE ATTEMPTS WITH RECOVERED SEATS	11	13	13	5	4	15	20	81
RELIABILITY BASED UPON IDENTIFIED FAILURES AMONG RECOVERED SEATS AT 90% LCL	.436	.590	.590	.343	.013	.560	.717	.730
RELIABILITY BASED UPON ALL IDENTIFIED FAILURES AMONG THE TOTAL ATTEMPTS AT 90% LCL	.604	.718	.641	.343	.423	.775	.737	.800

N.B.: THE U.S. NAVY, FOR REASONS STATED IN PARAGRAPH 3.2.6 OF MIL-STD-2067, DOES NOT RECOGNIZE IN-SERVICE USAGE DATA ESTIMATES OF RELIABILITY TO BE VALID ESTIMATES OF SYSTEM RELIABILITY. IN ADDITION, SINCE THE INDIVIDUAL SEAT TYPE USAGE POPULATIONS ARE SMALL, THESE IN-SERVICE USAGE DATA ESTIMATES OF RELIABILITY WOULD BE EXPECTED TO VARY CONSIDERABLY AS ADDITIONAL EJECTIONS OCCUR AND THE DATA IS RECORDED.

Figure 10

IN-SERVICE SYSTEM SAFETY ASPECTS OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

Frederick C. Guill

ABSTRACT

Almost every year groundcrew personnel are reported to have sustained serious or even fatal injuries while working near or upon major elements of aircrew automated escape systems (AAES). The trade-off made between groundcrew, normal inflight aircrew and in extreme aircrew safety are discussed in explaining why such systems are of necessity and by deliberate government specification decision inherently dangerous and why the options for reducing that dangerousness are limited if in extremis aircrew are to survive.

IN-SERVICE SYSTEM SAFETY ASPECTS OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

INTRODUCTION

Aircrew automated escape systems (AAES), their major elements, and many of their components are inherently and necessarily dangerous to ground personnel, aircrew, and all other personnel entering an AAES equipped crew station or cockpit or working with or near these systems and components outside of an aircraft -- a fact requiring both recognition by, and the exercise of appropriate precautions by, all U.S. Navy personnel encountering these equipments. Actions long have been taken by both Government and contractors to assure that all aircrew and groundcrew are fully aware of the hazards and the correct handling and operating procedures for these equipments. The majority of the major hazards posed by these equipments are related to the deliberate, necessary, extensive use of pyrotechnic (explosive) materials and to the requirement that to ensure the safety of aircrew of disabled aircraft requires that immediately upon firing control actuation these equipments must initiate and complete all sequenced operations without hestitation. The trade-offs in safety have been carefully and deliberately made with the full comprehension by Government aircrew automated escape system (AAES) requirements formulators and engineering managers of the benefits to be derived and the hazards faced as a consequence of requiring and accepting these designs. The use of pyrotechnic materials is dictated by the need to store within extremely small volumes and light weights for extended periods of time the large amounts of energy needed to propel aircrew from a disabled aircraft and to power specific functions at appropriate times during the escape sequences. In these terms, the most efficient adequate source of power is chemical (explosive) compositions. The requirement for immediate and complete system reaction following actuation of the firing controls is dictated by the often minimal time available between aircrew recognition of, and reaction to, in extremis conditions and the subsequent destruction of the aircraft and all that remains within it. It should be noted, however, that requiring and recognizing that a design be such that it is inherently hazardous does not mean that requirements have not been levied by the Government and implmented by AAES designers to, by design, reduce the likelihood of inadvertently actuating an AAES or its elements. For example, the U.S. Navy's ejection seat specification, MIL-S-18471, has long required a minimal pull force and pull distance for each firing control before it actuates the system. Similarly, there are component specification requirements imposed to enhance the safety of handling, maintenance and use such as the "no fire pressure" and "all fire pressure" stipulated for gas actuated initiators, minimum pull force and stroke distance for mechanically actuated firing pins, for the U.S. Navy could ill afford systems which frequently injured personnel or damaged aircraft. Accordingly, to repeat, government engineers and technical managers have knowingly exercised their best judgement concerning the needs of the service, and the need for systems which are safe to handle, transport and maintain and yet capable of the instantaneous reaction to an aircrew's oft delayed, in extremis decision and action to escape and thereby survive.

DISCUSSION

Controlling the inherent dangers of AAES requires extreme care, especially when attempting control through design or through the use of safety devices, to prevent hazarding the very lives AAES are procured to protect -- those of aircrew in extremis. Past experience has painfully demonstrated that safety devices often kill -- shipping/handling safety devices have been found still installed on critical components in AAES which aircrew unsuccessfully attempted to use and consequently perished in and parts of ground safety pins on several occasions remained in safety pin holes after removal of the pins, thereby fatally thwarting all attempts to escape. In MIL-S-18741, the U.S. Navy (as does the U.S. Air Force in MIL-S-9479) provides design guidance and requires that system safety and other "itlities" analyses be performed and used in AAES design efforts to control the AAES dangers to Navy-acceptable levels. However, the U.S. Navy long has recognized that there are severe limitations and potentially very severe consequences in attempting design control of these hazards and, therefore, has in the past relied upon, and currently relies upon the frequent use of warning placards on the equipment (requirements spelled out in MIL-S-18471 and other governing military specifications and standards); warning notices in manuals, instruction cards and materials; and training stressing correct procedures and the dangers involved, especially the dangers involved in using incorrect procedures.

AAES also pose a multitude of lesser, more mundane hazards to U.S. Navy personnel. Due to the non-spectacular nature of mishaps which can result from a great many of these lesser hazards, and since the incidents which might and do occur usually involve only very minor degree of injury or damage, very few of these lesser incidents result in reports, especially reports reaching repositories such as the Naval Safety Center, Norfolk. (The Naval Safety Center disseminates such information as is received to the equipment acquisition commands, such as the Naval Air Systems Command and to the equipment using activities through several media, including urgent naval messages as well as periodicals such as Approach.) Typically incidents involving lesser types of hazards result in cuts, abrasions and bruises, clothing rips and tears and similar minor consequences. Perhaps their most important consequence might be in inducing poorer quality maintenance of AAES, but such cause and effect relationships cannot as yet be documented with the types and detail of available in-service data and, therefore, remain speculative issues. Nevertheless, MIL-S-18471 does require a number of design and design analysis efforts and MIL-E-9426 a number of evaluation efforts aimed at eliminating these types of hazards.

Thus, recognizing both the existance of the many potentially severe hazards and the need for their existance in AAES, the U.S. Navy has attempted through both requirements governing contractor AAES design efforts as well as extensive personnel training and instruction to effect a difficult, judicious balance between aircrew inflight safety during emergencies and the safety of all personnel at all other times when encountering AAES, their major elements and hazardous components. The questions then are: How well has the Navy succeeded? Is the record improving or worsening? What guidance for improving system design safety for ground operations without degrading emergency performance can be gleaned from the Navy's failures and successes?

IN-SERVICE AAES SAFETY

Virtually the only evidence available within U.S. Navy records concerning in-service AAES safety are those reports delineating:

- o Inadvertent actuation of AAES during flight operations (code 5 ejections), this includes preparation for and the completing of such operations by the aircrew,
- o Inadvertent actuation of AAES or elements thereof during ground operations, including aircraft and cockpit maintenance,
- o Inadvertent actuation of AAES or elements thereof during AAES maintenance,
- o Failure of AAES to function or to function completely following deliberate actuation of firing controls by the crewmember.

and injuries and/or damage resulting from the inflight, ground handling, transportation, or maintenance anomalous behavior of the system or elements in question.

At the time this paper was prepared, AAES data pertinent to system safety, with the exception of inadvertent AAES actuation during flight operations, had not been examined in detail; however, some available data was assembled and are presented as Figure 1 concerning hazards posed by various ejection seats during ground operations and system maintenance and as Figure 2 concerning inadvertent ejections among all U.S. Navy AAES. In addition to the in-service inadvertent system and element actuations, there have been several which occurred at Navy field activities under controlled test conditions with specified safety precautions required. The data is presented not so much to focus upon those particular seats, but, rather to illustrate the seriousness as well as the severity of AAES safety problems to the Navy and, especially, to U.S. Navy personnel encountering AAES. It is intended that with the recent receipt of the Naval Safety Center, Norfolk, computer tapes for all aviation mishaps, AAES in-service safety will be examined in depth by the Naval Weapons Engineering Support Activity, Washington, D.C. and the results of such analyses published.

COSTS OF AAES INCIDENTS/ACCIDENTS

The cost of in-service AAES incidents/accidents are difficult to assess and it is doubted that presently available records will permit complete, accurate assessment of these costs. However, these costs will include:

- o DIRECT
  - damage to AAES and consequent cost of repair and associated aircraft downtime
  - damage to aircraft and consequent cost of repair and aircraft downtime
  - injury to personnel and consequent cost of medical treatment and loss of services.

o <u>INDIRECT</u>

- impact upon U.S. Navy budget plans
- impact upon unit operational readiness
- impact upon logistics system in providing unplanned spares
- impact upon maintenance personnel performance and therefore on safety of personnel, equipment and facilities
- impact upon aircrew performance (i.e., slower manning of aircraft, distraction from primary tasks by concern regarding AAES safety, etc.).

It appears that some, if not a majority of the cost data, can be acquired and it is planned that eventually the data will be acquired. The direct costs appear to be the most easily acquired and as other aspects of this AAES/ALSS data analysis project are pursued, much of that data can probably be obtained in a piggyback effort.

As data are acquired, reports will be prepared and published concerning these costs.

CONCLUSION

As indicated in the introduction to this paper, the U.S. Navy has been and is currently aware of the inherently hazardous nature of AAES. In addition, the U.S. Navy recognizes the need for, and strives to achieve, a reasonable trade-off between the safety of in extremis aircrew whose very lives depend upon the immediate, correct and complete functioning of those AAES features which pose the many hazards, and the safety of all personnel encountering AAES under other conditions. Accordingly, to enhance the U.S. Navy's ability to perform the necessary and difficult trade-offs, efforts are planned under the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis Program, using the newly acquired and some yet to be acquired in-service experience data, to attempt to identify design approaches proving to be most hazardous; both to encourage, where practicable, the retroactive correction of the hazards in existing systems and to aid AAES requirements formulators, designers, and systems evaluators avoid incorporating similar excessive hazards in future AAES designs.

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) EJECTION SEAT IN-SERVICE SAFETY GROUND ACCIDENTS

1/1/69 THROUGH 1/31/77

AIRCRAFT	EJECTION SEAT FAMILY	NUMBER OF GROUND ACCIDENTS	INJURY CODES	COMPONENTS INVOLVED	ACTIVITY LEADING TO ACCIDENT
A-7	ESCAPAC	1	1-F	ZDL (ZERO DELAY LANYARD)	—
F-4	MBA	3	1-A, 2B	BANANA LINKS	—
		1	1-A	ROCKET MOTOR	INSTALLING W/O SAFETY PIN
		1	2-B	ROCKET MOTOR	INSTALLING FIRING LANYARD W/O SAFETY PIN
		1	1-F	CATAPULT SAFETY PIN	CATAPULT SAFETY PIN FOULED DURING REMOVAL
		1	1-A	DROGUE GUN	INSTALLING SEAT DROGUE GUN LOADED AND COCKED W/O SAFETY PIN
		1	2-F		R10 IMPROPER PRE-FLIGHT
		1	1-A, 1-F	INTERDICTOR PIN	IMPROPER PROCEDURES REMOVAL OF INTERDICTOR PIN W/O SAFETY PIN
T-1A	MBA	1	1-A		INADEQUATELY QUALIFIED, HURRYING
T-2	NAA	1	1-A	INITIATOR LEVER	INADVERTENT ACTUATION
		1	1-G	DROGUE GUN	INADVERTENT ACTUATION W/O SAFETY PIN
AV-8A	SAEC	1	1-B	GROUND SAFETY & LOWER FIRING CONTROL	EXITING PILOT DID NOT USE GROUND SAFETY LEVER, INADVERTENTLY FIRED SEAT.

Figure 1

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE SAFETY INADVERTENT ACTUATIONS OF EJECTION SEATS

1/1/69 THROUGH 1/31/77

AIRCRAFT	EJECTION SEAT FAMILY	NUMBER OF INADVERTENT ACTUATIONS
TA-4	ESCAPAC	3
A-7	ESCAPAC	1
RA-5C	NAA	1
T-2	NAA	3
F-4	MBA	13
F-8	MBA	1
T-1A	MBA	1
AV-8A	MBA	1
AV-8A	SAEC	1

Figure 2

IN-SERVICE QUALITY ASSURANCE FOR AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)

A Major Design Problem

Frederick C. Guill

INTRODUCTION

In-service aircrew automated escape system (AAES) quality assurance (Q.A.) is primarily concerned with two aspects of maintaining the U.S. Navy's AAES inventory:

- Was required work accomplished when it was scheduled to occur, and
- Was the work accomplished correctly?

The first aspect is design related only insofar as design affects the frequency of need for such work. Furthermore, the AAES in-service usage data does not furnish adequate data for assessing this aspect, therefore the aspect is not analyzed in this paper. The second aspect is concerned with errors in performance of maintenance, an aspect that can be, and often is, strongly influenced by designs. It is also an aspect that can be expected to become increasingly critical to the safety and well being of aircrew and groundcrew alike if entry level maintenance personnel educational and skill levels continue to decline.[1] Not uncommonly design decisions which otherwise are valid, permit or even, upon occasion, encourage maintenance errors and misassembly. Q.A. then is faced with the task of finding the errors which often are subtle and well hidden. Thus in-service Q.A. is required to make up for what might be termed "overly human dependent design." Designs which the government has generally reviewed repeatedly prior to accepting them.

GENERAL DISCUSSION

During the design process many forces and considerations influence the design and many, if not most or all, seem of far greater importance than designing out human maintenance errors. From a defeatist viewpoint such design efforts, that is attempting to design out opportunities for human maintenance errors, are foredoomed since one cannot foresee all possible errors likely to occur for a given design. In addition there exists a self-comforting viewpoint held by many that if maintenance personnel would only perform the maintenance correctly, would carefully follow step-by-step the equipment maintenance instructions developed during the equipment acquisition process and upgraded as experience is obtained, there wouldn't be any misassemblies or other maintenance errors. This viewpoint holds that maintenance errors are not normally design problems, but people

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[1] The military supply of skill has become a well publicized critical problem. For instance The Wall Street Journal, 25 March 1980, on page 48 noted:
"While military leaders are trying to bolster America's ability to wage distant wars, they're losing a critical battle at home.

induced problems. There also is the viewpoint, apparently widely held, or at least frequently offerred to senior management, that maintenance errors with serious ejectee consequences are infrequent and few in number. These viewpoints, of course, overlook and simplify to an extreme the realities of human and human organizational behavior. Maintenance personnel do take shortcuts and often they fail to follow instructions step-by-step, not just for the simple tasks performed virtually every day, but also for many complex tasks performed far less frequently, believing that they know how to perform the individual specific tasks required to perform the total maintenance action. In addition, there is the very serious human problem of maintenance personnel becoming too familiar with the tasks and therefore relaxed concerning both the quality of the task performed as well as their own risks while performing the tasks. Also much maintenance must be performed on site, away from the ejection seat maintenance shop, and maintenance manuals and card decks often are not carried to the job site, possibly due to the weather, their being misplaced, their being forgotten, etc. Not uncommonly maintenance personnel are under extreme, pressure whether in fact deliberately exerted by their superiors or simply perceived by the maintenance personnel, to expedite their work, are working under less than ideal conditions (i.e., stormy weather heaving a ship, too few people to safely lift a heavy weight, etc.), are shifted or otherwise interrupted in mid-work, and often even possess lesser skills than needed to fully comprehend and execute safely and correctly the tasks assigned. Thus designs which fail to take into account the trend towards lowered skill levels among maintenance personnel, the potential working environment and conditions under which required maintenance may have to be performed, and the greater inherent susceptibility of some design approaches for human error would seem at present and in the foreseeable future to be likely to experience a high and increasing maintenance error rate; a rate translatable in AAES to a decrease in aircrew and groundcrew safety (e.g., the capability of installing an element backwards, etc.). (A classic example was the recent report that the ballistic hose connecting an initiator to a rocket catapult inlet port to permit initiator gases to ignite the catapult propellant had

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([1] cont.) "The armed forces can't keep enough highly trained enlisted personnel and junior officers to operate and maintain the equipment they already have, let alone the new weapons they hope to buy. Military technicians and middle managers are turning in their uniforms for higher paying and less arduous civilian jobs. So many are quitting after six to 12 years of service that military readiness is suffering.

"The Navy's shortage: 20,000 senior enlisted men.

"The Air Force is facing 'very serious problems' caused by shortages of skilled maintenance technicians and engineers, reports Air Force Secretary Hans Mark. 'Airplanes don't fly because we don't have maintenance people,' he says.

" '(We have some fairly serious personnel problems,' Gen. David Jones, Chairman of Joint Chiefs of Staff, admits. 'Our professional people are leaving the services, and when you lose someone with eight or 10 years of experience, you can't replace him easily).' "

been connected instead to the end of a nearby bolt. And there exist a multitude of reports of equally incredible maintenance errors, many of which could have been eliminated through design and evaluation efforts.) Designs which have not taken into account the inherent error potentials and the oft discussed lowered skill levels of today's maintenance personnel must then rely heavily upon in-service Q.A. to control the error rates to assure achieving lower, more acceptable levels. Yet in-service Q.A. suffers the same problems which are afflicting maintenance since the Q.A. personnel generally are specially assigned maintenance personnel. Recently designed Navy ejection seat type AAES have had to comply with a number of requirements in the more recent revisions of both MIL-S-18471, aimed at preventing many of the more common causes for human error in performing maintenance, and MIL-E-9426, aimed at identifying for possible correction design features which might permit or actually encourage maintenance errors. However, at this time the quantities of such systems having been designed to, design analyzed in accordance with, design evaluated in accordance with, and tested in accordance with, the newer revisions of these specifications, within the U.S. Navy's total AAES inventory, although growing, is small and their present impact upon overall in-service AAES maintenance quality is insignificant. At this time the problem of "overly human dependent design" has not been thoroughly evaluated, although several examples were noted while performing a rapid check for the occurrence of serious (leading to serious or fatal injury) maintenance errors in maintaining AAES. Analyzing this problem may prove impossible until further data is extracted from original MORs/FSRs (Medical Officer's Reports/Flight Surgeon's Reports) and other sources and entered into the program's data bank. The examples presented in the paper Aircrew Automated Escape Systems (AAES) Maintenance Caused Aircrew and Maintenanceman Fatalities and Severe Injuries illustrate in a limited fashion both the nature and potential severity of some of these problems.

Again, as in the examples employed in the discussions of other evaluations of AAES in-service "ilities" aspects, it is not important at this time (i.e., before the planned in-depth analyses have been performed) which seats provide these examples. The important point is recognizing that problems of "overly human dependent designs" are generally amendable to design action to reduce, or preferrably, eliminate the potential for maintenance (and even aircrew) error and to reduce the consequences of such errors if they occur. This, of course, is truer for systems in design than for systems either in production or already in service. Thus analysis of available U.S. Navy AAES in-service data concerning misassembly and other forms of maintenance error occurring in in-service escape systems is expected to suggest design practices and evaluation practices for controlling design over dependency upon human performance both for improving designs (1) of AAES currently in-service and experiencing these types of problems and (2) of future AAES. This author recognizes the effects of and, in fact has himself had to acquire systems for the Navy while under the extreme duress of, seemingly impossible schedules with lower than actually needed staffing. However, it has been this author's personal experience that even under these conditions, and probably especially under these conditions, attention to reducing design over dependancy upon human performance is a necessity and that, if it is kept in the forefront among the issues examined by project/program management, progress will be achieved.

CONCLUSION

The provisions of MIL-S-18471 and MIL-E-9426 (as well as similar statements in the U.S. Air Force specification MIL-S-9479) concerning design, design analyses, and evaluation procedures to eliminate designs unacceptably susceptible to maintenance error have resulted from in-service, in-test and design evaluation information and if followed stringently are expected to help reduce the AAES in-service maintenance and inservice Q.A. error problem and thereby enhance the safety of both aircrew and groundcrew personnel. That problem must be addressed and addressed continuously and conscientiously by designers and their supervisors, acquisition agency representatives throughout the design and evaluation cycle, by maintenance school instructors, and by Fleet personnel themselves -- maintenancemen, maintenance chiefs and maintenance officers. The problem is real. It is serious. It results in avoidable injuries and deaths each year. It will not disappear because we refuse to see it or choose to ignore it;[2] it requires positive action from each and every one of us.

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[2] This topic will be addressed in many forthcoming analyses to be performed by the Naval Weapons Support Activity, Washington, D.C., under the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-service Usage Data Analysis Project.

QUALITY ASSURANCE PLANNING OF AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) TESTING, TEST DATA ACQUISITION AND HARDWARE PRODUCTION

Frederick C. Guill

ABSTRACT

Human endeavors commonly encounter many obstacles and setbacks, some predictable and some not, some preventable and some not. Aircrew automated escape systems (AAES) programs are no exceptions. However, actions can be initiated during early program planning and during later stages to identify many of the likely problems which may arise during a program. One of the techniques, normally employed to assess system safety of design, which can be successfully employed to identify and thereby permit management to consider the potential problems and their consequences is the fault tree, whether presented in a formal or informal format. Two examples of such use of fault tree analysis are presented to illustrate their use as a management program planning tool.

QUALITY ASSURANCE PLANNING FOR AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) TESTING, TEST DATA ACQUISITION AND HARDWARE PRODUCTION -- SOME THOUGHTS

Frederick C. Guill

INTRODUCTION

This author is certain that many of us employed in the aircrew automated escape systems (AAES) and aircrew life support systems (ALSS) fields can and perhaps do periodically sorrowfully remember and reflect upon, tests gone awry at considerable expense, the loss of crucial test data, and worse, the loss of life occasioned by the failure of a sysem to perform correctly in an emergency. The author in conducting AAES programs for the Crew Systems Division (AIR-531), Naval Air Systems Command and its predecessor organization, has experienced the anger and frustration that accompanies the explanation that a system failure resulted from one or more bad parts or assemblies or that a test conducted at considerable expense failed to yield the required data and might need to be reconducted at further cost from one's very badly stretched program budget and with attendant slippage in a schedule that literally has been bursting at the seams since program initiation. Almost invariably the post-mortem reveals that underlying problem(s) leading to the failure could have been prevented had management and the entire organization paid proper attention to details and followed established procedures. Occasionally the post-mortem reveals flaws in the established procedures; flaws requiring immediate correction.

GENERAL DISCUSSION

The author, following some problems during and following an escape systems test resulting in the loss of some and the degrading of other critical data being obtained during that escape systems test, requested all of the parties involved in the test and in all of the phases related to the acquisition of the test data to aid in the creation of a tree depicting the means whereby test data could become not available or not usable. This tree (Figure 1), when examined, contains no surprises and no magical and inexplicable problems. The experience of this author and of those who aided in the creation of the tree was that virtually every type of problem leading to this undesirable and oft expensive consequence was predictable and, therefore, potentially avoidable.

Several years later, to this author's extreme chagrin and embarassment, one of the Navy's activities working in two capacities (one part helping to manage and oversee technical work and a distinctly separate part manufacturing critical elements) in one of the author's escape system programs succeeded in shipping a defective critical part (which, fortunately was subsequently detected by that activity, permitting recall of the defective part before it was installed). As a consequence of the findings as to how the defective article slipped through the activity's quality control system's procedures, the author requested the activity to assemble a fault tree examining how a bad item could be shipped (the title page is shown as Figure 2, the remaining 87 pages as Appendix F). Again the resultant product contained no surprises, as it would seem that between the various participants in the management and supervision of the preparation of the Figure 2 tree, virtually all of the causal factors and causal factor trains proposed by the preparers of the tree had been experienced, many more than once.

INTENDED USE OF THE FIGURES

The author's intent in having Figures 1 and 2 created and now in disseminating them was to demonstrate that the fault tree concept would be used as an effective management planning tool in allocating resources to critical aspects of programs and to cause the creation of, and make generally available, documents which might aid AAES/ALSS management and technical personnel in planning the successful, complete acquisition of test data (Figure 1) and in planning the delivery of AAES/ALSS free of critical (i.e., life endangering) manufacturing defects (Figure 2). Accordingly Figures 1 and 2 are offerred to the AAES/ALSS community in the hopes that they might aid in creating the quality requisite to all AAES/ALSS products and thereby enhance the safety of our Navy's aircrew and groundcrew personnel. It is further hoped that the concept represented in Figures 1 and 2 might be employed in other aspects of AAES/ALSS programs sufficiently early to help assure achievement of the requisite quality for AAES and ALSS.

CONCLUSION

Comments concerning possible additions or deletions to Figures 1 and/or 2 should be addressed to the author. It is suggested that the concept illustrated by these two figures can be, and probably should be, applied early in the planning of a program, of critical aspects of a program and of tests. Developing these data can aid in planning schedules, staffing, funding, and means for reducing the likelihood that expensive, time consuming and reputation damaging serious problems might occur. Upon programm implementation such documents can aid enormously in the management of the program. However, unless documents such as Figures 1 and 2 are used in these ways, they are useless and represent an excessive cost to the program, for by themselves the documents are unable to prevent any of the predictable problems from occurring. There is, however, one very serious danger that must constantly be borne in mind and that is that virtually no program has the luxury of having all of the funding and staffing required to prevent all serious problems. These types of documents, then, can but help the planner(s) and management assess risks versus cost, staffing and schedule impacts and to then make the necessary trade-off decisions that are the provence and responsibility of managers.

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE VULNERABILITY, A DESIGNER'S PROBLEM

Frederick C. Guill

ABSTRACT

Aircrew automated escape sytems (AAES) have a potentially unique set of problems associated with the frequent removal of major elements, especially ejection seats, to facilitate non-AAES cockpit maintenance actions. These potential problems and the specification requirements imposed to limit their adverse consequences are briefly addressed.

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE VULNERABILITY A DESIGNER'S PROBLEM

Frederick C. Guill

INTRODUCTION

Aircrew automated escape system vulnerability as defined in MIL-S-81471F (Para. 3.7.2.3) is uniquely broad in scope including not only the classic "damage induced by hostile actions", but also the following not so typical vulnerability damage causation factors:

a. Human induced damage while the system is installed in the aircraft.
b. Damage induced during system/component removal from, and/or installation in, the aircraft.
c. Damage occurring while the system/components have been removed (either damage of removed elements or of elements exposed within the aircraft as a result of removal of other system elements).
d. Damage resulting from incorrect/improper maintenance (i.e.: overtorquing, failure to connect, erroneous connections, etc.).
e. Damage induced by aircraft/weapons system failures.

Vulnerability currently is one of the several "ilities" which AAES designers and evaluators must consider throughout an AAES acquisition program.

GENERAL DISCUSSION

The U.S. Navy position is that much of the "friendly" damage, mainly incurred during aircraft and AAES maintenance, can be prevented by careful design and design analysis fed back into the system design to reduce design dependancy upon the care and performance of personnel. A considerable portion of the in-service damage experienced in existing and earlier AAES seems to have resulted from the removal of an ejection seat from a crew station. Removal of the seat, especially in older systems, generally leaves exposed sequencing and other ballistic lines within cockpits as well as other critical components in unprotected locations to be stepped upon, struck by tools and toolboxes, etc. The resultant damage often is not apparent (i.e., dents in or crimping of ballistic lines, kinking of cables, fraying of lanyards, slight bending of metal parts which must move) thereby restricting gas flow, weakening cables and lanyards, and jamming metal parts which must move, or causing parts which must strike to miss. In some instances, even when seemingly very apparent (i.e., extreme damage), damage has remained undetected or, if detected, uncorrected until escape system use or later maintenance actions. Removed seats themselves often have sustained damage of critical lines and components which protude outside the protective structural envelope of the seat when the seat was placed upon the ground or deck, pushed or dragged clear of the work area, etc. Again damage often has not been apparent or observed until a later event.

Another problem, and a very critical one from the AAES designers' and evaluators' viewpoints is the very human and understandable tendancy to not report such damage when discovered if it is suspected that it occurred within or was caused by one's own activity's personnel. The natural human tendancy when facing such a situation is to simply fix the problem and keep quiet about it. Thus, often, and how often we have no ready means for quantifying, no reports are generated and we in the requirements formulation, design and evaluation phases of AAES acquisition unfortunately are left in blessful ignorance of many problems which might be rectifiable by retroactive design actions and extra care during the initial design efforts and subsequent design analysis and evaluation efforts for future AAES.

CONCLUSION

At the time this report was being prepared, data pertinent to assessing in-service vulnerability of AAES designs had not been evaluated. Some such data has recently been received and, as priorities permit, will be culled and analyzed, however, by the very nature of the data and report contents this will entail a lengthy and tedious process, most of it manual, to establish a design vulnerability data base. As the evaluation of AAES in-service data progresses, the necessary efforts will be made both to identify current AAES and specific AAES design features particularly susceptible to sustaining "friendly" damage, critical system damage resulting from localized aircraft damage (whether combat induced or induced by failure of nearby systems) as well as those current AAES and AAES design features less likely to sustain such damage. The specific aims will be to develop information concerning the "friendly" damage casual factors and modes. In addition, to the extent that the combat escape data banks generated by and now in the possession of BioTechnology Incorporated, Arlington, permits, the aim will be also to develop data concerning reducing system total vulnerability to hostile actions (combat induced, localized crew station area damage). This data is expected to be of value in developing guidelines both for retrospective incorporation into existing AAES and for inclusion in future new AAES design for reducing both the incidence rate and severity of "friendly" and other damage to U.S. Navy AAES.

As the results of these analyses become available, they will be reported to the AAES community and, where feasible, will be reflected in the U.S. Navy AAES specifications.

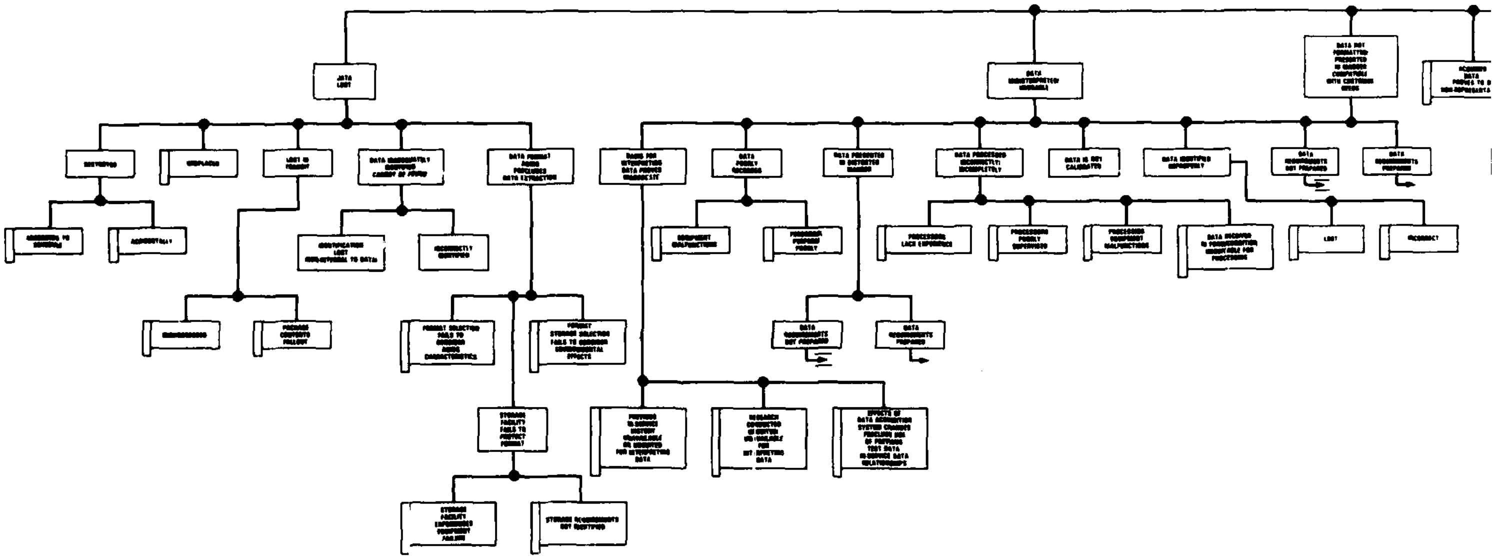
IN-SERVICE QUALITY ASSURANCE FOR AIRCREW AUTOMATED ESCAPE SYSTEMS (ALSS): A MAJOR DESIGN PROBLEM

Frederick C. Guill

ABSTRACT

A major factor affecting an aircrew automated escape systems's (AAES) in-service success rate, groundcrew injury rate and general cost of ownership is the achievable maintenance quality. Many of the problems often dismissed as "maintenance error" have their genesis in design choices, some of which are very limited while others are virtually unlimited except by the designer's experience concerning and consideration of the problems of the operational world -- the world in which the designed system will be maintained and kept operational. The designer of an AAES through his design choices and decisions, therefore, has the potential to greatly enhance or to greatly degrade the in-service quality achieved during operational maintenance.

AAES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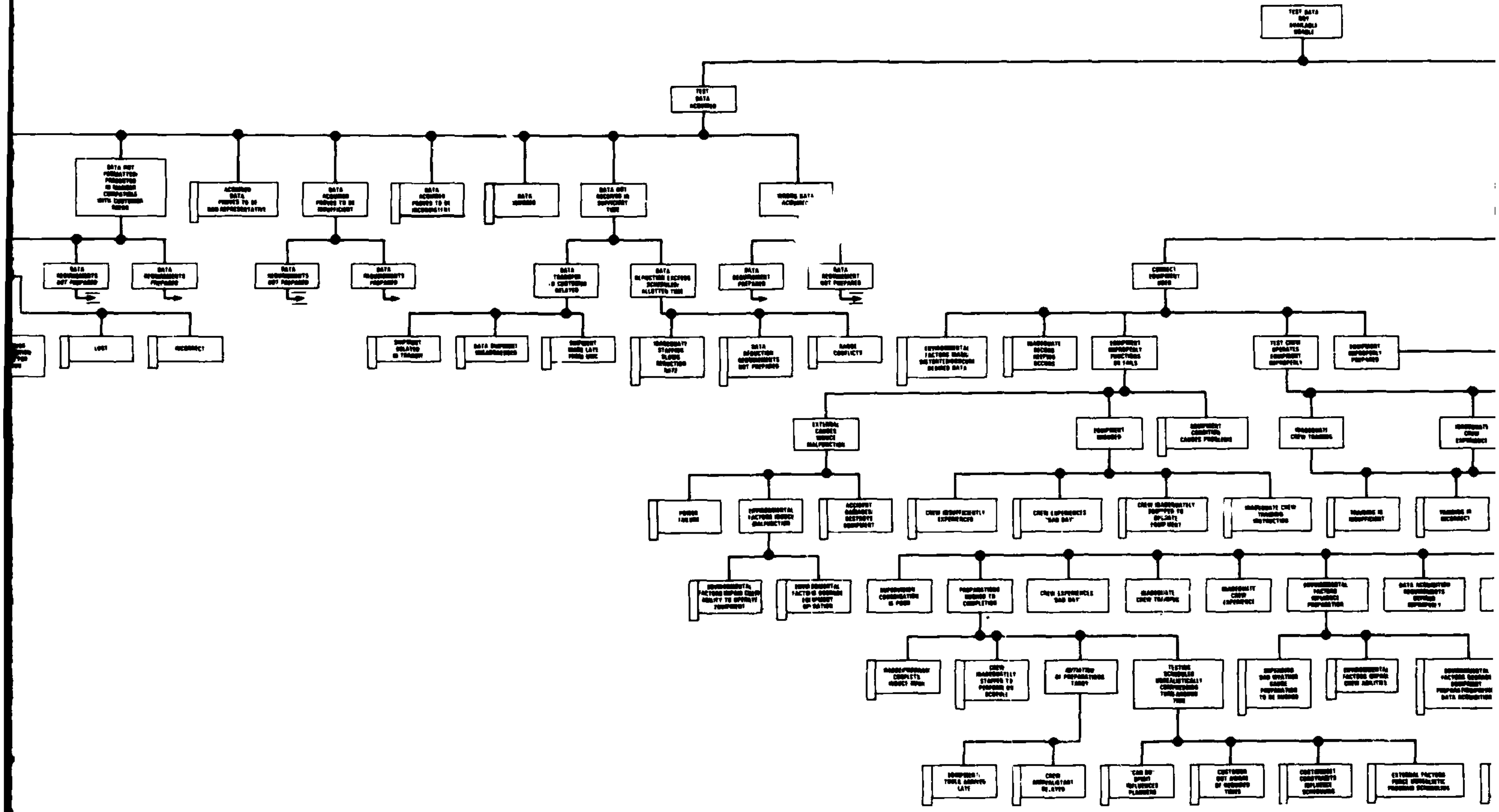
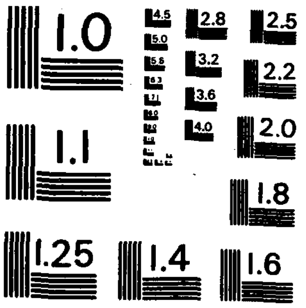
DESTROYED
MISPLACED
LOST IN TRANSIT
DATA INADEQUATELY IDENTIFIED CANNOT BE FOUND
DATA FORMAT PRECLUDES DATA EXTRACTION
ACCIDENTALLY
IDENTIFICATION LOST
INCORRECTLY IDENTIFIED
PACKAGE CONTENTS FALLOUT
FORMAT SELECTION FAILS TO CONSIDER CHARACTERISTICS
FORMAT STORAGE SELECTION FAILS TO CONSIDER ENVIRONMENTAL EFFECTS
STORAGE FACILITY FAILS TO PROTECT FORMAT
STORAGE FACILITY EXPERIENCES EQUIPMENT FAILURE
STORAGE REQUIREMENTS NOT IDENTIFIED
DATA MISINTERPRETED (UNUSABLE)
DATA NOT FORMATTED/PRESENTED IN MANNER COMPATIBLE WITH CUSTOMER NEEDS
ACQUIRED DATA PROVES TO B
NON-REPRESENTA
BASIS FOR INTERPRETING DATA PROVES INADEQUATE
DATA POORLY RECORDED
DATA PRODUCED IN DISTORTED MANNER
DATA PROCESSED INCORRECTLY/ INCOMPLETELY
DATA IS NOT CALIBRATED
DATA IDENTIFIED IMPROPERLY
DATA REQUIREMENTS NOT PREPARED
DATA REQUIREMENTS PREPARED
EQUIPMENT MALFUNCTIONS
PROCESSORS LACK EXPERIENCE
PROCESSORS POORLY SUPERVISED
PROCESSING EQUIPMENT MALFUNCTIONS
DATA RECEIVED IN FORM/CONDITION UNSUITABLE FOR PROCESSING
LOST
INCORRECT
DATA REQUIREMENTS NOT PREPARED
DATA REQUIREMENTS PREPARED
DATA

AAES TEST DATA FAULT TREE (INFORMAL)



2

AD-A134 833 AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE 3/6
USAGE DATA ANALYSES VO..(U) NAVAL WEAPONS ENGINEERING
SUPPORT ACTIVITY WASHINGTON DC C W STOKES ET AL.
UNCLASSIFIED 05 NOV 83 NAVWESA-1-83-VOL-1 F/G 1/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AL)

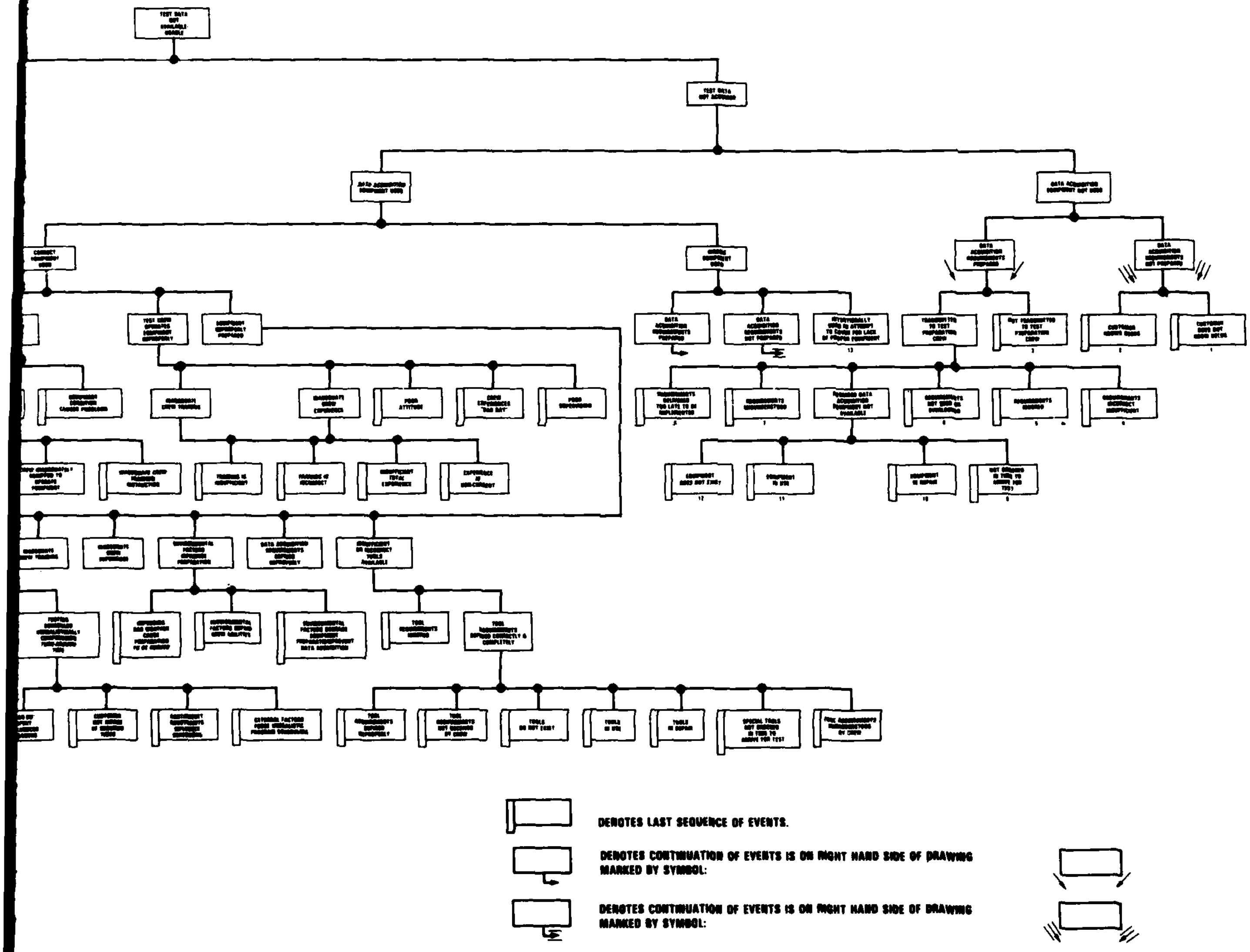

TEST DATA
TEST DATA
DENOTES LAST SEQUENCE OF EVENTS.
DENOTES CONTINUATION OF EVENTS IS ON RIGHT HAND SIDE OF DRAWING MARKED BY SYMBOL:
DENOTES CONTINUATION OF EVENTS IS ON RIGHT HAND SIDE OF DRAWING MARKED BY SYMBOL:

Figure 1

3

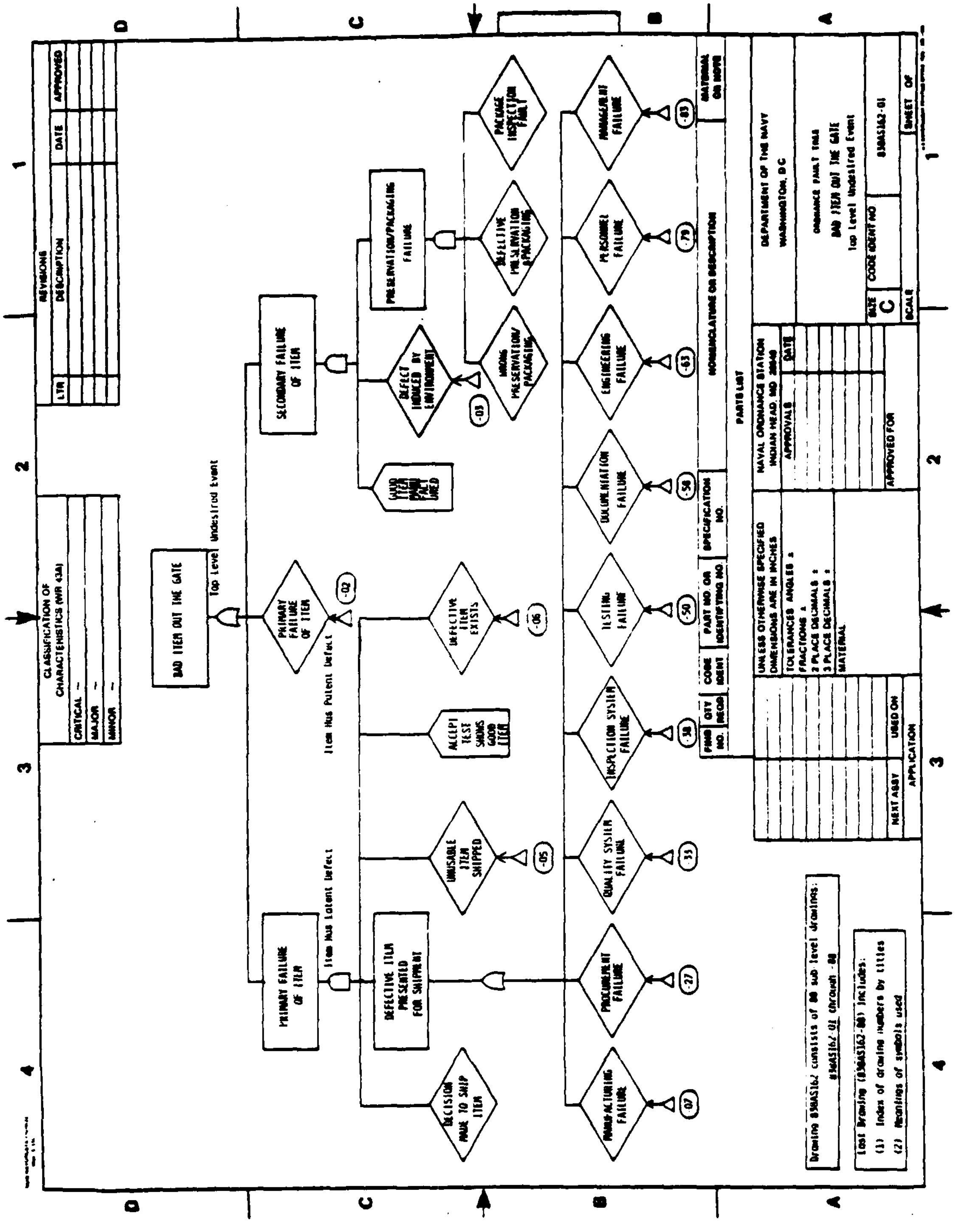

BAD ITEM OUT THE GATE
Top Level Undesired Event
PRIMARY FAILURE OF ITEM
SECONDARY FAILURE OF ITEM
Item Has Patent Defect
Item Has Latent Defect
DEFECTIVE ITEM PRESENTED FOR SHIPMENT
DECISION MADE TO SHIP ITEM
UNUSABLE ITEM SHIPPED
ACCEPT TEST SHOWS GOOD ITEM
DEFECTIVE ITEM EXISTS
GOOD ITEM PUNC TURED
DEFECT INDUCED BY ENVIRONMENT
PRESERVATION/PACKAGING FAILURE
WRONG PRESERVATION/PACKAGING
DEFECTIVE PRESERVATION/PACKAGING
PACKAGE INSPECTION FAULT
MANUFACTURING FAILURE
PROCUREMENT FAILURE
QUALITY SYSTEM FAILURE
INSPECTION SYSTEM FAILURE
TESTING FAILURE
DOCUMENTATION FAILURE
ENGINEERING FAILURE
PERSONNEL FAILURE
MANAGEMENT FAILURE
-02
-03
-05
-06
-07
-27
-33
-38
-50
-58
-63
-79
-83
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
CLASSIFICATION OF CHARACTERISTICS (WR 43A)
CRITICAL -
MAJOR -
MINOR -
Drawing 83bAS162 consists of 88 sub level drawings:
83bAS162-01 through -88
Last Drawing (83bAS162-88) includes:
(1) Index of drawing numbers by titles
(2) Meanings of symbols used
PARTS LIST
FIND NO.
QTY REQD
CODE IDENT
PART NO OR IDENTIFYING NO
SPECIFICATION NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL OR NOTE
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ANGLES ±
FRACTIONS ±
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
MATERIAL
NAVAL ORDNANCE STATION INDIAN HEAD, MD 20640
APPROVALS
DATE
APPROVED FOR
DEPARTMENT OF THE NAVY WASHINGTON, D.C.
ORDNANCE FAULT TREE
BAD ITEM OUT THE GATE
Top Level Undesired Event
SIZE
C
CODE IDENT NO
83bAS162-01
SCALE
SHEET OF
A
B
C
D
1
2
3
4

Figure 2.

INTRODUCTORY NOTES

ANALYSES OF IN-SERVICE USAGE DATA

The prime function being performed currently by the Analytical Systems Division (ESA-31), Naval Weapons Engineering Support Activity, Washington, D.C. under the tasking for the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-Service Usage Data Analysis project is the development of an analytical system with which to analyze in-service usage and ownership data to identify and define problems in a manner aiding the Crew Systems Division (AIR-531), Naval Air Systems Command, Washington, D.C., make decisions concerning the optimal allocation of funds for projects to enhance aircrew safety. The analyses are expected to be useful also in aiding the Crew Systems Division seek and justify additional resources for projects aimed at resolving problems identified as occurring among current AAES/ALSS on a non-isolated incident basis having significant adverse impact upon aircrew and/or groundcrew safety.

In pursuing its primary function, the project team has had to (1) identify sources of AAES/ALSS in-service usage and ownership data, (2) acquire that data, (3) enter that data into the Analytical Division's computers, (4) gain familiarity with that data, and (5) at the same time, gain a degree of familiarity with and understanding of its customer's (Crew Systems Division's and its field activities') needs and ways of using the results of data compilations and analyses. During the past year the project team has undertaken a number of special assignments, the performance of which aided in their achieving one or more of the preceding subobjectives.

Eight of these special assignments have advanced to the point, even when not as yet completed, that information of probable value to the AAES/ALSS community has been obtained and at least partially analyzed or the planned analysis approach is well defined and actively being purused. In several instances involving the latter stage, efforts are being made to acquire and enter into the Analytical Division (ESA-31) computers new data such as configuration changes data, more detailed ALSS equipments data for mishap aircrew, more detailed mishap sequence of events and transient and permanent effects upon mishap aircrew data, and more complete AAES/ALSS maintenance data.

Several efforts previously reported, especially that concerning The Production of Aircrew Fatalities In Navy Ejection Seat Equipped Aircraft are continuing, but either time for preparing a paper or progress in developing and analyzing the data were insufficient to permit further reportage at this time.

The reader will note that with the sole exception of the paper, U.S. Navy Mishap Aircrew Anthropometry; 1 January 1969 through 31 December 1979, the papers in this section pertain to mishap data acquired concerning aircrew and their ALSS in AAES equipped aircraft. As reported earlier in this document, computerized MOR/FSR (Medical Officer's Report/Flight Surgeon's Report) data extract tapes covering all aviation mishaps occurring since 1 January 1969 have been received from the Naval Safety Center, Norfolk. Progress has been made in analyzing the data format and in entering data into the Analytical Division (ESA-31) computers and it is anticipated that as resources permit some initial analyses will be performed during the coming year with the priority likely to be concerning helicopter mishaps.

ANALYSIS OF THE REPORTED INCIDENTS OF WINDBLAST, FLAIL, AND TUMBLE DURING EJECTION

G. Ronald Herd

ABSTRACT

Ejection seat designs have often included features aimed at reducing the incidence of windblast problems, flail and tumble. A major question has been and remains: How successful have these features been in reducing the incidence of these undesirable phenomena? This paper presents an analysis of the response rate for each of the phenomena. The evidence on flail, tumble and windblast problems were developed from the medical officers' assessments presented in their reports. Knowledge of the speed at ejection and the percent of the ejectees experiencing the phenomenon allows the threshold speeds for experiencing each of these phenomena to be established for each type of seat. The threshold speeds at which the phenomena occur among ejectees were determined and comparisons made among seat designs. The differences observed among seat designs are shown to be consistent with the presence or absence of those design features that are incorporated to reduce the impact of windblast, flail or tumble.

Analysis of the Reported Incidents of Windblast, Flail, and Tumble During Ejection.

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This study was supported by Union Carbide Corporation under Subcontract 62X-43190C and developed for the Naval Weapons Engineering Support Activity (ESA-31)

Table of Contents

SUMMARY

The data analysis allowed comparisons among seat types with respect to the risk of flail, windblast problems and tumble at various airspeeds. The tenth percentile, the airspeed at which 10% of the surviving ejectees experience the phenomenon, have been determined for the various seat types. The seat types were combined if there were no difference between the projected median values of the types. The higher the airspeed for a given percent of respondants indicates less sensitivity of the seat and surviving ejectees to the phenomenon of windblast, flail or tumble.

Designs aimed at reducing the incidence of windblast problems, flail and tumble have been and can be successful. The differences in susceptability to windblast, flail and/or tumble among ejection seats can be shown by comparing the expected 10th percentile airspeed for the various seat designs. The 10th percentile value of airspeed is that airspeed at which only one ejectee in ten is expected to experience a response (windblast problems, flail or tumble). The higher the expected 10th percentile value the more resistant the ejectee-seat combination is to the phenomenon. Since most ejections occur at airspeeds below 300 knots suppose there exists a requirement that the ejectee-seat shall experience windblast problem, flail or tumble phenomena not more frequently than one time in ten ejections. The Martin-Baker seat designs will satisfy such a requirement for flail and tumble but not for windblast. The ESCAPAC seat designs will not satisfy such a requirement for any of the response phenomena. A summary of the response situation for each phenomenon is presented in the following paragraphs.

For the windblast response reported for the surviving ejectees there was no difference between the ESCAPAC seats with both Group I and Group II (definitions in table 3, page 5) having about the same median response. Also, there was no difference between the Martin-Baker seats with both Group III and Group IV having about the same expected median. The ESCAPAC seats appear to be slightly more sensitive to windblast than do the Martin-Baker seats at the higher speeds while the differences are not so noticable at the lower speeds. The expected median airspeed and the expected ten percentile value of airspeed are presented in the Table S-1 to show the difference in sensitivity to windblast for ejectees employing the various seat types.

Table S-1. The airspeed-at-ejection for which a percentage of the surviving ejectees reported windblast.

Design	10% Percentile	50% Percentile	
	Expected	Expected	90% Confidence Band
Group I & II	257 knots	397 knots	379-414
Group III & IV	263	452	434-471

For the flail response reported for the surviving ejectees there was a difference in speeds at which the ejectees in ESCAPAC Group I and Group II designs experienced flail. There was no difference between the Martin-Baker Group III and Group IV designs with respect to the airspeeds at which the ejectees experienced flail. The median airspeed and the expected 10-percentile airspeed are presented in Table S-2 to show the difference in sensitivity to flail for surviving ejectees employing the various seat types.

Table S-2. The airspeed-at-ejection for which a percentage of the surviving ejectees reported flail.

Design	10% Percentile	50% Percentile	
	Expected	Expected	90% Confidence Band
Group I	220	453	424-483
Group II	254	535	457-613
Group III & IV	333	494	460-528

For the Tumble response reported for the ejectees there was no difference in speeds at which the ejectees in Group I and Group II designs experienced tumble. There was no discernable difference between Group III and Group IV designs with respect to the airspeeds at which the surviving ejectees experienced tumble. Ejectees in Group III & IV designs were much less sensitive to tumble than were ejectees in the Group I & II seat designs. The median airspeed and the expected 10-percentile airspeed are presented in table S-3 to show the difference in sensitivity to tumble for ejectees employing the various seat types.

Table S-3. The airspeed-at-ejection for which a given percentage of the surviving ejectees reported tumble.

Design	10% Percentile	50% Percentile	
	Expected	Expected	90% Confidence Band
Group I & II	170	711	651-771
Group III & IV	344	985	917-1053

A word of caution, however, is necessary concerning these data and the resulting analyses. First, the data require the survivors, witnesses, and/or the medical officers to determine and report the presence of these phenomena. The survivor might have been dazed or unconscious and there might have been no witness. Second, some of these phenomena, such as tumble, can be perceived without actually occuring. Third, flail, per se, unaccompanied by flail-induced injury, is of interest to the Navy and may reflect a problem without actually producing a sufficiently serious sensation to cause reporting. Fourth, particularly, with respect to windblast problems, some of the phenomena are reported as a consequence of the medical officer's expectation and training without evidence of the problem. Nonetheless, it was decided to examine these data because those factors, tending to reduce the validity of the data, are nearly equally represented among all systems throughout the range of useage conditions.

ANALYSIS OF THE REPORTED INCIDENCE OF TUMBLE, FLAIL AND WINDBLAST BY EJECTEES.

Aircrew Automated Escape Systems (AAES) are intended to provide a means of escape for the aircrew from a disabled aircraft. Many contemporary escape systems are capable of providing survivable ejection from a variety of flight profiles such as profiles that range from an aircraft parked on the ramp to one flying at high speed and high altitude. Escape systems at present are typically rocket powered seats with subsystems that provide (1) stabilization of the ejected seat and pilot, (2) positive seat-man separation, and (3) a fully inflated parachute after ejection from the aircraft.

The Navy is interested in using information concerning the usage of existing in-service equipments to provide guidance in reducing the risk of injury to ejectees. This guidance may take the form of changes in operational doctrine for existing systems, changes in current system designs, or improvements in the specifications for future systems. Although other problems frequently overshadow the flail, tumble and windblast-caused injuries these problems are still important to the Navy, especially since such injuries can degrade an ejectee's ability to perform tasks necessary for his survival and/or ability to avoid capture.

During the ejection process an ejectee will, on occasion, experience flail, tumble and/or windblast problems phenomena. It has generally been accepted in the AAES community that the magnitude of the forces and the rapid changes in the force vectors during the ejection sequence are the causes of these flail, windblast and tumble incidents. Furthermore, it is expected that a major portion of these forces will be a function of the aircraft speed at the time of ejection. However, there is little common agreement as to the speed at which these phenomena cease to exist or are virtually free of risk of injury. If aircraft velocity at ejection is the dominant cause, then the incidence of flail, tumble and/or windblast phenomena would differ for the different aircraft speeds. Also, since some ejection seat types are designed to limit or control flail or tumble during the ejection, it could be expected that, other things being equal, these seat types should exhibit lower incidence rates than those not so designed.

It may be that, for flail phenomena occuring in unstablized seats, the centrifugal forces are dominant in the low speed region while wind forces are dominant in the higher speed range. At very low ejection airspeeds the aerodynamic stabilizing forces are low, often permitting the ejection seats to tumble. At zero aircraft speed the centrifugal forces from the tumbling of the seat are dominant since there are no significant wind forces due to aircraft speed. However, at some aircraft speed the wind forces become dominant. The speed at which wind forces become dominant cannot be determined precisely but in general wind forces should be dominant at speeds above 100 knots. Between 0 and 100 knots the forces would entail a mix of centrifugal and wind forces with the centrifugal forces dominant near zero speed while wind forces become more dominant as the speed increases above zero.

TYPES OF SEATS AND MANUFACTURERS.

There are four major manufacturers of the escape systems, currently or recently, used in Navy aircraft, and the types of seats for each manufacturer are identified in Table 1 by Navy model identification.

Table 1. The manufacturer and Models of the principle Escape Systems in the Navy Inventory.(1969 - 1979)

Manufacturer	Models
Douglas	ESCAPAC 1, 1A-1, 1C-2, 1C-3, 1E-1 1F-3, 1G-2, 1G-3.
Martin-Baker	Mk H5, H7, A5, A7, F5, F7, L5, Z5, GRU5, GRUEA5, GRU7, GRUEA7.
North American	HS-1, HS-1A, LS-1, LS-1A, LW-3B
Stencel	SEU-3/A (SIIIS-3AV8)

The escape system is designed to be an integral part of the aircraft in which it is installed. Therefore, as a consequence of cockpit geometry and other factors no exact design duplication occurs between ejection seats installed in different aircraft models, although the same generic design may be employed. A new designation is made for each escape seat type/aircraft installation. A complete list of the ejection seats and the aircraft in which they are installed is presented in Table 2.

Table 2. The Ejection Seat Type Aircrew Automated Escape Systems and the Navy Aircraft in Which They Are Installed

Escape System	Aircraft
MARTIN-BAKER MK A5	TF-9J (F9F-8T)
MARTIN-BAKER MK F5	F-8 Series (F8U Series)
MARTIN-BAKER MK H5	F-4 Series (F4H Series
MARTIN-BAKER MK L5	T-IA (T2V-1)
MARTIN-BAKER MK Z5	AF-9J (F9F-8B)
MARTIN-BAKER MK GRU 5	A-6 Series (A2F Series)
MARTIN-BAKER MK GRUEA 5	EA-6B
MARTIN-BAKER MK J5	OV-1
MARTIN-BAKER MK M5	F-3 Series (F3H Series)
MARTIN-BAKER MK N5	AF-1E (FJ-4B)
MARTIN-BAKER MK P5	F-6A (F4D-1)
MARTIN-BAKER MK X5	F-11 (F11F-1) Later Redesignated MK Z5 for RF-9J (F9F-P)
MARTIN-BAKER MK Z5	AF-9J (F9F-8B)
ESCAPAC 1	A-4 Series (A4D Series)
ESCAPAC 1A-1	A-4 Series (A4D Series)
ESCAPAC 1C-2	A-7 Series
ESCAPAC 1C-3	A-4 Series (A4D Series)
USAF F-5E	F-5E
NAMC CATAPULT	Various Aircraft
NORTH AMERICAN HS-1	A-5 Series (A3J Series)
NORTH AMERICAN HS-1A	A-5 Series (A3J Series)
NORTH AMERICAN LS-1/1A	T-2 Series (T2J Series)
NORTH AMERICAN LW-3B	OV-10
NORTH AMERICAN LS-1A	T-2 Series
MARTIN-BAKER MK A7	TF-9J
MARTIN-BAKER MK F7	F-8 Series
MARTIN-BAKER MK H7	F-4 Series
MARTIN-BAKER MK GRU7	A-6 Series
MARTIN-BAKER MK GRU7A	F-14 Series
MARTIN-BAKER MK GRUEA7	EA-6B
MARTIN-BAKER H-9	AV-8A
ESCAPAC 1E-1	S-3 Series
ESCAPAC 1F-3	A-4/TA-4 Series
ESCAPAC 1G-2	A-7 Series
ESCAPAC 1G-3	A-4/TA-4 Series
ESCAPAC 1G-4	TA-7 Series-Forward Seat
ESCAPAC 1G-5	TA-7 Series-Aft Seat (Same as ESCAPAC 1G-2)
STENCEL SEU-3/A (SIIIS-3)	AV-8A

There is limited experience on the Stencel and North American escape systems; in the first case because of the small number of aircraft in which the seats are installed and in the latter case because of the variations in design and the limited utilization of the escape system. This lack of ejection experience with these two manufacturers' seats restricts this study to the two other manufacturers' seats, namely Douglas and Martin-Baker. The Douglas and Martin-Baker seat types each can also be grouped by some common design characteristics that reflect the evolutionary aspect of the design of escape systems. Table 3 partitions the Douglas and Martin-Baker seats by these characteristics.

There is no reason to expect the response phenomena (flail, tumble, windblast) to be the same at any given speed or that they will be the same for any two seat designs. Differences due to these phenomena might be expected among the ESCAPAC design groups since the man-seat separation occurs later in the sequence for the early designs (Group I) than for the later designs (Group II), and the differences in type, magnitude, rate of onset, and location of the forces used to separate man from seat. Hence, for a given ejection speed, the man-seat separation initiation speed will be lower and possibly less violent for the early designs.

The Martin-Baker seats employ leg restraints to reduce flail of the legs during the ejection sequence while the ESCAPAC designs do not. Thus, for a given ejection speed, the incidence of flail might be different for the ESCAPAC designs in comparison to the Martin-Baker designs. Such differences will be more significant if leg flail is the dominant contributor to flail incidents.

The ESCAPAC seats are not stablized, while the Martin-Baker seats shortly after seat separation from the guide rails are stabilized by drogues attached to the top of the seat; therefore, differences between manufacturers might be expected. Furthermore differences in tumble response might be expected between the early and late designs of the Martin-Baker seats due to differences in timing in the drogue gun firing.

DATA AND ITS SOURCES.

The data on flail, tumble and windblast events were developed from interviews with survivors/witnesses and/or medical officer assessments of the causes of injuries as reported in MORS/FSR's (Medical Officer's Reports/Flight Surgeon's Reports). This study will be limited to examining the incidence of flail, tumble and windblast phenomena among

Table 3. Common Characteristics, Manufacturer, and Design Evolution for Selected Escape Systems

Manufacturer	Design Stages	Seats	Common Characteristics
Martin-Baker	Early Design Group I	MK 5 Series (B5, A5, GRU 5, GRUEA 5)	Ballistic catapult, 1.00 second drogue firing, 5 ft. stabilizer drogue, 1.75 sec. TRM shackle release for parachute deployment before man-seat separation, garter-type leg restraints.
	Late Design Group II	MK 7 Series (B7, A7, GRU 7A, GRUEA 7)	Reduced charge ballistic catapult with separate rocket sustainer motor, 0.50 sec. drogue firing, 5 ft. stabilizer drogue, 2.00 sec. TRM shackle release for parachute deployment before man-seat separation, garter-type leg restraints.
Douglas	Early Design Group III	ESCAPACs I, IA-1, IC-2, IC-3	No drogue, DART stabilized for initial travel, bladder-induced man-seat separation before parachute deployment, no leg restraints
	Late Design Group IV	ESCAPACs IF-3, IG-2, IG-3	No drogue, DART stabilized for initial travel, rocket-induced man-seat separation before parachute deployment with faster timing for all events, no leg restraints.

surviving ejectees since the occurrence or non-occurence of many non-injurious flail, tumble and/or windblast incidents can only be ascertained through the survivors' statements. Those survivors of ejections during the period from 1 January 1969 through 31 December 1979 are the source of the basic data on incidents. Although flail injuries might be recognizable in some fatalities, in many others, especially unwitnessed ejections, determining flail, let alone tumble and windblast, as an occurrence is very difficult if not impossible.

There are limitations on the precision of the data. Flail, tumble or windblast phenomena occurring in the in-service environment can not be precisely defined or measured as might be desired; nor, can these phenomena be accurately replicated in test environments. The report of an incident generally depends upon the ejectees being conscious of the phenomena; and, there is probably a threshold of senstivity for each individual and the threshold may vary from ejectee to ejectee. In addition, under certain conditions an individual may believe that tumbling has been experienced when, in fact, no tumbling occurred (i.e. effects of forces acting upon an individual's otoliths). Other sources of verification such as observers are used when available. Regardless of these variations, which should essentially impact all systems' in service usage data equally, these data form the basic knowledge about the experience of flail, tumble and windblast and it is from these data that inferences will have to be drawn about the population of seats and their operational characteristics.

For each ejection incident there is, in general, data on aircraft altitude, speed and attitude so that each incident of flail, tumble or windblast can be associated with the aircraft situation at ejection. A common perception,as stated earlier, is that these incidents are high speed ejection phenomena, so it would be expected that the frequency of flail, tumble or windblast incidents will be, at least, a function of speed with the incidence increasing with velocity. Furthermore, it is expected that for the same speed there would be differences in the frequency of occurrence and/or the severity of these phenomena between types of seats. The data on the number of ejectees and the number that reported incidents of flail, tumble or windblast problems are presented by seat groupings according to the speed at time of ejection. As one might expect, the survivors interviewed had ejected at various aircraft speeds. The speed at ejection had varied over a wide range with only six interviewees for ejection speeds greater than 500 knots while most of the survivors had ejected at speeds between 100 and 300 knots.

METHOD OF ANALYSIS.

Since speed is fixed at the instant of each exposure to the ejection risks, all responses are conditional upon those fixed speeds. These data yield the percentage response to risk as defined or measured by the speed at ejection. These data, then, represent an example of a classical sensitivity test for which several analytical techniques have been developed. The specific technique selected for this application is called Probit Analysis in the literature.

Assume that each ejectee-seat combination has an associated critical level or threshold value of velocity for experiencing flail, tumble and/or windblast phenomena. If the velocity is equal to or greater than this critical level, the ejectee will experience flail, tumble or windblast upon ejection. Assume also that if the ejectee does not experience an ejection velocity equal to or greater than his threshold level, the ejectee will not experience flail, tumble or windblast during the ejection incident. For any particular ejectee, the exact critical level cannot be determined. However, several ejectees may be subjected to the same or about the same velocity at ejection and the proportion responding or sensitive to that velocity can be established. Inferences can then be made about the distribution of the threshold levels in a population of ejectees from which the sample came. The proportion responding at each level of velocity represents that portion of the population of ejectees that has a threshold at or below the given level of velocity. Thus, if the velocity is low, the percentage of the ejectees, whose threshold is equal to or less than that given velocity level, will be low. As the velocity level is increased, the proportion of ejectees, whose sensitivity level or threshold value is exceeded, will increase until at some velocity level it is expected that all thresholds will be exceeded and the proportion responding will be 100 percent.

The analytical procedures are based upon the threshold concept discussed above and the assumption that these threshold values vary among individuals according to a Normal or Gaussian distribution. Thus, the percentage of individuals who respond can be expressed as a function of aircraft speed at the time of ejection. Conceptually, the probability of surviving ejectees experiencing a response (flail, tumble or windblast problems) phenomena at speeds equal to or less than v can be expressed as:

$$\text{Prob (response} \leq v) = 1 - \exp - \int_{-\infty}^{v} \left[f(x)/R(x) \right] dx$$

where f(x) is the probability distribution of threshold speeds among surviving ejectees and for the Normal or Gaussian distribution

$$R(x) = (1/\sqrt{2\pi}) \int_{-\infty}^{(x-\mu)/\sigma} \exp -t^2/2 \, dt$$

The transformation that converts the percentage response into a standardized normal variate is the "probit" transform and yields the following relation (including a linear shift of 5 units to eliminate negative values during calculations):

$$Z_p + 5 = (x - \mu)/\sigma$$

and where Z_p is the value of the standard normal variate that corresponds to the percent responding, x is the airspeed at time of ejection, and μ and σ are the parameters of the normal distribution of threshold values. The method of weighted least squares is used to determine the values for μ and σ.

In conducting the probit analysis on these data the following assumptions have been made:

(1) The expected proportion responding will be greater for the higher speed.

(2) The distribution of ejectee sensitivity or threshold values are normally distributed.

(3) For each interval of speed a single point is representative of that interval.

The method of probit analysis is one of several generalized least squares methods that could be considered.

ANALYTICAL RESULTS.

The data from the reports concerning ejectees have been compiled for each phenomenon - windblast, flail and tumble. These data have been analyzed to obtain some descriptive characteristics of each phenomenon. The number of surviving ejectees reported upon, the number of ejectees reported to have experienced the phenomenon, and the airspeed at the time of ejection form the basis of the analysis discussed herein. The comparative analysis will consist of comparison of the differences in the expected median airspeed at the time of the ejection. The median airspeed is that airspeed at which 50% of the ejectees would be expected to experience the particular phenomenon (windblast problem, flail or tumble). If differences in the median airspeed values between designs are too great to be attributed to chance, then it will be concluded that the response is different for the designs.

Windblast

The data on windblast incidents among ejectees is presented in Table 4 for each of the four groups of seats defined earlier. The data is grouped into airspeed intervals of 50 knots. The number of ejectees experiencing windblast problems and the number of ejectees reported on are shown for each airspeed interval.

A comparison of the ESCAPAC early design (group I) with the later design (group II) was made employing probit analysis. Probit analysis was discussed in a previous section and the worksheets on the calculations are given in the appendix. The projected median airspeed on reported incidents of windblast problems was 393 knots for group I and 375 knots for group II. This difference is not significantly different between the two design groups, i.e. the difference is so small that it could be due to random sampling fluctuations. Combining the two samples yields the data presented as figure 1 where the expected percent of response is shown for the various airspeeds and superimposed as a straight line representing the best fit to the data points. The fitted line is a generalization of the observed response-airspeed relationship and can be used to assess the differences among seats. For not more than a one-in-ten response rate, based upon the generalized relationship, the airspeed at ejection would have to be equal to or less than 257 knots.

A comparison of the Martin-Baker early design (Group III) with their later design (Group IV) indicates that the two designs groups are not significantly different with respect to the windblast problem incidence. The percent response for Group III & IV is plotted against airspeed in figure 2. The best linear relation between the percent (probit) and airspeed has been superimposed on the figure for visual presentation. The expected one-in-ten response frequency would require that the airspeed at ejection to be equal to or less than 263 knots for this design group.

Thus, the ESCAPAC designs (Group I & II) and the Martin-Baker designs (Group III & IV) appear to be dissimilar in the frequency of windblast problems experienced by ejectees. The ejectees from aircraft employing the Martin-Baker designs (Group III & IV) appears to be a little less susceptible to windblast at the higher speeds while the differences are not so noticable at the lower speeds. These differences are shown in table 5.

WINDBLAST

Airspeed	Type Seats										Total		
	Group I		Group II		Group III		Group IV		Other				
	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	%
0 - 49	0	26	0	7	0	0	0	19	1	8	1	60	1.7
50 - 99	1	20	0	6	0	4	2	28	0	13	3	71	4.2
100 - 149	1	57	1	16	2	31	1	105	0	29	5	238	2.1
150 - 199	0	67	2	18	1	22	2	112	1	15	6	234	2.6
200 - 249	8	89	3	19	2	26	9	79	0	19	22	232	9.5
250 - 299	5	32	1	5	0	19	6	47	6	6	18	109	16.5
300 - 349	6	18	0	6	3	9	8	50	1	6	18	[illegible]	20.2
350 - 399	4	9	3	5	1	4	6	16	3	5	17	39	43.6
400 - 449	1	2	1	1	0	3	8	10	3	5	13	21	61.9
450 - 499	5	5	2	2	3	3	4	11	1	1	15	22	68.2
500 - 549	2	2			0	1	1	1			3	4	75.0
550 - 599					0	1	1	1			1	2	50.0
Unknown	2	5	2	3	0	1	0	5			4	14	28.6
Total	35	332	15	88	12	124	48	484	16	107	126	1,135	11.1

Table 4. The number of ejections and the number of ejectees that reported windblast problems for various ejection airspeed intervals and seat types during the period 1 January 1969 through 31 December 1979.

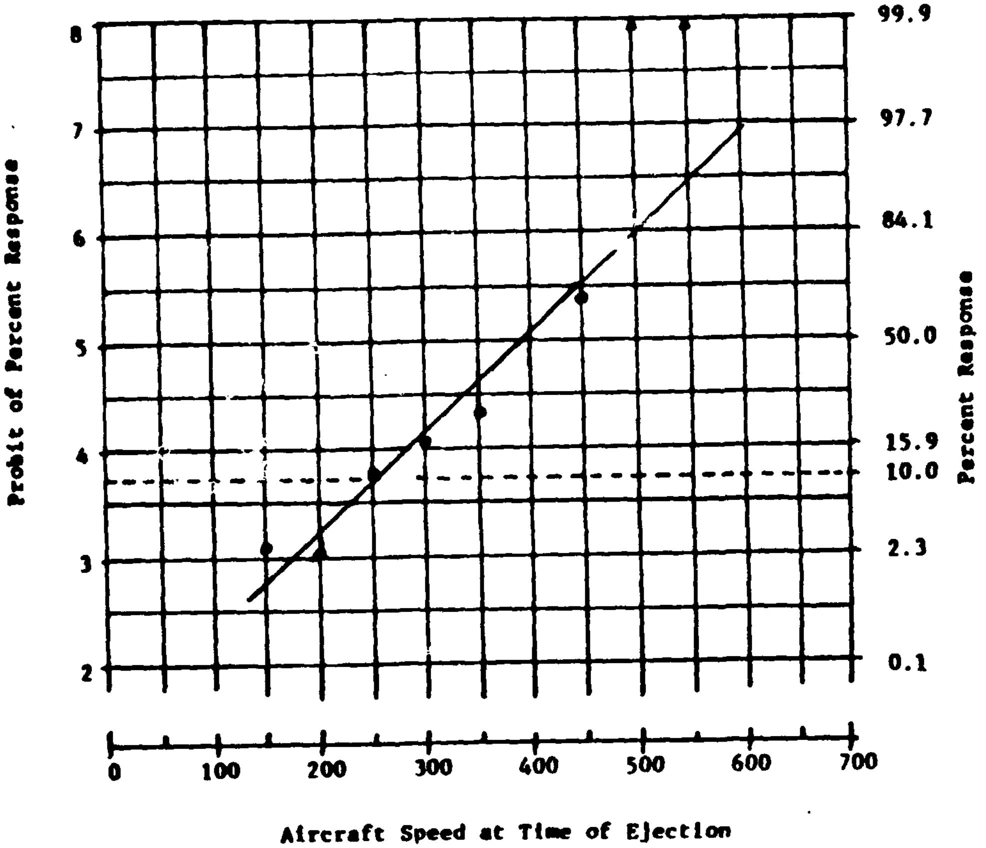

Figure 1. The percent of ejectees that reported windblast problems for various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat types Group I + II (ESCAPAC).

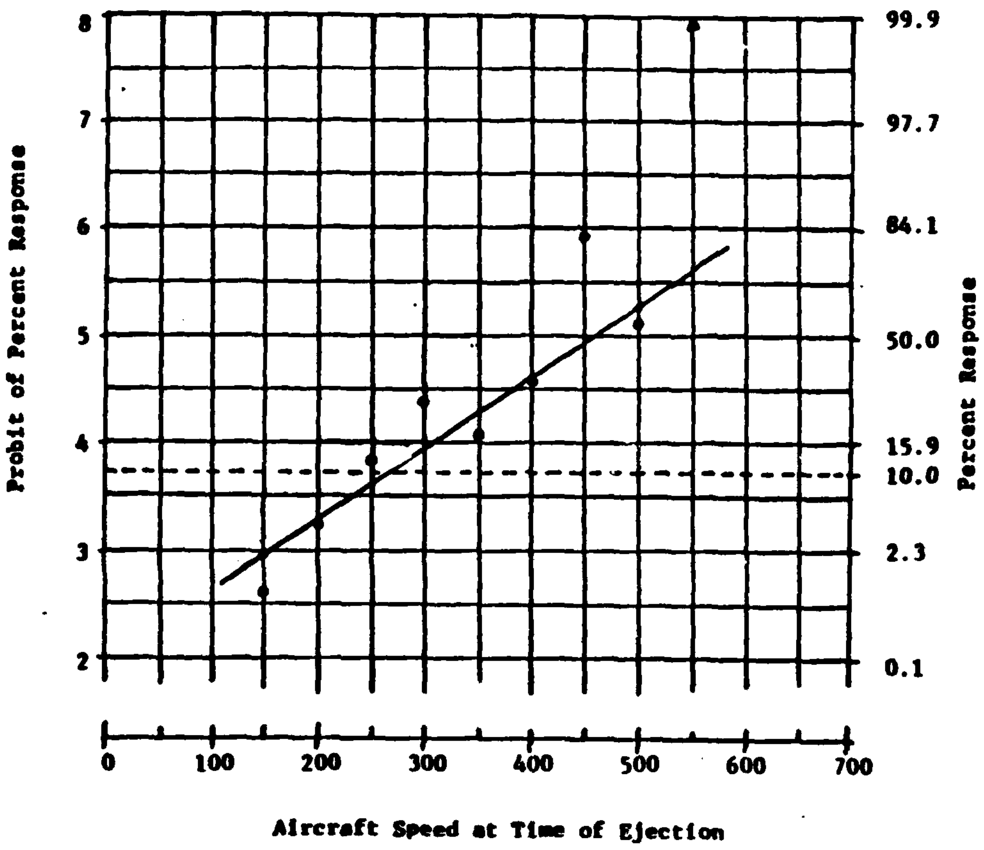

Figure 2. The percent of ejectees that reported windblast problems for various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat type Group III + IV(Martin-Baker).

Table 5. The airspeed-at-ejection for which a percentage of the surviving ejectees experience windblast problems.

Design	10th Percentile	50th Percentile	
	Expected	Expected	90% Confidence Band
ESCAPAC Group I&II	257	397	379-414
Martin-Baker Group III&IV	263	452	434-471

Flail

The data on the frequency with which ejectees experience flail during their ejection is presented in Table 6. The data presents the airspeed at time of ejection in 50 knot intervals and the number of ejectees along with the number of ejectees that reported flail for each interval.

The ESCAPAC seats differed between the early (Group I) and later designs (Group II) in the frequency of the incidence of flail. The ejectees using the early designs (Group I) reported flail at lower speeds than did the ejectees using the later designs (Group II). The data for group I are plotted in figure 4 along with the best linear fit to the observed points. The expected 10th percentile (10 % of the ejectees would be expected to experience flail) for this group is 220 knots. The data for group II are shown graphically in figure 5 with the best linear fit superimposed on the chart. The expected 10th percentile for this group is 254 knots.

The Martin-Baker seats did not show a difference in flail incidence between their early or later designs. The ejectees using the early designs and the ejectees using the later designs reported the incidence of flail equally at various speeds. The percent response data are shown in figure 6 with the best linear relationship between response and airspeed superimposed on the graph. The expected 10th percentile for these combined groups is 333 knots.

The ejectees reported flail at lower speeds for the ESCAPAC early designs than did the ejectees for the later ESCAPAC designs or the Martin-Baker designs. These differences are summarized in table 7.

FLAIL

Airspeed	Type Seats										Total		
	Group I		Group II		Group III		Group IV		Other				
	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	%
0 - 49	5	26	0	7		0	0	19	0	8	5	60	8.3
50 - 99	1	20	1	6	0	4	2	28	0	13	4	71	5.6
100 - 149	3	57	1	16	0	31	0	105	1	29	5	238	2.1
150 - 199	6	67	1	18	1	22	3	112	0	15	11	234	4.7
200 - 249	11	89	2	19	0	26	8	79	0	19	21	232	9.1
250 - 299	6	32	0	5	0	19	7	47	0	6	13	109	11.9
300 - 349	6	18	0	6	1	9	10	50	0	6	17	89	19.1
350 - 399	2	9	1	5	1	4	2	16	2	5	8	39	20.5
400 - 449	0	2	1	1	0	3	8	10	3	5	12	21	57.1
450 - 499	4	5	1	2	2	3	5	11	1	1	13	22	59.1
500 - 549	2	2			0	1	1	1			3	4	75.0
550 - 599					0	1	0	1			0	2	0
Unknown	1	5	1	3	0	1	0	5			2	14	14.3
Total	47	332	9	88	5	124	46	484	7	107	114	1,135	10.0

Table 6. The number of ejections and the number of ejectees that reported flail for the various ejection saispeed intervals and seat types during the period 1 January 1969 through 31 December 1979.

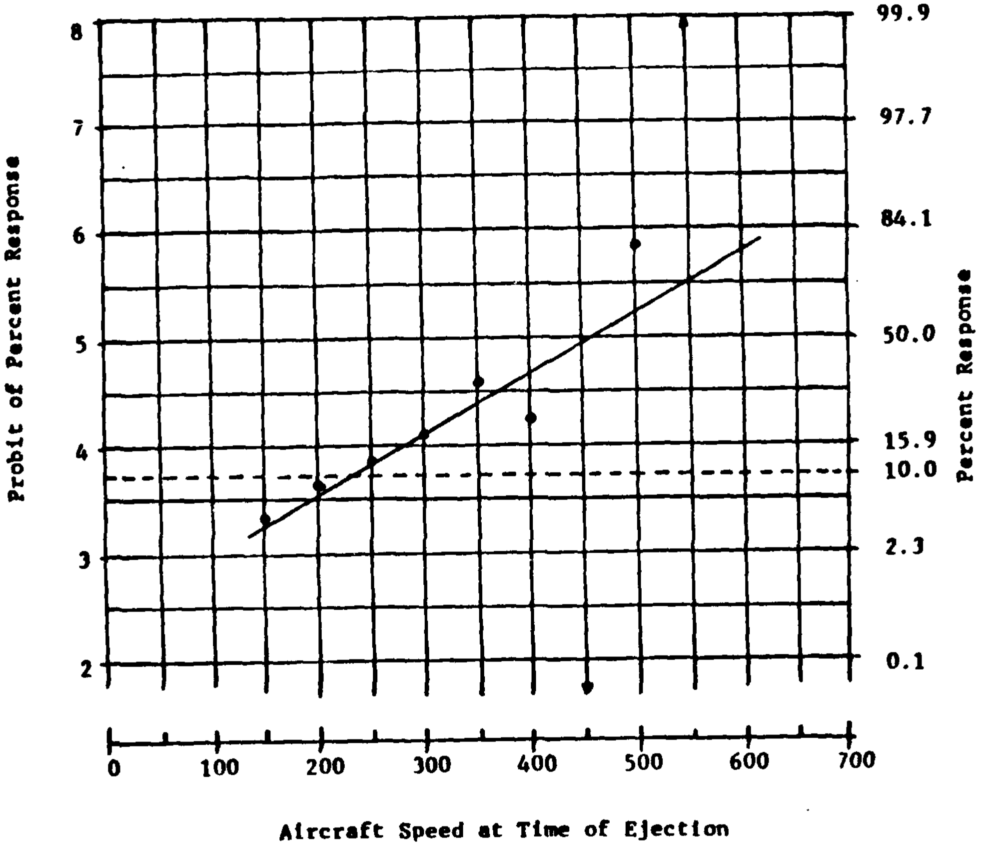

Figure 4. The percent of ejectees that reported Flail for various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat type Group I (ESCAPAC).

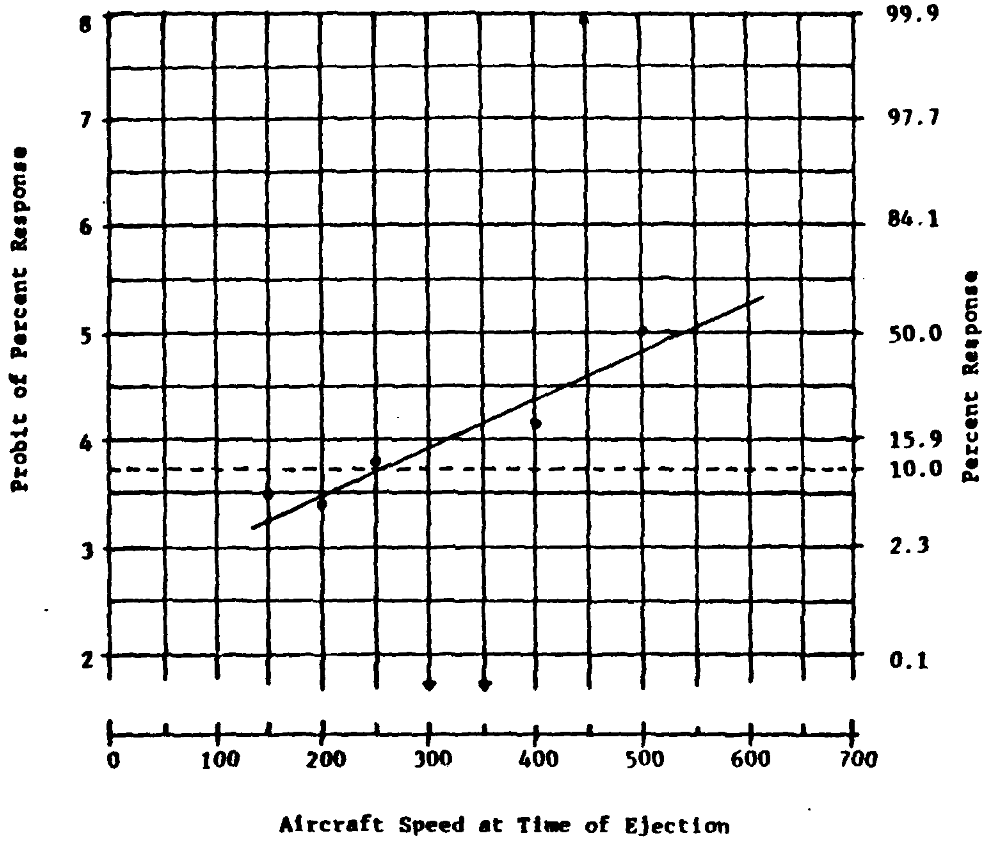

Figure 5. The percent of ejectees that reported Flail for various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat type Group II (ESCAPAC).

Table 7. The airspeed-at-ejection for which a percentage of the surviving ejectees reported flail.

Design	10th Percentile	50th Percentile	
	Expected	Expected	90% Confidence Band
ESCAPAC Group I Group II	220 254	453 535	424-483 457-613
Martin-Baker Group III & IV	333	531	460-528

Tumble

The data on the frequency with which ejectees reported tumble during their ejection is presented in Table 8. The number of surviving ejectees is presented by airspeed interval along with the number that reported tumble.

A comparison between the early and later ESCAPAC designs indicates about the same incidence rate for tumble. The paucity of the reported incidents of tumble makes it difficult to draw firm conclusions for each group individually. The combined data for the two design groups is presented in figure 7 and the linear relationship between response percentage and airspeed is described by the superimposed least-squares line. The expected 10th percentile value for the ESCAPAC designs is 170 knots.

The incident rate of tumble reported by ejectees was not different for the two Martin-Baker design groups. The small number of survivors for ejections at airspeeds greater than 250 knots, during the period studied, does not allow reliable estimates of the percentage response for group III. The data on Group III & IV combined are presented in Figure 8 and shows the observed percentages and the least-squares fitted linear relationship between airspeed and percentage response (probits). The Group III & IV seats are different from the ESCAPACS with respect to tumble during ejection. The expected 10th percentile for Group III & IV designs is 344 knots.

TUMBLE

Airspeed	Type Seats										Total		
	Group I		Group II		Group III		Group IV		Other				
	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	Yes	Total	%
0 - 49	7	26	0	7	0	0	0	19	0	8	7	60	11.7
50 - 99	1	20	0	6	0	4	1	28	0	13	2	71	2.8
100 - 149	6	57	1	16	1	31	5	105	3	29	16	238	6.7
150 - 199	7	67	2	18	0	22	5	112	0	15	14	234	6.0
200 - 249	10	89	7	19	0	26	7	79	1	19	25	232	10.8
250 - 299	4	32	1	5	3	19	8	47	0	6	16	109	14.7
300 - 349	2	18	0	6	0	9	6	50	0	6	8	89	9.0
350 - 399	4	9	0	5	0	4	2	16	1	5	7	39	17.9
400 - 449	1	2	1	1	0	3	1	10	0	5	3	21	14.3
450 - 499	0	5	0	2	0	3	2	11	0	1	2	22	9.1
500 - 549	0	2			0	1	0	1			0	4	0
550 - 599					0	1	0	1			0	2	0
Unknown	0	5	0	3	0	1	0	5			0	14	
Total	42	332	12	88	4	124	37	484	5	107	100	1,135	8.8

Table 8. The number of ejections and the number of ejectees that reported Tumble for various ejection airspeed intervals and seat types during the period 1 January 1969 through 31 December 1979.

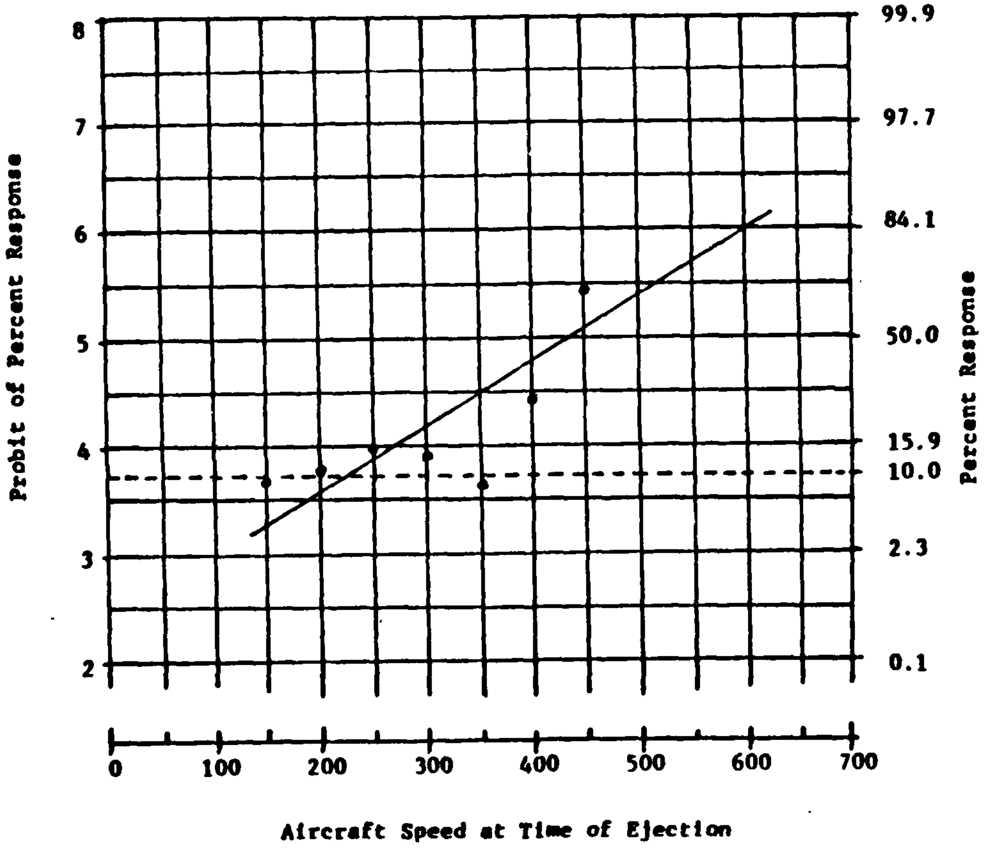

Figure 7. The percent of ejectees that reported Tumble for the various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat types Group I + II (ESCAPAC)

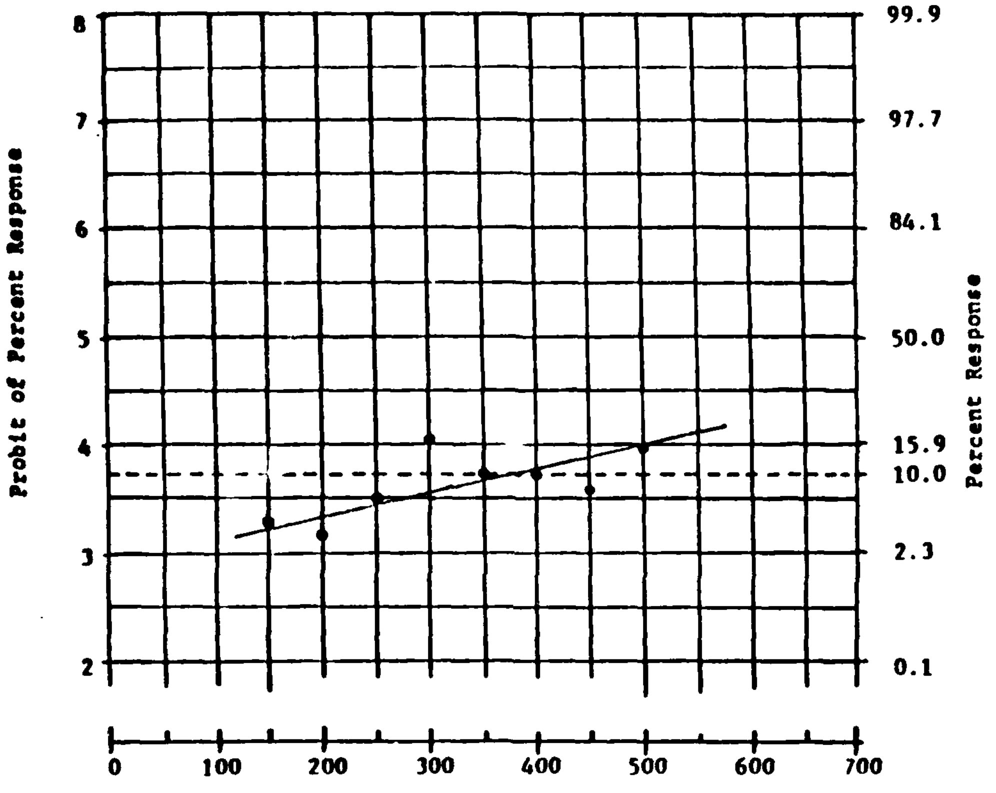

Figure 8. The percent of ejectees that reported Tumble for the various airspeed intervals and the weighted least squares fit (probit versus airspeed) to these data points for seat type Group III + IV (Martin-Baker)

Table 9. The airspeed-at-ejection for which a given percentage of the ejectees reported tumble.

Design	10th Percentile	50th Percentile	
	Expected	Expected	90% Confidence Band
ESCAPAC Group I & II	170	711	651-771
Martin-Baker Group III & IV	344	985	917-1053

Design Considerations

Comparisons among the median threshold speeds, i.e. the speeds at which 50% of the ejectees will experience a response, were discussed earlier and the median criterion was used to determine differences among the design groups for each response phenomenon. It is worthwhile to consider the impact of the differences among designs if all ejections occurred at a single speed of, say, 250 knots. Table 10 presents the expected percent response, the 90% confidence band for the expected percent, and the 90% confidence band for the individual sample percent for each response phenomenon for ejections occurring at 250 knots airspeed based upon the experience represented by the data presented earlier.

Table 10. The expected percent at 250 knots airspeed and 90% confidence bands for the expected percent for the various response phenomena and design groups.

Response Phenomena	Design Group	Expected Percent Response at 250 knots	90% Confidence Bands for the Expected Percent
Windblast	Group I&II	9.0	6.0-15.0
	Group III&IV	8.5	3.2-18.9
Flail	Group I	13.3	6.9-28.8
	Group II	9.6	2.0-28.8
	Group III&IV	2.6	0.2-13.5
Tumble	Group I&II	13.6	7.7-22.2
	Group III&IV	7.1	2.9-14.6

Conclusions

Designs aimed at reducing the incidence of windblast problems, flail and tumble have been and can be successful. The differences in susceptability to windblast, flail and/or tumble among ejection seats have been shown by comparing the expected 10th and 50th percentiles airspeed for the various seat designs. The P-th percentile value of airspeed is that airspeed at which only P percent of the ejectees are expected to experience a response (windblast problems, flail or tumble). The higher the expected P-th percentile value the more resistant the ejectee-seat combination is to the phenomenon.

For the windblast response reported for the surviving ejectees there was no difference between the ESCAPAC seats with both Group I and Group II having about the same median response. Also, there was no difference between the Martin-Baker seats with both Group III and Group IV having about the same expected median. The ESCAPAC seats appear to be slightly more sensitive to windblast at the higher speeds while the differences are not so noticable at the lower speeds.

For the flail response reported for the surviving ejectees there was a difference in speeds at which the ejectees in ESCAPAC Group I and Group II designs experienced flail. There was no difference between the Martin-Baker Group III and Group IV designs with respect to the airspeeds at which the ejectees experienced flail.

For the Tumble response reported for the ejectees there was no difference in speeds at which the ejectees in Group I and Group II designs experienced tumble. There was no discernable difference between Group III and Group IV designs with respect to the airspeeds at which the surviving ejectees experienced tumble. Ejectees in Group III & IV designs were much less sensitive to tumble than were ejectees in the Group I & II seat designs.

APPENDICES

Appendix A. Exact Probit Solutions

Appendix B. Goodness of fit Tests

APPENDIX A

Work Sheets for
the exact solution to
the various probit analyses

Probit Analysis

The exact probit solution entails an iterative procedure. An expected value is established for the line representing the percentage response given a speed. Using the expected value of Y one can determine from tables the weights (developed from the normal distribution) for each interval and the the working probit, y, The working probit is determined from the observed percentage and the expected probit for each interval. The weighted solution for y as a function of speed yields a new line which forms the expected values for the next iteration, if required. After a few iterations the expected values will not differ from the expected values of the previous iteration. At that time you have what we have called the exact solution. The final iterations for each analysis are shown in the following tables.

Probit Solution For Windblast Responses

Ejection Seat : Group I

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	57	.018	2.75	.084	2.936	4.788
200	67	0	3.20	.180	2.745	12.060
250	89	.090	3.60	.302	3.662	26.878
300	32	.156	4.10	.471	3.995	15.072
350	18	.333	4.60	.601	4.569	10.818
400	9	.444	5.00	.637	4.860	5.733
450	2	.500	5.50	.581	4.956	1.162
500	5	1.000	6.00	.439	6.656	2.195
550	2	1.000	6.40	.302	6.939	.604
						79.310

$\Sigma NWX = 22{,}403.4$

$\Sigma NWy = 307.652$

$\Sigma NWX^2 = 6{,}835{,}735$

$\Sigma NWXy = 92{,}046.321$

$$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.89 + .0101(x - 282.419)$$

$$\bar{\bar{x}} = \bar{x} + (5 - \bar{y}) / \hat{b} = 393.409$$

$$\hat{\sigma}_{\bar{\bar{x}}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 11.077$$

$$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 5141.129$$

$$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 507{,}247.652$$

$$\hat{b} = Sxy / Sxx = .0101$$

$$\hat{\sigma} = \hat{b}^{-1} = 98.674$$

Probit Solution For Windblast Responses

Ejection Seat : Group II

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	16	.063	3.1	.154	3.623	2.464
200	18	.111	3.6	.302	3.802	5.436
250	19	.158	4.2	.502	4.014	9.557
300	5	.200	4.7	.616	4.223	3.080
350	6	0	5.2	.627	3.719	3.762
400	5	.600	5.7	.532	5.194	2.660
450	1	1.000	6.2	.370	6.793	.370
500	2	1.000	6.7	.208	7.174	.416
						27.745

$\Sigma NWX = 7{,}525.25$

$\Sigma NWy = 114.268$

$\Sigma NWX^2 = 2{,}212{,}762.5$

$\Sigma NWXy = 32{,}011.547$

$$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 4.12 + .00593(x - 271.229)$$

$$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 375.108$$

$$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 31.99$$

$$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 1{,}018.746$$

$$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 171{,}696.089$$

$$\hat{b} = Sxy / Sxx = .00593$$

$$\hat{\sigma} = \hat{b}^{-1} = 168.54$$

Probit Solution For Windblast Responses

Ejection Seat : Group III

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	31	.065	3.1	.154	3.65	4.774
200	22	.045	3.5	.269	3.33	5.918
250	26	.077	3.8	.370	3.60	9.620
300	19	.000	4.2	.503	3.47	9.557
350	9	.333	4.5	.581	4.57	5.229
400	4	.250	4.9	.634	4.37	2.536
450	3	.000	5.2	.627	3.72	1.881
500	3	1.000	5.6	.558	6.42	1.674
						154.093

$\Sigma NWX = 11,699.8$

$\Sigma NWy = 167.319$

$\Sigma NWX^2 = 3,651,230$

$\Sigma NWXy = 49,837.850$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 4.062 + .007(x - 284.052)$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 418.300$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 14.98$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 2,310.626$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 327,833.47$

$\hat{b} = Sxy / Sxx = .00704$

$\hat{\sigma} = \hat{b}^{-1} = 96.15$

Probit Solution For Windblast Responses

Ejection Seat : Group IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	105	0	3.0	.131	2.579	13.755
200	112	.027	3.3	.208	3.113	23.296
250	79	.101	3.6	.302	3.735	23.858
300	47	.149	3.9	.405	3.961	19.035
350	50	.200	4.2	.503	4.159	25.150
400	16	.125	4.6	.601	4.004	9.616
450	10	.800	4.9	.634	5.756	6.340
500	11	.455	5.3	.616	4.873	6.776
550	1	1.000	5.6	.558	6.423	.558
						128.384

$\Sigma NWX = 37{,}594.25$

$\Sigma NWy = 488.70$

$\Sigma NWX^2 = 12{,}211{,}682.5$

$\Sigma NWXy = 153{,}627.55$

$$\hat{y} = \bar{y} + b(x - \bar{x}) = 3.81 + .0088(x - 292.827)$$

$$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 420.713$$

$$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 10.09$$

$$S_{xy} = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 10{,}523.191$$

$$S_{xx} = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 1{,}203{,}085.16$$

$$\hat{b} = S_{xy} / S_{xx} = .00875$$

$$\hat{\sigma} = \hat{b}^{-1} = 114.327$$

Probit Solution For Windblast Responses

Ejection Seat : Group I & II

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	73	.027	2.8	.092	3.17	6.716
200	85	.024	3.2	.180	3.05	15.300
250	108	.102	3.7	.336	3.73	36.288
300	37	.162	4.1	.471	4.02	17.427
350	24	.250	4.6	.601	4.34	14.424
400	14	.500	5.0	.637	5.00	8.918
450	3	.667	5.5	.581	5.43	1.743
500	7	1.000	5.9	.471	6.59	3.297
550	2	1.000	6.3	.336	6.86	.672
						104.785

$\Sigma NWX = 29{,}785.55$

$\Sigma NWy = 416.357$

$\Sigma NWX^2 = 9{,}173{,}847.5$

$\Sigma NWXy = 124{,}785.9$

$$\hat{y} = \bar{y} + b(x - \bar{x}) = 3.97 + .00915(x - 284.254)$$

$$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 396.5$$

$$\hat{\sigma}_{\tilde{x}} = \sigma(\Sigma NW)^{-1/2} = 10.7$$

$$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 6{,}434.779$$

$$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 707{,}187.302$$

$$\hat{b} = Sxy / Sxx = .00915$$

$$\hat{\sigma} = \hat{b}^{-1} = 109.3$$

Probit Solution For Windblast Responses

Ejection Seat : Group III & IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	136	.022	2.98	.127	2.73	17.272
200	134	.022	3.31	.211	3.24	28.274
250	105	.105	3.64	.316	3.80	33.180
300	66	.091	3.97	.429	4.23	28.314
350	59	.186	4.30	.532	4.10	31.388
400	20	.350	4.63	.604	4.31	12.080
450	13	.615	4.96	.636	5.80	8.268
500	14	.500	5.29	.615	4.84	8.616
550	1	1.000	5.62	.553	6.43	0.553
						167.939

$\Sigma NWX = 49{,}182.4$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.92 + 0.00677(x - 292.86)$

$\Sigma NWy = 658.551$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 452.4$

$\Sigma NWX^2 = 15{,}913{,}472$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 11.40$

$\Sigma NWXy = 203{,}084.97$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 10{,}222.765$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 1{,}510{,}007.24$

$\hat{b} = Sxy / Sxx = .00677$

$\hat{\sigma} = \hat{b}^{-1} = 147.7$

Probit Solution For Flail Responses

Ejection Seat : Group I

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	57	.053	3.4	.238	3.384	13.566
200	67	.090	3.6	.302	3.662	20.234
250	89	.124	3.8	.370	3.846	32.930
300	32	.188	4.1	.471	4.115	15.072
350	18	.333	4.3	.532	4.592	9.576
400	9	.222	4.5	.581	4.254	5.229
450	2	0	4.7	.616	3.698	1.232
500	5	.800	4.9	.634	5.756	3.170
550	2	1.000	5.1	.634	6.259	1.268
						102.277

$\Sigma NWX = 27{,}115.8$

$\Sigma NWy = 405.630$

$\Sigma NWX^2 = 7{,}964{,}450$

$\Sigma NWXy = 111{,}800.734$

$$\hat{y} = y + \hat{b}(x - \bar{x}) = 3.97 + .00549(x - 265.121)$$

$$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 453.463$$

$$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 18.011$$

$$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 4{,}259.626$$

$$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 775{,}476.823$$

$$\hat{b} = Sxy / Sxx \quad .00549$$

$$\hat{\sigma} = \hat{b}^{-1} = 182.149$$

Probit Solution For Flail Responses

Ejection Seat : Group II

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	16	.063	3.23	.188	3.54	3.008
200	18	.056	3.46	.257	3.41	4.626
250	19	.105	3.69	.333	3.75	6.327
300	5	.000	3.93	.415	3.30	2.075
350	1	.000	4.15	.487	3.44	0.487
400	5	.200	4.39	.555	4.18	2.775
450	1	1.000	4.61	.603	6.38	0.603
500	2	.500	4.85	.631	5.00	1,262
						21.163

$\Sigma NWX = 5,763.45$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.800 + .00457(x - 272.3)$

$\Sigma NWy = 80.411$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 535$

$\Sigma NWX^2 = 1,776,172.5$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 47.5$

$\Sigma NWXy = 22,843.6$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy) / NW = 944.36$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2 / \Sigma NW = 206,576.70$

$\hat{b} = Sxy / Sxx = .00457$

$\hat{\sigma} = \hat{b}^{-1} = 218.5$

Probit Solution For Flail Responses

Ejection Seat : Group III

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	31	0	2.42	.040	2.06	1.240
200	22	.045	2.75	.084	3.68	1.848
250	26	0	3.08	.154	2.66	4.004
300	19	0	3.41	.238	2.91	4.522
350	9	.111	3.74	.353	3.78	3.177
400	4	.250	4.07	.471	4.35	1.884
450	3	0	4.40	.558	3.58	1.674
500	3	.667	4.73	.619	5.45	1.857
						20.206

$\Sigma NWX = 6{,}460.55$

$\Sigma NWy = 69.483$

$\Sigma NWX^2 = 2{,}252{,}907.5$

$\Sigma NWXy = 23{,}592.25$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.44 + .00735(x - 319.734)$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 532.115$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 30.267$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 1{,}376.156$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 187{,}248.473$

$\hat{b} = Sxy / Sxx = .00735$

$\hat{\sigma} = \hat{b}^{-1} = 136.054$

Probit Solution For Flail Responses

Ejection Seat : Group IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	29	.034	2.60	.062	3.75	1.798
200	15	0	3.22	.186	2.76	2.790
250	19	0	3.84	.384	3.24	7.296
300	6	0	4.46	.572	3.60	3.432
350	6	0	5.08	.635	3.75	3.810
400	5	.400	5.70	.532	4.55	2.660
450	5	.600	6.32	.329	4.53	1.645
500	1	1.000	6.94	.145	7.34	.145
						23.576

$\Sigma NWX = 6,891.55$

$\Sigma NWy = 85.344$

$\Sigma NWX^2 = 2,178,622.5$

$\Sigma NWXy = 25,895.1$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.62+.00578(x - 292.312)$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 531.066$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 35.632$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 948.016$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 164,139.068$

$\hat{b} = Sxy / Sxx = .00578$

$\hat{\sigma} = \hat{b}^{-1} = 173.01$

Probit Solution For Flail Responses

Ejection Seat : Group III & IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	60	.017	2.23	.026	3.870	1.56
200	37	.027	2.68	.073	3.275	2.70
250	45	0	3.13	.162	2.687	7.29
300	25	0	3.58	.295	3.045	7.38
350	15	.067	4.03	.449	3.621	6.74
400	9	.333	4.48	.576	4.570	5.18
450	8	.375	4.93	.635	4.685	5.08
500	4	.750	5.36	.607	5.651	2.43
						38.35

$\Sigma NWX = 12,742.05$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.716 + .00794(x - 332.2)$

$\Sigma NWy = 142.55$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 493.89$

$\Sigma NWX^2 = 4,552,692.5$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 20.34$

$\Sigma NWXy = 49,892.5$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 2,546.737$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 320,719.147$

$\hat{b} = Sxy / Sxx = .00794$

$\hat{\sigma} = \hat{b}^{-1} = 125.93$

Probit Solution For Tumble Responses

Ejection Seat : Group I

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	57	.105	3.60	.302	3.76	17.214
200	67	.105	3.75	.353	3.75	23.651
250	89	.112	3.90	.405	3.79	36.045
300	32	.125	4.05	.455	3.87	14.560
350	18	.111	4.20	.503	3.85	9.054
400	9	.444	4.35	.545	4.95	4.905
450	2	.500	4.50	.581	6.04	1.162
						106.591

$\Sigma NWX = 26{,}345.35$

$\Sigma NWy = 412.53$

$\Sigma NWX^2 = 7{,}025{,}787.5$

$\Sigma NWXy = 103{,}574.2$

$$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.87 + .00314(x - 247.163)$$

$$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 607.036$$

$$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 30.847$$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 1{,}612.053$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 514{,}192.088$

$\hat{b} = Sxy / Sxx = .00314$

$\hat{\sigma} = \hat{b}^{-1} = 318.471$

Probit Solution For Tumble Responses

Ejection Seat : Group II

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	16	.063	3.94	.405	3.567	6.480
200	18	.111	4.02	.439	3.803	7.902
250	19	.368	4.10	.471	4.791	8.949
300	5	.200	4.18	.497	4.159	2.485
350	6	0	4.26	.520	3.497	3.120
400	5	0	4.34	.542	3.551	2.710
450	1	1.000	4.41	.588	6.579	.588
						32.234

$\Sigma NWX = 7{,}975.75$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 4.057 + .00168(x - 247.43)$

$\Sigma NWy = 130.778$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 808.74$

$\Sigma NWX^2 = 2{,}179{,}712.5$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 104.8$

$\Sigma NWXy = 32{,}705.396$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 346.625$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 206{,}250.067$

$\hat{b} = Sxy / Sxx = .00168$

$\hat{\sigma} = \hat{b}^{-1} = 595$

Probit Solution For Tumble Responses

Ejection Seat : Group III

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	16	.063	3.95	.424	3.57	6.784
200	18	.111	4.03	.448	4.22	8.064
250	19	.368	4.11	.474	4.79	9.006
300	5	.200	4.19	.500	4.16	2.500
350	6	0	4.27	.524	3.53	3.144
400	5	0	4.35	.545	3.58	2.725
450	1	1.000	4.41	.567	6.58	.567
						32.790

$\Sigma NWX = 8{,}077.45$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 4.16 + .00103(x - 246.339)$

$\Sigma NWy = 136.373$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 1{,}062.844$

$\Sigma NWX^2 = 2{,}199{,}032.5$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 169.732$

$\Sigma NWXy = 33{,}809.25$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 215.286$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 209{,}242.976$

$\hat{b} = Sxy / Sxx = .00103$

$\hat{\sigma} = \hat{b}^{-1} = 971.93$

Probit Solution For Tumble Responses

Ejection Seat : Group IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	105	.048	3.51	.269	3.355	28.245
200	112	.045	3.62	.309	3.361	34.608
250	79	.089	3.73	.346	3.654	27.334
300	47	.170	3.84	.384	4.083	16.356
350	50	.120	3.95	.422	3.834	21.100
400	16	.125	4.06	.458	3.878	7.328
450	10	.100	4.17	.493	3.814	4.930
500	11	.182	4.28	.526	4.108	5.786
						145.687

$\Sigma NWX = 38,326.35$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.635+.00241(x - 263.07)$

$\Sigma NWy = 529.626$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 829.46$

$\Sigma NWX^2 = 11,402,302.5$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 34.40$

$\Sigma NWXy = 142,508.8$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 3,178.376$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 1,319,665.72$

$\hat{b} = Sxy / Sxx = .00241$

$\hat{\sigma} = \hat{b}^{-1} = 415.2$

Probit Solution For Tumble Responses

Ejection Seat : Group I & II

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	73	.096	3.7	.319	3.70	23.287
200	85	.106	3.8	.364	3.75	30.940
250	108	.157	3.9	.405	4.00	43.740
300	37	.135	4.0	.445	3.90	16.465
350	24	.083	4.1	.484	3.73	11.616
400	14	.286	4.3	.520	4.44	7.280
450	3	.667	4.4	.553	5.59	1.659
						134.987

$\Sigma NWX = 33,279.7$

$\Sigma NWy = 526.285$

$\Sigma NWX^2 = 8,900,880.$

$\Sigma NWXy = 131,400.6$

$\hat{y} = \bar{y} + b(x - \bar{x}) = 3.899 + .00237(x - 246.5)$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 711$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 36.3$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 1650.29$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 696,101.53$

$\hat{b} = Sxy / Sxx = .00237$

$\hat{\sigma} = \hat{b}^{-1} = 421.8$

Probit Solution For Tumble Responses

Ejection Seat : Group III & IV

Speed At Ejection X	Number Of Ejectees Reporting N	Proportion Responding P	Y	W	y	NW
150	136	.044	3.3	.208	3.29	28.288
200	134	.037	3.4	.238	3.24	31.892
250	105	.067	3.5	.269	3.50	28.245
300	66	.167	3.6	.302	4.18	19.932
350	59	.102	3.7	.336	3.73	19.824
400	20	.100	3.8	.370	3.72	7.400
450	13	.077	3.9	.405	3.63	5.265
500	14	.143	4.0	.439	3.94	6.146
						146.992

$\Sigma NWX = 39{,}003.1$

$\hat{y} = \bar{y} + \hat{b}(x - \bar{x}) = 3.561 + .002(x - 265.342)$

$\Sigma NWy = 523.371$

$\tilde{x} = \bar{x} + (5 - \bar{y}) / \hat{b} = 984.842$

$\Sigma NWX^2 = 11{,}686{,}455$

$\hat{\sigma}_{\tilde{x}} = \hat{\sigma}(\Sigma NW)^{-1/2} = 41.24$

$\Sigma NWXy = 141{,}934.677$

$Sxy = \Sigma NWXy - (\Sigma NWX)(\Sigma NWy)/\Sigma NW = 3{,}062.552$

$Sxx = \Sigma NWX^2 - (\Sigma NWX)^2/\Sigma NW = 1{,}337{,}308.04$

$\hat{b} = Sxy / Sxx = .00200$

$\hat{\sigma} = \hat{b}^{-1} = 500$

Appendix B.

Goodness of Fit Tests

Goodness of Fit Tests

To test whether the regression lines presented in Figures 1 - 8 are adequate representations of the observed percentage data a goodness of fit test was employed. The test statistic in each situation was obtained by measuring the deviations of the observed number in each speed interval from the expected number as follows:

$$\chi^2_{k-2} = \sum_{i=1}^{k} \frac{(r_i - n_i P_i)^2}{n_i P_i (1 - P_i)}$$

If the calculated value of chi-square, χ^2, is equal to or less than the 95-percentile value of the chi-square distribution there is no reason to believe the line does not adequately represent the percentage data.

Goodness of Fit Tests

WINDBLAST Group I & II

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	73	2	2.74	1.19	0.87	1.49
200	85	2	3.20	3.59	3.05	0.38
250	108	11	3.66	9.01	9.73	0.16
300	37	6	4.11	18.67	6.91	0.15
350	24	6	4.57	33.36	8.01	0.76
400	14	7	5.03	51.20	7.17	0.01
450	3	2	5.49	68.79	2.06	0.01
500	7	7	5.94	82.64	5.78	1.47
550	2	2	6.40	91.92	1.84	0.18

$$x_7^2 = 4.63$$

Goodness of Fit Tests

WINDBLAST Group III & IV

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	121	1	2.96	2.03	2.46	0.884
200	130	5	3.29	4.34	5.64	0.076
250	98	11	3.63	8.53	8.36	0.911
300	52	11	3.96	14.92	7.76	1.590
350	56	10	4.29	22.90	12.82	0.804
400	21	5	4.62	35.20	7.39	1.192
450	11	9	4.96	48.40	5.32	4.932
500	13	7	5.29	61.40	7.98	0.312
550	1	1	5.62	73.23	0.73	0.358

$$x^2_7 = 11.059$$

Goodness of Fit Tests

FLAIL Group I

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	57	3	3.33	4.75	2.71	0.03
200	67	6	3.61	8.24	5.54	0.04
250	89	11	3.88	13.15	11.70	0.05
300	32	6	4.16	20.05	6.42	0.03
350	18	6	4.43	28.40	5.11	0.22
400	9	2	4.71	38.60	3.47	1.01
450	2	0	4.98	49.20	0.98	1.93
500	5	4	5.26	60.25	3.01	0.82
550	2	2	5.53	70.20	1.40	0.86

$\chi_7^2 = 4.99$

Goodness of Fit Tests

FLAIL Group II

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	16	1	3.24	3.90	0.62	0.24
200	18	1	3.44	5.95	1.07	0.01
250	19	2	3.64	8.69	1.65	0.08
300	5	0	3.84	12.30	0.62	0.71
350	6	0	4.04	16.85	1.01	1.21
400	5	1	4.23	22.07	1.10	0.01
450	1	1	4.43	28.40	0.28	2.59
500	2	1	4.63	35.60	0.71	0.18

$x_6^2 = 5.03$

Goodness of Fit Tests

FLAIL Group III & IV

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	60	1	2.27	0.32	0.19	3.45
200	37	1	2.67	0.92	0.34	1.28
250	45	0	3.06	2.60	1.17	1.20
300	25	0	3.46	6.20	1.55	1.66
350	15	1	3.86	12.70	1.91	0.50
400	9	3	4.25	22.70	2.04	0.58
450	8	3	4.65	36.30	2.90	0.01
500	4	3	5.05	52.00	2.08	0.85

$\chi^2_6 = 10.38$

Goodness of Fit Tests

TUMBLE Group I & II

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	73	7	3.67	9.18	6.70	0.01
200	85	9	3.79	11.31	9.61	0.04
250	108	17	3.91	13.79	14.89	0.35
300	37	5	4.03	16.60	6.14	0.25
350	24	2	4.14	19.49	4.68	1.90
400	14	4	4.26	22.96	3.21	0.25
450	3	2	4.38	26.76	0.80	2.44

$x_5^2 = 5.24$

Goodness of Fit Tests

TUMBLE Group III & IV

x	n	r	Y	P	nP	$\frac{(r - nP)^2}{nP(1-P)}$
150	136	6	3.30	4.45	6.05	0.00
200	134	5	3.40	5.50	7.37	0.08
250	105	7	3.50	6.70	7.04	0.00
300	66	11	3.60	8.70	5.74	3.46
350	59	6	3.70	9.70	5.72	0.02
400	20	2	3.80	11.50	2.30	0.04
450	13	1	3.90	13.55	1.76	0.38
500	14	2	4.00	15.90	2.23	0.03

$x^2_6 = 4.74$

FACTORS INFLUENCING THE INCIDENCE AND SEVERITY OF "EJECTION ASSOCIATED" NECK INJURIES SUSTAINED BY U.S. NAVY EJECTEES 1 JANUARY 1969 THROUGH 31 DECEMBER 1979

Frederick C. Guill

ABSTRACT

Investigating medical officers when confronted by an ejectee having a serious neck injury (sprain, strain, fracture, subluxation, transection) have generally examined the ejection process as the sole source of the forces necessary to produce the injury. A number of "classical" explanations have evolved to explain these injuries: poor positioning of the body, ejection boost forces too high, windscoop effect acting upon the ejectee's helmet, and parachute opening shock effects being among the commonest. Some medical officers have truly strained to force fit the data into one of these "classical" causal factors. In-depth review of original medical officer's reports suggests several injury causal factors often overlooked include pre-ejection aircraft maneuver, post-separation collisions of man and seat, ground contact, and rescue attempts, and that often several potential causal factors were present at various times during an escape and rescue process.

BACKGROUND

Largely as a consequence of a perceived relationship between ejection, and especially certain phases of ejection, with the incidence of neck injuries sustained by ejectees; over the past decade major attention has been focused on developing information concerning the causal mechanisms of neck injuries reported to have been sustained by ejectees. Inasmuch as a large proportion, if not the majority, of these injuries appear to be indirectly induced and not directly induced (i.e., when directly induced the neck would be physically struck by an object) much of this attention has been focused upon determining head and neck dynamic response to parachute opening shock and to means for reducing these forces, the attendant extreme movements, and their potential deleterious effects upon the ejectee.

It needs, however, to be emphasized that the "ejection associated" neck injury problem is not a new phenomenon, that the problem has existed for many years, with the first severe neck injury among U.S. Navy ejectees occurring 26 June 1957 and the first moderate neck injury occurring 20 February 1953. During the period beginning with the U.S. Navy's first reported ejection on 9 August 1949 through 31 December 1968 there was a total of 1,965 ejections with 12 severe neck injuries and 109 moderate neck injuries, 0.61 per cent and 5.55 per cent, respectively. During the eleven year period under study (1 January 1969 through 31 December 1979) there were 21 severe and 114 moderate "ejection associated" neck injuries among

1,391 ejectees, while during the following 2 1/2 year period (through mid 1982) there have been an additional 6 severe and 24 moderate "ejection associated" neck injuries. (These total ejection attempts and associated rates cannot, on the basis of information available to this project at present, be correlated or realistically compared on an equivalent basis to the data studied and reported herein, but are presented simply to illustrate that the problem has been a protracted one that is continuing.)

Furthermore, this problem in recent years has been the subject of several probes. One, in late 1974, suggested a correlation between the occurrence of neck injuries among ESCAPAC ejectees and the absence (or presence in the event of non-injury) of ballistically powered haulback type inertia reels. The problems faced with each of these earlier studies into "ejection associated" neck injuries among the U.S. Navy ejectees were (1) the small population sizes induced by the Privacy Act related cut-off of ready access to historical records at 1 January 1969 and (2) the level of detail obtainable from Naval Safety Center computerized data tapes.

As a consequence of the major improvements in modern escape systems, wherein the range of inflight conditions from which aircrew escape is now feasible is extensive, the next major steps in the evolution of these systems undoubtedly will be, and must be, understanding fully the causal factors and causal mechanisms for various signficant aircrew "escape associated" injuries and the devising of means for reducing or even, hopefully, eliminating the incidence of these injuries. Among these significant "escape associated" injuries are those sustained in the neck region, classifiable as shown in Table I as severe or moderate. These can result and have resulted, in death, in disablement and also in significant periods of post-escape grounding among ejectees.

DATA COLLECTION

During the past year the Crew Systems Division (AIR-531), Naval Air Systems Command, and the Analytical Systems Division (ESA-31), Naval Weapons Engineering Support Activity, with the assistance of the Naval Safety Center, have undertaken an in-depth review of the available data concerning those ejections in which the ejectees were reported to have sustained any of the following forms of neck injury:

TABLE I

Group I (severe)	transection
	fracture-dislocation
	subluxation
	simple fracture
	avulsive fracture
	compression fracture
	compound fracture
	comminuted fracture
	compound-comminuted fracture
Group II (moderate)	strain
	sprain

Other injuries such as riser burns, abrasions and similar types of minor wounds were grouped into a third set, which although not subjected to analysis at this time, is being prepared for future study, especially as these additional data might aid in explaining some of the Group I or II injuries' causation. This effort was initiated by searching data tapes provided by the Naval Safety Center. The data in these tapes is in both codified form and in narrative form extracted from all U.S. Navy ejection MORs/FSRs (Medical Officer's Reports/Flight Surgeon's Reports) for all ejectees who ejected clear of the aircraft, within the performance envelope of their escape system,[1] and sustained any type of neck injury. Ejections in which the above Table I listed specific types of neck injuries were reported to have been sustained by the ejectees were then identified. Upon request, the Naval Safety Center then made available for detailed review copies of almost all of the original MORs/FSRs for each of the mishaps so identified (several records could not be located, probably due to errors in listing the mishap identification and an attempt will be made to locate them).

During the review the exact words the medical officers used to describe each neck injury were extracted along with any descriptive notes describing its severity, location and/or how it was diagnosed. In addition, the entire mishap sequence of events was reviewed and summarized from the onset of the emergency, through escape initiation, escape, parachute opening and descent, surface contact, and rescue. Of particular interest among the events were those which either input a force to the crewmember/ejectee or could modify the crewmember/ejectee capability to withstand without injury the applied forces associated with the various phases of the emergency and/or the escape.

Historically, it should be noted, that there have been two primary camps concerning the cause of neck injuries: Those who believe such injuries result from poor body positioning, especially of head and neck, and/or ejection forces, during the catapult boost stroke; and those who believe that such injuries result from direct (an object bearing upon or striking the neck producing a neck load) or indirect loads (inertial) imparted upon the head and neck during parachute opening shock. Interestingly, until the mid 1970's poor body position for catapult boost stroke appears to have been the primary contender with parachute opening forces occasionally suggested as the probable causal factors. More recently it would appear that parachute opening forces have become the favored explanation. In addition, periodically other theories have been advanced, such as the helmet forming a windscoop, and have gained their adherents.

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[1] At this stage of the investigation, the reports' statements concerning whether ejections occurred in or out of envelope were accepted non-critically. Potentially, as better analytical tools are developed, tested and proven, these statements might be checked at a later date.

It should also be noted, even though virtually obvious to all, that compilations of data such as those maintained by the Naval Safety Center must, of necessity, resort to simplifying codes and abbreviated synopses if the data are to be economically storable, retrievable and capable of being manipulated (analyzed) for multiple and often unpredefined purposes. Thus such data compilations cannot be expected to be sufficient in and of themselves for conducting detailed investigations of this nature. Without such carefully prepared and maintained data compilations, however, an investigator would face a monumental and virtually hopeless task of sorting through original records in an attempt to locate those records pertinent to the investigation at hand; and, therefore, few would ever undertake the task.

THE BASIC DATA

For the period studied, 1 January 1969 through 31 December 1979, the Naval Safety Center tapes identified a total of 1,816 crewmembers in ejection seat equipped aircraft involved in mishaps.[2] Of these, 1,391 attempted ejection, 1,188 reportedly having been initiated and accomplished within the escape systems' performance envelopes. Among these in-envelope ejectees there were 76 fatalities.

Within the reported in-envelope ejectee population there were reported twenty-one (21) severe and 114 moderate neck injuries (incidence rates of 1.77 per cent and 9.6 per cent, respectively). In all, 135 or 11.36 per cent of the U.S. Navy in-envelope ejectees of this period were reported to have sustained a moderate or severe neck injury as earlier defined. The severe neck injuries included twelve (12) survivors and nine (9) fatalities. Five (5) of the fatalities suffered transections of the spinal cord, two suffered dislocations of cervical vertebrae with probable fatal injury to the spinal cord, and two suffered simple fractures of cervical vertebrae and subsequently drowned. Two of the survivors suffered fractures of two cervical vertebrae each, while the remaining ten survivors suffered fractures of only one cervical vertebra each. The distribution and types of cervical vertebral fractures among the survivors is shown in Table II.

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[2] Refer to Preliminary Overview Analyses of U.S. Navy Aircrew Automated Escape Systems (AAES) In-service Usage Data, Charles W. Stokes et al, presented at the 19th Annual SAFE Symposium, December 1981, for the basic distribution of ejection data for the period 1 January 1969 through 31 December 1979.

TABLE II

TYPE AND LOCATION OF CERVICAL FRACTURES AMONG SURVIVING EJECTEES

CERVICAL VERTEBRAE TYPE FRACTURE	C-1	C-2	C-3	C-4	C-5	C-6	C-7
SIMPLE	-	5	-	-	2	2	1
COMPRESSION	-	-	-	-	1	-	2
COMMINUTED	-	1	-	-	-	-	-
TOTALS	-	6	-	-	3	2	3

The distribution and types of cervical injuries among the ejectee fatalities are shown in tables III and IV.

TABLE III

CERVICAL DISLOCATION AND SPINAL CORD TRANSECTION QUANTITIES AND SITES AMONG EJECTEE FATALITIES

C-1	C-1/2	C-2/3	C-3/4	C-4/5	C-5/6	C-6/7
2	-	2	-	1	1	-

TABLE IV

TYPE, QUANTITY AND LOCATION OF CERVICAL FRACTURES AMONG EJECTEE FATALITIES

	C-1	C-2	C-3	C-4	C-5	C-6	C-7
SIMPLE	-	-	-	-	1**	1**	-
COMPRESSION	2*	-	-	-	-	-	-

* one drowned, one subluxed
** same individual, drowned

Attached in Appendix A, Part I, are tables of limited, pertinent data extracted from the MOR/FSR data tape and from the original MORs/FSRs for those ejectees sustaining severe neck injuries, while Appendix A, Part II, contains similar data compilations for those sustaining moderate injury of the neck. Appendix A, Part III, provides limited data extracted from MOR/FSR data tapes concerning (6) identified cases wherein reportedly fully strapped in Navy crewmembers sustained an inflight, i.e., non-ejection, non-bailout, non-crash or hard landing, neck injury. Part IV of Appendix A provides similar data for strapped in Navy crewmembers sustaining neck injuries during crash and/or hard landings.

Before examining these data further, it would be well to examine both the emergency occurrence and the escape process which subjects those who sustained these neck injuries and the many ejectees not sustaining any of the Table I listed severe or moderate neck injuries to various, rapidly changing force vectors, i.e., changing magnitudes and directions, as well as changing rates of onset and points of force application. What is the source of the forces acting upon the individual? In what manner are they generated and applied? What are their likely consequences? And what are their likely relative magnitudes?

ESCAPE SYSTEMS PHASES VS. INJURY POTENTIAL (Figure I)

Figure (2) (in two sheets) roughly depicts the various phases of an inflight emergency resulting in an escape attempt. Figures (3) through (6), respectively, provide a general and brief illustration and discussion of the role of pre-escape emergency phase force(s) in producing injury and in producing the factors affecting the potential that a force produced during the escape attempt might induce an injury. Figures (7) and (8), respectively, discuss the general nature of escape system forces and the factors affecting their potential for inducing injury. Figures (9) through (17) describe the types of forces likely to be experienced by aircrew in an inflight emergency and during the other phases of escape identified in Figure (2). Note that these figures do not attempt to indicate the magnitudes of the likely forces, nor their direction or application sites since they vary from system to system and from escape condition to escape condition. Nor do these figures make any attempt to estimate the likelihood of injury causation. These figures are presented only to provide a brief frame of reference with which to consider the summarized individual case data presented in Appendix A, Parts I, II and III, and the various injury case groupings such as injury vs. type of pre-ejection maneuver, injury vs. speed at ejection, injury vs. maneuver at ejection, injury vs. mode of canopy used during the escape, etc. Using this series of figures (2 through 17) also is of interest when one examines all of the mishaps seeking potential explanations and causal factors for the injuries sustained and their severity. As will be shown, in many of the mishaps there were many potentially injury-producing factors present and an individual examining but one of the mishaps would be extremely hard put in many instances to obtain and report a satisfactory explanation, especially if that individual's thinking had been colored by popular "classical" explanations as so often has been the case.

DATA EXAMINATION APPROACHES USED

As earlier reported, the candidate ejectees were selected from among the population of 1,816 mishap crewmembers during the period 1 January 1969 through 31 December 1979 who (1) accomplished an ejection (deliberate or inadvertent) clear of the aircraft and (2) were reported within the Naval Safety Center MOR/FSR data extract computer tapes to have sustained a neck injury. This group then was further divided into three groups and the evaluation then concentrated on those sustaining a neck injury falling into either group I or II as listed in Table I.

The next step was to print out and examine the computerized data for each of the individual ejections. Based upon personal knowledge concerning many of these ejections and the reports submitted for them, the author decided that the data base required expansion, for much of the information known to have been reported could not be acquired from the computer tapes. Accordingly, the author then visited the Naval Safety Center and with their permission and assistance, examined completely the record for each mishap in which an ejectee reportedly sustained either a Table I classified severe or moderate neck injury and extracted information defining the emergency and its effect upon the crew, the conditions of the escape and the impressions of ejectees and witnesses of the escape, the medical officer's description of the injury sustained and the effects of that injury, the conditions attendant to the ejectees's contact with the surface, and his subsequent rescue. As earlier reported, of particular interest were those aspects indicating the application of forces upon the ejectee or potential alteration of the ejectee's ability to withstand without injury the forces being applied. In this connection, a supplementary pre-ejection aircraft manuever category was created since the Naval Safety Center maneuver category covered only that maneuver occurring at ejection. This supplementary maneuver describes the aircraft maneuvers prior to, as well as, during the escape attempt.

The present analyses were predicated upon (1) a physical count in each mishap of the factors present which might either have caused or helped to cause the reported injury, (2) a frequency count of the occurrence of these factors versus type of injury reportedly sustained, and (3) the nature of the aircraft manuever immediately preceding and during the escape from the aircraft. These efforts are yielding preliminary results as reported in the following section. The results as stated, however, must be considered as only preliminary for the population being examined is specifically that population with the observed result of interest, i.e., a type of neck injury. Thus, although there may appear to be a direct relationship between a specific factor and injury within this population, what cannot at this time be ascertained is how many times that specific factor occurred without being associated with that type of, or any, neck injury. There remain in the total population of ejectees, accomplishing their escape clear of the aircraft and within the system envelope during the period under study, another 1,053 ejectees who did not sustain a reported Table I type "ejection associated" neck injury and whose cases require the same careful, thorough in-depth review of the original reports before these analytical efforts can be completed.

THE PROCESSED DATA

Tables V through XIII depict the numbers of ejectees sustaining an "ejection associated" neck injury by (1) category of aircraft pre-ejection maneuver, (2) category of aircraft pre-ejection maneuver and type of ejection seat (3) by type of ejection seat, and (4) by type of ejection seat and category of aircraft pre-ejection maneuver. Figures 18 through 23 illustrate the frequency of injury rate by type of injury sustained versus the ejection airspeed (NOTE: Since several ejectees sustaining "severe" "ejection associated" neck injuries sustained more than one such injury/injury type, the data presented in Figures 19 through 23 are not additive).

Appendix A, Parts I and II, respectively, summarize the data concerning the pre-ejection, ejection, descent, surface contact, and rescue factors which conceivably might have contributed to, or caused, the ejectee to sustain the reported "ejection associated" neck injuries.

The data presented in these tables and figures reveal, especially when considered in conjunction with the U.S. Navy's inflight neck injuries and crash associated neck injuries (Appendix A, Parts III and IV, respectively) and the recent U.S. Air Force's inflight F-4 incident in which an aft cockpit pilot suffered the fracture and subluxation of C-6, many potentials exist for both pre-ejection injury and for pre-ejection malpositioning for ejection in ways which could result in neck injury during the catapult boost phase of the escape. These data also clearly indicate in some instances system malfunctions, such as post man-seat separation entanglement of the seat in the deploying parachute only to be dislodged by inertial forces upon parachute opening and then colliding with the decelerating ejectee. Additionally, these data often suggest the presence in a given case of several, not just one, potential injury producing mechanism.

CONCLUSIONS

At this interim stage of this effort there exists evidence as disclosed and discussed herein and in Appendix A, to support the following preliminary conclusions:

(1) Sprain/strain and fracture type neck injuries can and do occur inflight (i.e., without ejection, bailout, crash, or hard landing) and therefore that some proportion, probably significant, of the "ejection associated" neck injuries have occurred prior to ejection.

(2) Sprain/strain and fracture type neck injuries can occur during the catapult boost phase of ejection, especially when the ejectee's head and neck are poorly positioned to withstand the boost forces.

(3) Several fatal neck injuries have occurred as a consequence of improper functioning of the ejection seats.

(4) Sprain/strain and possibly fracture type neck injuries may have occurred during surface contact, generally contact in a manner beyond the control of system designers and users, e.g., parachute snagging a branch causing the ejectee to be slammed to the ground on his back and head.

(5) Sprain/strain type neck injuries have probably occasionally been induced after surface contact, e.g., ejectee being dragged.
(6) Sprain/strain type neck injuries have probably occasionally been induced during rescue attempts, e.g., one ejectee while in the water was repeatedly struck on his helmet very hard by the helicopter, other ejectees have bumped hard against helicopter structures while being hoisted.
(7) Stabilized ejection seats appear to sustain significantly fewer severe, i.e., fractures, transections, neck injuries than non-stabilized seats and have virtually no post man-seat separation collisions of seat with man.
(8) (Based on earlier work) ballistic haulback type inertial reels can reduce the incidence of sprain/strain type "ejection associated" neck injuries.

The evidence obtained and the analyses performed to date in this effort do not support parachute opening shock as a frequent causal or contributory factor of "ejection associated" neck injuries. However, neither the data nor the analyses can rule out the likelihood that an occasional "ejection associated" neck injury results from parachute opening shock, especially where the risers bear upon or impact against the ejectee's neck and, in fact, there are several mishaps in which such conditions existed apparently without other potential injury inducing factors being present.

As stated, these are preliminary conclusions based upon an evaluation of a specific segment of the U.S. Navy's ejectee population: those sustaining a moderate or severe neck "ejection associated" neck injury (defined in Table I) during the period from 1 January 1969 through 31 December 1979. There remains to be accomplished the same detailed data acquisition effort and subsequent analyses for the 1,053 ejectees during that same period who did not sustain "ejection associated" neck injuries in order to identify the differences between those two populations. In addition, there remains the task of evaluating the records pertaining to the earlier and later ejectees, both those who did not sustain and those who did sustain an "ejection associated" neck injury to ascertain whether analyses of the data for those populations confirms or not the results obtained when the analyses of the study period population has been completed.

FINAL COMMENT

Examination of these original MORs/FSRs clearly reveals and even underscores the very critical need for medical personnel preparing these reports to collect and present all obtainable information, even when not fully understood. A number of the MORs/FSRs examined by the author were exceptionally complete, sometimes far beyond the levels prescribed by the report forms. Unfortunately, there were also a sizable number of MORs/FSRs where, although there were survivors and/or witnesses, the preparer of the report did not seem to have availed himself of all of the available resources of information, much of which is now lost forever. It is hoped that this paper and especially Figures 2 through 17, the tables and Appendix A (all parts) might help FSR preparers in their investigation of a mishap and search for information by suggesting for this single objective, the study of "ejection associated" neck injuries, many of the factors of critical interest to an investigator studying a large body of mishap data.

Note: Data prepared by Mr. Robert Cox

TABLE V
DISTRIBUTION OF SEVERE "EJECTION ASSOCIATED" NECK INJURIES BY PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER
1	DISINTEGRATING, POST RAMP STRIKE
1	DIVE, HIGH SPEED
2	ENGINE FAILURE
2	FLAME OUT (ONE WITH FIRE IN COCKPIT)
1	INADV. EJT., ATTEMPTING TO STOW RADIATION SHIELD
5	INFLIGHT FIRE 1 (NO OTHER MANEUVER) 1 (PROBABLE) HIGH SPEED DIVE 1 FIRE IN 0_2 SYSTEM 2 WITH LOSS OF ALL HYDRAULIC CONTROLS
3	POST MID-AIR COLLISION
3	SPIN 1 FLAT 1 OSCILLATING 1 UNCONTROLLED FLIGHT
1	SPIRAL, 80° NOSE DIVE, AFCS MALFUNCTION
1	STRUCK DITCH AND ROLLING INVERTED
1	UNCONTROLLED FLIGHT, HIGH SPEED

TABLE VI
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER
1	CATAPULT LAUNCH: ENGINE MALFUNCTIONED AS STROKE BEGAN
1	COLD CATAPULT SHOT (BRIDLE BROKE)
1	CONTROL LOSS CAUSED BY CANOPY STRIKING TAIL DURING CATAPULT LAUNCH
1	DISINTEGRATION FOLLOWING MISSILE STRIKE
1	ENGINE EXPLOSION AND LOSS OF HYDRAULIC CONTROLS
9	ENGINE FAILURE 3 (NO OTHER MANEUVER) 2 DURING LANDING APPROACH (ONE WITH FIRE) 1 DUE TO BIRD STRIKE 1 DURING CVA APPROACH 1 ATTEMPTING A NO POWER LANDING ("DEAD STICK" LNDG ATTEMPT) 1 FIRE
5	ENGINE FIRE 3 (NO OTHER MANEUVER) 2 LOSS OF HYDRAULIC CONTROLS
3	ENGINE SEIZURE 2 (NO OTHER MANEUVER) 1 FLAME OUT
6	FLAME OUT 4 (NO OTHER MANEUVER) 1 DURING APPROACH 2 DUAL
2	HARD LANDING 1 ON CV 1 SHEARING MLG – LEAVING RUNWAY
1	IMPROPER POWER RESPONSE DURING LANDING APPROACH, LATE RECOGNITION OF EXTREMIS CONDITION
9	INFLIGHT FIRE 6 (NO OTHER MANEUVER) 1 EXPLOSION 2 LOSS OF CONTROLS
3	INVERTED 1 DUE TO FLAP FAILURE 1 UNCONTROLLED FLIGHT AFTER CATAPULT LAUNCH 1 UNCONTROLLED, AFTER AIRCRAFT STRUCK BY MISSILE

TABLE VI (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER
1	LANDED ON SIDE OF RUNWAY AND LOST CONTROL
1	LEVELLING OUT AFTER DIVE FOLLOWING INADV. CANOPY LOSS
1	LOCKED FLIGHT CONTROLS
1	LOSS OF POWER
1	MUSHING – LOST POWER DURING CATAPULT LAUNCH
1	NOSE DOWN ATTITUDE DURING AND FOLLOWING CATAPULT LAUNCH
2	NOSE FALLING THROUGH 1 AFTER GEAR CONTACTED FLIGHT DECK (LATE WAVE OFF) 1 AT EJECTION, POST ENGINE EXPLOSION ZOOM CLIMB
1	NOSE PITCHED UP AFTER AIRCRAFT WAS STRUCK BY MISSILE
1	NOSE PITCHING UP AND DOWN, STEEP DIVE
2	OVERROTATION 1 STALL POST CATAPULT LAUNCH 1 POST CAT. LAUNCH – RADAR SCOPE SHIFTED AFT AGAINST STICK
1	OVERRUNNING END OF RUNWAY FOLLOWING FAST LANDING
1	PITCH OSCILLATION, VIOLENT
1	PITCHING NOSE DOWN, POST CATAPULT LAUNCH
1	PLANNED EJT.: UTILITY HYD. FAILURE PREVENTED FLAPS AND MLG EXTENSION
12	POST MID-AIR COLLISION 6 (NO OTHER MANEUVER) 1 TUMBLING 1 DIVE 1 PITCH DOWN 1 FIRE WITH LOSS OF PORTION OF WING 1 INVERTED, UNCONTROLLED 1 OUT OF CONTROL
1	POST RAMP STRIKE, ENGINE SEIZURE DURING CLIMBOUT

TABLE VI (Continued)

DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES

BY PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER
3	PULLOUT 2 POST ROCKET RUN, EXPLOSION AND INFLIGHT FIRE 1 POST BOMBING RUN, GRAYING OUT
8	ROLLING 5 UNCONTROLLED, IMMEDIATELY AFTER CATAPULT LAUNCH 1 GENTLE, AFTER HYD CONTROL FAILURE 1 INFLT. FIRE, FOL. LOSS OF FUEL TANK DURING CAT. LAUNCH 1 DURING APPROACH TO FIELD 2 POST-STALL 1 INDUCED BY RAISING FLAPS PREMATURELY DURING TAKE-OFF 1 CONTROLS STIFF FOLLOWING CATAPULT LAUNCH 1 NOSE DOWN
1	RUNNING OFF DECK UNDER UNCOMMANDED ENGINE POWER
2	SLIDING DOWN FLIGHT DECK AFTER RAMP STRIKE
21	SPIN 4 (NO OTHER MANEUVER) 1 OSCILLATING 4 FLAT 9 NOSE DOWN 3 ROLLING (ONE DURING APPROACH TO CV)
2	STALL, LOW LEVEL
3	UNCONTROLLED FLIGHT 2 (NO OTHER MANEUVER) 1 PILOT DISORIENTED
1	ZOOM CLIMB, POST ENGINE FAILURE

TABLE VII

DISTRIBUTION OF SEVERE "EJECTION ASSOCIATED" NECK INJURIES BY PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER	SEAT MODEL
1	DISINTEGRATING, POST RAMP STRIKE	MK H7
1	DIVE, HIGH SPEED	LS-1
2	ENGINE FAILURE	ESCAPAC IA-1, ESCAPAC IC-3
2	FLAME OUT (ONE WITH FIRE IN COCKPIT)	ESCAPAC IG-3, ESCAPAC IA-
1	INADV. EJT., ATTEMPTING TO STOW RADIATION SHIELD	ESCAPAC IC-2
5	INFLIGHT FIRE	
	1 (NO OTHER MANEUVER)	MK GRU5
	1 (PROBABLE) HIGH SPEED DIVE	MK GRU7
	1 FIRE IN O_2 SYSTEM	ESCAPAC IF-3
	2 WITH LOSS OF ALL HYDRAULIC CONTROLS	2 HS-1A
3	POST MID-AIR COLLISION	MK GRU5, ESCAPAC IC-2, ESCAPAC IG-3
3	SPIN	
	1 FLAT	ESCAPAC IG-2
	1 OSCILLATING	ESCAPAC IC-2
	1 UNCONTROLLED FLIGHT	ESCAPAC IA-1
1	SPIRAL, 80° NOSE DIVE, AFCS MALFUNCTION	ESCAPAC IG-3
1	STRUCK DITCH AND ROLLING INVERTED	MK H7
1	UNCONTROLLED FLIGHT, HIGH SPEED	ESCAPAC IC-3

TABLE VIII
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER	SEAT TYPE
1	CATAPULT LAUNCH: ENGINE MALFUNCTIONED AS STROKE BEGAN	MK H7
1	COLD CATAPULT SHOT (BRIDLE BROKE)	MK H7
1	CONTROL LOSS CAUSED BY CANOPY STRIKING TAIL DURING CATAPULT LAUNCH	ESCAPAC IC-2
1	DISINTEGRATION FOLLOWING MISSILE STRIKE	ESCAPAC IF-3
1	ENGINE EXPLOSION AND LOSS OF HYDRAULIC CONTROLS	LS-1
9	ENGINE FAILURE	
	3 (NO OTHER MANEUVER)	MK F7, ESCAPAC IC-2
	2 DURING LANDING APPROACH (ONE WITH FIRE)	ESCAPAC IG-2, SIIIS-3
	1 DUE TO BIRD STRIKE	ESCAPAC IC-3
	1 DURING CVA APPROACH	TYPE 9
	1 ATTEMPTING A NO POWER LANDING ("DEAD STICK" LNDG ATTEMPT)	ESCAPAC IG-3
	1 FIRE	MK H7
5	ENGINE FIRE	
	3 (NO OTHER MANEUVER)	ESCAPAC IC-2, LW-3b, SLLS-3
	2 LOSS OF HYDRAULIC CONTROLS	2 MK GRU5
3	ENGINE SEIZURE	
	2 (NO OTHER MANEUVER)	MK F7; ESCAPAC IG-2
	1 FLAME OUT	ESCAPAC IA-1
6	FLAME OUT	
	4 (NO OTHER MANEUVER)	3 ESCAPAC IC-2, ESCAPAC IF-3
	1 DURING APPROACH	MK GRU5
	2 DUAL	LS-1, MK H7
2	HARD LANDING	
	1 ON CV	MK F7
	1 SHEARING MLG — LEAVING RUNWAY	MK H7
1	IMPROPER POWER RESPONSE DURING LANDING APPROACH, LATE RECOGNITION OF EXTREMIS CONDITION	ESCAPAC IC-2

TABLE VIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER	SEAT TYPE
9	INFLIGHT FIRE	
	6 (NO OTHER MANEUVER)	4 MK H7, MK GRU5, MK GRU7A
	1 EXPLOSION	MK GRUEA5
	2 LOSS OF CONTROLS	2 MK GRU7A
3	INVERTED	
	1 DUE TO FLAP FAILURE	ESCAPAC IA-1
	1 UNCONTROLLED FLIGHT AFTER CATAPULT LAUNCH	ESCAPAC IC-2
	1 UNCONTROLLED, AFTER AIRCRAFT STRUCK BY MISSILE	ESCAPAC IA-1
1	LANDED ON SIDE OF RUNWAY AND LOST CONTROL	ESCAPAC IA-1
1	LEVELLING OUT AFTER DIVE FOLLOWING INADV. CANOPY LOSS	ESCAPAC IC-2
1	LOCKED FLIGHT CONTROLS	ESCAPAC IC-2
1	LOSS OF POWER	ESCAPAC IC-2
1	MUSHING – LOST POWER DURING CATAPULT LAUNCH	ESCAPAC IA-1
1	NOSE DOWN ATTITUDE DURING AND FOLLOWING CATAPULT LAUNCH	MK H7
2	NOSE FALLING THROUGH	
	1 AFTER GEAR CONTACTED FLIGHT DECK (LATE WAVE OFF)	MK H7
	1 AT EJECTION, POST ENGINE EXPLOSION ZOOM CLIMB	ESCAPAC I
1	NOSE PITCHED UP AFTER AIRCRAFT WAS STRUCK BY MISSILE	MK GRU7A
1	NOSE PITCHING UP AND DOWN, STEEP DIVE	MK GRU5
2	OVERROTATION	
	1 STALL POST CATAPULT LAUNCH	MK GRU5
	1 POST CAT. LAUNCH – RADAR SCOPE SHIFTED AFT AGAINST STICK	ESCAPAC IA-1
1	OVERRUNNING END OF RUNWAY FOLLOWING FAST LANDING	ESCAPAC IC-2
1	PITCH OSCILLATION, VIOLENT	MK H7
1	PITCHING NOSE DOWN, POST CATAPULT LAUNCH	MK H7

TABLE VIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

INJURED MISHAP AIRCREW	*PRE-EJECTION AIRCRAFT MANEUVER*	SEAT TYPE
1	PLANNED EJT.: UTILITY HYD. FAILURE PREVENTED FLAPS AND MLG EXTENSION	MK H7
12	POST MID-AIR COLLISION	
	6 (NO OTHER MANEUVER)	2 MK H7, MK GRUEA7, 2 ESCAPAC IC-2 ESCAPAC IG-2
	1 TUMBLING	ESCAPAC IC-2
	1 DIVE	ESCAPAC IC-2
	1 PITCH DOWN	LS-1
	1 FIRE WITH LOSS OF PORTION OF WING	LW-3B
	1 INVERTED, UNCONTROLLED	MK H7
	1 OUT OF CONTROL	MK H7
1	POST RAMP STRIKE, ENGINE SEIZURE DURING CLIMBOUT	ESCAPAC IC-2
3	PULLOUT	
	2 POST ROCKET RUN, EXPLOSION AND INFLIGHT FIRE	2 MK H7
	1 POST BOMBING RUN, GRAYING OUT	ESCAPAC IC-2
8	ROLLING	
	5 UNCONTROLLED, IMMEDIATELY AFTER CATAPULT LAUNCH	
	1 GENTLE, AFTER HYD CONTROL FAILURE	ESCAPAC IC-2
	1 INFLT. FIRE, FOL. LOSS OF FUEL TANK DURING CAT. LAUNCH	HS-1A
	1 DURING APPROACH TO FIELD	MK H7
	2 POST-STALL	MK H5
	1 INDUCED BY RAISING FLAPS PREMATURELY DURING TAKE-OFF	MK A7
	1 CONTROLS STIFF FOLLOWING CATAPULT LAUNCH	ESCAPAC IA-1
	1 NOSE DOWN	ESCAPAC IF-3
1	RUNNING OFF DECK UNDER UNCOMMANDED ENGINE POWER	MK GRU7A
2	SLIDING DOWN FLIGHT DECK AFTER RAMP STRIKE	MK F7, MK GRU7A

TABLE VIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES
BY PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1971

INJURED MISHAP AIRCREW	PRE-EJECTION AIRCRAFT MANEUVER	SEAT TYPE
21	SPIN	
	4 (NO OTHER MANEUVER)	ESCAPAC HS-1, ESCAPAC IA-1,2 ESCAPAC IG-3
	1 OSCILLATING	MK H7
	4 FLAT	MK GRU7A, MK H7, ESCAPAC IC-2, ESCAPAC IG-2
	9 NOSE DOWN	MK F7, MK GRU5, MK GRUEA7, 3 MK H7, LS-1, ESCAPAC IC-2, ESCAPAC IF-3
	3 ROLLING (*ONE DURING APPROACH TO CV*)	MK H7, 2 LS-1A
2	STALL, LOW LEVEL	MK H7, HS-1
3	UNCONTROLLED FLIGHT	
	2 (NO OTHER MANEUVER)	MK H7, LS-1
	1 PILOT DISORIENTED	ESCAPAC IC-2
1	ZOOM CLIMB, POST ENGINE FAILURE	ESCAPAC IC-2

TABLE IX.
DISTRIBUTION OF "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT
1 January 1969 through 31 December 1979

SEAT	TOTAL EJECTIONS 1 & 5	SEVERE NECK INJURY		MODERATE NECK INJURY
		FATAL	NON-FATAL	
MK A5	19	0	0	0
MK F5	17	0	0	0
MK GRU5	84	0	2	7
MK GRUEA5	5	0	0	1
MK H5	14	0	0	1
MK L5	6	0	0	0
MK M5	0	0	0	0
MK N5	0	0	0	0
MK P5	0	0	0	0
MK X5	0	0	0	0
MK Z5	7	0	0	0
ESCAPAC I	7	0	0	1
ESCAPAC IA-1	89	2	1	8
ESCAPAC IC-2	158	1	2	23
ESCAPAC IC-3	124	1	1	1
HS-1	25	0	0	2
LS-1	53	0	0	5
LW-3B	22	0	0	2
MK A7	8	0	0	1
MK F7	88	0	0	5
MK GRU7	38	1	0	0
MK GRUEA7	17	0	0	2
MK GRU7A	67	0	0	7
MK H7	348	0	2	29
ESCAPAC IF-3	19	1	0	4
ESCAPAC IG-2	41	0	1	6
ESCAPAC IG-3	43	0	3	3
ESCAPAC IG-4	1	0	0	0
ESCAPAC IG-5	0	0	0	0
ESCAPAC IE-1	8	0	0	0
HS-1A	9	2	0	1
LS-1A	4	1	0	2
SEU-3/A (SIIIS-3)	7	0	0	2
NAMC II	1	0	0	0
F-5E	1	0	0	0
TYPE 9	8	0	0	0

TABLE X
DISTRIBUTION OF SEVERE "EJECTION ASSOCIATED" NECK INJURIES BY TYPE
EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

MK GRU5
- 1 INFLIGHT FIRE
- 1 POST MID-AIR COLLISION, ROLLING

ESCAPAC IA-1
- 1 ENGINE FAILURE
- 1 FLAME OUT, FIRE IN COCKPIT
- 1 SPIN, UNCONTROLLED FLIGHT

ESCAPAC IC-1
- 1 INADVERTENT EJECTION WHILE ATTEMPTING TO STOW RADIATION SHIELD
- 1 POST MID-AIR COLLISION, TUMBLING
- 1 SPIN, OSCILLATING

ESCAPAC IC-3
- 1 ENGINE FAILURE
- 1 UNCONTROLLED FLIGHT, HIGH SPEED

LS-1
- 1 DIVE, HIGH SPEED NEGATIVE G CONDITIONS, AIRCRAFT DISINTEGRATING

MK GRU7
- 1 INFLIGHT FIRE (PROBABLE), HIGH SPEED DIVE

MK H7
- 1 DISINTEGRATING, POST RAMP STRIKE
- 1 STRUCK DITCH & ROLLING INVERTED

ESCAPAC IF-3
- 1 INFLIGHT FIRE — FIRE IN O_2 SYSTEM

ESCAPAC IG-2
- 1 SPIN, FLAT

ESCAPAC IG-3
- 1 FLAME OUT
- 1 POST MID-AIR COLLISION, MUSHING
- 1 SPIRAL, 80 DEG NOSE DIVE, AFCS MALFUNCTION

HS-1A
- 2 INFLIGHT FIRE WITH LOSS OF ALL HYDRAULIC CONTROLS

TABLE XI

DISTRIBUTION OF SURVIVORS SUSTAINING SEVERE "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

MK GRU5
- 1 INFLIGHT FIRE
- 1 POST MID-AIR COLLISION, SNAP ROLLING/TUMBLING/NEGATIVE G CONDITIONS

ESCAPAC IA-1
- 1 ENGINE FAILURE

ESCAPAC IC-2
- 1 INADVERTENT EJECTION WHILE ATTEMPTING TO STOW RADIATION SHIELD
- 1 SPIN OSCILLATING

ESCAPAC IC-3
- 1 ENGINE FAILURE

MK H7
- 1 DISINTEGRATING, POST RAMP STRIKE
- 1 STRUCK DITCH AND ROLLING INVERTED

ESCAPAC IG-2
- 1 SPIN, FLAT

ESCAPAC IG-3
- 1 FLAME OUT
- 1 POST MID-AIR COLLISION, MUSHING
- 1 SPIRAL, 80 DEG. NOSE DIVE, AFCS MALFUNCTION

TABLE XII

DISTRIBUTION OF FATALITIES SUSTAINING SEVERE "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

ESCAPAC IA-1
1 FLAME OUT, FIRE IN COCKPIT
1 UNCONTROLLED FLIGHT

ESCAPAC IC-2
1 POST MID-AIR COLLISION, TUMBLING

ESCAPAC IC-3
1 UNCONTROLLED FLIGHT, HIGH SPEED

LS-1
1 DIVE, HIGH SPEED NEGATIVE G CONDITIONS, AIRCRAFT DISINTEGRATING

MK GRU7
1 INFLIGHT FIRE (PROBABLE) HIGH SPEED DIVE

ESCAPAC IF-3
1 INFLIGHT FIRE, FIRE IN O_2 SYSTEM

HS-1A
2 INFLIGHT FIRE WITH LOSS OF ALL HYDRAULIC CONTROLS

TABLE XIII
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

MK GRU5
- 2 ENGINE FIRE, LOSS OF HYDRAULIC CONTROLS
- 1 FLAME OUT DURING APPROACH
- 1 INFLIGHT FIRE
- 1 NOSE PITCHING UP AND DOWN, STEEP DIVE
- 1 OVERROTATION AND STALL, POST CATAPULT LAUNCH
- 1 SPIN, NOSE DOWN

MK GRUEA5
- 1 INFLIGHT FIRE WITH EXPLOSION

MK H5
- 1 ROLLING UNCONTROLLED, INDUCED BY RAISING FLAPS PREMATURELY DURING TAKE OFF

ESCAPAC 1
- 1 NOSE FALLING THROUGH AT EJECTION, POST ENGINE EXPLOSION ZOOM CLIMBOUT

ESCAPAC IA-1
- 1 ENGINE SEIZURE/FLAME OUT
- 2 INVERTED
  - 1 DUE TO FLAP FAILURE
  - 1 UNCONTROLLED AFTER AIRCRAFT STRUCK BY MISSILE
- 1 LANDING ON SIDE OF RUNWAY AND LOST CONTROL
- 1 MUSHING — LOST POWER DURING CATAPULT LAUNCH
- 1 OVERROTATION OF A/C POST CAT. LAUNCH — RADAR SCOPE SHIFTED *AFT AGAINST STICK*
- 1 ROLLING, CONTROLS STIFF FOLLOWING CATAPULT LAUNCH
- 1 SPIN

ESCAPAC IC-2
- 1 CONTROL LOSS CAUSED BY CANOPY STRIKING TAIL DURING CATAPULT LAUNCH
- 1 ENGINE FIRE
- 1 ENGINE FAILURE
- 3 FLAME OUT
- 1 INVERTED, UNCONTROLLED FLIGHT AFTER CATAPULT LAUNCH
- 1 IMPROPER POWER RESPONSE DURING LANDING APPROACH
- 1 LEVELLING OUT AFTER DIVE FOLLOWING INADV. CANOPY LOSS
- 1 LOSS OF POWER
- 1 LOCKED FLIGHT CONTROLS
- 4 POST MID-AIR COLLISION
  - 2 (NO OTHER DESCRIPTION)
  - 1 DIVE
  - 1 TUMBLING
- 1 POST RAMP STRIKE; ENGINE SEIZURE DURING CLIMBOUT
- 1 PULL OUT, POST BOMBING RUN, GRAYING OUT
- 1 OVERRUNNING END OF RUNWAY FOLLOWING FAST LANDING
- 1 ROLLING, UNCONTROLLED, AFTER HYD CONTROL FAILURE

TABLE XIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

ESCAPAC IC-2 (Continued)
- 2 SPIN
  - 1 FLAT
  - 1 NOSE DOWN
- 1 UNCONTROLLED FLIGHT, PILOT DISORIENTED
- 1 ZOOM CLIMB, POST ENGINE FAILURE

ESCAPAC IC-3
- 1 ENGINE FAILURE DUE TO BIRD STRIKE

HS-1
- 1 SPIN
- 1 STALL, LOW LEVEL

LS-1
- 1 ENGINE EXPLOSION AND LOSS OF HYDRAULIC CONTROLS
- 1 FLAME OUT, DUAL
- 1 POST MID-AIR COLLISION PITCH DOWN
- 1 SPIN NOSE DOWN
- 1 UNCONTROLLED FLIGHT

LW-3B
- 1 ENGINE FIRE
- 1 POST MID-AIR COLLISION, FIRE WITH LOSS OF PORTION OF WING

MK A7
- 1 ROLLING, UNCONTROLLED, POST-STALL

MK F7
- 1 ENGINE FAILURE
- 1 ENGINE SEIZURE
- 1 FOLLOWING HARD LANDING ON CV
- 1 SLIDING DOWN FLIGHT DECK AFTER RAMP STRIKE
- 1 SPIN, NOSE DOWN

MK GRUEA7
- 1 POST MID-AIR COLLISION
- 1 SPIN, NOSE DOWN

MK GRU7A
- 3 INFLIGHT FIRE
  - 1 (NO OTHER DESCRIPTION)
  - 2 WITH LOSS OF CONTROLS
- 1 NOSE PITCHED UP AFTER AIRCRAFT WAS STRUCK BY MISSILE
- 1 RUNNING OFF DECK UNDER UNCOMMANDED ENGINE POWER
- 1 SLIDING DOWN FLIGHT DECK AFTER RAMP STRIKE
- 1 SPIN, FLAT

TABLE XIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER
1 JANUARY 1969 THROUGH 31 DECEMBER 1979

MK H7
- 1 CATAPULT LAUNCH; ENGINE MALFUNCTIONED AS STROKE BEGAN
- 1 COLD CATAPULT SHOT (BRIDLE BROKE)
- 1 ENGINE FAILURE/FIRE
- 1 FLAME OUT, DUAL
- 4 INFLIGHT FIRE
- 1 HARD LANDING SHEARING MLG — LEAVING RUNWAY
- 1 NOSE DOWN ATTITUDE DURING AND FOLLOWING CATAPULT LAUNCH
- 1 NOSE FALLING THROUGH AFTER GEAR CONTRACTED DECK (LATE WAVE OFF)
- 1 PITCH OSCILLATION, VIOLENT
- 1 PITCHING NOSE DOWN, POST CATAPULT LAUNCH
- 4 POST MID-AIR COLLISION
    - 2 (NO OTHER DESCRIPTION)
    - 1 OUT OF CONTROL
    - 1 INVERTED, UNCONTROLLED
- 1 PLANNED EJT.; UTILITY HYD FAILURE PREVENTED FLAPS AND MLG EXTENSION
- 1 PULL-OUT, POST ROCKET RUN, EXPLOSION AND INFLIGHT FIRE
- 1 ROLLING UNCONTROLLED DURING APPROACH TO FIELD
- 6 SPIN
    - 1 ROLLING
    - 3 NOSE DOWN
    - 1 FLAT
    - 1 OSCILLATING
- 1 STALL, LOW LEVEL
- 1 UNCONTROLLED FLIGHT

ESCAPAC IF-3
- 1 DISINTEGRATION FOLLOWING MISSILE STRIKE
- 1 FLAME OUT
- 1 ROLLING, NOSE DOWN
- 1 SPIN, NOSE DOWN

ESCAPAC IG-2
- 2 ENGINE FAILURE (ONE WITH FIRE DURING LANDING APPROACH)
- 1 ENGINE SEIZURE
- 1 POST MID-AIR COLLISION
- 1 ROLLING, UNCOMMANDED, AFTER CATAPULT LAUNCH
- 1 SPIN, FLAT

ESCAPAC IG-3
- 1 ENGINE FAILURE, ATTEMPTING A NO POWER LANDING ("DEAD STICK")
- 2 SPIN

HS-1A
- 1 ROLLING UNCONTROLLABLY, INFLIGHT FIRE, FOLLOWING LOSS OF FUEL TANK DURING CATAPULT LAUNCH

TABLE XIII (Continued)
DISTRIBUTION OF SPRAIN/STRAIN "EJECTION ASSOCIATED" NECK INJURIES BY TYPE EJECTION SEAT AND PRE-EJECTION AIRCRAFT MANEUVER

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

LS-1A
  2 SPIN, ROLLING

SIIIS-3
  1 ENGINE FAILURE DURING LANDING APPROACH
  1 ENGINE FIRE

PHASES OF EMERGENCY AND OF ESCAPE SYSTEM FUNCTIONING

vs.

POTENTIAL FOR INJURY

Figure 1

PHASES OF EMERGENCY AND OF ESCAPE

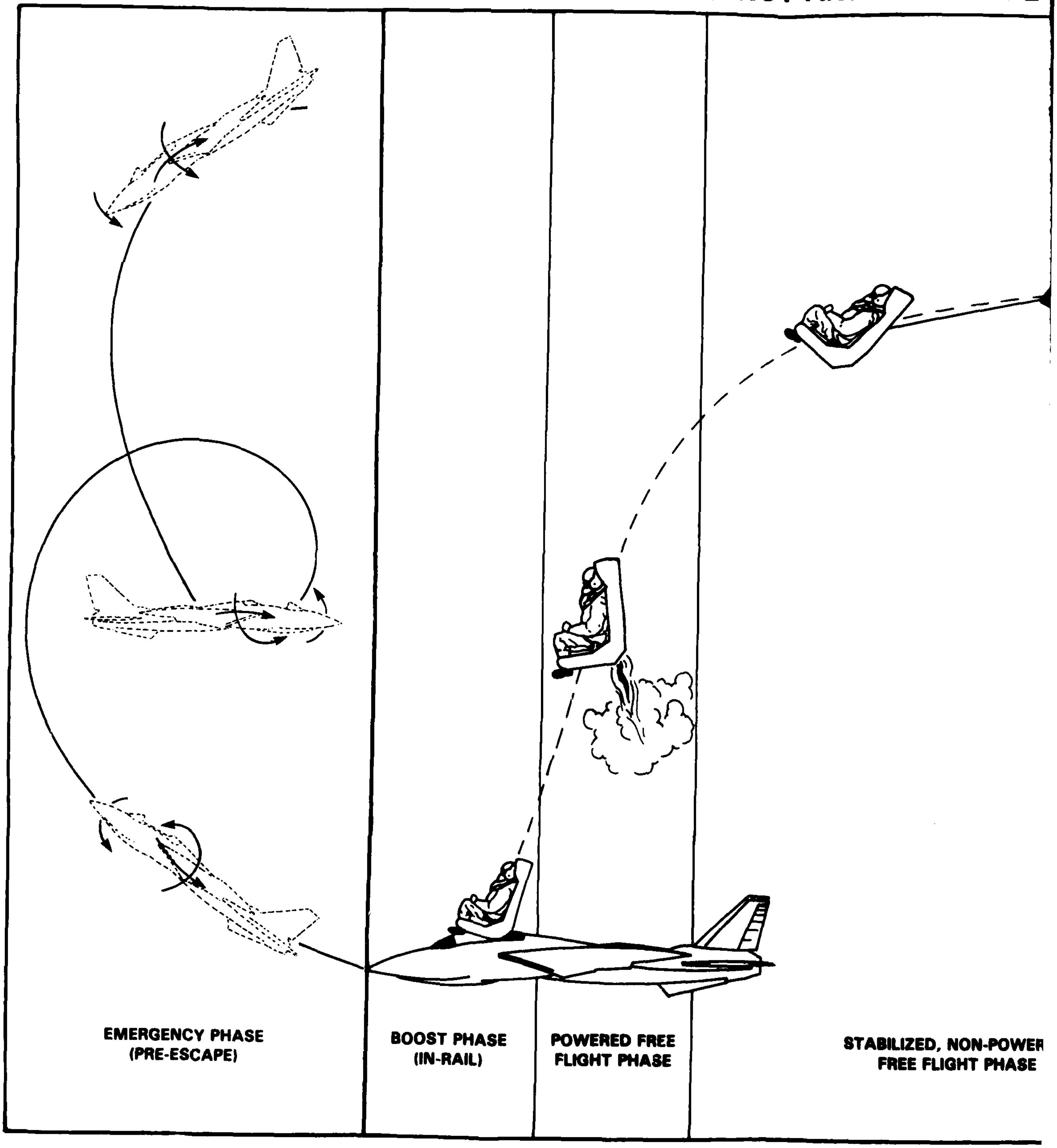


Figure 2

ENCY AND OF ESCAPE SYSTEM FUNCTIONING vs. POTENTIAL FOR INJURY

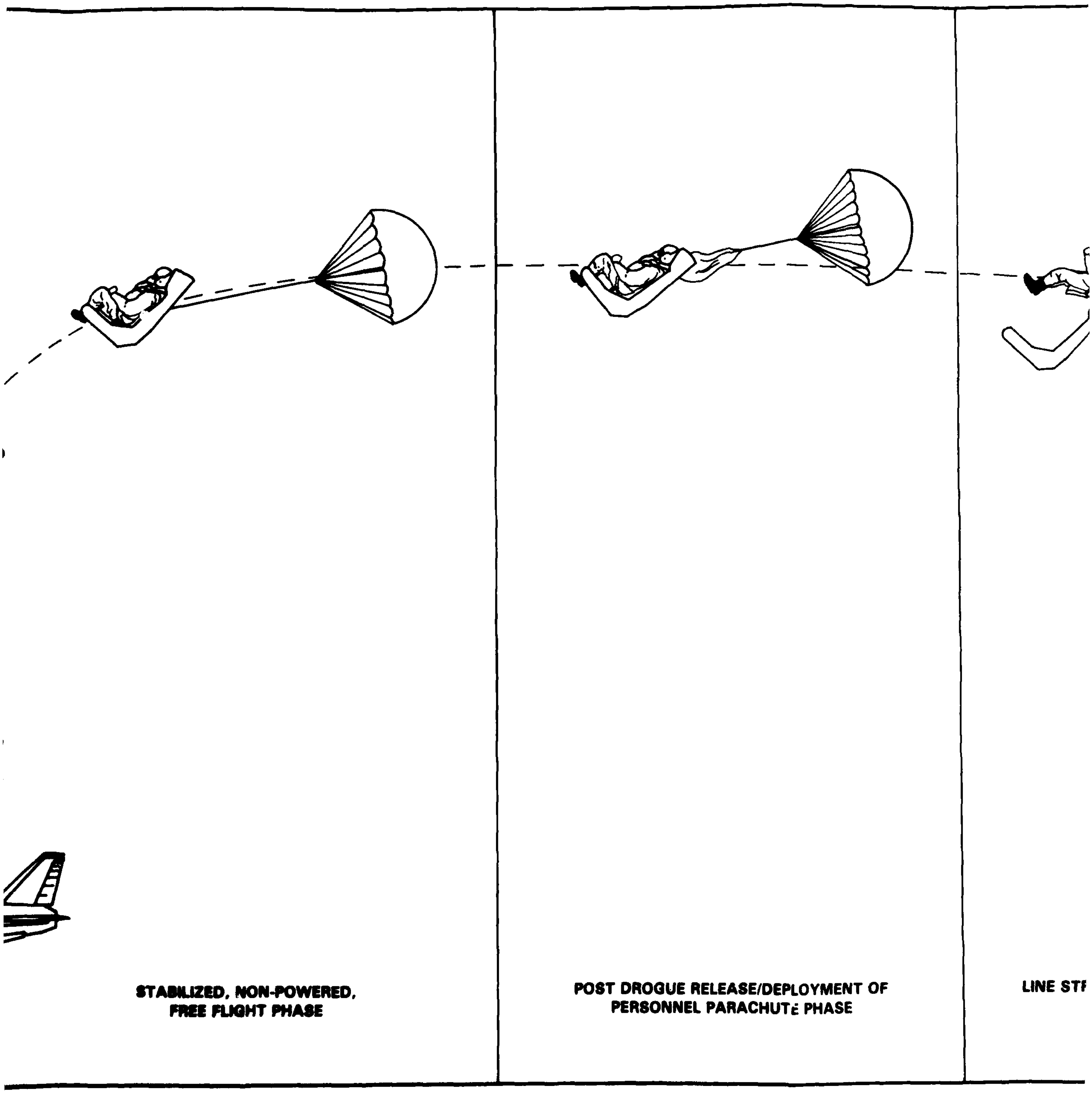
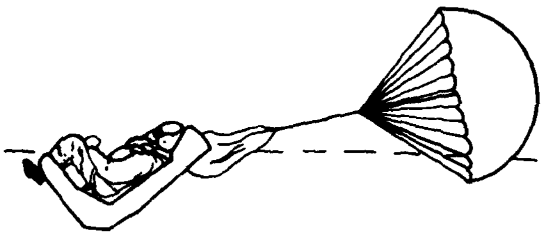
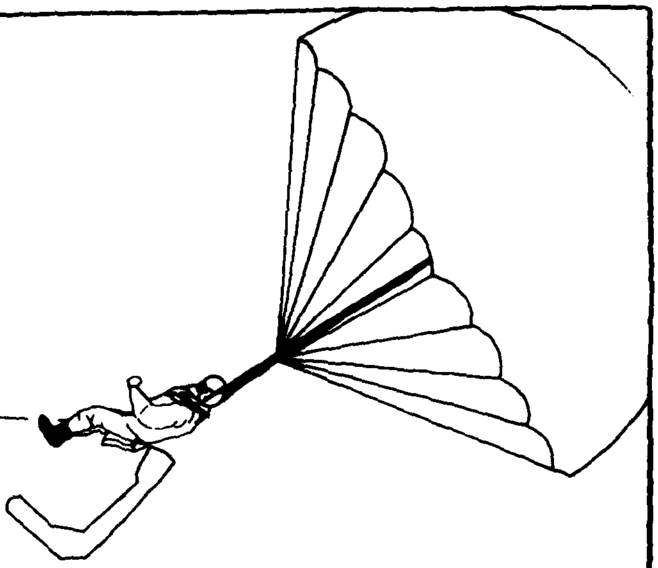


Figure 2 (Sheet 1 of 2)

ONING vs. POTENTIAL FOR INJURY



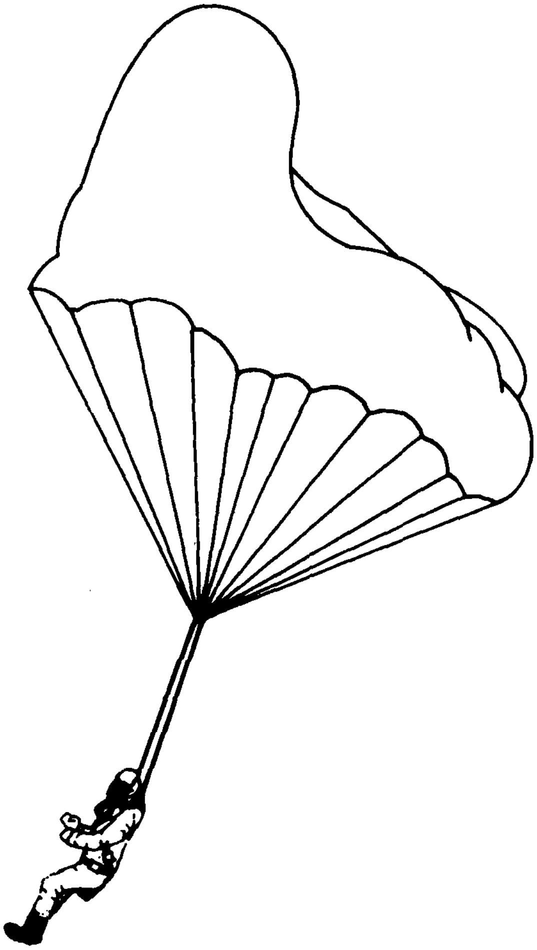
POST DROGUE RELEASE/DEPLOYMENT OF PERSONNEL PARACHUTE PHASE



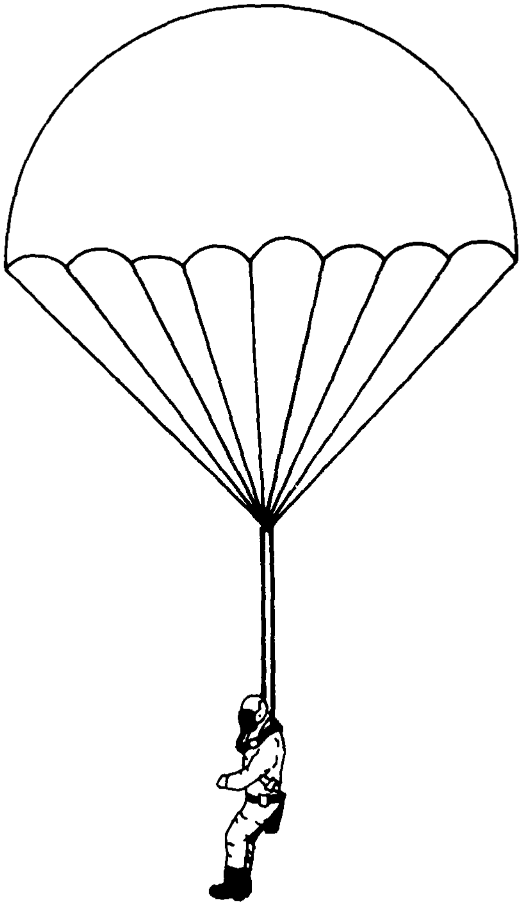
LINE STRETCH/SNATCH FORCE & PARACHUTE OPENING SHOCK PHASE

3

PHASES OF EMERGENCY AND OF ESCAPE SYSTEM FUNCTIONI



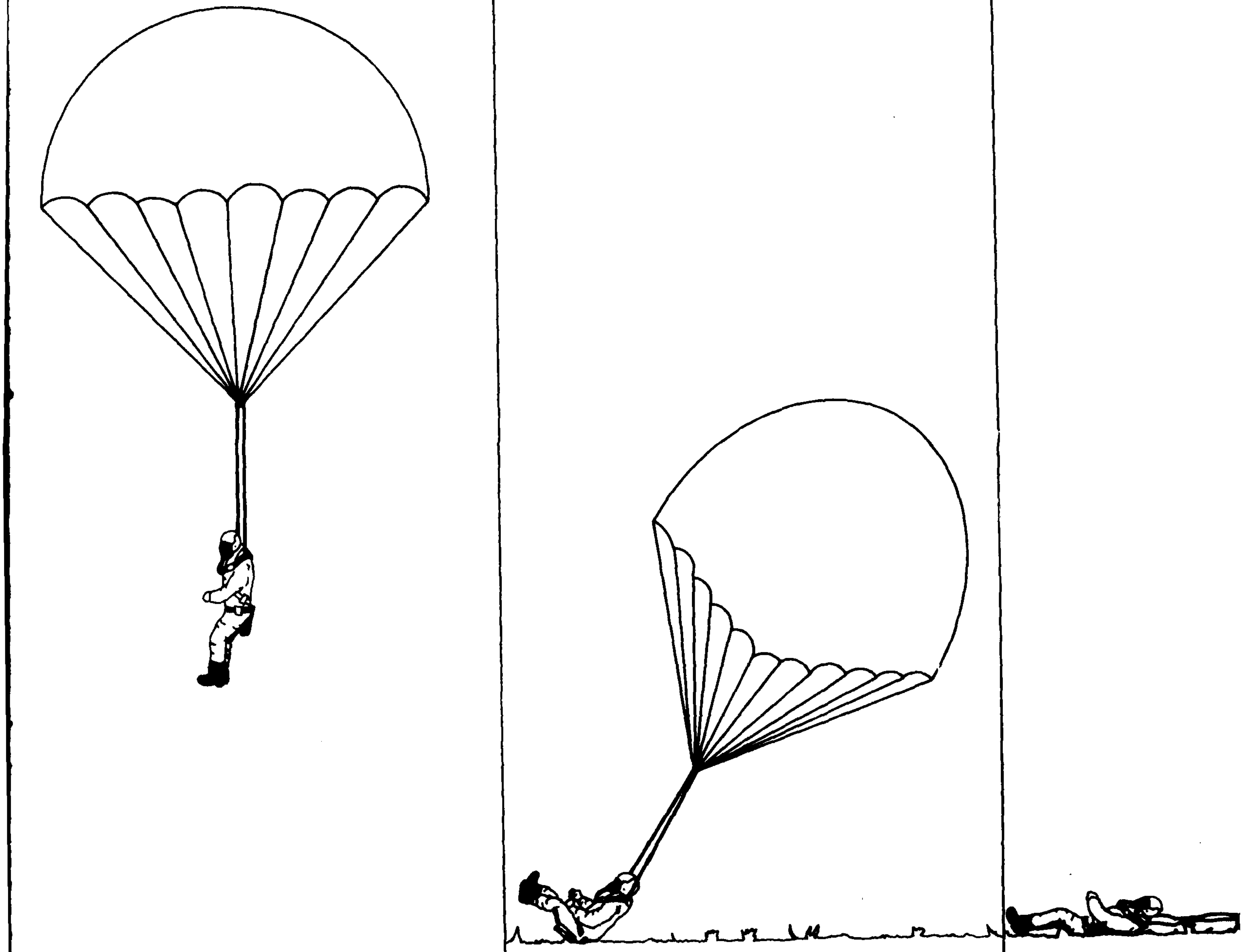
POST-INFLATION COLLAPSE & SWING THROUGH PHASE



STEADY STATE DESCENT PHASE

Figure 2 (Sheet 2 of 2

Y AND OF ESCAPE SYSTEM FUNCTIONING vs. POTENTIAL FOR INJURY (CONTI



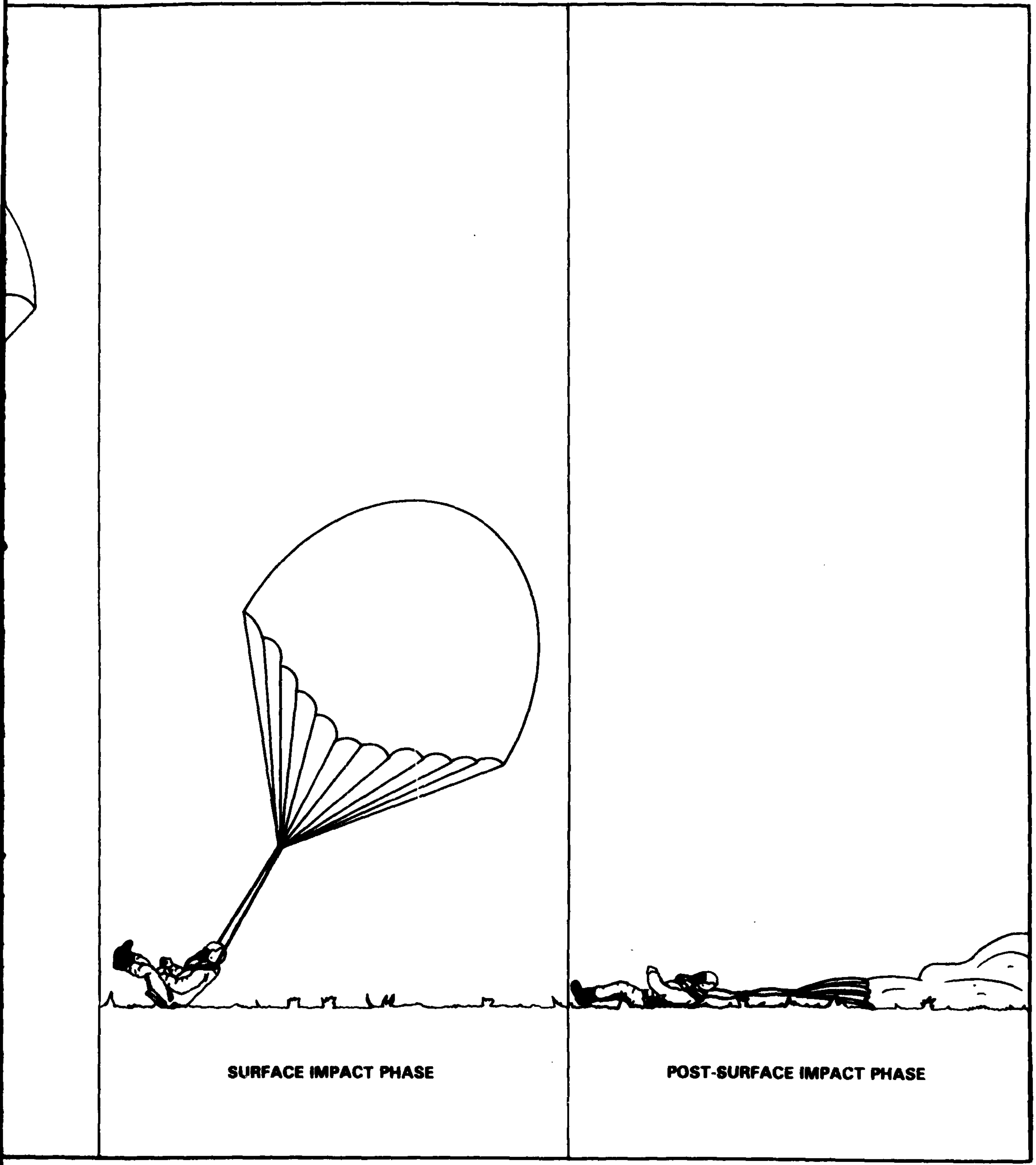
STEADY STATE DESCENT PHASE

SURFACE IMPACT PHASE

POST-SURFAC

Figure 2 (Sheet 2 of 2)

EM FUNCTIONING vs. POTENTIAL FOR INJURY (CONTINUED)



igure 2 (Sheet 2 of 2)

2

3

ROLE OF EMERGENCY (PRE-ESCAPE) PHASE IN AIRCREW INJURY PRODUCTION

DIRECT

- APPLICATION OF FORCES DIRECTLY UPON AIRCREW
  - SPIN
  - TUMBLING
  - MID-AIR COLLISION
  - RAMP STRIKES
  - EXCESSIVELY HARD LANDING WITH STRUCTURAL FAILURES
  - LEAVING RUNWAY ONTO UNPREPARED/ROUGH SURFACES

INDIRECT

- INDUCING POOR AIRCREW BODY POSITIONING FOR WITHSTANDING FORCES INCURRED DURING INITIAL PHASES OF ESCAPE

Figure 3

AD-A134 833 AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE DATA ANALYSES VO..(U) NAVAL WEAPONS ENGINEERING SUPPORT ACTIVITY WASHINGTON DC C W STOKES ET AL. 05 NOV 83 NAVWESA-1-83-VOL-1

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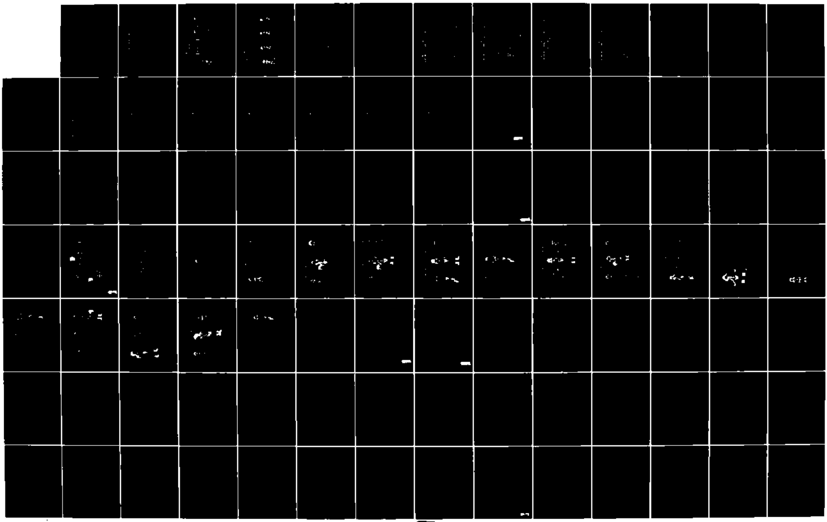

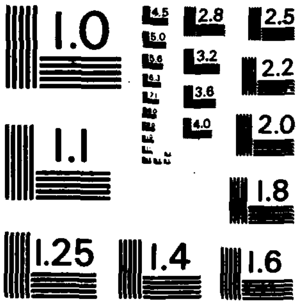

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SOURCES OF FORCES EXERTED UPON AIRCREW DURING EMERGENCY (PRE-ESCAPE) PHASE

INERTIAL

- RAPID BODY SPATIAL POSITION CHANGE INDUCING EXCESSIVE RAPID HEAD-BODY MOVEMENT (STRAIN, SPRAIN, "WHIPLASH")

DIRECT CONTACT

- BODY/HEAD IMPACTS WITH CANOPY OR OTHER AIRCRAFT STRUCTURE DUE TO BODY MOVEMENT WITHIN RESTRAINT SYSTEM
- LOOSE ARTICLES IN CREW STATION IMPACT AIRCREW BODY/HEAD

Figure 4

ROLE OF EMERGENCY (PRE-ESCAPE) PHASE IN AIRCREW INJURY PRODUCTION

INDIRECT CONTACT

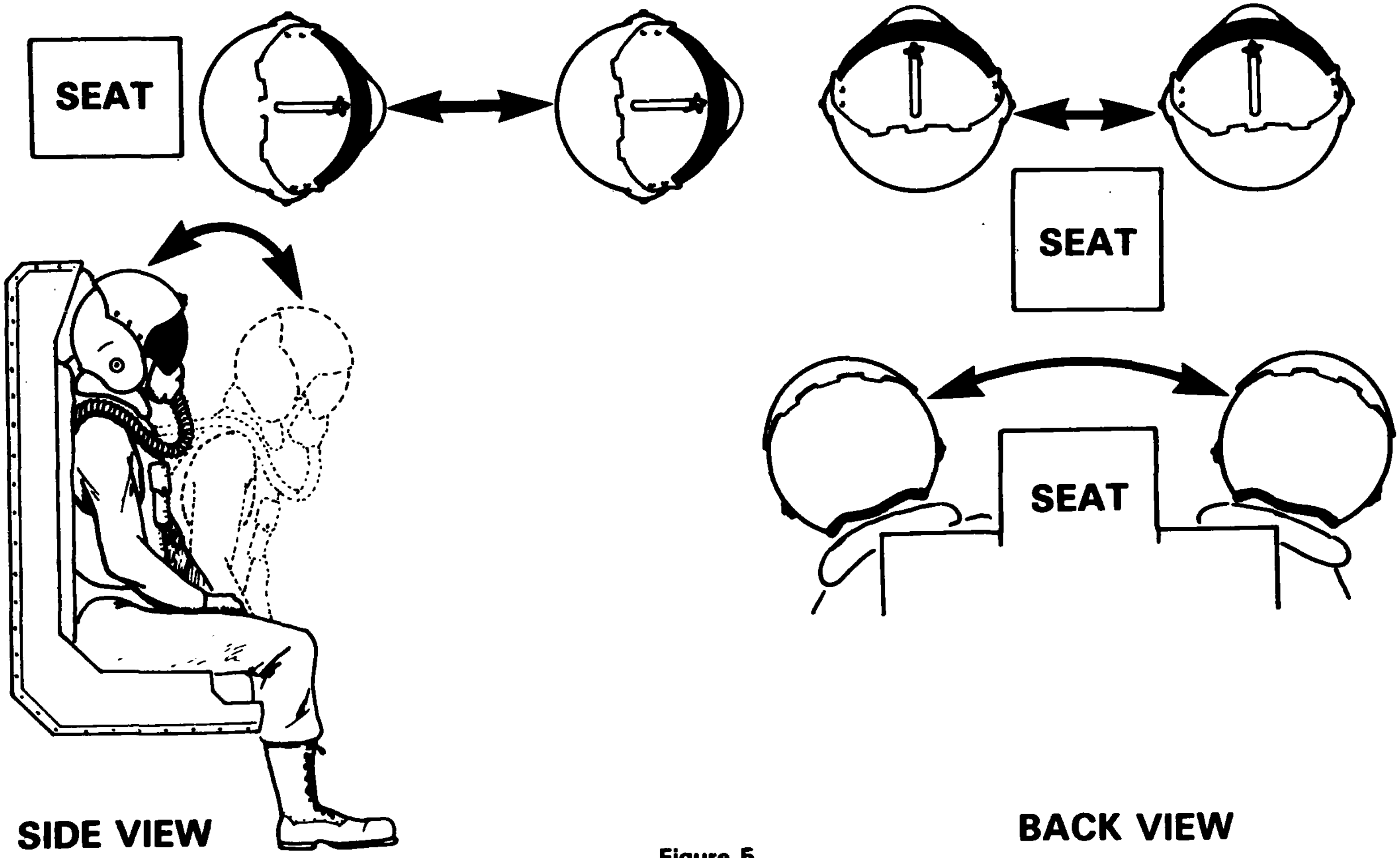

Figure 5

ROLE OF EMERGENCY (PRE-ESCAPE) PHASE IN AIRCREW INJURY PRODUCTION

DIRECT CONTACT

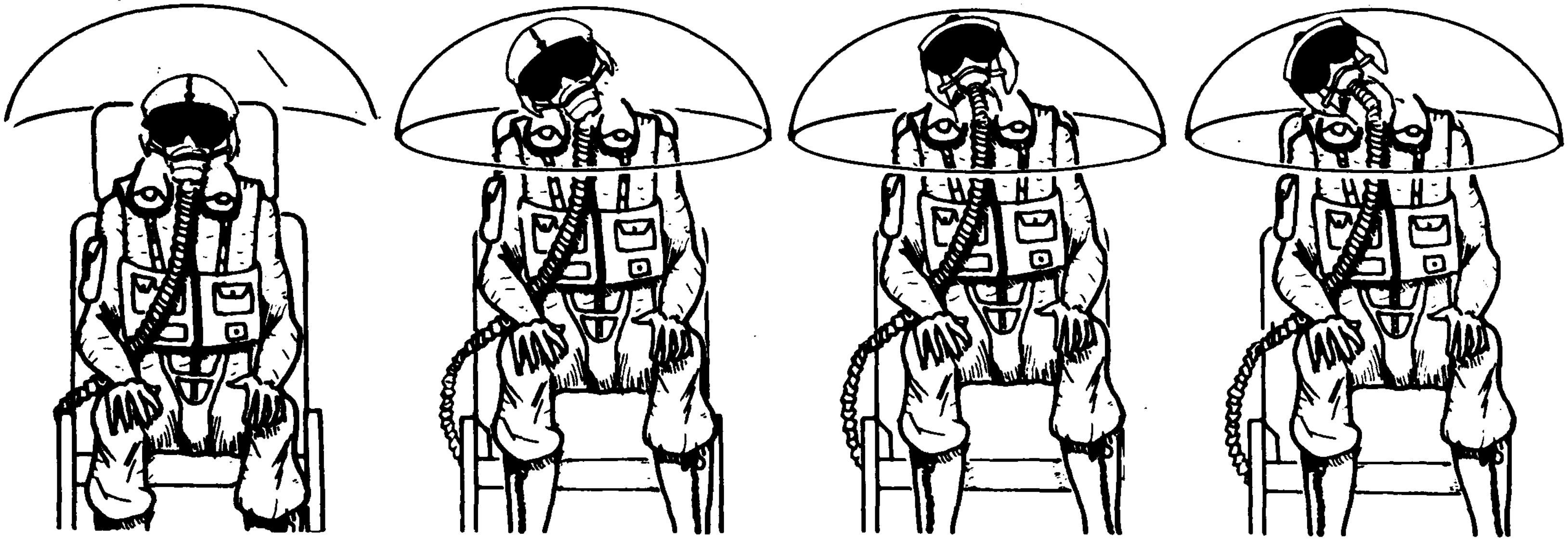

Figure 6

- PRODUCTION OF ESCAPE SYSTEM INDUCED INJURY, OTHER THAN THERMAL BURN AND DROWNING, REQUIRES APPLICATION OF FORCES UPON AIRCREW
  - INERTIAL—ACCELERATION/DECELERATION
  - DIRECT IMPACT—OBJECT DIRECTLY CONTACTING AIRCREW

Figure 7

- **POTENTIAL FOR INJURY AND INJURY SEVERITY AFFECTED BY:**
  - **MAGNITUDE OF FORCE**
  - **RATE OF FORCE APPLICATION (ONSET)**
  - **DURATION OF FORCE APPLICATION**
  - **FORCE APPLICATION SITE**
  - **BODY ALIGNMENT**
  - **OBJECT SHAPE/AREA (DIRECT CONTACT ONLY)**

Figure 8

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

BOOST PHASE (IN-RAIL)

INERTIAL

- CATAPULT BOOST ACCELERATIONS
- AERODYNAMIC LIFT ACCELERATIONS
- AIRCRAFT ACCELERATIONS
- ACCELERATION CHANGES DURING CANOPY CONTACT AND PENETRATION

DIRECT CONTACT

- WINDBLAST (q)
- WINDBLAST MOVEMENT OF LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF ESCAPE SYSTEM
- WINDBLAST MOVEMENT OF CREW EQUIPMENTS AGAINST BODY
- CANOPY GLASS-BODY CONTACTS DURING CANOPY PENETRATION
- CANOPY GLASS FRAGMENT CONTACTS WITH BODY

Figure 9

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

STABILIZED, NON-POWERED, FREE FLIGHT PHASE

INERTIAL

- AERODYNAMIC LIFT/DRAG ACCELERATIONS
  - —FRONTAL AREA LIFT/DRAG
  - —STABILIZATION LIFT/DRAG
- ACCELERATIONS INDUCED BY ANGULAR MOTION EFFECTS
  - —STABILIZATION EFFECTS
  - —AERODYNAMIC EFFECTS

DIRECT CONTACT

- WINDBLAST (q)
- WINDBLAST MOVEMENT OF LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
- WINDBLAST MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- ANGULAR MOTION EFFECTS INDUCE
  - —MOVEMENT OF CREW LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
  - —MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- FOULING/ENTANGLEMENT OF SYSTEM ELEMENTS ON AIRCREW

Figure 10

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

POWERED FREE FLIGHT PHASE
OR
POWERED, STABILIZED FREE FLIGHT PHASE

INERTIAL

- ROCKET THRUST ACCELERATIONS
- AERODYNAMIC LIFT/DRAG ACCELERATIONS
  - —FRONTAL AREA LIFT/DRAG
  - —STABILIZATION LIFT/DRAG
- ACCELERATIONS INDUCED BY ANGULAR MOTION EFFECTS
  - —TIP-OFF EFFECTS
  - —CHANGE IN DIRECTION OF PROPULSION VECTOR
  - —DYNAMIC C.G. SHIFT EFFECTS
  - —STABILIZATION EFFECTS
  - —AERODYNAMIC EFFECTS

DIRECT CONTACT

- WINDBLAST (q)
- WINDBLAST MOVEMENT OF LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
- WINDBLAST MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- ANGULAR MOTION EFFECTS INDUCE
  - —MOVEMENT OF CREW LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
  - —MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- IMPACT WITH AIRCRAFT
- IMPACT WITH AIRCRAFT DEBRIS

Figure 11

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

POST DROGUE RELEASE/DEPLOYMENT OF PERSONNEL PARACHUTE PHASE

INERTIAL

- AERODYNAMIC LIFT/DRAG ACCELERATIONS
  - —FRONTAL AREA LIFT/DRAG
- ACCELERATIONS INDUCED BY ANGULAR MOTION EFFECTS
  - —DEPLOYMENT EFFECTS
  - —AERODYNAMIC EFFECTS

DIRECT CONTACT

- WINDBLAST (q)
- WINDBLAST MOVEMENT OF LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
- WINDBLAST MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- ANGULAR MOTION EFFECTS INDUCE
  - —MOVEMENT OF CREW LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
  - —MOVEMENT OF CREW EQUIPMENT AGAINST BODY
- FOULING/ENTANGLEMENT OF DEPLOYING PARACHUTE ELEMENTS ON AIRCREW/AIRCREW EQUIPMENT

Figure 12

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

LINE STRETCH/SNATCH FORCE & PARACHUTE OPENING SHOCK PHASE

INERTIAL

- SNATCH FORCE ACCELERATIONS
- OPENING SHOCK ACCELERATIONS
- AERODYNAMIC LIFT/DRAG ACCELERATIONS
  —FRONTAL AREA LIFT/DRAG
- ACCELERATIONS INDUCED BY ANGULAR MOTION EFFECTS
- AERODYNAMIC EFFECTS

DIRECT CONTACT

- DIRECT CONTACT WITH SEAT DURING OR FOLLOWING MAN-SEAT SEPARATION
- FOULING/ENTANGLEMENT OF DEPLOYING PARACHUTE ELEMENTS ON AIRCREW/AIRCREW EQUIPMENT
- ANGULAR MOTION EFFECTS INDUCE
  —MOVEMENT OF CREW LIMBS/HEAD/BODY PAST NATURAL LIMITS AND/OR AGAINST PORTIONS OF SEAT
  —MOVEMENT OF CREW EQUIPMENT AGAINST BODY OF CREW EQUIPMENT AGAINST BODY

Figure 13

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

POST-INFLATION COLLAPSE & SWING THROUGH TO VERTICAL/RE-INFLATION

INERTIAL

- RE-INFLATION SHOCK
- ANGULAR MOTION EFFECTS

DIRECT CONTACT

- PREMATURE GROUND IMPACT

Figure 14

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

STEADY STATE DESCENT PHASE

<u>INERTIAL</u>

- OSCILLATION INDUCED
  - —ACCELERATIONS
  - —ANGULAR MOTION EFFECTS

<u>DIRECT CONTACT</u>

- NONE

Figure 15

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

SURFACE IMPACT PHASE

<u>INERTIAL</u>

- SURFACE IMPACT ACCELERATIONS

<u>DIRECT CONTACT</u>

- SURFACE IMPACT FORCES
  —HARD/SOFT/IRREGULAR SURFACE

Figure 16

SOURCES OF FORCES EXERTED UPON AIRCREW DURING ESCAPE SEQUENCE

POST-SURFACE IMPACT PHASE

INERTIAL

- NONE

DIRECT CONTACT

- FOULING/ENTANGLEMENT OF AIRCREW BY PARACHUTE ELEMENTS
- DRAGGING OF AIRCREW ACROSS SURFACE

Figure 17

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED
BY TYPE INJURY DIAGNOSIS FOR
EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

SPRAIN/STRAIN

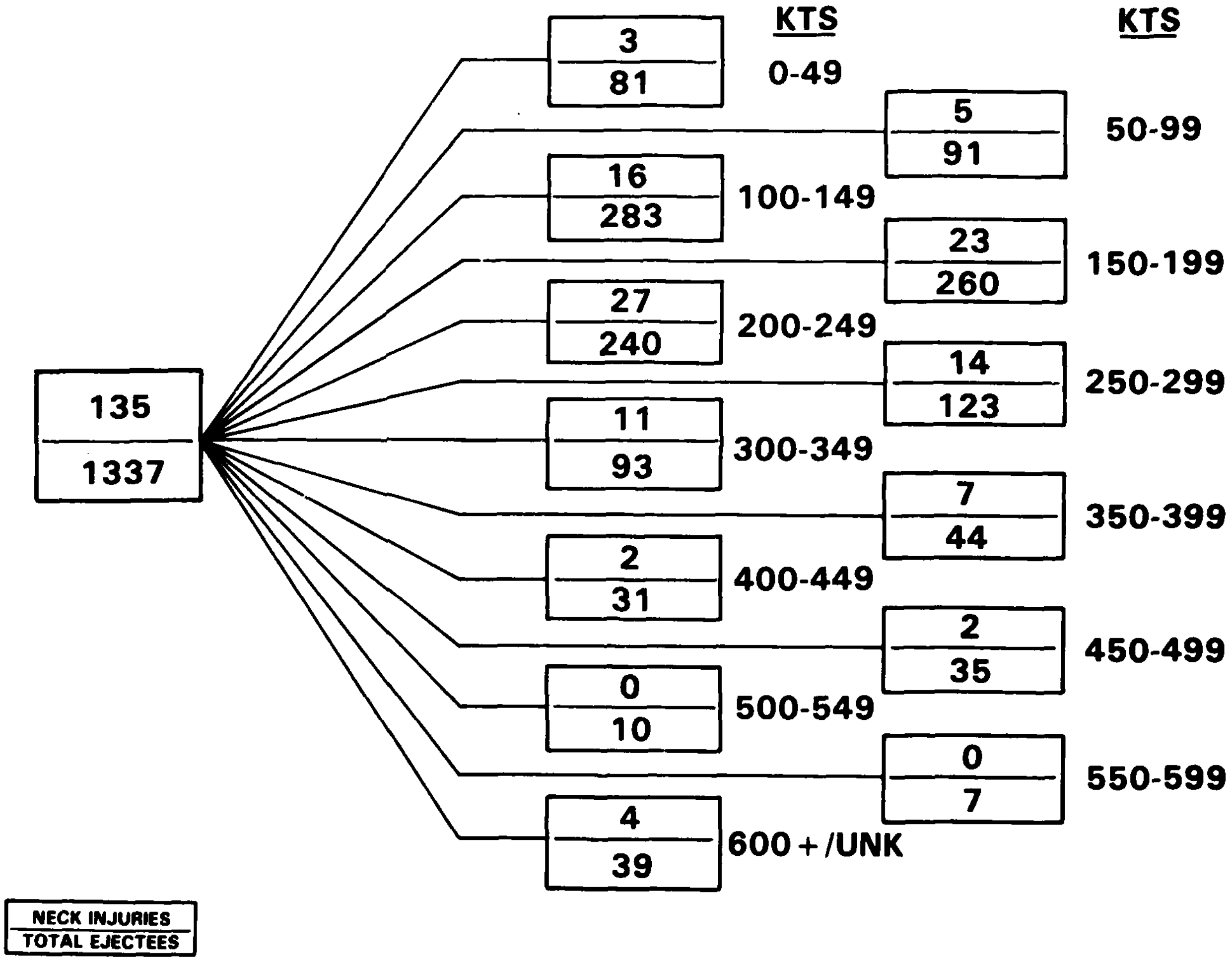

Figure 18.

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED BY TYPE INJURY DIAGNOSIS FOR EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

COMMINUTED FRACTURE

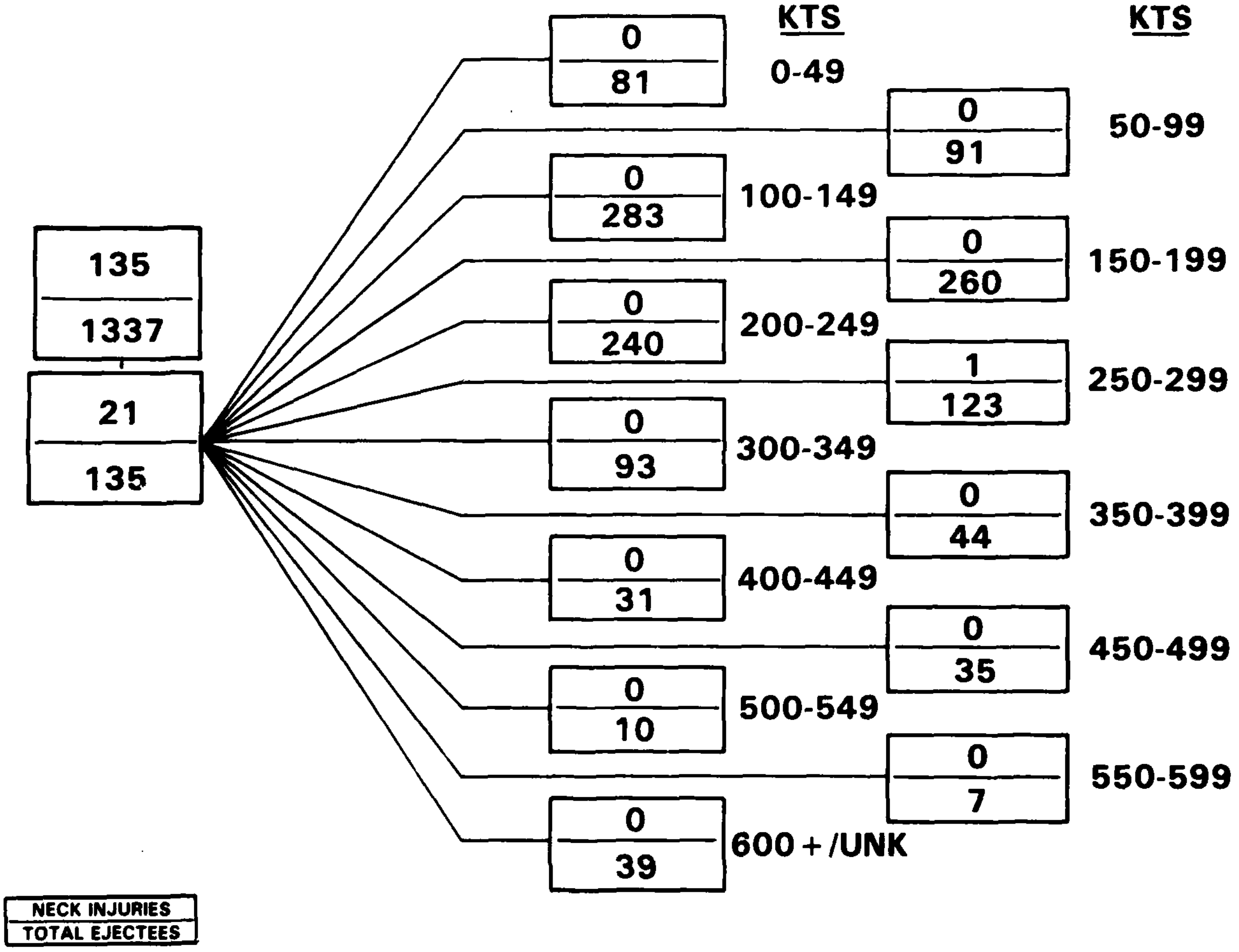

Figure 19.

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED BY TYPE INJURY DIAGNOSIS FOR EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

COMPRESSION FRACTURE

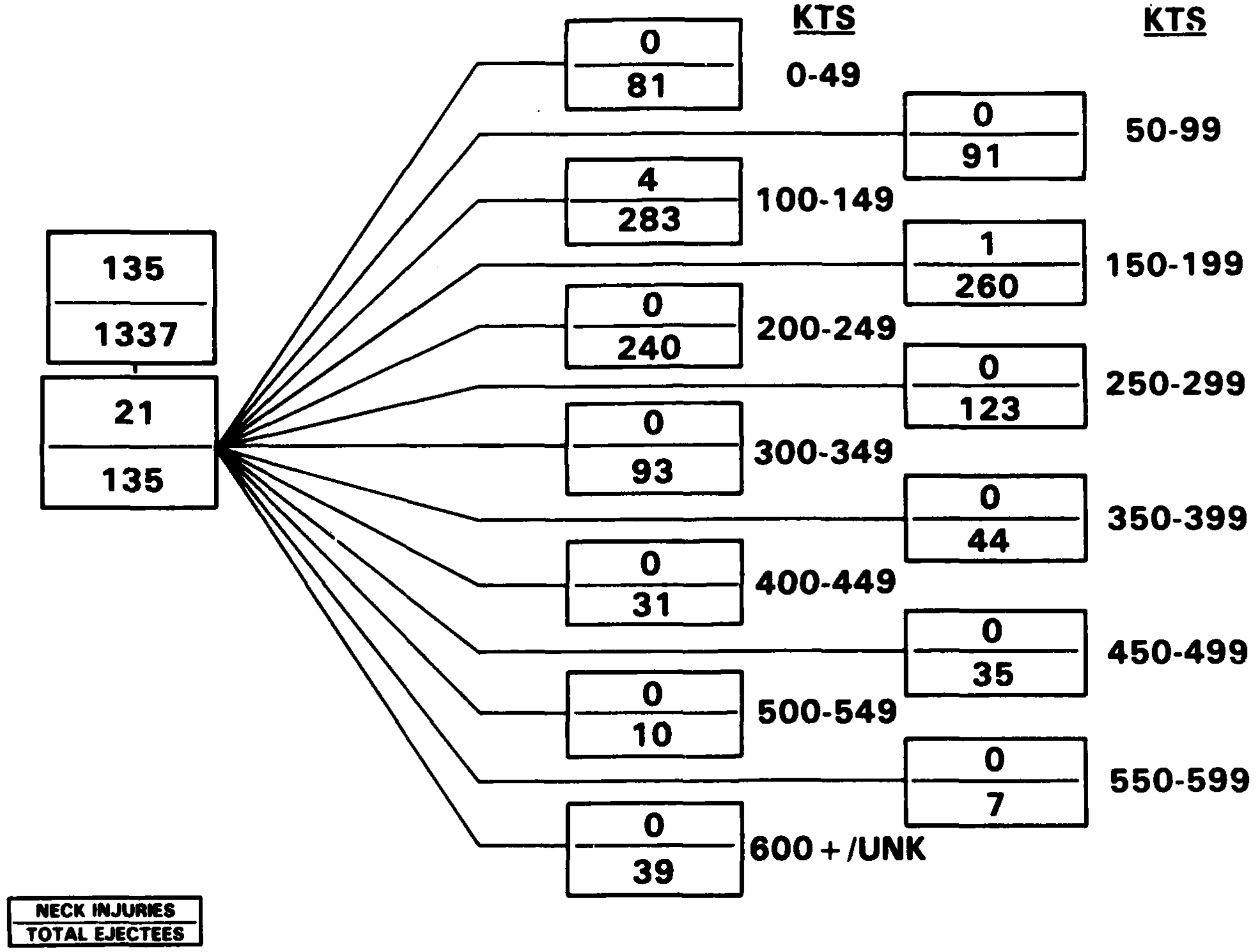

Figure 20.

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED BY TYPE INJURY DIAGNOSIS FOR EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

SIMPLE FRACTURE

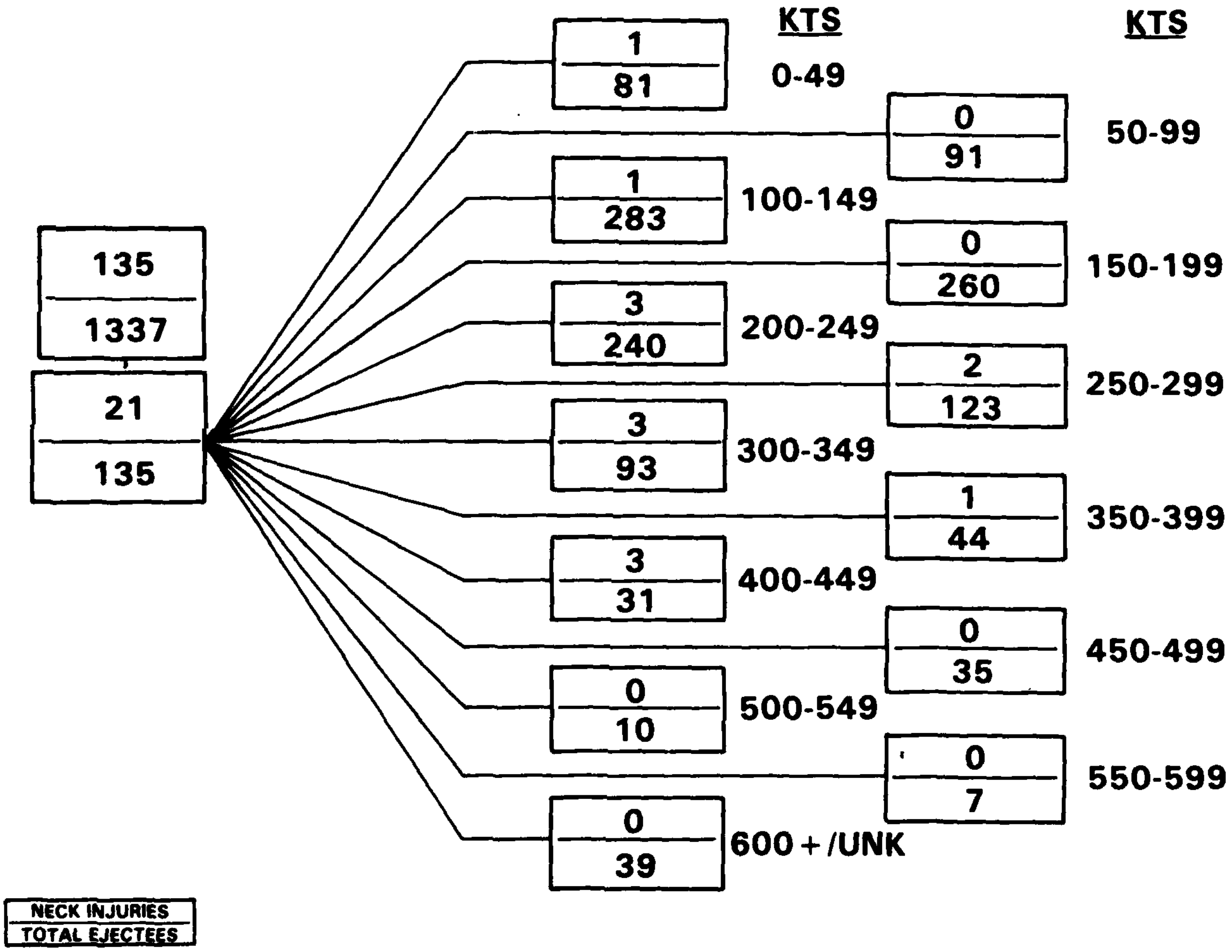

Figure 21.

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED BY TYPE INJURY DIAGNOSIS FOR EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

DISLOCATION

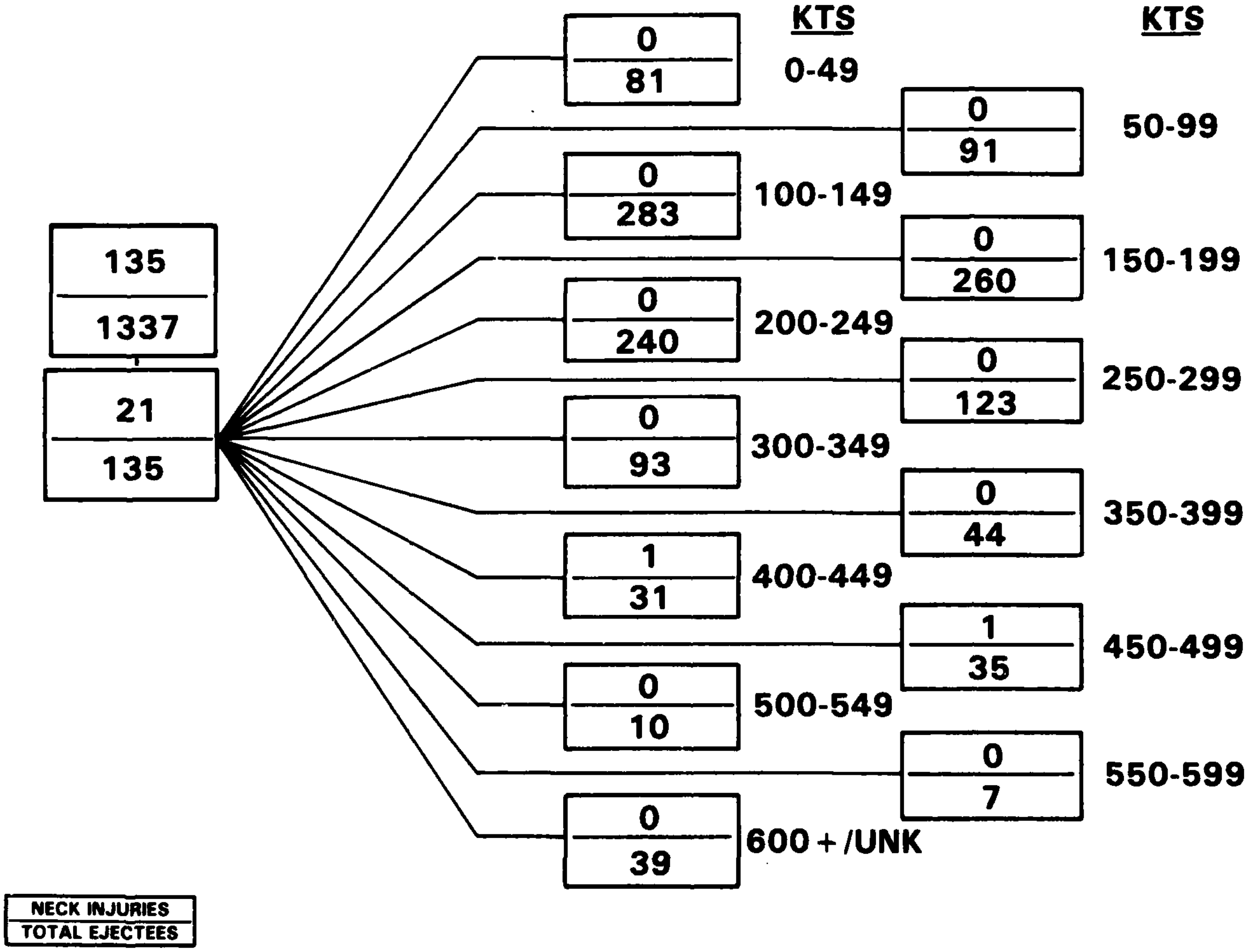

Figure 22.

U.S. NAVY
"EJECTION ASSOCIATED" NECK INJURIES vs. EJECTION AIRSPEED BY TYPE INJURY DIAGNOSIS FOR EJECTION CODES 1 AND 5

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

TRANSECTION

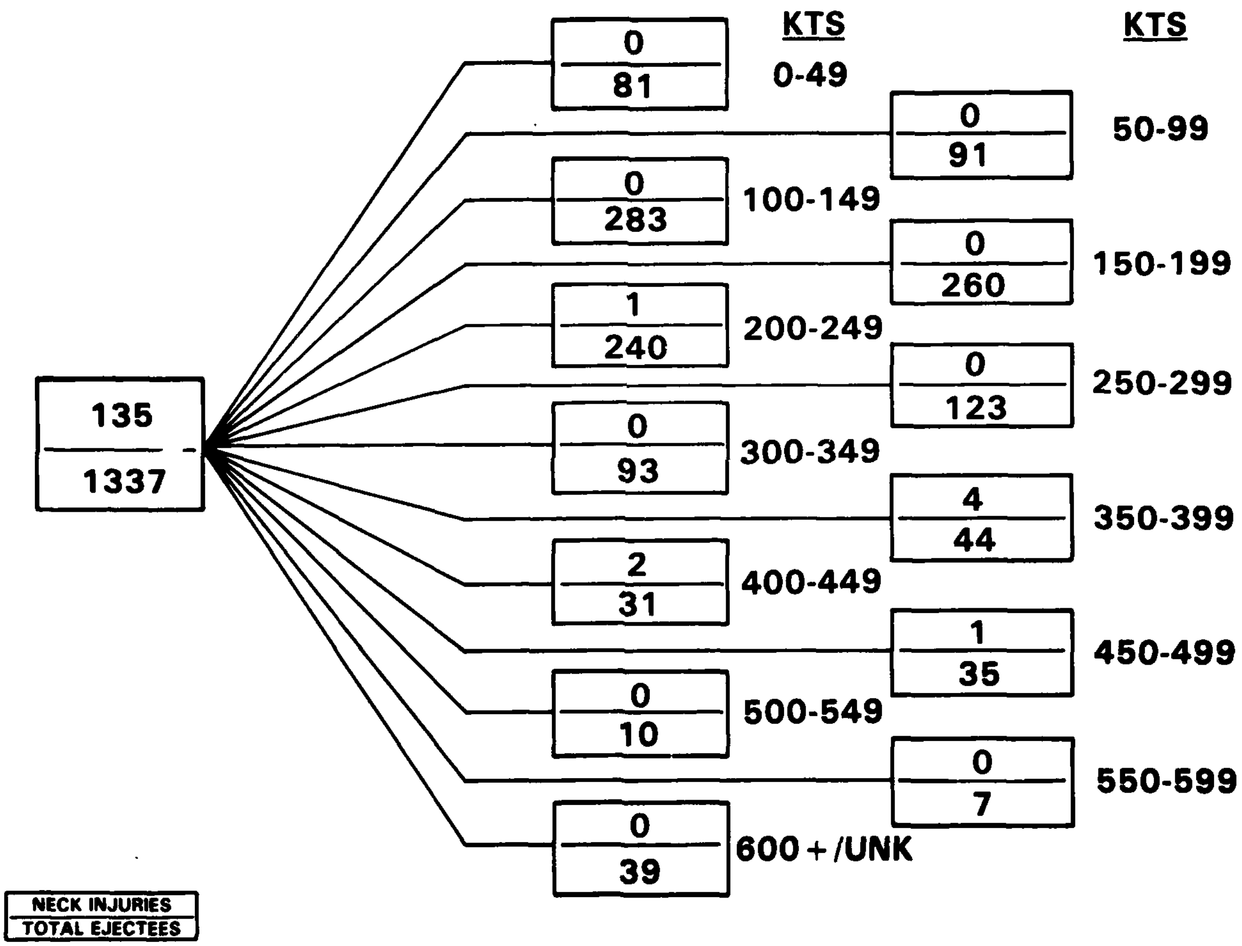

Figure 23.

U.S. NAVY AVIATION MISHAP AIRCREW ANTHROPOMETRY

1 January 1969 through 31 December 1979

Frederick C. Guill

ABSTRACT

The U.S. Navy has periodically conducted major anthropometric surveys at considerable expense to define its aircrew personnel for aiding in the design of cockpits, design of escape systems, design and sizing of life support equipments, design of equipment stocking plans, etc. Major problems associated with these surveys include when to conduct a new one and whether the aircrew population is homogeneous across all types of aircraft. In each mishap requiring medical officer investigative participation, the standard report form provides for the submittal of mishap aircrew anthropometry representing basically a random sampling of aircrew. These data are being examined to ascertain their value in answering the above questions. Unfortunately, this study has revealed (1) a major failure to furnish the data and (2) a significant error rate among the data which call into question, for example, studies seeking to ascertain the roll of aircrew anthropometry in mishap causation. Several data checking methodologies for the report preparer and the data user are discussed.

INTRODUCTION

In an earlier paper[1] the anthropometry reported for aircrew in aircrew automated escape systems (AAES) equipped aircraft involved in aviation mishaps were reported. For the 1,816 aircrewmen involved, values were reported for the following morphological features for the indicated numbers of crewmembers:

o height	1,679
o weight	1,687
o functional reach	1,389
o trunk height	1,518
o sitting height	1,557
o buttock-knee length	1,507
o leg length	1,524
o shoulder width	1,513
o age	1,765

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[1] U.S. Navy Ejectee Anthropometry, 1 January 1969 through 31 December 1979 by Frederick C. Guill presented at the 20th Annual SAFE Symposium December 1982.

As reported in that earlier paper a large number of seemingly obvious errors were present in the data; errors which were traceable directly to the original MORs/FSRs (Medical Officer's Reports/Flight Surgeon's Reports) and, based upon personal review by this author of the original documents, could not be attributed to transcriptional or encoding errors at the Naval Safety Center, Norfolk, which had supplied the data to the Naval Weapons Engineering Support Activity, Washington, D.C., in the form of computer tapes. These data also demonstrated inexplicable and inconsistent shifts from the standard U.S. Navy aviation personnel populations as described in two anthropometric studies.[2,3] An obvious potential explanation for these shifts and their inconsistencies is simply error; error in the original measurement and its recordation, error in transcribing from the original record to the MOR/FSR, error induced by poor handwriting and/or typewriting, or error of some other form. Another potential explanation for the differences observed is that, due to cockpit and other constraints, the aircrewmen flying in AAES equipped aircraft form a unique subset of the total aircrew personnel population of the U.S. Navy. Yet another potential explanation might lie in the manner in which the representative populations were developed for the anthropometric studies.

DIFFERENCES BETWEEN THE 1964 AND 1982 ANTHROPOMETRIC SURVEY REPORTS

There are several differences between the two cited standard naval aviation personnel anthropometric surveys which require consideration even though an accurate assessment concerning their criticality or significance or even the relative superiorty of one technique vs. the other are issues beyond the scope of this paper:

(1) NATURE OF THE SAMPLE POPULATION

Neither survey attempted to measure the entire naval aviation population but relied upon sampling techniques to permit assembling a representative sample of that population. Both were restricted to the commissioned officer personnel segment of that population. The earlier survey confined its choice of subjects to active duty naval aviation commissioned officer personnel selected through a sampling plan while the latter was restricted to only personnel (whether commissioned or not) satisfying the commissioned naval aviation officer entrance requirements for height and weight.

---

[2] Naval Air Test Center Report SY-121R-82

[3] Naval Air Engineering Center (ACEL) Report ACEL-533

(2) CHANGES IN POPULATION BETWEEN SURVEYS

After the earlier survey had been completed and published and before the commencement of the later survey, the entrance requirements for stature were changed, increasing the range by 4 inches (i.e., lowering the lower limits by 2 inches and raising the upper limits by 2 inches). Since the change occurred in 1965/1966, it should have impacted the major portion of the actively flying population of naval aviators and its effects should have stabilized prior to the more recent survey.

The data being examined in this paper are those reported for all aircrew and, in the case of passengers, only those designated as DNA or NFO (designated naval aviator/naval flight officer, the only passenger categories which are considered a portion of the aircrew population which were the subject of the previously referenced surveys) involved in reported aviation mishaps for which an MOR or FSR (Medical Officer's Report/Flight Surgeon's Report) was submitted and presented anthropometric data for the individual(s). These data might reflect, to some limited degree the characteristics of those commissioned under the earlier, more restrictive entrance requirements since the data cover the period from 1 Janaury 1969 through mid-1982, but are likely to represent to a significantly greater degree the characteristics of those commissioned under the present, broader entrance requirements. These mishap aircrew anthropometric data also reflect to some undefined degree the differences between entrance requirements and requirements for retention of the aviator in whom a considerable investment has been made and who has acquired the skills and knowledge that only post-educational experience can instill; skills and knowledge that can greatly affect the success of any mission employing naval aviation.

PURPOSE OF THE STUDY

There were several purposes in conducting this study of the MOR/FSR reported mishap aircrew anthropometric data. These include:

(1) assessing the potential accuracy of the data base available and means for enhancing its accuracy.
(2) ascertaining the size of the data base available and especially the size of the data base remaining after enhancement of the data accuracy.
(3) ascertaining whether there might be different subpopulations identifiable by type aircraft involved in the mishap, i.e., fixed wing AAES equipped, other fixed wing, helicopters.
(4) ascertaining whether there might be differences between the anthropometry of mishap aircrew population(s) and the aviation personnel survey anthropometry and assessing, if such difference(s) exist, the significance and causation of such difference(s).

with respect to the latter aspect and as a consequence of the normal effects of aging, in general, upon human anthropometry, the data reviewed and presented for each mishap aircrew population examined includes the age distributions.

GENERAL

Underlying this review of the mishap aircrew anthropometry is the presumption that a sufficiently large proportion of the mishaps are not caused by, or seriously aggravated by, aircrew anthropometric factors as to significantly bias these data in comparison to the actual naval aviation personnel population distribution or those of the standard distributions reported in the standard Navy anthropometric studies, i.e., that a sufficiently large quantity of the mishaps occur due to engine malfunction, inflight fire, flame-outs, and other types of problems non-anthropometrically induced or aggravated. Although this potentiality could not be totally disproven for the AAES mishap aircrewmen whose data were examined, two factors suggested that such a bias probably did not exist:

(1) the large number of mishaps involving flameout, engine seizure, fire, impact of weapons, cold catapult launches, controlled flight into the surface, control systems malfunctions, and similar types of mishaps for which an anthropometric cause or major contribution had been ruled out by the mishap investigators, and
(2) the largely normal distributions for each of the eight morphological features measured, reported and evaluated.

Recently the Naval Safety Center, Norfolk, furnished to the Naval Weapons Engineering Support Activity, Washington, D.C., expanded MOR/FSR computer tapes, including data for non-AAES equipped fixed wing aircraft and rotary wing (helicopter) aircraft mishaps. The anthropometric data for these mishap aircrewmen have been examined in a manner similar to that employed in examining the AAES equipped aircraft mishap aircrew anthropometry to ascertain whether, perhaps, there are two or three, unique subsets of aircrew populations in the U.S. Navy; subpopulations peculiar to their specific types of aircraft and which, if combined, approximate or fail to approximate the standard populations described in the earlier referenced anthropometric surveys.

POPULATION SIZES

For the period 1 January 1969 through 31 December 1979 there were 9,671 naval aviation personnel involved in aviation mishaps as follows:

1,816 in AAES equipped aircraft
3,929 in helicopters
3,949 in fixed wing non-AAES aircraft.

As earlier noted, passengers, except NFO's or DNA's (Naval Flight Officers or Designated Naval Aviators), i.e., therefore personnel who would be represented in the earlier referenced standard aircrew anthropometric surveys, are excluded from these data and the enclosed graphs and tables since the purpose of this paper is to examine the relationship, if any, between the anthropometry of mishap aviators with the representative aviator populations created, measured and analyzed in the anthropometric surveys. At this stage, however, the data have not been sorted by commissioned officer and enlisted aircrew status. Enlisted aircrew personnel are not numerous in AAES equipped aircraft but are in fixed wing aircraft not equipped with AAES and in helicopters.

A brief summarization of the population sizes for each morphological feature reported in MORs/FSRs and the features evaluated in the previously referenced paper are depicted in Table I.

TABLE I

COUNTS OF MISHAP AIRCREW FOR WHOM SPECIFIC MORPHOLOGICAL INFORMATION WAS FURNISHED
BY TYPE MISHAP AIRCRAFT CLASS

	AAES EQUIPPED AIRCRAFT	HELICOPTERS	FIXED WING, NON-AAES AIRCRAFT	ALL MISHAP AIRCRAFT
Total aircrew	1793	3929	3949	9671
Height	1679	1347	1384	4410
Weight	1687	1346	1386	4419
Sitting height	1557	840	945	3342
Trunk height	1518	817	922	3257
Functional arm reach	1389	751	858	2998
Buttock knee length	1507	814	926	3247
Leg length	1524	811	923	3258
Shoulder width	1513	812	918	3243
Age	1765	1504	1527	4796

Examination of Table I quickly reveals serious imbalances merely in the quantities of data presented even before the data are examined for reasonableness. The AAES mishap aircrew anthropometric data represents a disproportionally large segment of the total data for all morphological parameters, even for the three commonest and easiest obtained parameters, height, weight and age. This extreme imbalance as set forth in Tables II and III strongly suggests that (1) the combined mishap aircrew anthropometric data might not be representative of the actual Naval aircrew population and (2) the helicopter and fixed wing (non AAES) subpopulations might not be representative of their segments of actual Naval aircrew populations.

TABLE II

PER CENT MISHAP AIRCREW FOR WHOM MORPHOLOGICAL INFORMATION WAS FURNISHED BY TYPE MISHAP AIRCRAFT CLASS

	AAES EQUIPPED AIRCRAFT	HELICOPTERS	FIXED WING, NON-AAES AIRCRAFT	ALL MISHAP AIRCRAFT
Total aircrew				
Height	93.64%	34,28%	35.05%	45.60%
Weight	94.09%	34.26%	35.10%	45.69%
Sitting height	86.84%	21.38%	23.93%	34.56%
Trunk height	84.66%	20.79%	23.35%	33.68%
Functional arm reach	77.47%	19.11%	21.73%	31.00%
Buttock knee length	84.05%	20.72%	23.45%	33.57%
Leg length	85.00%	20.64%	23.37%	33.69%
Shoulder width	84.38%	20.67%	23.25%	33.53%
Age	98.44%	38.28%	38.67%	49.59%

TABLE III

PERCENTAGE OF ALL MISHAP AIRCRAFT MISHAP AIRCREW MORPHOLOGICAL INFORMATION FURNISHED RESULTING FROM AAES EQUIPPED AIRCRAFT MISHAP AIRCREW MORPHOLOGICAL INFORMATION FURNISHED

Total aircrew	18.54%
Height	38.07%
Weight	38.18%
Sitting height	46.59%
Trunk height	46.61%
Functional arm reach	46.33%
Buttock knee length	46.41%
Leg length	46.78%
Shoulder width	46.65%
Age	36.80%

In addition to creating the above illustrated imbalances and raising the previously cited doubts concerning representativeness of the populations, this gross failure to furnish the MOR/FSR requested minimal anthropometric data weakens and quite likely invalidates studies assessing the role of aircrew anthropometry in the causation of emergencies and in the prevention of their progressing into mishaps.

POPULATION CHARACTERISTICS

In the earlier referenced paper the data were presented in several forms. First, in tables illustrating 3rd and 97th percentile limit values for each morphological feature, the numbers of mishap AAES aircrew falling into each of the extreme tails, numbers of individuals for whom values were not reported, and the number for whom values were reported. Second, in graphs of aircrew distribution vs. morphological feature values and, third, in aircrew percentile vs morphological feature values. Despite the extremely large lack of data for helicopter and fixed wing (non AAES) aircraft mishap aircrew and the questions that the problem raises, the latter data display formats were also planned to be employed in this paper.

DATA PROBLEMS

As in the AAES mishap aircrew population data, these non-AAES fixed wing and rotary wing aircraft aircrew data contain several significant problems, especially incomplete data and seemingly obvious errors, e.g., one rotary wing aviators's stature is reported as 26 inches, although, as depicted in Figure 1, it was initaily facetiously suggested that perhaps this was his post crash stature. However, unfortunately, further examination of this individual's anthropometric data which include his weight as 670 pounds (over 1/3 of a ton!) indicates that the explanation is to be found not in his being altered in appearance in the mishap, but rather in errors of measurement, recordation and/or transcription. Such errors significantly reduced the already small data populations.

METHODS FOR DETECTING PROBABLY ERRONEOUS ANTHROPOMETRIC DATA

In last year's paper, as a service to current and future anthropologists or others interested in the extreme variations occasionally observed in human forms and proportions, the most interesting of these were presented as A Gaggle of Naval Aviation Anthropomorphs. After reviewing the larger quantities of data available for analyses covering mishap aircrews in all types of Navy aircraft, it slowly became apparent that these anthropomorphs were to be discovered among all of the aircrew populations, that they were not indigenous only to AAES equipped aircraft aircrews. Therefore presented with this paper as a further service to anthropologists is The U.S. Naval Aviation Anthropomorph Competition Amongst Mishap Crewmembers in Helicopters, Fixed Wing Aircraft without AAES, and Fixed Wing Aircraft with AAES, (Figures 2 through 18). This author has as yet not personally met or observed any of these anthropomorphs but is constantly on the lookout for them since the flight surgeons' documentation clearly suggests that they are not so rare that one would seldom expect to meet one within the naval aviation community.

The collections of naval aviation anthropomorphs displayed in last year's paper and in this one, humerous as they may seem, were presented not simply in fun but to illustrate a simple point: erroneous anthropometric data have been and are entering the MORs/FSRs (Medical Officer's Reports/Flight Surgeon's Reports). How serious is the problem? There are two measures of that: (1) the quantity or proportion of the data which is erroneous and (2) the consequences that flow from the entry of erroneous data into the data banks and the criticality of their subsequent usage. At the moment quantifying the first measure is difficult and is, in fact, a major subtask of this effort to examine mishap aircrew anthropometric data. When considered in conjunction with the extremely large failure to obtain and report mishap aircrew anthropometric data, even small error rates have a very major impact upon the data base and its validity and usefulness. As would be expected, as a consequence in part of the varying difficulty in measuring each of the eight morphological parameters, the quantity of definitely erroneous and suspected erroneous data for each of the eight parameters reported in MORs/FSRs varies considerably. As for the second measure, consider but a few of the past and potential uses of these data: searching for anthropometric patterns which might have caused, contributed to or prevented the correction of, the conditions resulting in mishaps; verifying the in-service aviation populations' anthropometry and anthropometry trends for designers of crew stations, life support and flight equipments, and ejection seats to assure proper accommodation or fit; formulating policies concerning aircrew size for various aircraft to assure aircrew safety; and assessing future recruitment policies.

It is important that these mishap aircrew anthropometric data be obtained, screened and entered into the FSR. It also is incumbent upon those who would use the resultant data banks to first carefully screen the data to identify and eliminate from their analyses those data whose characteristics, whether as singular data or in combination with other data, suggest a high probability that the data are erroneous.

There are a number of simple to use, fairly effective screening techniques available both for the medical officer preparing an FSR and for the data analyzer. The simplest is to review the data against existing standards imposed for entry into the service and into the particular sector of the service in which the mishap crewmember (or passenger) is serving. In the U.S. Navy these standards are listed in the Manual of the Medical Department, U.S. Navy. In preparing the FSR, however, entrance standards data such as those displayed in Tables IV through VI must be used with caution for the individual might have entered under older, different standards or received a waiver and, in addition, the standards for retaining a member of the service after the service has made a major investment in that crewmember's training and building experience are often significantly different from the entry standards.

Another screening technique evolves from the requirement expressed in the Manual of the Medical Department, U.S. Navy for those individuals admitted to the service to be generally well proportioned (which causes this author to wonder: From whence cometh the wonderful anthropomorphs so frequently reported present in the naval aviation community?). There therefore does exist not only the obvious range of errors which should be readily, visually detectable (the anthropomorph collections, for example), but also a general proportionality for the range of human sizes admitted to and retained by the services that permit the generation of morphological feature measurement comparisons by both additive/subtractive techniques and ratios techniques with reasonable expectations that the resultant comparison values will lie within certain bounds unless one or more of the basic recorded measures are in error. A major portion of the effort expended to date has been to test several means which have been recommended to this project for screening anthropometric data. Several of these screening techniques and their associated "normal" value ranges are illustrated in Table VII. Figure 19 illustrates the methodology finally developed and employed during this study for combining all of the available information concerning aircrew morphological parameter "norms" and "extremes" for screening the mishap aircrew anthropometric data. The impact of these first stage admissions standards and then second stage Table VII asterisked (*) screening techniques upon the mishap aircrew anthropometry data is demonstrated in Tables VIII through XIII.

EVALUATION OF MISHAP AIRCREW REPORTED ANTHROPOMETRY

As shown in Tables VIII and XIII, the screening technique illustrated in Figure 19 and employing the admission to commissioned aviator service values of Table VI and the recommended limit values of Table VII significantly diminished several populations of mishap aircrew morphological values in each class of mishap aircraft. The admissions standards stage of the screening process eliminated a large proportion of the data responsible for the creation of the anthropomorph collection. Trunk height and shoulder width, not being governed by admission standards were checked against the first and ninety-ninth percentile values of the reference 2 survey. Large numbers of values fell outside these limits, however, many of these were very close to the limits and their elimination at this stage is difficult to justify. Since the survey might contain biased populations, it is possible that this screening eliminates valid values.

The asterisked (*) second stage screening formulae appear, as shown in Table XII, to perform at or below the expected reject rate. However several of the non-asterisked formulae would induce extremely high rates of rejection among what otherwise appear to be valid data. One problem which will be examined further and reported on later is establishing cross-check screening formulae to assist in establishing which specific values are questionable to thereby avoid the present situation in which a screening formula result that is out of bounds requires rejection of all values used in that formula.

CONCLUSION

There is an unacceptably low amount of anthropometric data being furnished for mishap aircrew, especially those involved in helicopter and fixed wing (non AAES) aircraft mishaps. This problem is compounded by the large proportion of data evidencing errors, many of which can be readily detected by simple arithmetic comparative checks and common sense. It is probable that a great many of these are simple errors of transposing numbers, incomplete entries, and entering the data into the wrong box; errors which the exercise of self-imposed quality control should detect anyway.

There is needed a better system to acquire and maintain current naval aircrew, both commissioned and enlisted, anthropometric data and to input that data into the mishap record. The Naval Air Test Center, Patuxent River, is currently developing a measuring system which is expected to be simple and easy to use and which will contain built-in error screening procedures. It is anticipated that operation of this system to acquire accurate measurement of the basic, primary interest aircrew morphological features will not require highly trained personnel and that the collection of each individual's data will be accomplishable in a matter of only a few minutes. With such a system, an individual's anthropometry records could be periodically updated. Eventually, a total measuring, data storage and data retrieval system might permit the Naval Safety Center, Norfolk, to access the system directly for each mishap crewmember's anthropometric data and eliminate the current burdensome and error prone approach.

Until that system has been developed, procured and placed in operation, the careful assistance of the medical personnel preparing the FSR is needed to ensure that the anthropometric data are obtained and accurately presented in the FSR for each mishap aircrewmember. These data are needed to permit fulfillment of a multitude of critical, aircrew safety related and other important requirements. Measurement, transcriptional and other errors as well as the failure to furnish the required FSR data at best preclude fulfilling these requirements and, worse, might in fact be misleading with long term adverse effects upon aircrew safety and other aircrew related matters.

Note: Development and presentation formatting of the data used herein are the result of the efforts of Messrs. Robert Cox and Lanny Moffett and Mrs. Joyce Roy. Cartoons of anthropomorphs drawn by Mr. Marlon Leake.

TABLE IV

15-19. Height, Weight, and Body Build

(2) Weight.-The applicant shall be weighed, in undergarments only, on a standard set of scales which is known to be correct. The weight shall be recorded in pounds (with kilograms shown in parentheses). Fractions of pounds shall not be recorded. To convert to kilograms, multiply pounds by 0.45. The applicant's weight should be well distributed and in proportion to age, sex, and skeletal structure. The following tables (1,2, and 3) set forth the suggested minimum and maximum weight limits as related to age and height. The tables are provided as a guide to medical examiners and should not be construed too strictly. For example, an individual may fall between the extremes of the minimum and maximum and be not qualified because of marked variations in physical proportions. An applicant, however, whose weight falls at the extremes of either the minimum or maximum range is acceptable only if applicant is obviously active, of firm musculature, and evidently vigorous and healthy. When doubt exists as to proper proportionment, photographs taken in appropriate attire (such as bathing suit) to show trunk and limb development should be forwarded with the physical examination report to the Bureau for consideration; this applies also to individuals above the maximum weight who present proper proportionment and are evidently vigorous and healthy.

Table 2. Weight standards for Navy and Marine Corps aviation personnel, including aviation officer candidates

Height (inches)	(Centimeters)	Weight Minimum (pounds)	(kilograms)	Maximum (pounds)	(kilograms)
64	(162.56)	105	(47.25)	160	(72.00)
65	(165.10)	106	(47.70)	165	(74.25)
66	(167.64)	107	(48.15)	170	(76.50)
67	(170.18)	111	(49.95)	175	(78.75)
68	(172.72)	115	(51.75)	181	(81.45)
69	(175.26)	119	(53.55)	186	(83.70)
70	(177.80)	123	(55.35)	192	(86.40)
71	(180.34)	127	(57.15)	197	(88.65)
72	(182.88)	131	(58.95)	203	(91.35)
73	(185.42)	135	(60.75)	209	(94.05)
74	(187.96)	139	(62.55)	214	(96.30)
75	(190.50)	143	(64.35)	219	(98.55)
76	(193.04)	147	(66.15)	225	(101.25)
77	(195.58)	151	(67.95)	230	(103.5)
78	(199.12)	153	(68.85)	235	(105.75)

Source: Manual of the Medical Department, U.S. Navy (15-19) Change 95 dated 25 Nov 1980

TABLE V

15-19. Height, Weight, and Body Build

(1) Height.-The applicant's height shall be measured in inches to the nearest one-half inch (1.27 cm) (aviation to the nearest tenth of an inch (0.25 cm), art. 15-70(4)(a)(3)), without shoes, by a measuring scale known to be accurate. Height shall be recorded in inches (with centimeters shown in parentheses). To convert to centimeters multiply inches by 2.54. The table below sets forth the minimum and maximum height acceptable for the several categories of naval service.

Minimum and maximum standards of height

Category	Minimum		Maximum
	in.	cm	
1. Officer Training Programs:			
a. Unrestricted Line Input	62	(157.48)	*
b. Restricted Line & Staff Corps Input	60	(152.40)	*
c. Marine Corps, All Programs	66	(167.64)	*
2. Appointment; USN & USNR:			
a. Unrestricted Line	62	(157.48)	*
b. Restricted Line & Staff Corps	60	(152.40)	*
c. Warrant Officer & Limited Duty Officer:			
(1) Deck, Operations & Ordnance Designators	62	(157.48)	*
(2) All Other Designators	60	(152.40)	*
3. Appointment, USMC, USMCR:			
a. All Categories, Including WO	66	(167.64)	*
4. Navy and Marine Corps, Females:			
a. All Categories	60	(152.40)	*

*Maximum height for all categories is 78 inches (198.12 cm).

Source: Manual of the Medical Department, U.S. Navy (15-19) Change 95 dated 25 Nov 1980

TABLE VI

15-70 (4) Height and Weight (qualification for duty involving flying)

	minimum (in/cm)	maximum (in/cm)
(a) Height	64/162.56	78/198.12
(b) Sitting Height	32/81.28	41/104.14
(c) Buttock Leg Length	36/91.44	50/127.00
(d) Buttock Knee Length	21.9/55.63	28.0/71.12
(e) Functional Reach	28.0/71.12	---

(5) These measurements shall be obtained on all class 1 personnel and naval flight officers and recorded to the nearest tenth of an inch (0.25 cm)

Source: Manual of the Medical Department, U.S. Navy (15-70)
Change 95 dated 25 Nov 1980

TABLE VII

Recommended Screening Techniques With Limit Values For An Individual's Anthropometry

Derived Value	Lower Limit (1st Percentile)	Upper Limit (99th Percentile)
Additive/Subtractive		
1. SH - TH *	9.90	14.30
2. SH + BLL	72.10	88.70
3. SW + 2 X FR	74.40	94.00
4. BLL - BKL	15.20	22.90
5. (SH + BLL)-H *	6.90	12.80
6. (SW X H)/100 *	10.60	16.10
7. SW/FR *	0.49	0.67
8. TH/FR	0.65	0.89
9. SH/H *	0.50	0.56
10. BKL/BLL *	0.50	0.62
11. TH/SH	0.61	0.73
12. H/(SW + 2 X FR)	0.78	0.90

EXPLANATIONS

1. Sitting height (SH), trunk height (TH) comparison yielding an approximation of head and neck height.
2. Sitting height (SH), buttock leg length (BLL) comparison yielding an approximation of stature.
3. Shoulder width (SW), functional reach comparison yielding an approximation of total finger tip to finger tip outstretched span.
4. Buttock leg length (BLL), buttock knee length comparison yielding an approximation of lower leg length.
5. Sitting height (SH), buttock leg length (BLL) approximation of height comparison with height.
6. Shoulder width (SW) and height (H) comparative ratio.
7. Shoulder width (SW) and functional reach (FR) comparative ratio.
8. Trunk height (TH) and functional reach (R) comparative ratio.
9. Sitting height (SH) and height (H) comparative ratio.
10. Buttock knee length (BKL) and buttock leg length (BLL) compartive ratio.
11. Trunk height (TH) and sitting height (SH) comparative ratio
12. Height (H) and constructed span (see 3) comparative ratio.

FOOTNOTES

1. An asterisk (*) indicates those comparisons techniques considered to yield the best results - - techniques numbers 1, 5, 6, 7, 9, and 10.

2. Source: Private communications between the author and Lcdr. Mothershead, MC, USN.

TABLE VIII
AAES EQUIPPED AIRCRAFT MISHAP AIRCREW ANTHROPOMETRIC VALUE FIRST STAGE SCREENING RESULTS
TOTAL NUMBER OF AAES EQUIPPED AIRCRAFT MISHAP AIRCREW: 1793

MORPHOLOGICAL PARAMETERS	TOTAL VALUES PRESENTED	TOTAL BLANK VALUES PRESENTED	TOTAL VALUES ELIMINATED BY ADMISSIONS STANDARDS	TOTAL VALUES CONSIDERED PROBABLY VALID	PERCENT VALUES PRESENTED REJECTED BY ADMISSIONS STANDARDS TECHNIQUE
HEIGHT	1679	114	7	1672	0.42
WEIGHT*	1687	106	21	1606	1.24
SITTING HEIGHT	1557	236	4	1553	0.26
TRUNK HEIGHT*	1518	275	94	1267	6.19
FUNCTIONAL ARM REACH	1389	404	203	1186	14.61
BUTTOCK KNEE LENGTH	1507	286	60	1447	3.98
LEG LENGTH	1524	269	17	1507	1.12
SHOULDER WIDTH*	1513	280	129	1257	8.53

*NOTE: MORPHOLOGICAL PARAMETERS NOT COVERED BY ADMISSIONS STANDARDS, HENCE NATC SY-121R-82 SURVEY 1ST AND 99TH PERCENTILE VALUES USED.

TABLE IX
HELICOPTER MISHAP AIRCREW ANTHROPOMETRIC VALUE FIRST STAGE SCREENING RESULTS
TOTAL NUMBER OF HELICOPTER MISHAP AIRCREW: 3929

MORPHOLOGICAL PARAMETERS	TOTAL VALUES PRESENTED	TOTAL BLANK VALUES PRESENTED	TOTAL VALUES ELIMINATED BY ADMISSIONS STANDARDS	TOTAL VALUES CONSIDERED PROBABLY VALID	PERCENT VALUES PRESENTED REJECTED BY ADMISSIONS STANDARDS TECHNIQUE
HEIGHT	1347	2582	10	1337	0.74
WEIGHT*	1346	2583	18	1328	1.34
SITTING HEIGHT	840	3089	23	817	2.74
TRUNK HEIGHT*	817	3112	89	728	10.89
FUNCTIONAL ARM REACH	751	3178	113	638	15.05
BUTTOCK KNEE LENGTH	814	3115	47	767	5.77
LEG LENGTH	811	3118	31	780	3.82
SHOULDER WIDTH*	812	3117	70	742	8.62

*NOTE: MORPHOLOGICAL PARAMETERS NOT COVERED BY ADMISSIONS STANDARDS, HENCE NATC SY-121R-82 SURVEY 1ST AND 99TH PERCENTILE VALUES USED.

TABLE X
NON-AAES FIXED WING AIRCRAFT MISHAP, AIRCREW ANTHROPOMETRIC VALUE FIRST STAGE SCREENING RESULTS
TOTAL NUMBER OF NON-AAES FIXED WING AIRCRAFT MISHAP AIRCREW: 3949

MORPHOLOGICAL PARAMETERS	TOTAL VALUES PRESENTED	TOTAL BLANK VALUES PRESENTED	TOTAL VALUES ELIMINATED BY ADMISSIONS STANDARDS	TOTAL VALUES CONSIDERED PROBABLY VALID	PERCENT VALUES PRESENTED REJECTED BY ADMISSIONS STANDARDS TECHNIQUE
HEIGHT	1384	2565	7	1377	0.51
WEIGHT*	1386	2563	21	1365	1.52
SITTING HEIGHT	945	3004	18	927	1.90
TRUNK HEIGHT*	922	3027	103	819	11.17
FUNCTIONAL ARM REACH	858	3091	120	738	13.99
BUTTOCK KNEE LENGTH	926	3023	56	870	6.05
LEG LENGTH	923	3026	34	889	3.68
SHOULDER WIDTH*	918	3031	93	825	10.13

*NOTE: MORPHOLOGICAL PARAMETERS NOT COVERED BY ADMISSIONS STANDARDS, HENCE NATC SY-121R-82 SURVEY 1ST AND 99TH PERCENTILE VALUES USED.

TABLE XI
ALL MISHAP AIRCREW ANTHROPOMETRIC VALUE FIRST STAGE SCREENING RESULTS
TOTAL NUMBER OF ALL MISHAP AIRCREW: 9671

MORPHOLOGICAL PARAMETERS	TOTAL VALUES PRESENTED	TOTAL BLANK VALUES PRESENTED	TOTAL VALUES ELIMINATED BY ADMISSIONS STANDARDS	TOTAL VALUES CONSIDERED PROBABLY VALID	PERCENT VALUES PRESENTED REJECTED BY ADMISSIONS STANDARDS TECHNIQUE
HEIGHT	4410	5260	24	4386	0.54
WEIGHT*	4419	5251	60*	4359	1.36
SITTING HEIGHT	3342	6329	45	3297	1.35
TRUNK HEIGHT*	3257	6414	321*	2936	9.86
FUNCTIONAL ARM REACH	2998	6673	436	2562	14.54
BUTTOCK KNEE LENGTH	3247	6424	163	3084	5.02
LEG LENGTH	3258	6413	82	3176	2.52
SHOULDER WIDTH*	3243	6428	292*	2987	9.00

*NOTE: MORPHOLOGICAL PARAMETERS NOT COVERED BY ADMISSIONS STANDARDS, HENCE NATC SY-121R-82 SURVEY 1ST AND 99TH PERCENTILE VALUES USED.

TABLE XII
PERCENTAGE OF PRESENTED MISHAP AIRCREW ANTHROPOMETRIC VALUES REJECTED BY FIRST STAGE (ADMISSIONS STANDARDS) SCREENING

MORPHOLOGICAL PARAMETERS	AAES EQUIPPED AIRCRAFT	HELICOPTERS	NON-AAES FIXED WING AIRCRAFT	ALL AIRCRAFT
HEIGHT	0.42%	0.74%	0.51%	0.54%
WEIGHT*	1.24%	1.34%	1.52%	1.36%
SITTING HEIGHT	0.26%	2.74%	1.90%	1.35%
TRUNK HEIGHT*	6.19%	10.89%	11.17%	9.86%
FUNCTIONAL ARM REACH	14.61%	15.05%	13.99%	14.54%
BUTTOCK KNEE LENGTH	3.98%	5.77%	6.05%	5.02%
LEG LENGTH	1.12%	3.82%	3.68%	2.52%
SHOULDER WIDTH*	8.53%	8.62%	10.13%	9.00%

*NOTE: MORPHOLOGICAL PARAMETERS NOT COVERED BY ADMISSIONS STANDARDS, HENCE NATC SY-121R-82 1ST & 99TH PERCENTILE VALUES USED.

TABLE XIII

MISHAP AIRCREW ANTHROPOMETRY VALUE SECOND STAGE SCREENING RESULTS NUMBERS OF FIRST STAGE ACCEPTED VALUES REJECTED BY SECOND STAGE FORMULAE

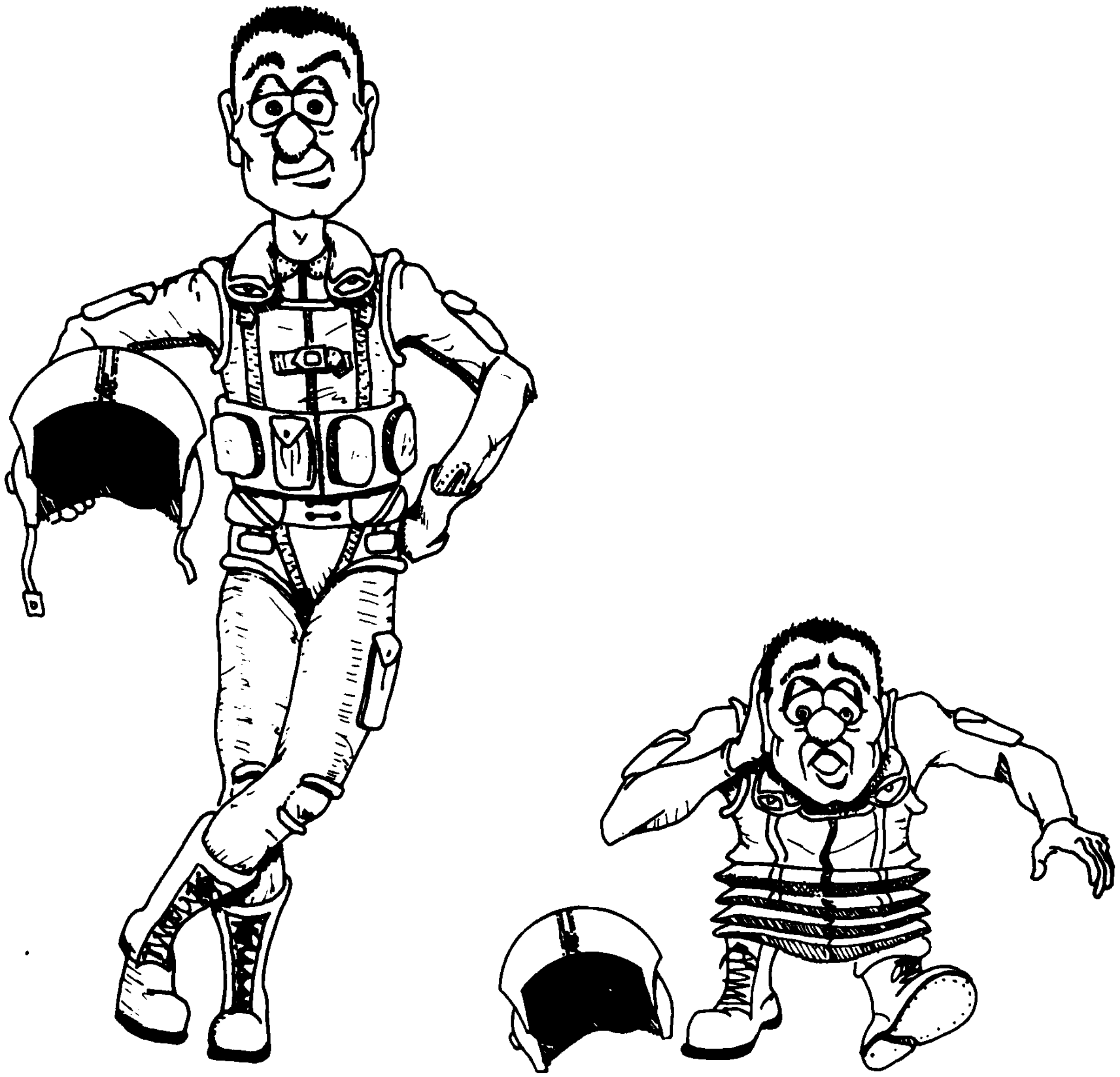
(1 JANUARY 1969 — MID 1982)

	SCREENING FORMULAE	AAES EQUIPPED FIXED WING AIRCRAFT	HELICOPTER	NON-AAES EQUIPPED FIXED WING AIRCRAFT	ALL AIRCRAFT
ASTERISKED (*) FORMULAE	1. SITTING HEIGHT — TRUCK HEIGHT	59	34	48	141
	5. SITTING HEIGHT + BUTTOCK LEG LENGTH — HEIGHT	49	35	47	131
	6. SHOULDER WIDTH × HEIGHT ÷ 100	0	27	0	27
	7. SHOULDER WIDTH ÷ FUNCTIONAL ARM REACH	51	0	38	89
	9. SITTING HEIGHT ÷ HEIGHT	52	35	40	127
	10. BUTTOCK KNEE LENGTH ÷ BUTTOCK LEG LENGTH	25	10	11	46
NON-ASTERISKED FORMULAE	2. SITTING HEIGHT + BUTTOCK LEG LENGTH	4	2	3	9
	3. SHOULDER WIDTH + 2 (FUNCTIONAL ARM REACH)	66	47	39	142
	4. BUTTOCK LEG LENGTH — BUTTOCK KNEE LENGTH	29	24	20	73
	8. TRUNK HEIGHT ÷ FUNCTIONAL ARM REACH	138	101	84	223
	11. TRUNK HEIGHT ÷ SITTING HEIGHT	58	33	48	139
	12. HEIGHT ÷ (SHOULDER WIDTH + 2 (FUNCTIONAL ARM REACH))	348	188	189	725

NOTE: FORMULAE DEFINED IN TABLE VII

HELICOPTER AIRCREWMAN

STATURE: 26 INCHES



BEFORE HELICOPTER IMPACT

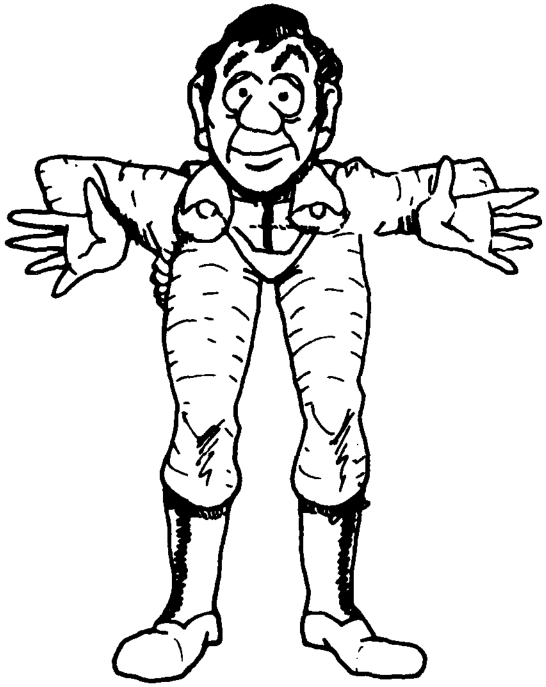
AFTER HELICOPTER IMPACT

Figure 1.

THE U.S. NAVAL AVIATION ANTHROPOMORH COMPETITION AMONGST MISHAP CREW MEMBERS IN HELICOPTERS, FIXED WING AIRCRAFT WITHOUT AAES, AND FIXED WING AIRCRAFT WITH AAES (1 January 1969 through mid-1982)

Figure 2

SITTING HEIGHT



HELICOPTER

3.7″

Figure 3

SITTING HEIGHT

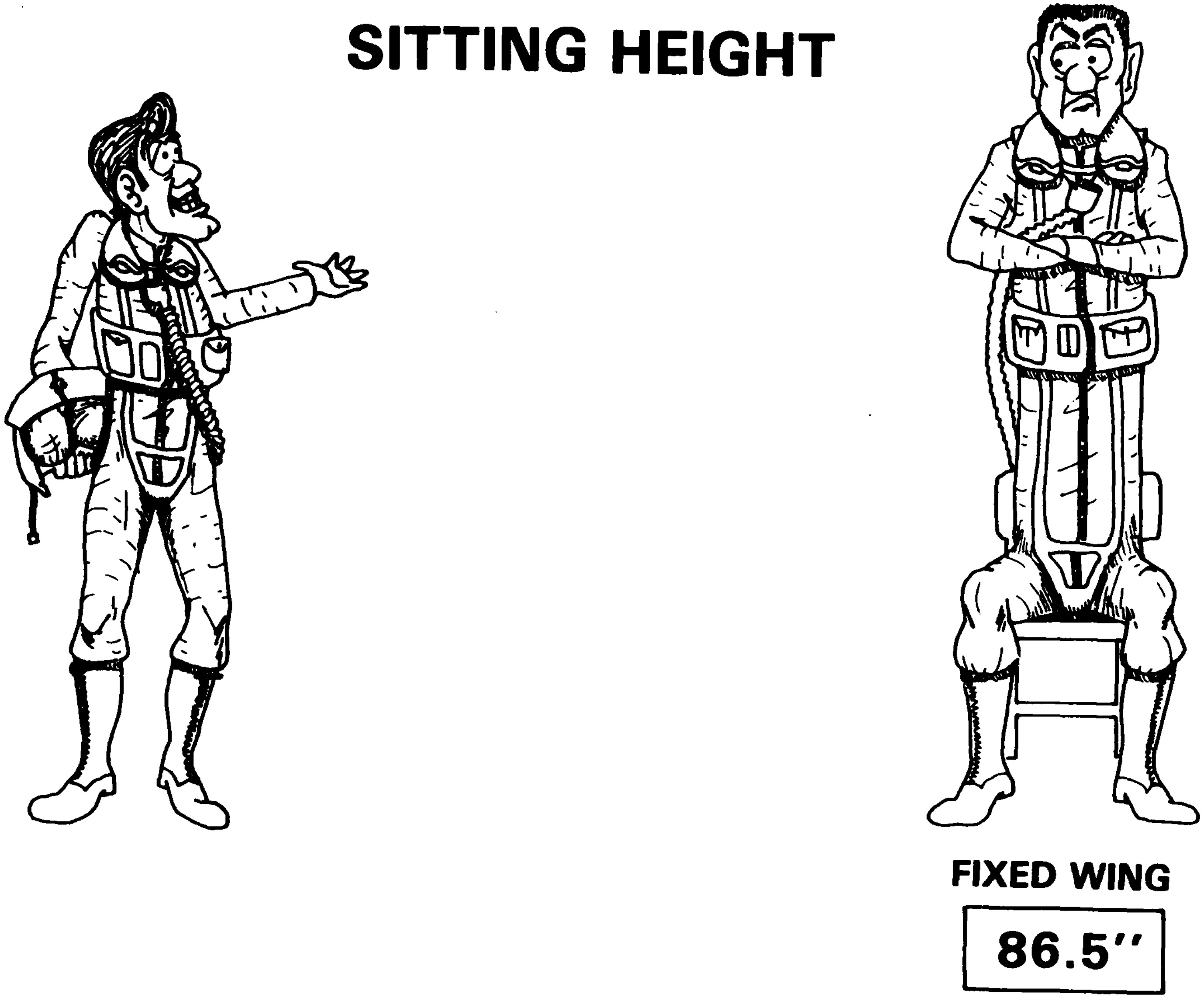


Figure 4

LEG LENGTH — BUTTOCK KNEE LENGTH

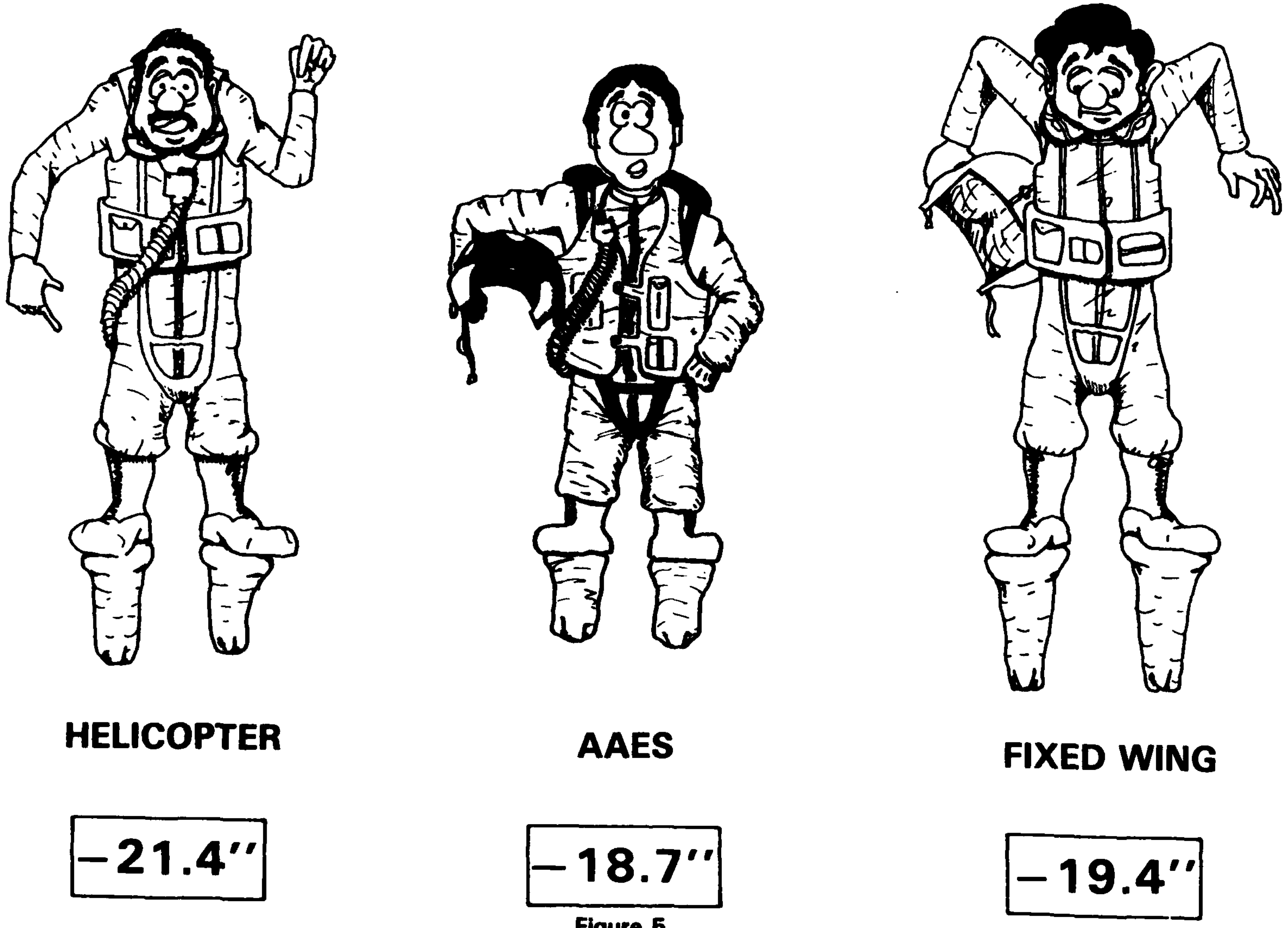


Figure 5

LEG LENGTH — BUTTOCK KNEE LENGTH

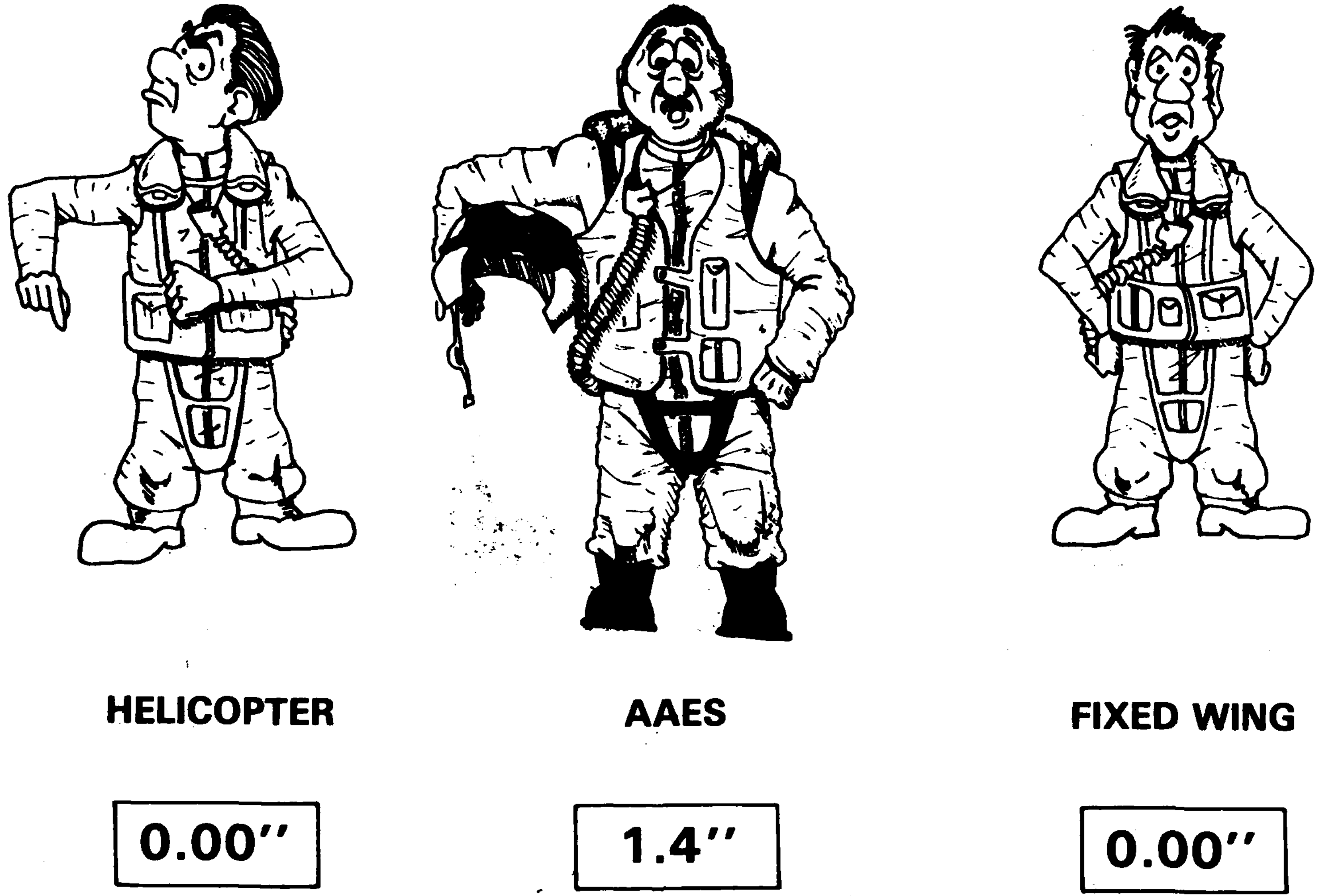
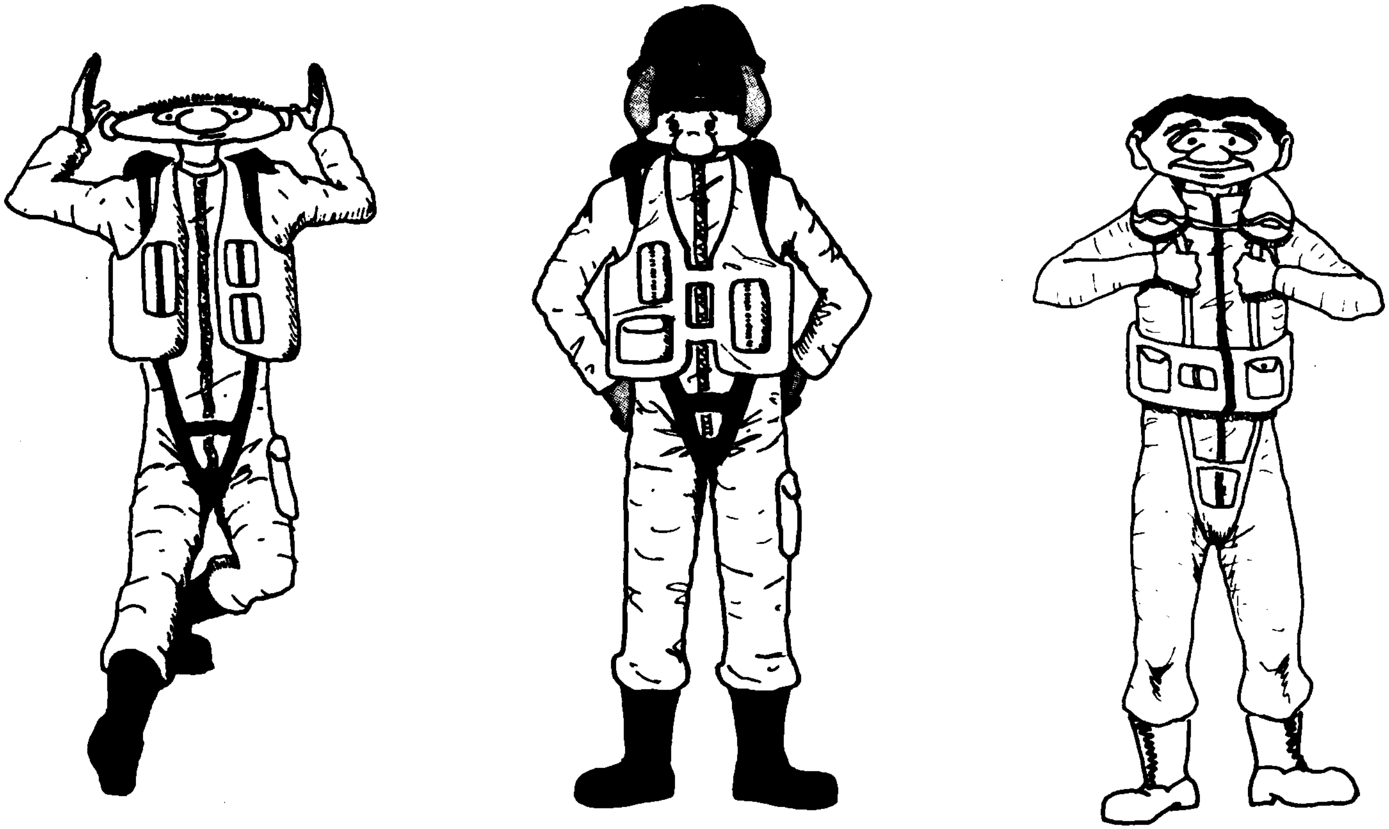


Figure 6

SITTING HEIGHT — TRUNK HEIGHT



FIXED WING

0.00″

AAES

0.3″

HELICOPTER

0.3″

Figure 7

SITTING HEIGHT — TRUNK HEIGHT

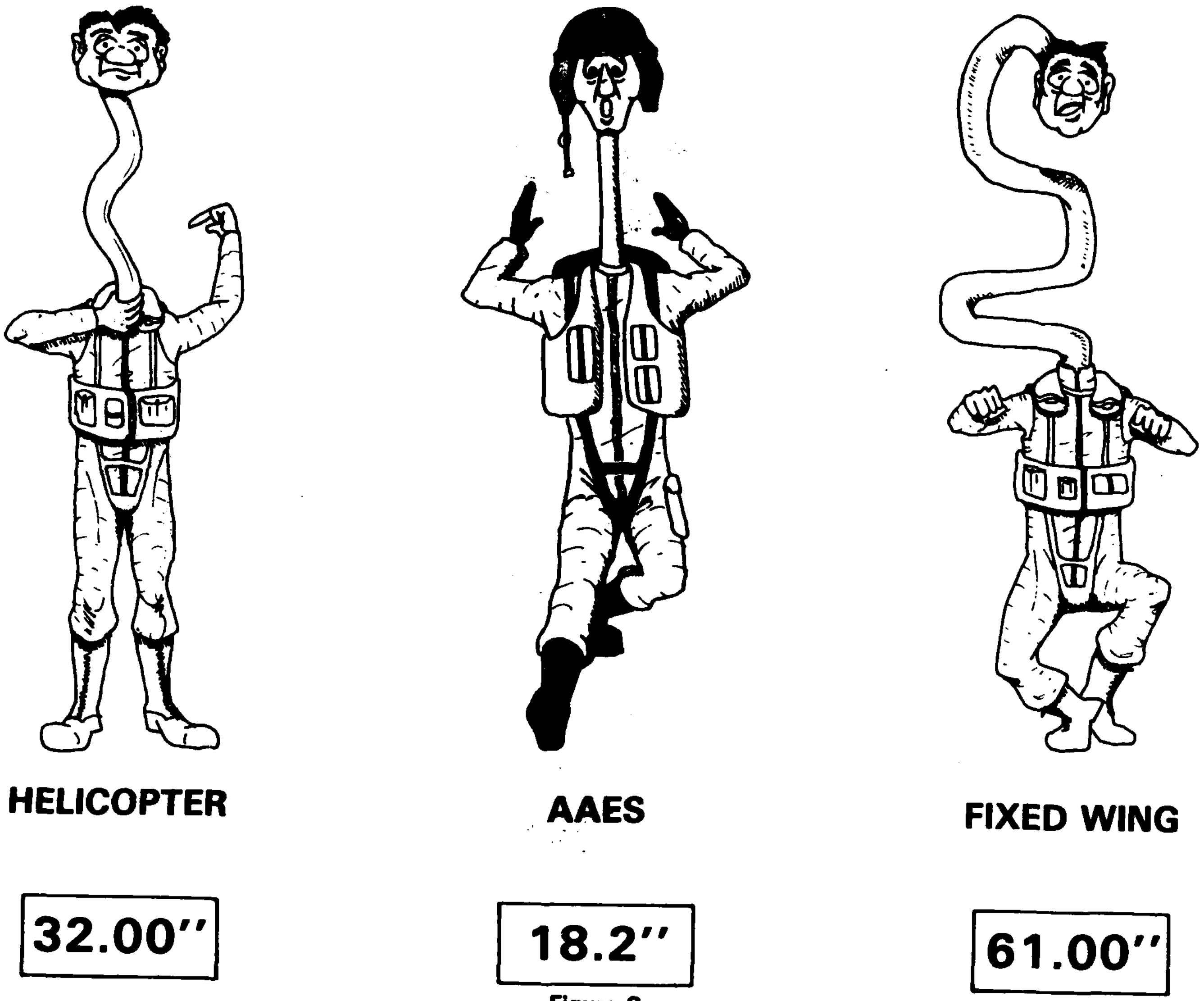


Figure 8

SITTING HEIGHT — TRUNK HEIGHT

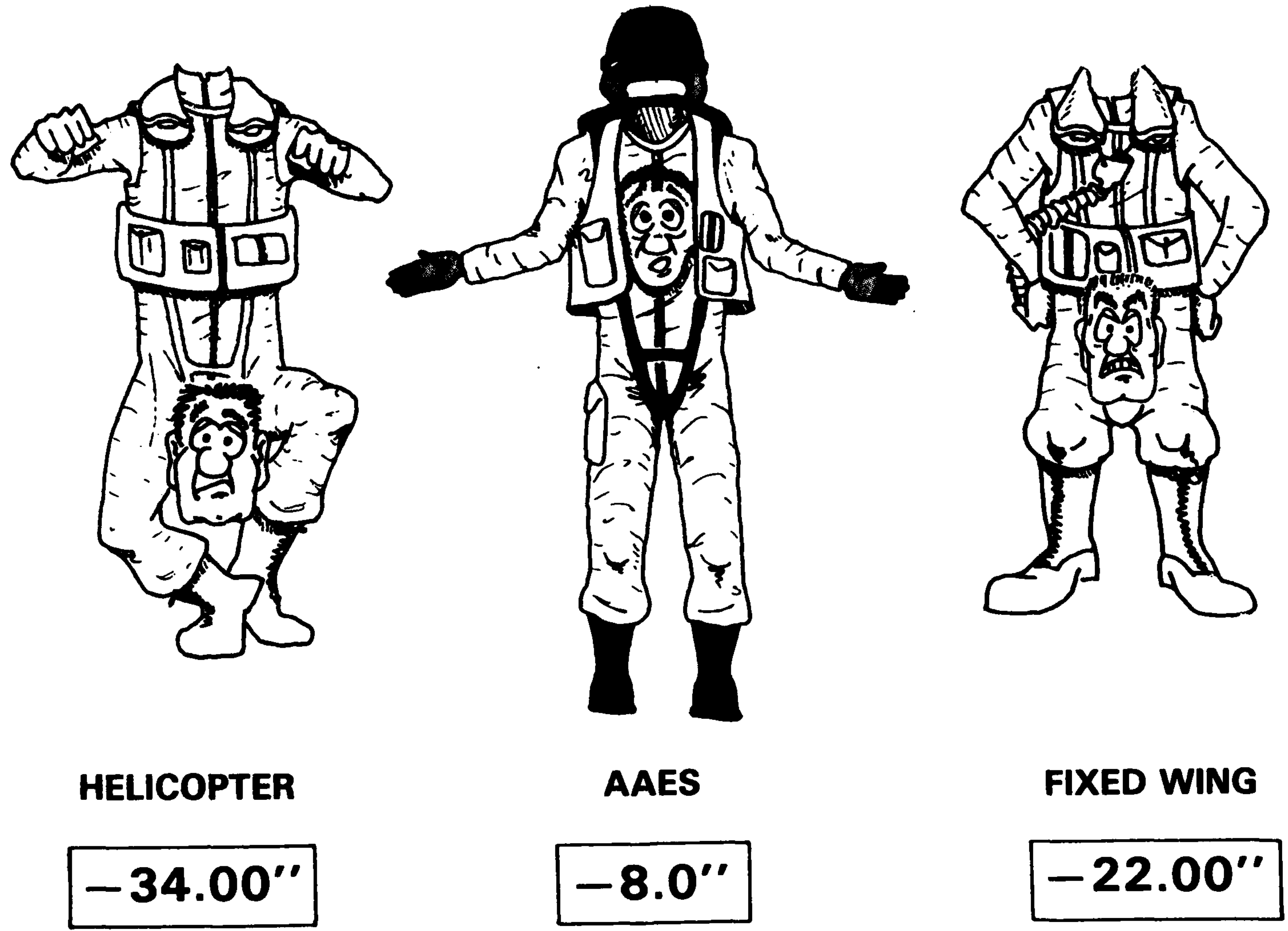


Figure 9

SITTING HEIGHT + LEG LENGTH — HEIGHT

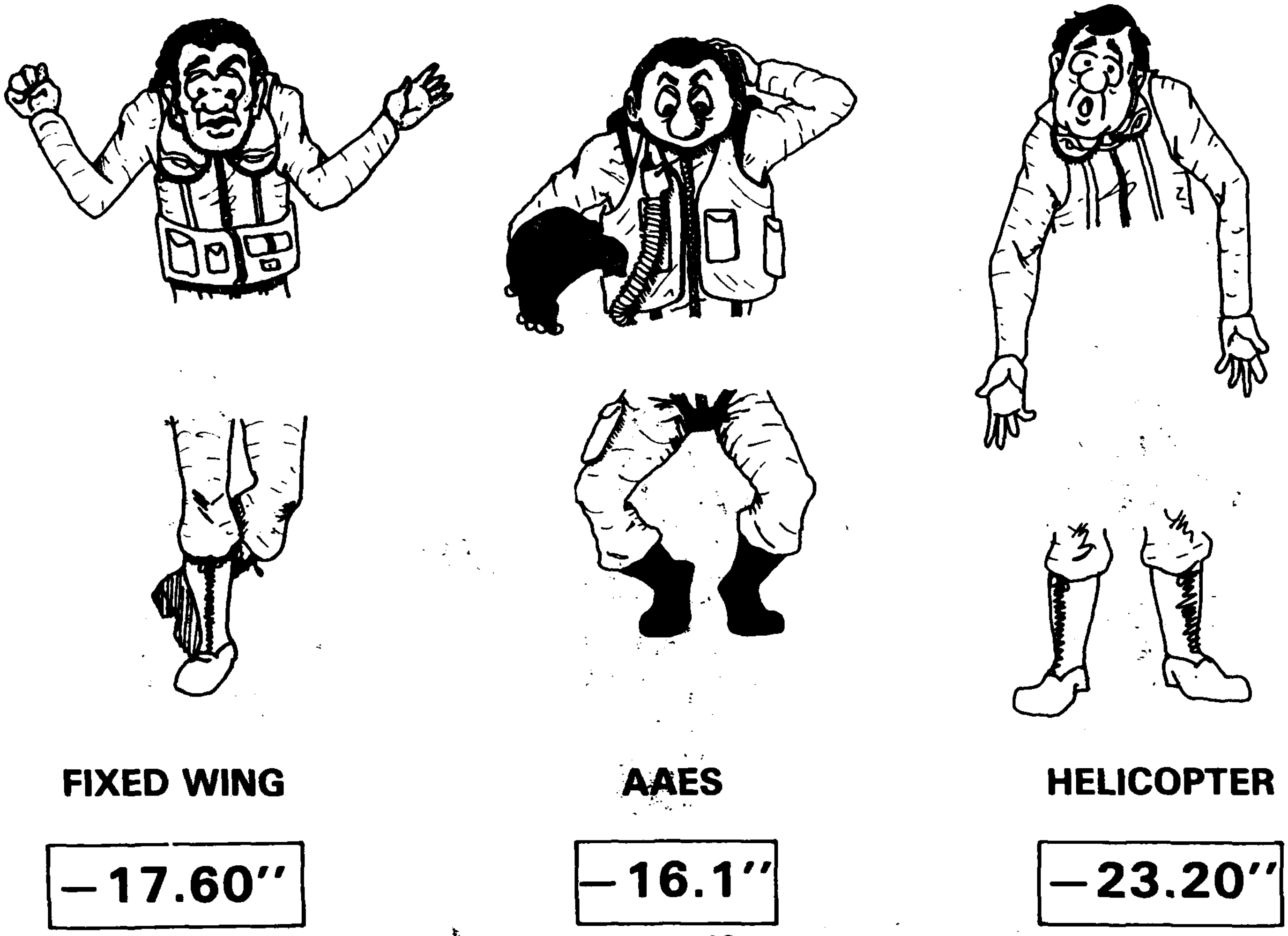


Figure 10

WEIGHT/HEIGHT

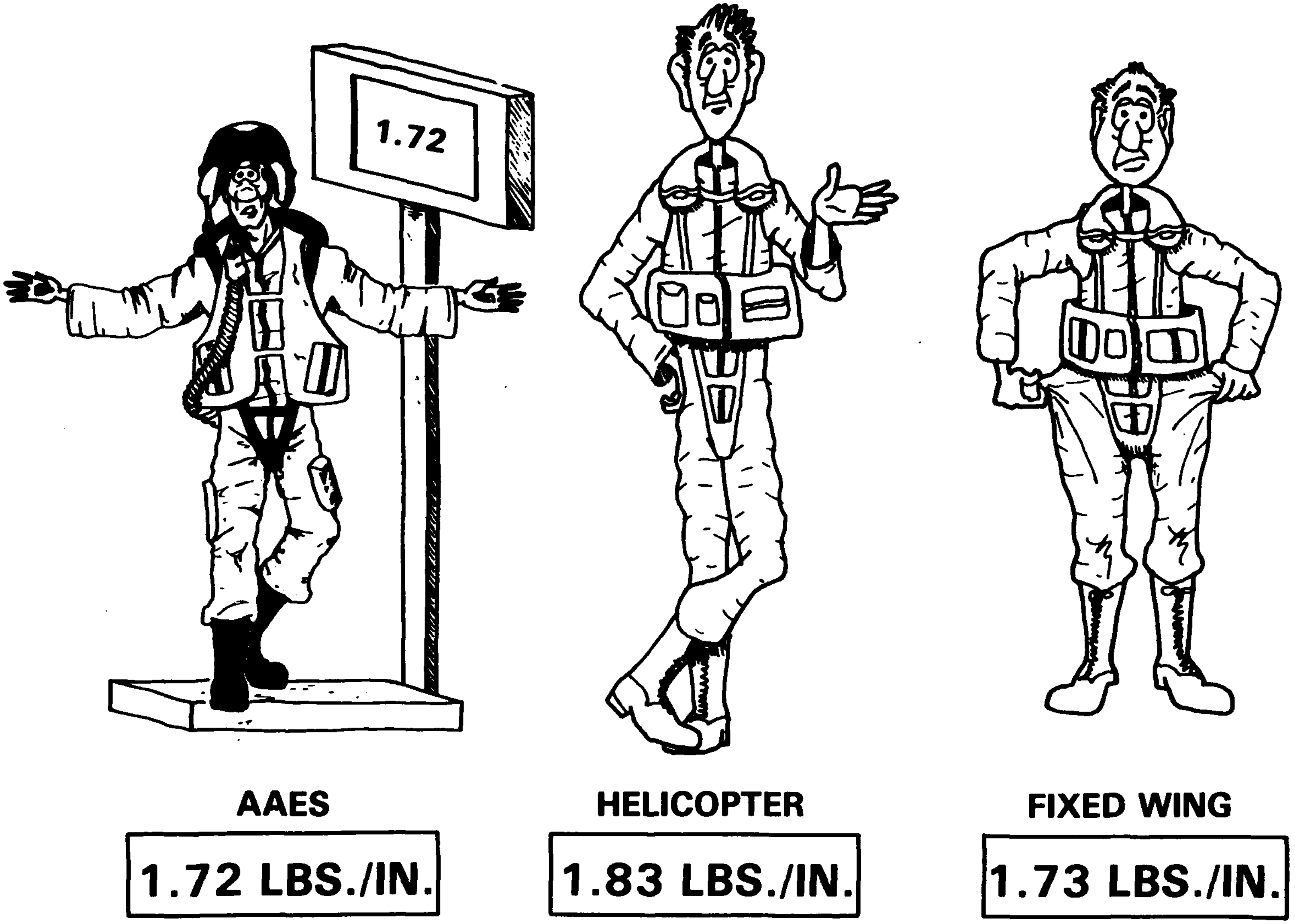
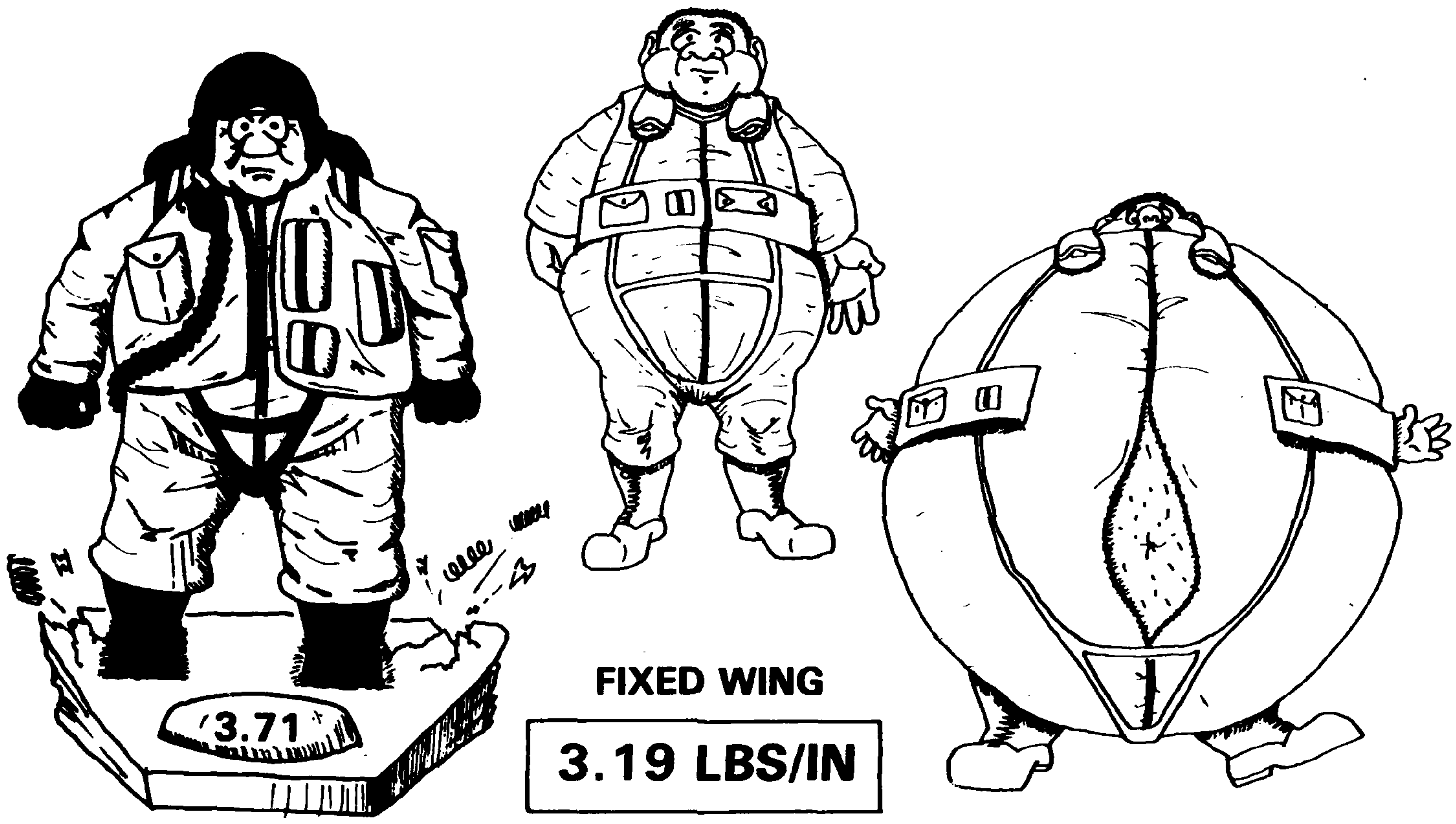


Figure 11

WEIGHT/HEIGHT



FIXED WING

3.19 LBS/IN

AAES

3.71 LBS/IN

HELICOPTER

25.76 LBS/IN

Figure 12

STANDING HEIGHT

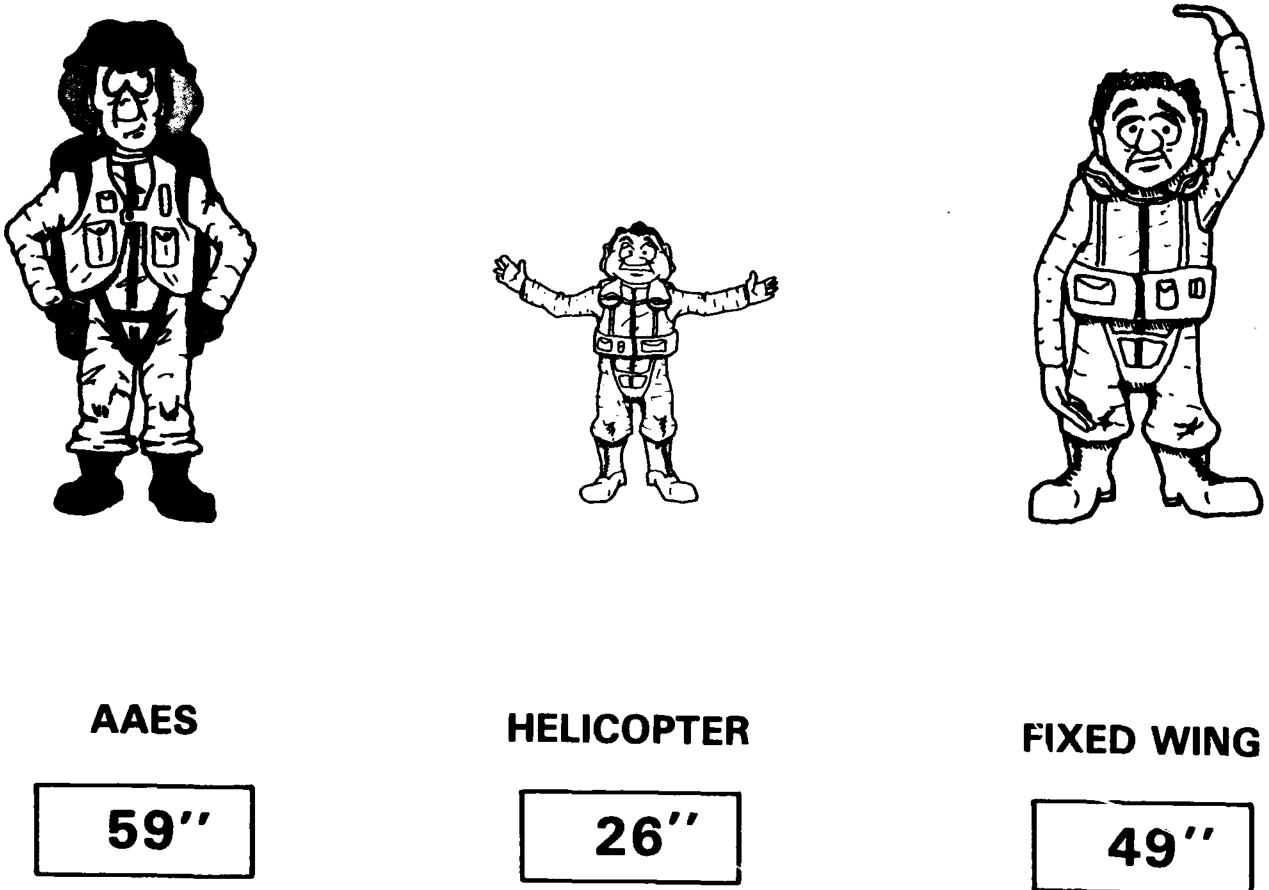


Figure 13

STANDING HEIGHT

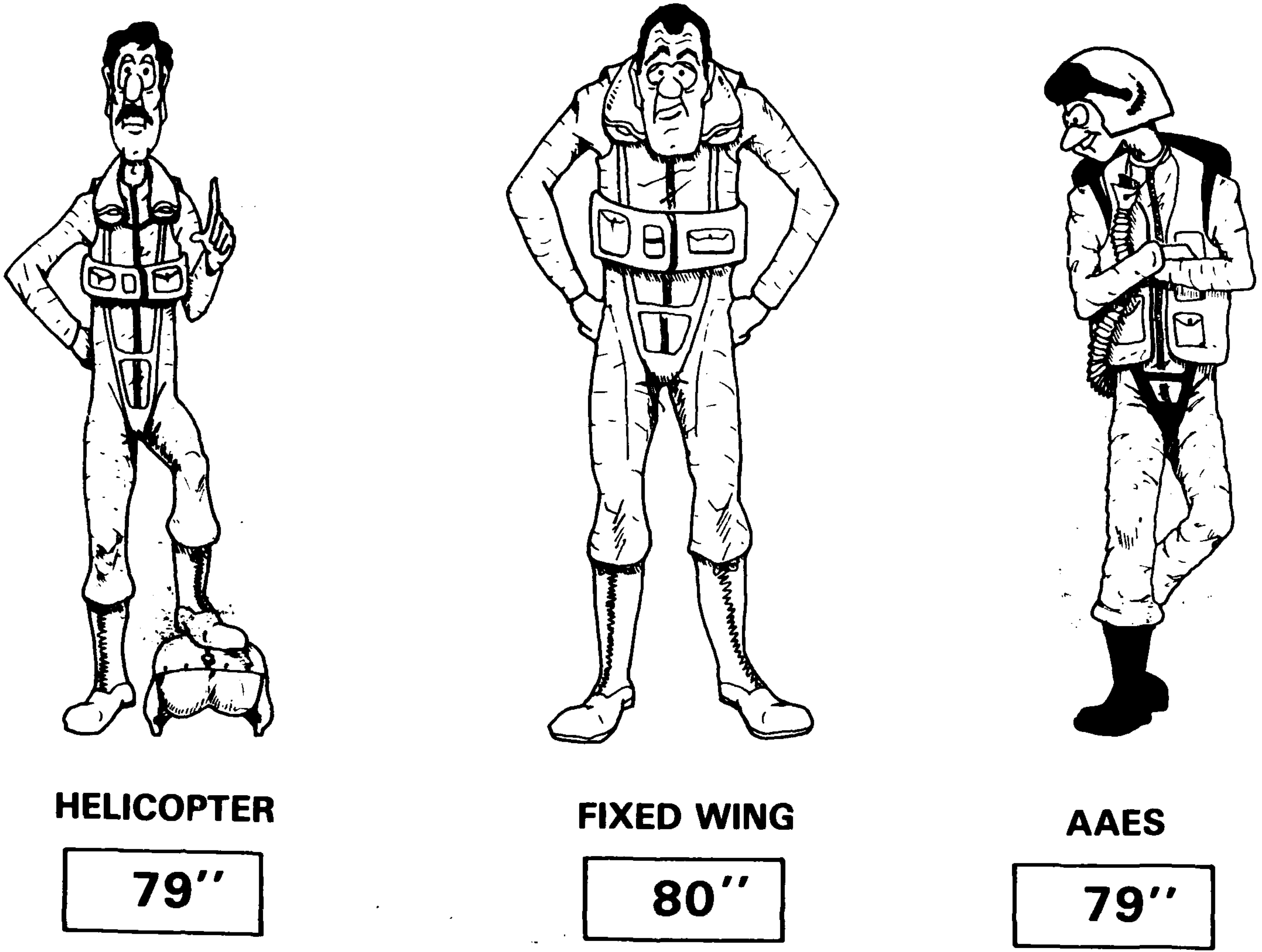


Figure 14

FUNCTIONAL REACH

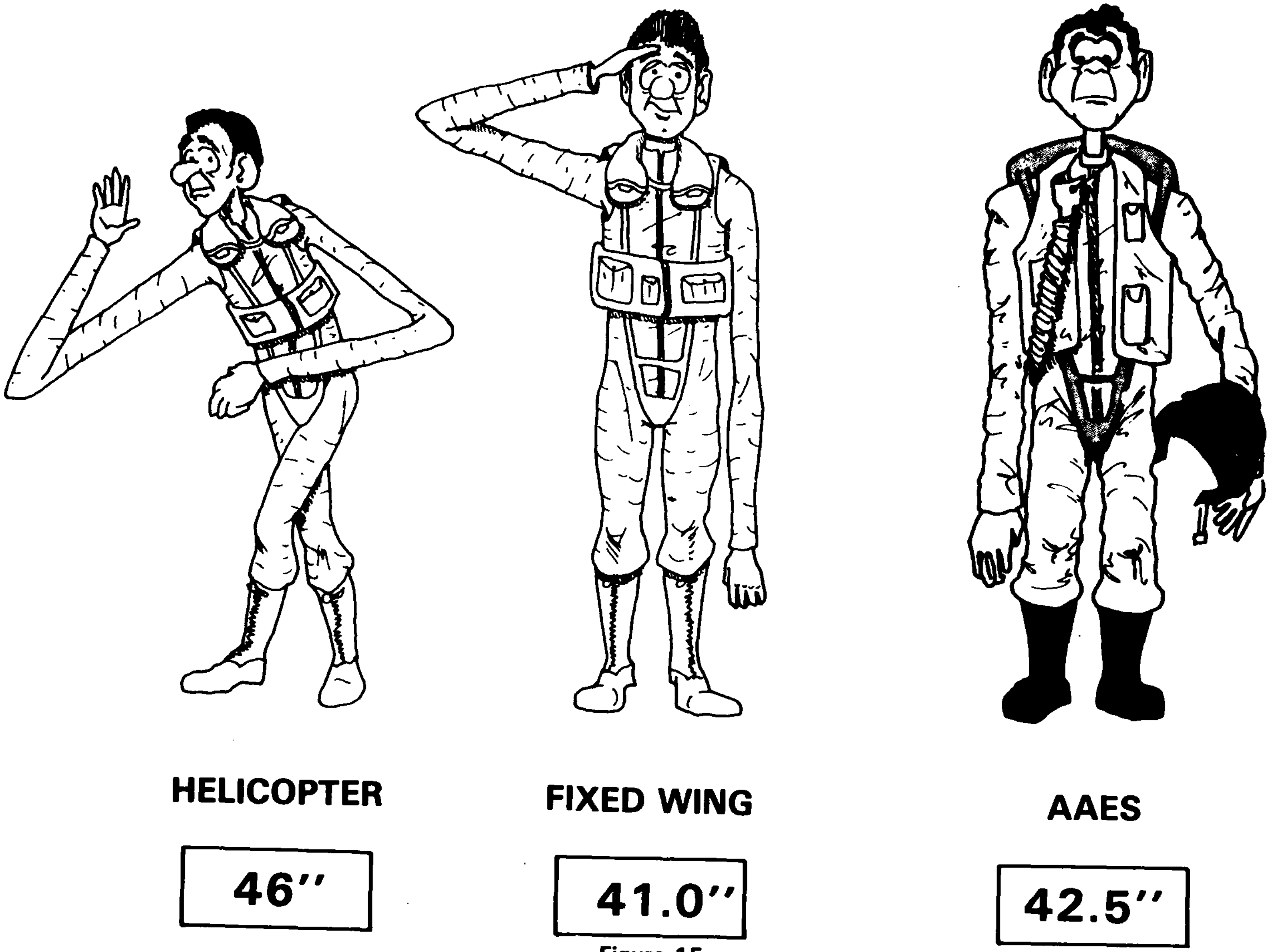


Figure 15

FUNCTIONAL REACH

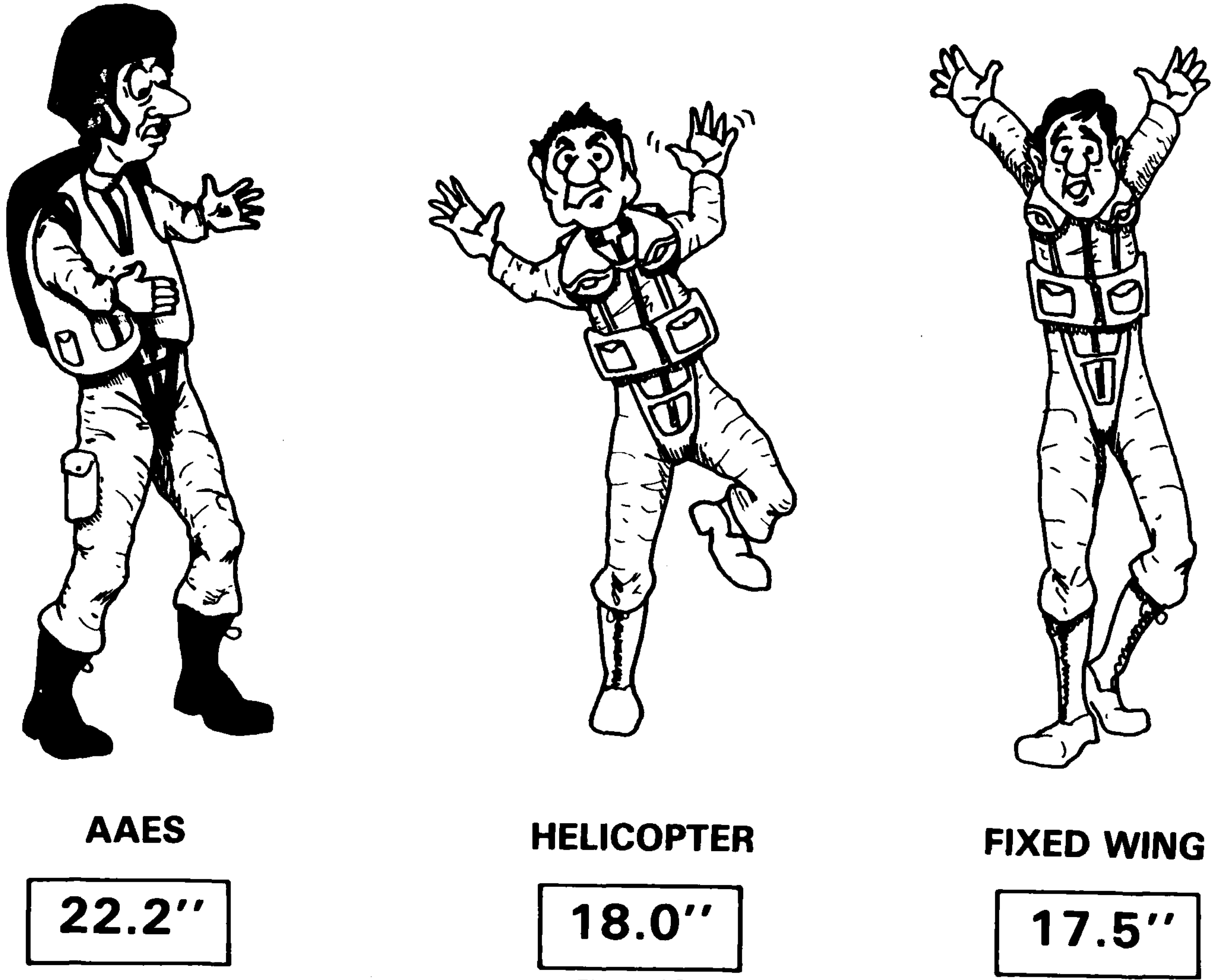


Figure 16

BUTTOCK — KNEE LENGTH

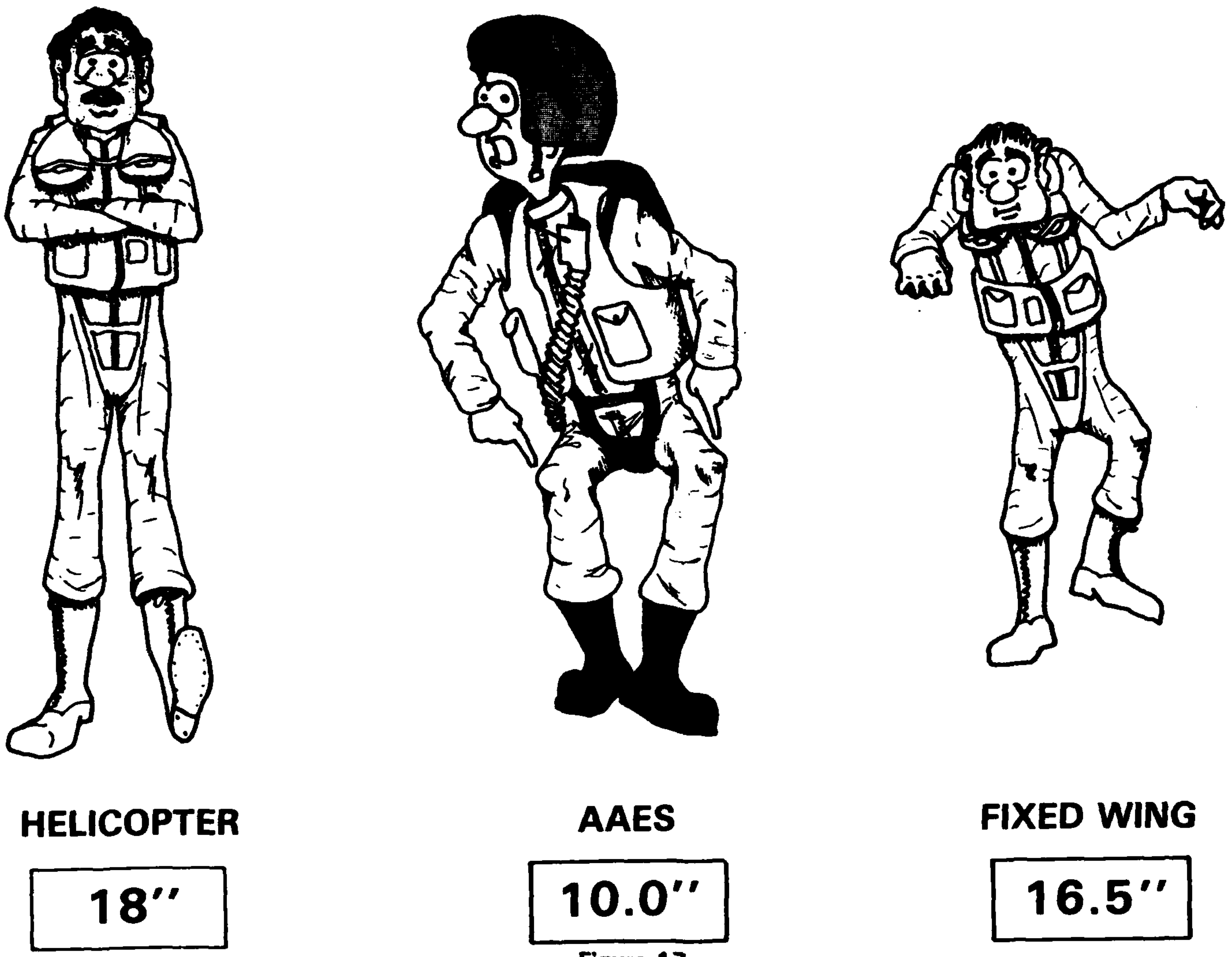


Figure 17

SHOULDER WIDTH

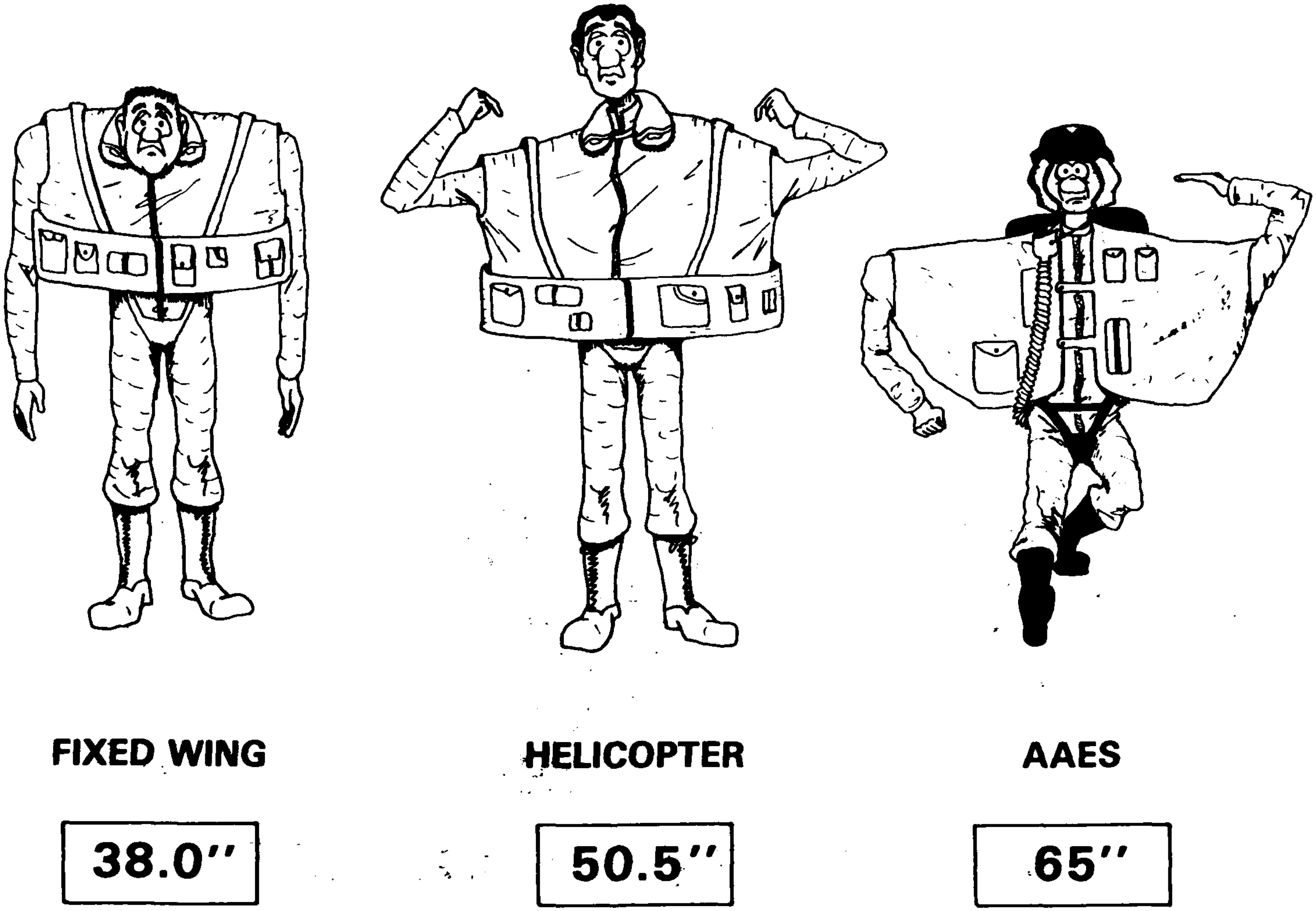


Figure 18

U.S. NAVY MISHAP AIRCREW
ANTHROPOMETRIC DATA SCREENING FLOW
(FOR VALIDATING EACH INDIVIDUAL ANTHROPOMETRIC DATA VALUE)

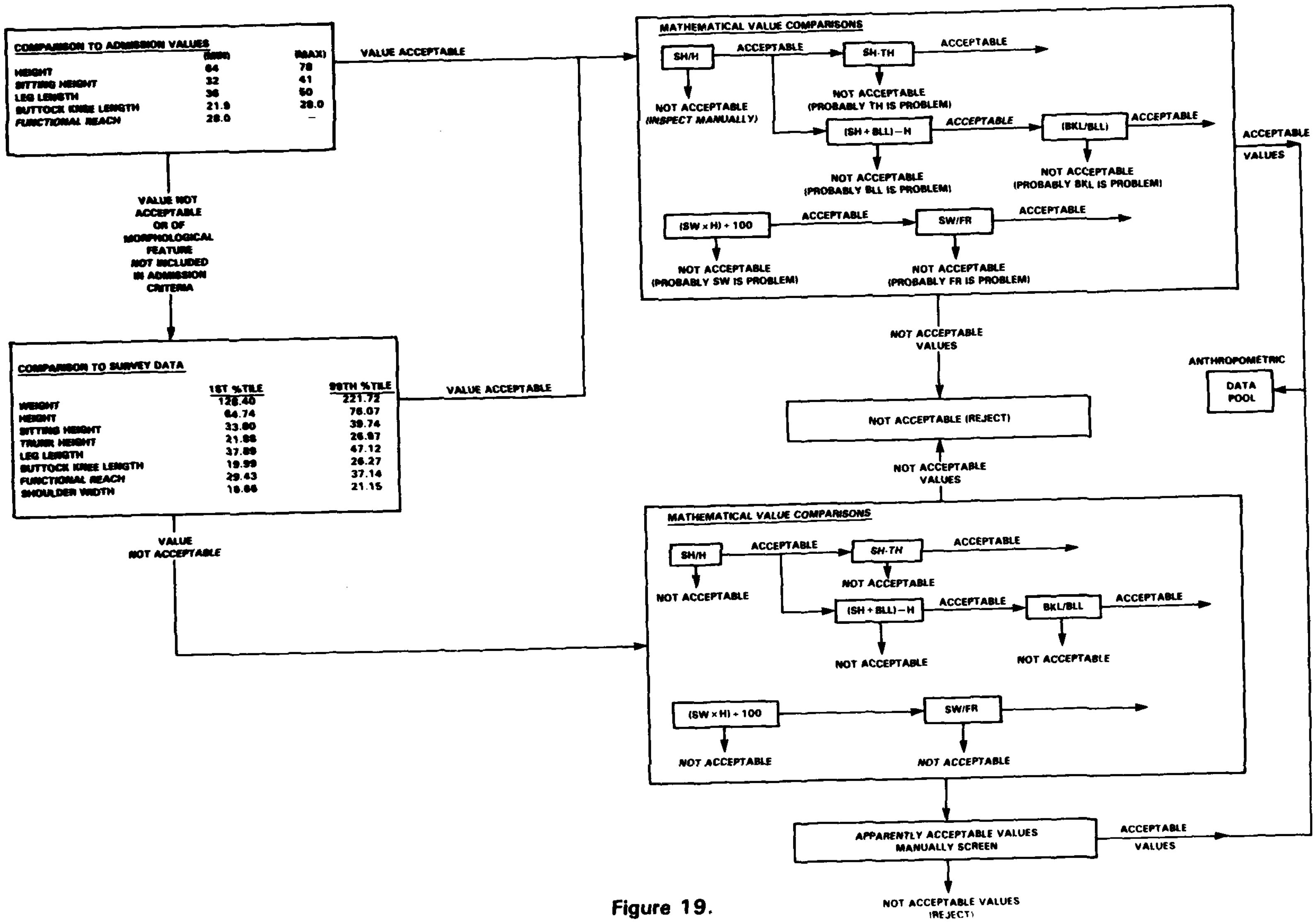


Figure 19.

ADDENDUM A

TO

U.S. NAVY AVIATION MISHAP AIRCREW ANTHROPOMETRY
1 January 1969 through 31 December 1979

(Consisting of data distribution tables, frequency distribution charts and cumulative percentage distribution charts for mishap aircrew weight, stature and sitting height which were prepared following completion of the basic paper.)

TABLE A-1

PERCENTILE VALUES FOR FULLY SCREENED ANTHROPOMETRIC PARAMETERS BY AIRCRAFT TYPE

WEIGHT

PERCENTILE	NATC MALE VALUE	FIXED WING (AAES)	FIXED WING (NON-AAES)	HELO	ALL
3	132	140	140	137	140
50	169	172	172	170	171
98	215	210	210	214	210

STATURE

PERCENTILE	NATC MALE VALUE	FIXED WING (AAES)	FIXED WING (NON-AAES)	HELO	ALL
3	66	66	66	66	66
50	70	70	70	70	70
98	75	75	75	75	75

SITTING HEIGHT

PERCENTILE	NATC MALE VALUE	FIXED WING (AAES)	FIXED WING (NON-AAES)	HELO	ALL
3	34.4	34.8	34.9	35.0	34.7
50	36.8	36.9	36.9	37.0	36.9
98	39.5	39.2	39.2	39.4	39.3

TABLE A-2

GRAPH VALUES AND SUMMARY STATISTICS FOR FULLY SCREENED ANTHROPOMETRIC PARAMETERS BY AIRCRFT TYPE

WEIGHT								
MEASUREMENT STATISTIC	FIXED WING (AAES)		FIXED WING (NON-AAES)		HELICOPTER		ALL	
	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %
121-130	3	.18	6	.44	11	.83	20	.46
131-140	53	3.4	53	4.3	58	5.2	164	4.2
141-150	146	12.1	138	14.4	152	16.6	436	14.2
151-160	248	27.0	177	27.4	221	33.3	646	29.0
161-170	336	47.2	280	47.9	253	52.3	869	49.0
171-180	364	69.0	274	68.0	234	70.0	872	69.0
181-190	293	86.6	211	83.4	188	84.1	692	84.8
191-200	126	94.1	142	93.8	121	93.2	389	93.8
201-210	73	98.5	58	98.1	56	97.4	187	98.1
211-220	25	100.0	25	99.9	32	99.8	82	99.9
221-230	0	100.0	1	100.0	2	100.0	3	100.0
NO. OF INDIV.	1667		1365		1328		4360	
MINIMUM	128		129		128		128	
MAXIMUM	220		221		222		222	
RANGE	92		92		94		94	
MEAN	172.5		172.5		171.1		172.1	
ST. DEV.	17.51		18.54		19.35		18.42	

TABLE A-3

GRAPH VALUES AND SUMMARY STATISTICS FOR FULLY SCREENED ANTHROPOMETRIC PARAMETERS BY AIRCRFT TYPE

STATURE								
MEASUREMENT/ STATISTIC	FIXED WING (AABS)		FIXED WING (NON-AABS)		HELICOPTER		ALL	
	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %
64	3	.20	3	.25	9	.08	15	.38
65	12	.98	16	1.6	17	2.2	45	1.5
66	44	3.9	38	4.7	37	5.3	119	4.5
67	101	10.5	82	11.4	93	13.1	276	11.6
68	151	20.4	126	21.8	120	23.1	397	21.7
69	198	33.4	171	35.8	133	34.3	502	34.4
70	255	50.1	189	51.4	192	50.4	636	50.6
71	263	67.3	176	65.8	188	66.1	627	66.5
72	215	81.4	190	81.4	182	81.4	587	81.4
73	123	89.5	98	89.5	98	89.6	319	89.5
74	96	95.8	62	94.6	63	94.9	221	95.1
75	34	98.0	43	98.1	39	98.2	116	98.1
76	19	99.3	15	99.3	19	99.7	53	99.4
77	9	99.9	7	99.9	3	100.0	19	99.9
78	2	100.0	1	100.0	0	100.0	3	100.0
NO. OF INDIV.	1525		1217		1193		3935	
MINIMUM	64		64		64		64	
MAXIMUM	78		78		77		78	
RANGE	14		14		13		14	
MEAN	70.5		70.4		70.4		70.5	
ST. DEV.	2.34		2.42		2.46		2.40	

TABLE A-4

GRAPH VALUES AND SUMMARY STATISTICS FOR FULLY SCREENED ANTHROPOMETRIC PARAMETERS BY AIRCRFT TYPE

SITTING HEIGHT								
MEASUREMENT/ STATISTIC	FIXED WING (AAES)		FIXED WING (NON-AAES)		HELICOPTER		ALL	
	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %	OBSERVATIONS	CUMM %
33.1-33.5	3	.22	4	.54	1	.15	8	.29
33.6-34.0	8	.81	3	.94	6	1.04	17	.9
34.1-34.5	25	2.7	13	2.7	15	3.3	53	2.8
34.6-35.0	52	6.5	30	6.7	23	6.7	105	6.6
35.1-35.5	92	13.3	49	13.3	54	14.8	195	13.7
35.6-36.0	173	26.1	96	26.2	67	24.8	336	25.8
36.1-36.5	189	40.0	125	43.0	102	40.0	416	40.8
36.6-37.0	232	57.1	114	58.3	122	58.2	468	57.7
37.1-37.5	203	72.1	103	72.2	81	70.3	387	71.7
37.6-38.0	178	85.2	95	84.9	85	83.0	358	84.6
38.1-38.5	100	92.6	57	92.6	55	91.2	212	92.3
38.6-39.0	60	97.0	31	96.8	37	96.7	128	96.9
39.1-39.5	24	98.8	18	99.2	16	99.1	58	99.0
39.6-40.0	11	99.6	1	99.3	6	100.0	18	99.6
40.1-40.5	5	100.0	4	99.9	0	100.0	9	100.0
40.6-41.0	0	100.0	1	100.0	0	100.0	1	100.0
NO. OF INDIV.	1355		744		670		2769	
MINIMUM	33.3		33.2		33.5		33.2	
MAXIMUM	40.5		41.0		40.0		41.0	
RANGE	7.2		7.8		6.5		7.8	
MEAN	36.9		36.9		36.9		36.9	
ST. DEV.	1.17		1.19		1.21		1.18	

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982

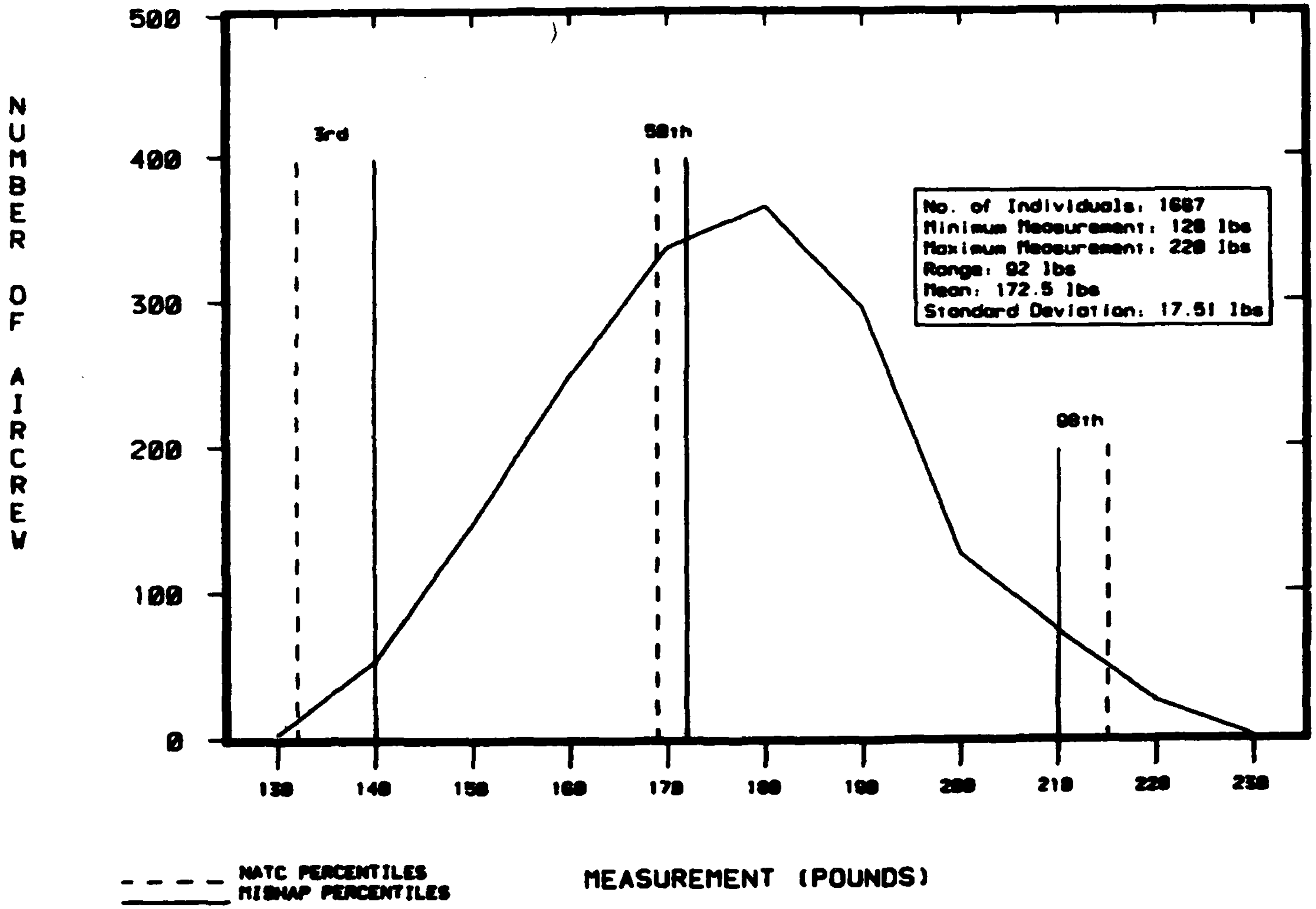
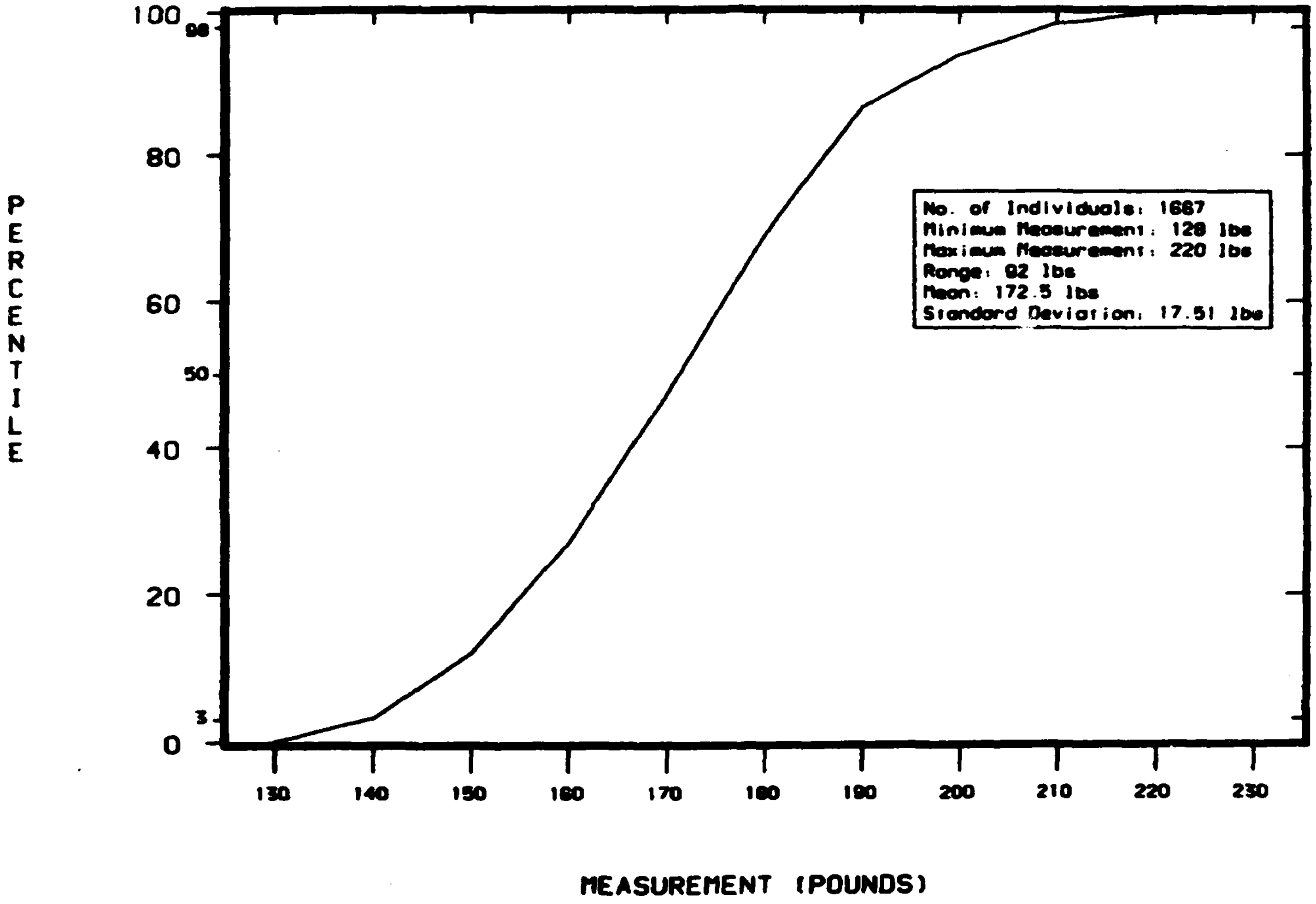


Figure A-1

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982



No. of Individuals: 1687
Minimum Measurement: 128 lbs
Maximum Measurement: 220 lbs
Range: 92 lbs
Mean: 172.5 lbs
Standard Deviation: 17.51 lbs

Figure A-2

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1980 THROUGH MID 1982

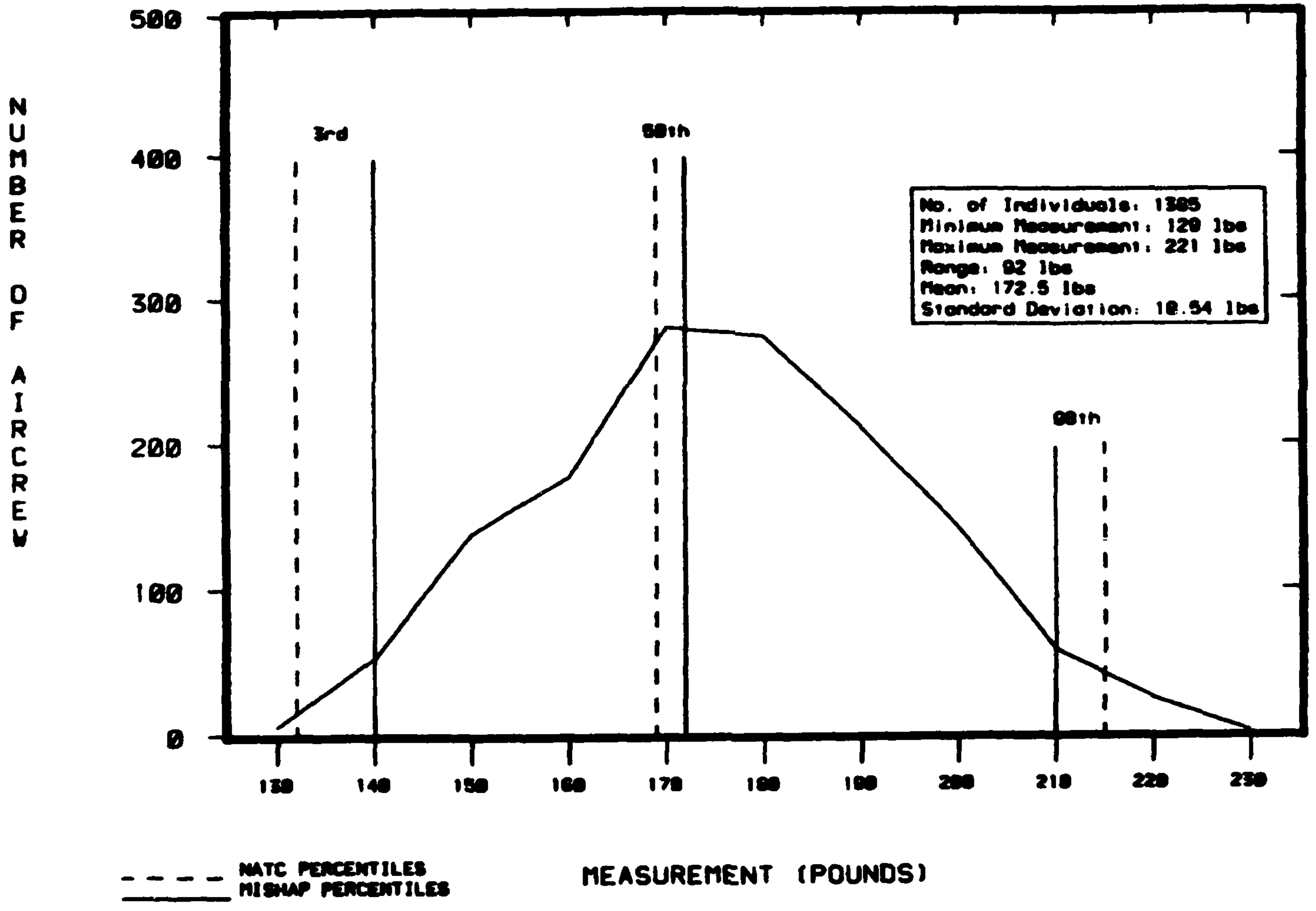
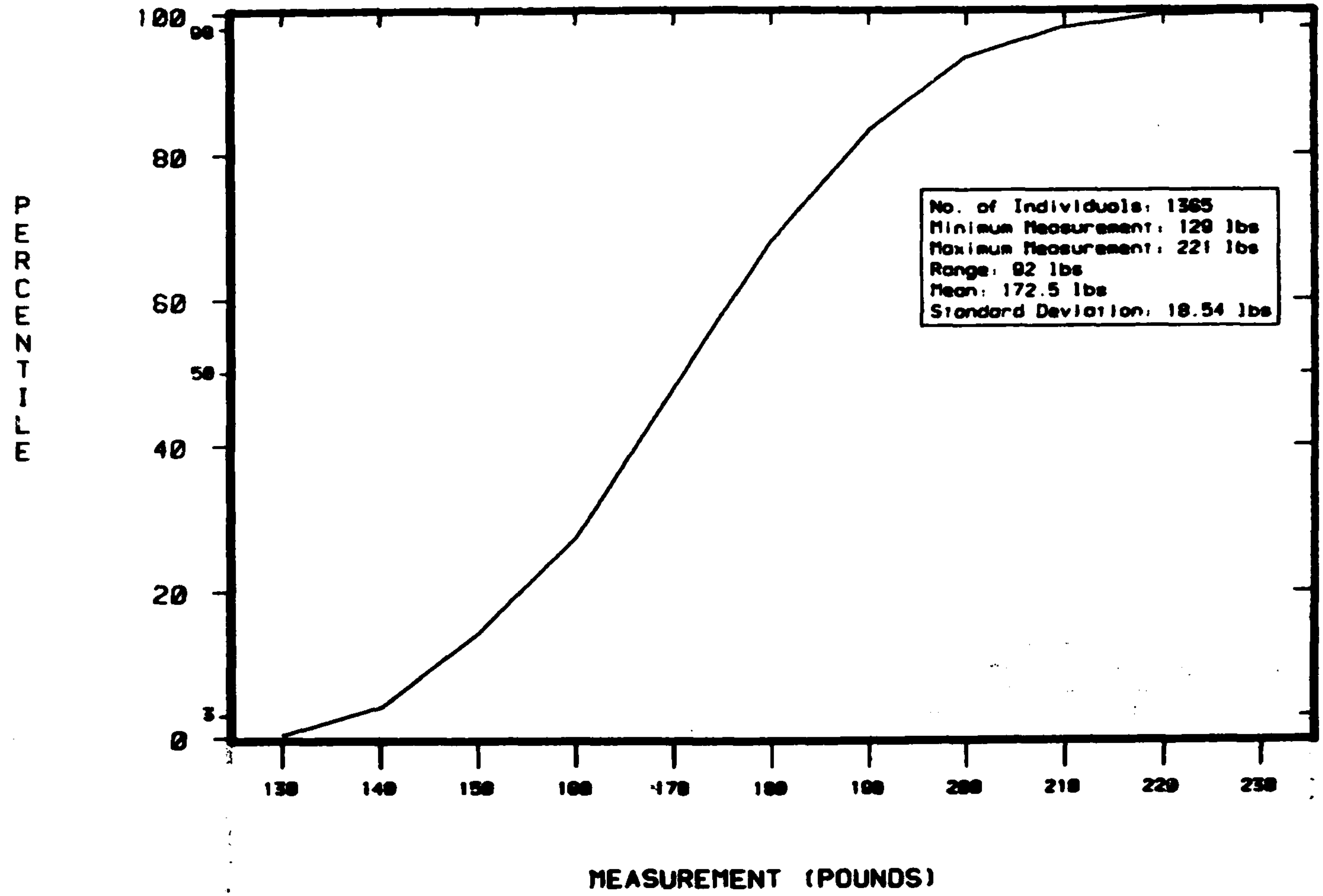


Figure A-3

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982



No. of Individuals: 1365
Minimum Measurement: 129 lbs
Maximum Measurement: 221 lbs
Range: 92 lbs
Mean: 172.5 lbs
Standard Deviation: 18.54 lbs

Figure A-4

U.S. NAVY AIR.REW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982

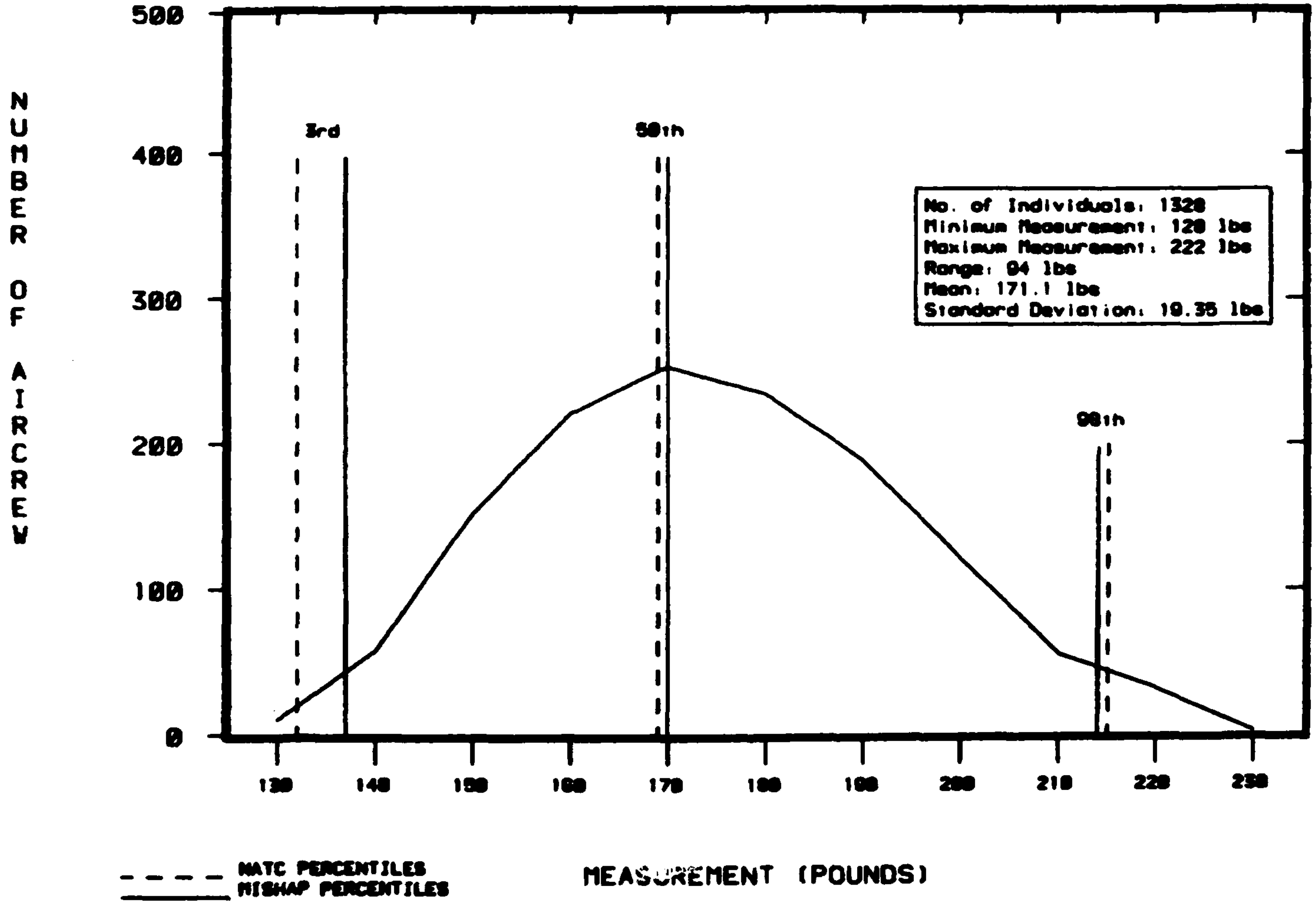


Figure A-5

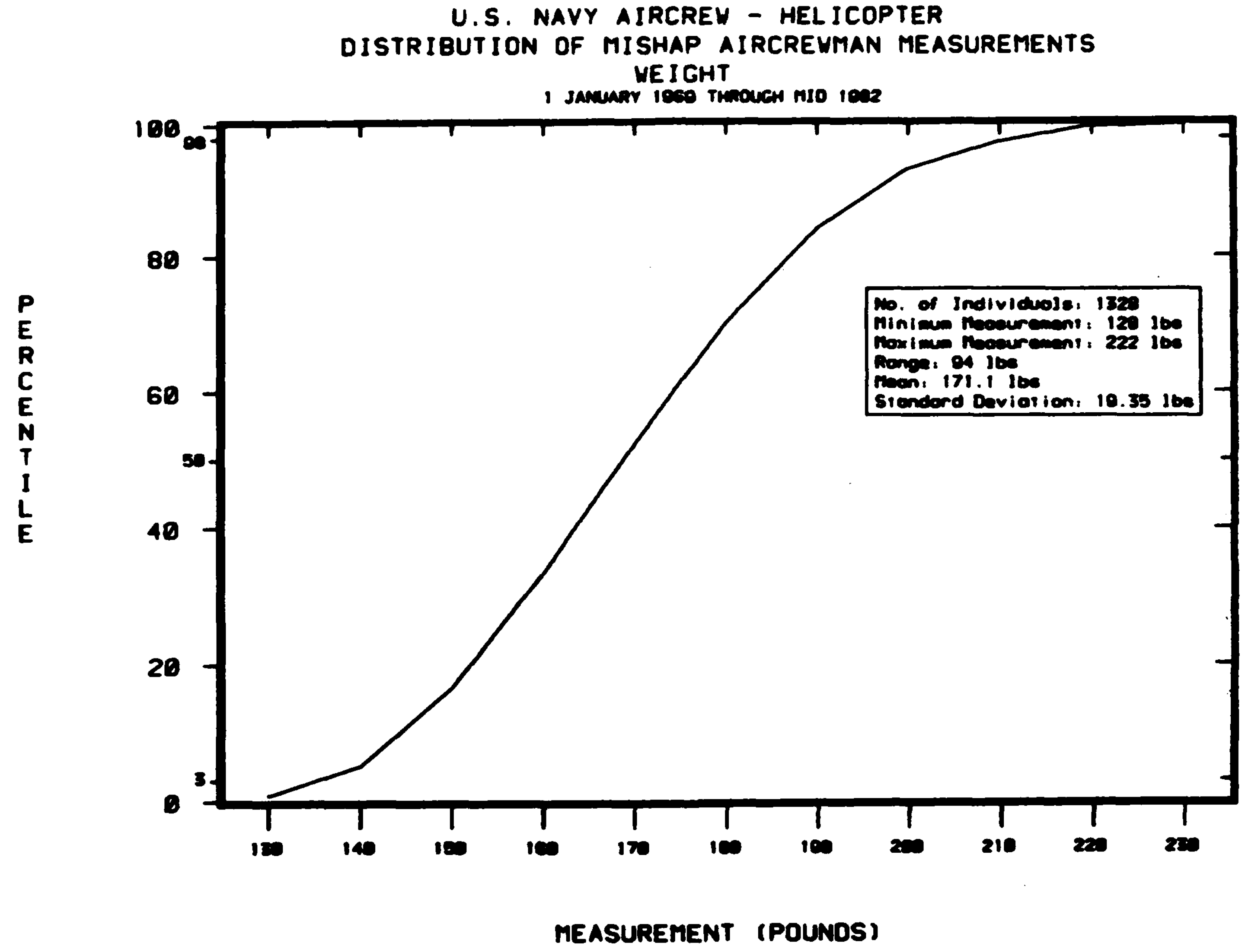

U.S. NAVY AIRCREW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982
PERCENTILE
100
98
80
60
50
40
20
3
0
No. of Individuals: 1328
Minimum Measurement: 128 lbs
Maximum Measurement: 222 lbs
Range: 94 lbs
Mean: 171.1 lbs
Standard Deviation: 18.35 lbs
130
140
150
160
170
180
190
200
210
220
230
MEASUREMENT (POUNDS)

Figure A-6

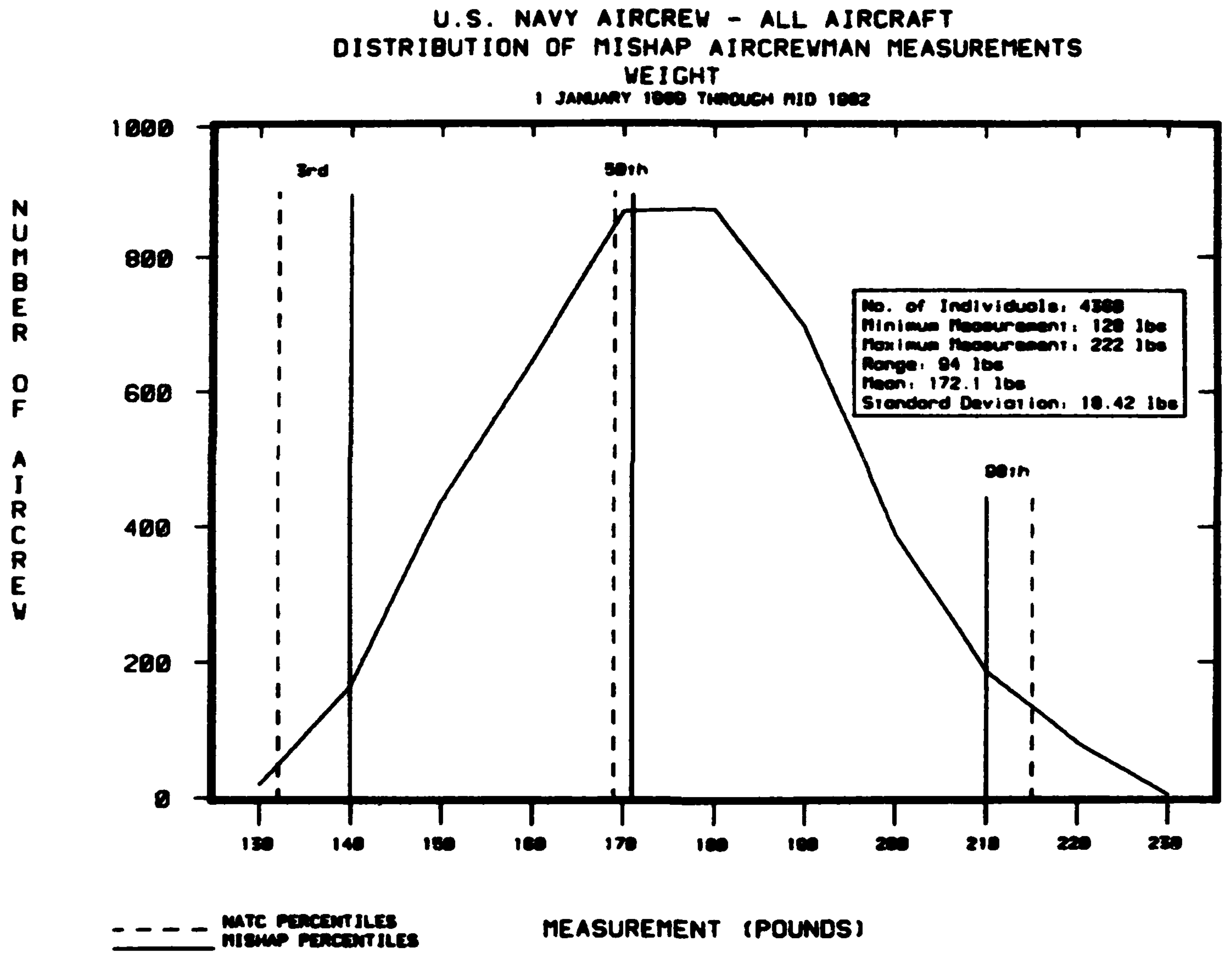

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1980 THROUGH MID 1982
NUMBER OF AIRCREW
1000
800
600
400
200
0
130
140
150
160
170
180
190
200
210
220
230
MEASUREMENT (POUNDS)
3rd
50th
98th
No. of Individuals: 4388
Minimum Measurement: 128 lbs
Maximum Measurement: 222 lbs
Range: 94 lbs
Mean: 172.1 lbs
Standard Deviation: 18.42 lbs
NATC PERCENTILES
MISHAP PERCENTILES

Figure A-7

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
WEIGHT
1 JANUARY 1969 THROUGH MID 1982

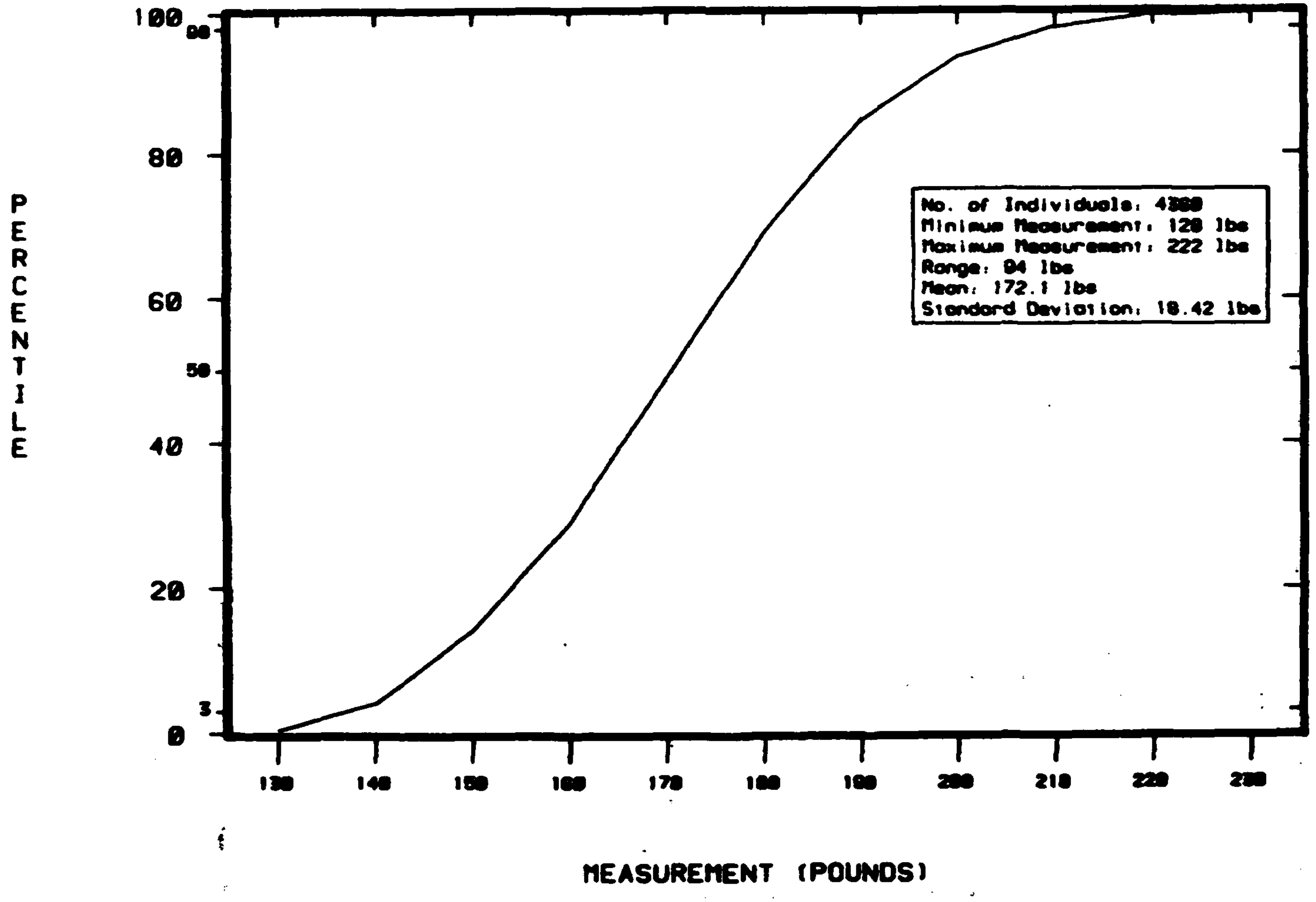


Figure A-8

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE

1 JANUARY 1969 THROUGH MID 1982

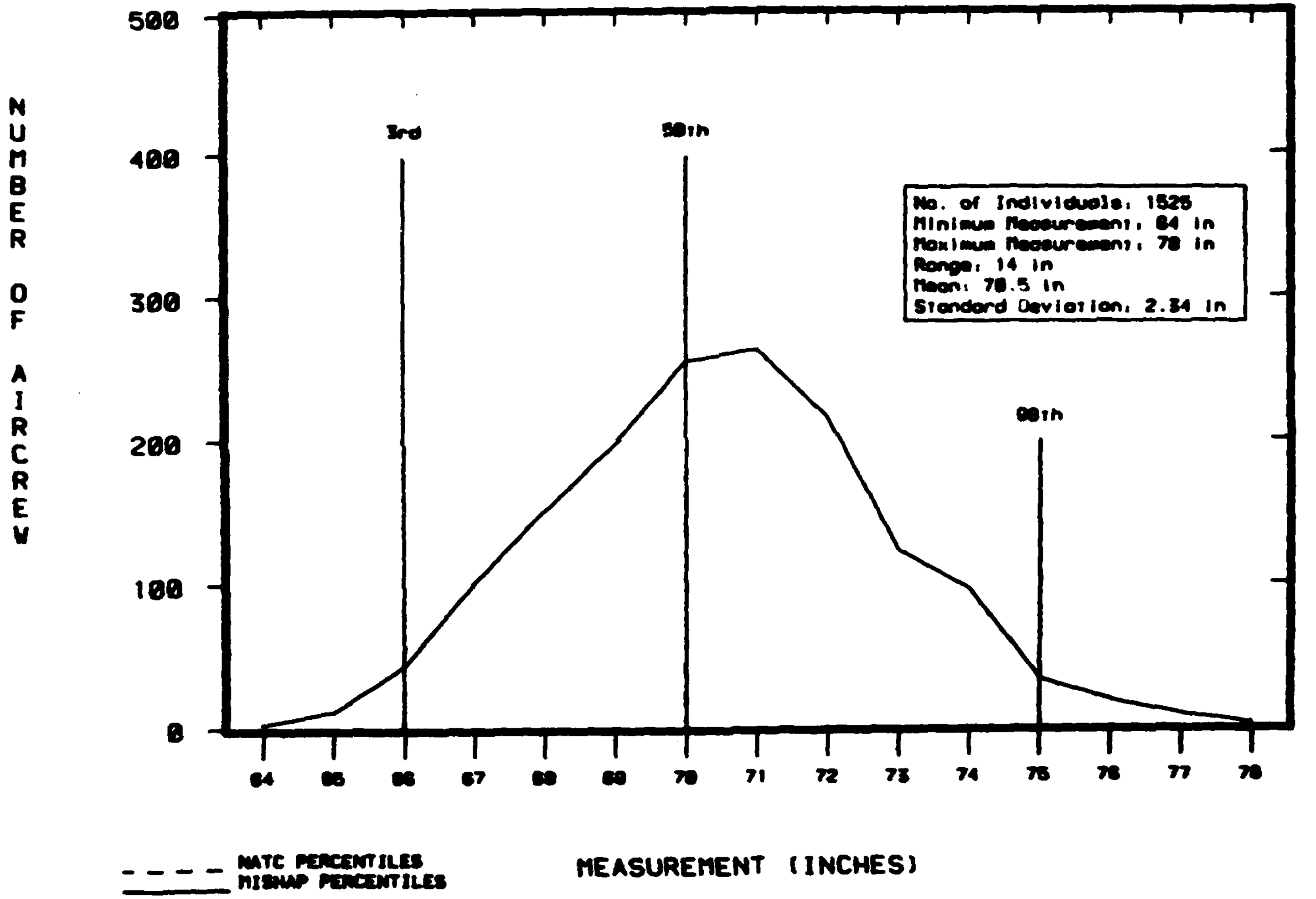


Figure A-9

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982

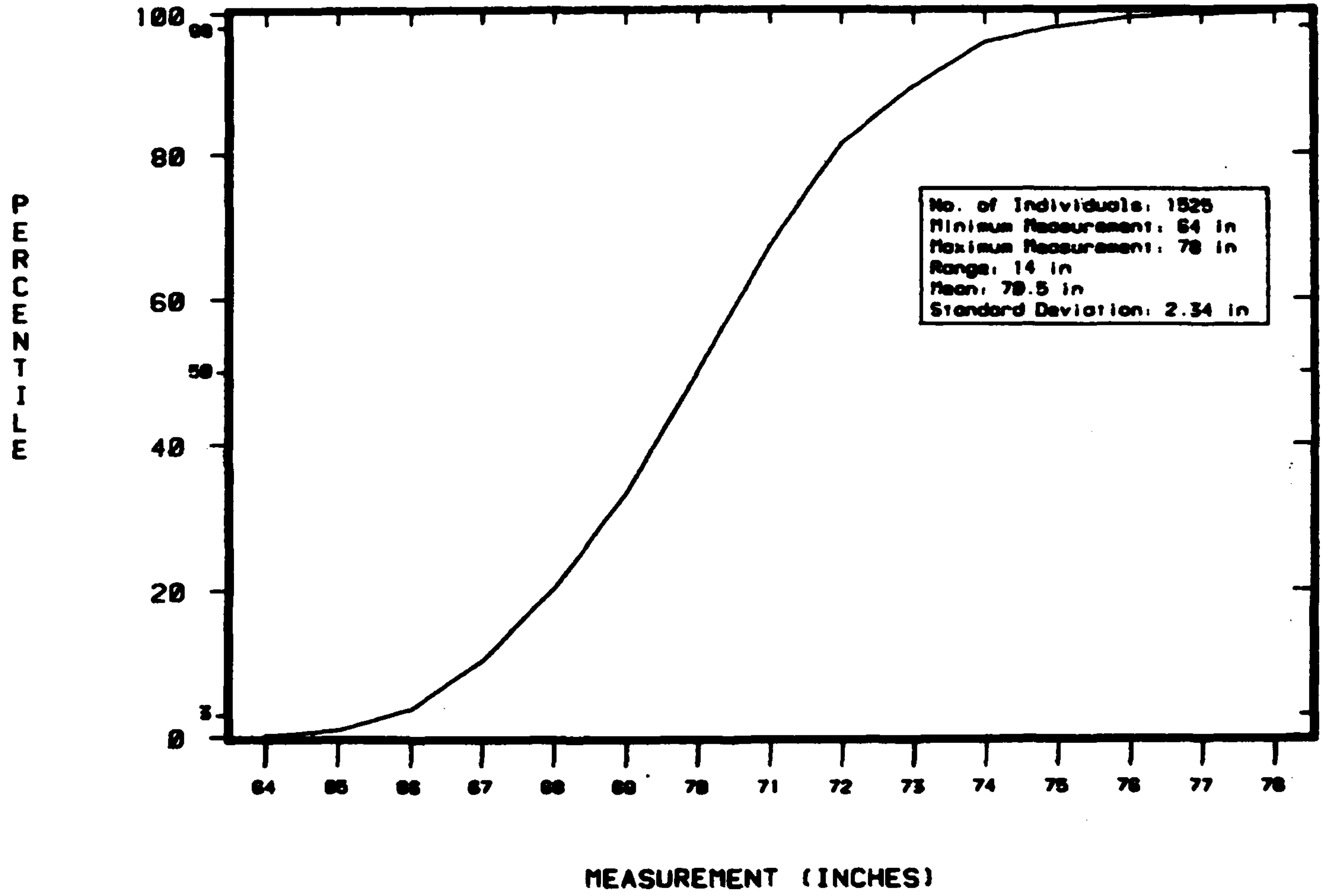


Figure A-10

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982

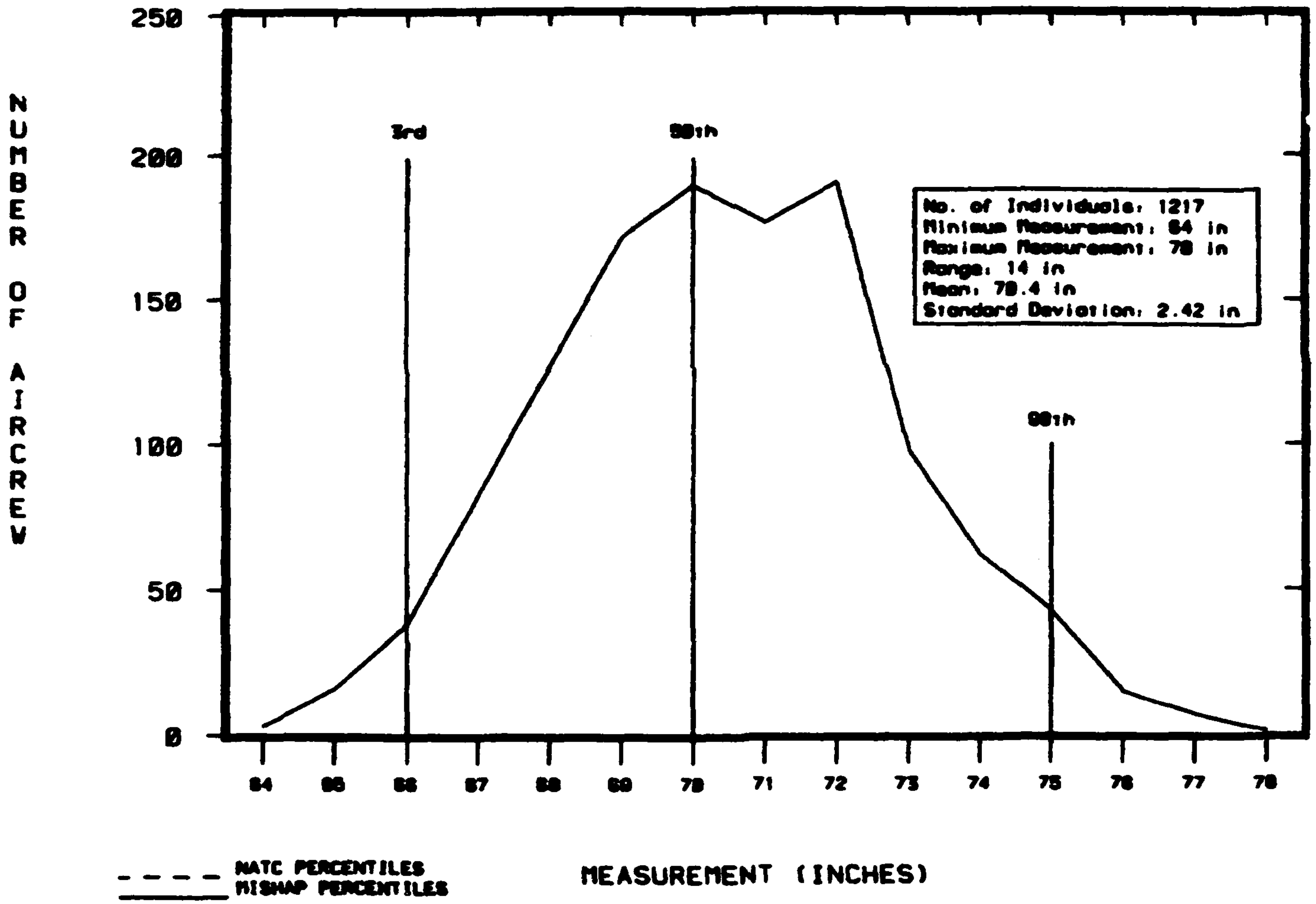


Figure A-11

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982

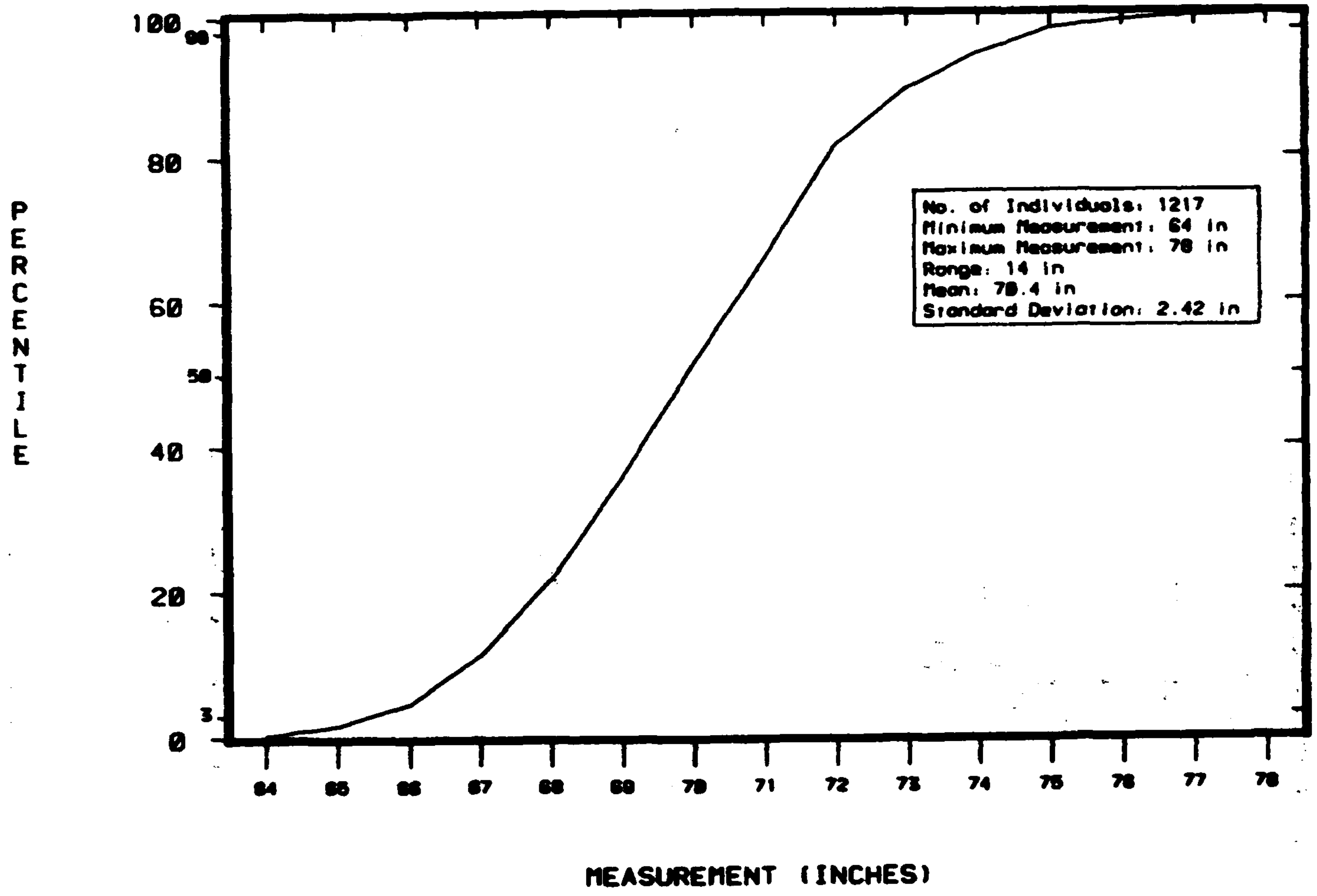


Figure A-12

U.S. NAVY AIRCREW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982

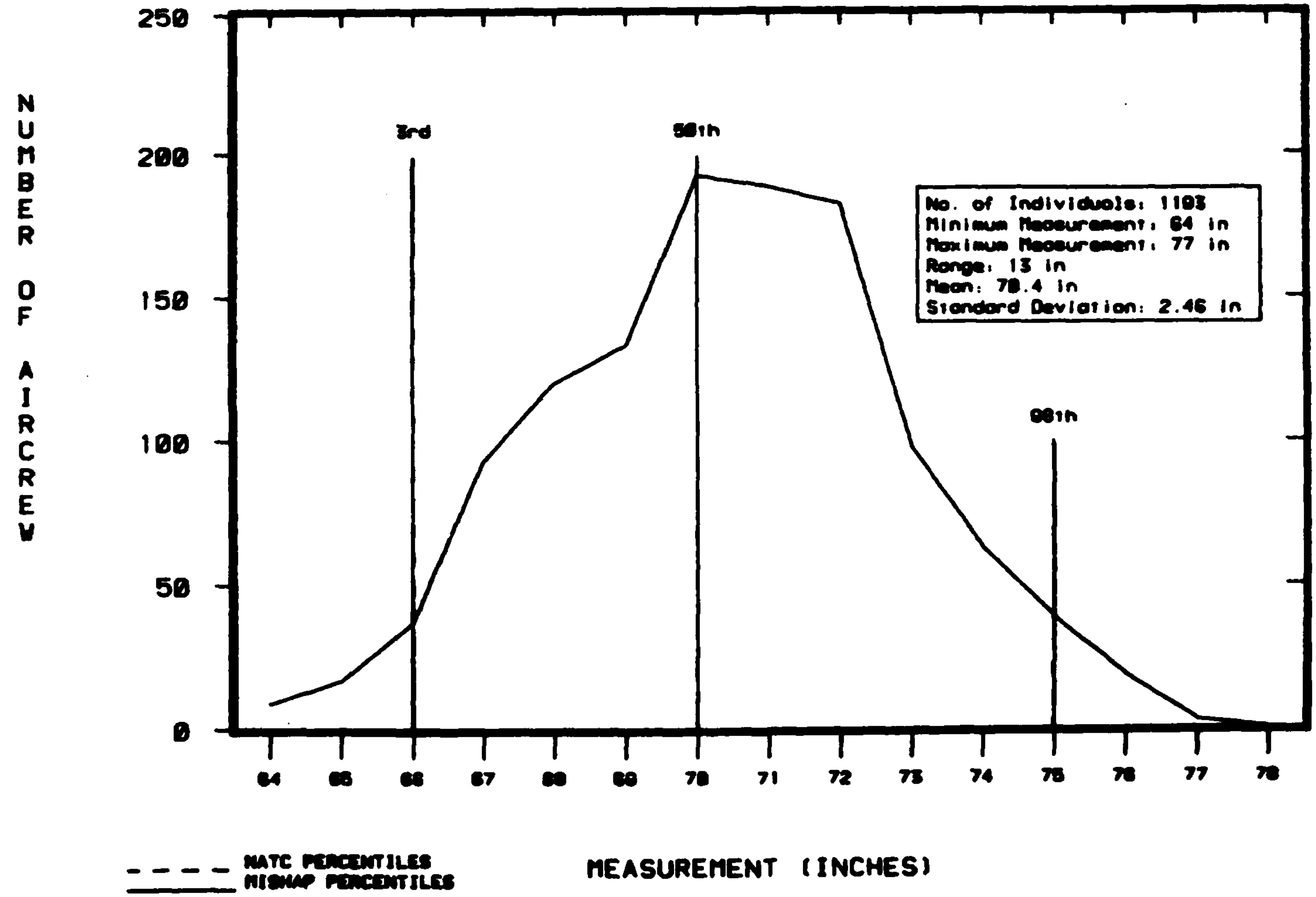
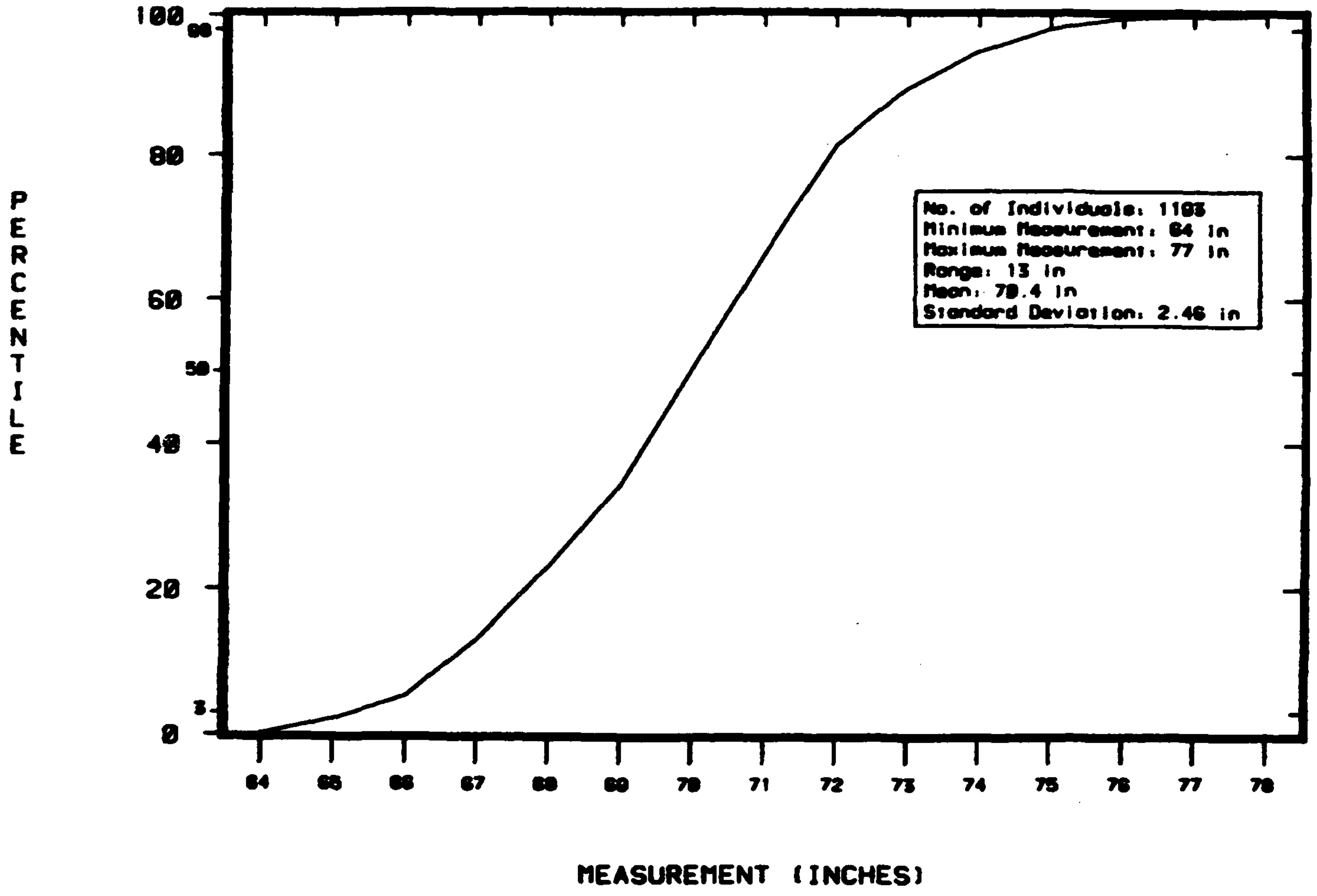


Figure A-13

U.S. NAVY AIRCREW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982



No. of Individuals: 1193
Minimum Measurement: 64 in
Maximum Measurement: 77 in
Range: 13 in
Mean: 70.4 in
Standard Deviation: 2.46 in

Figure A-14

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1969 THROUGH MID 1982

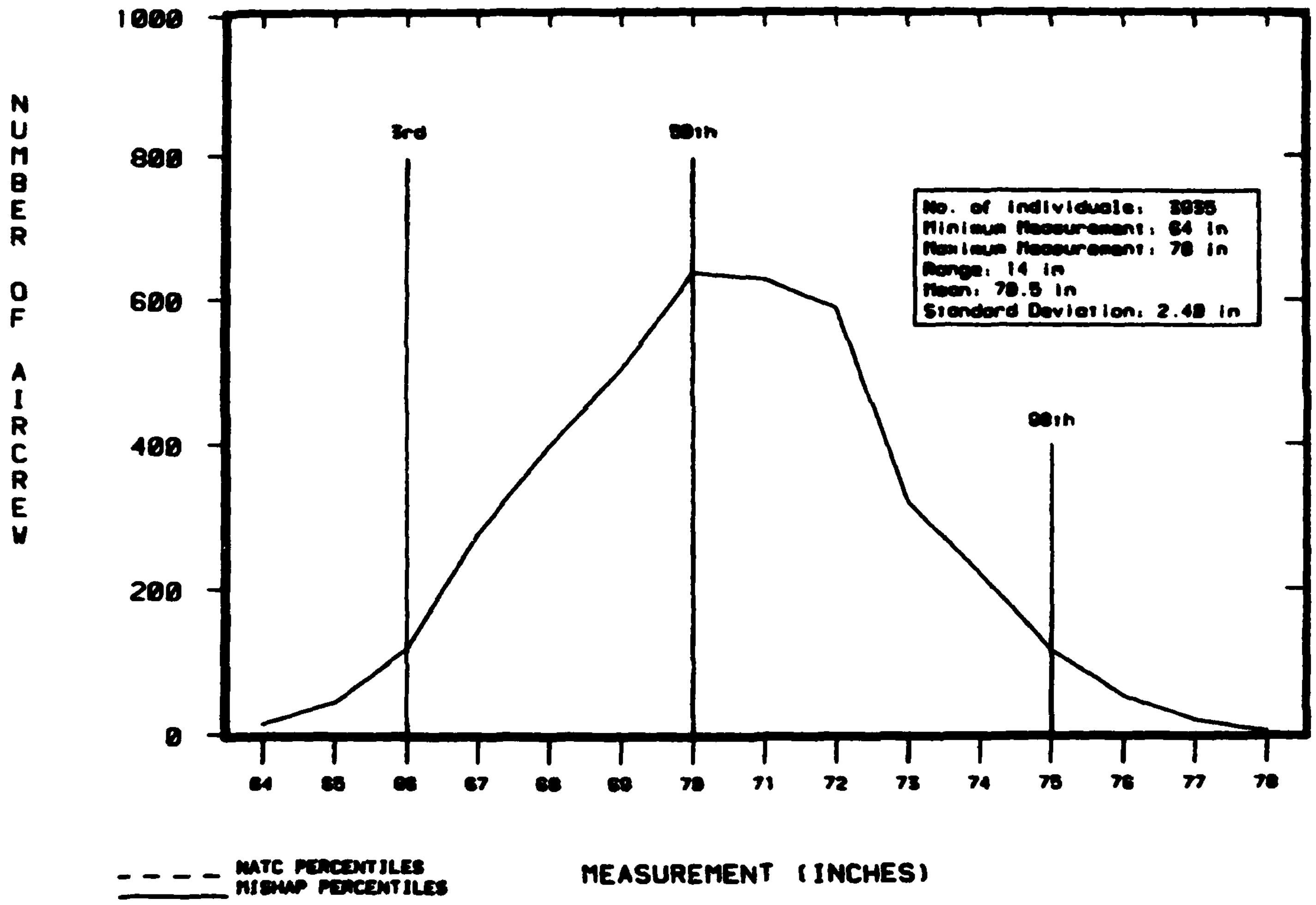
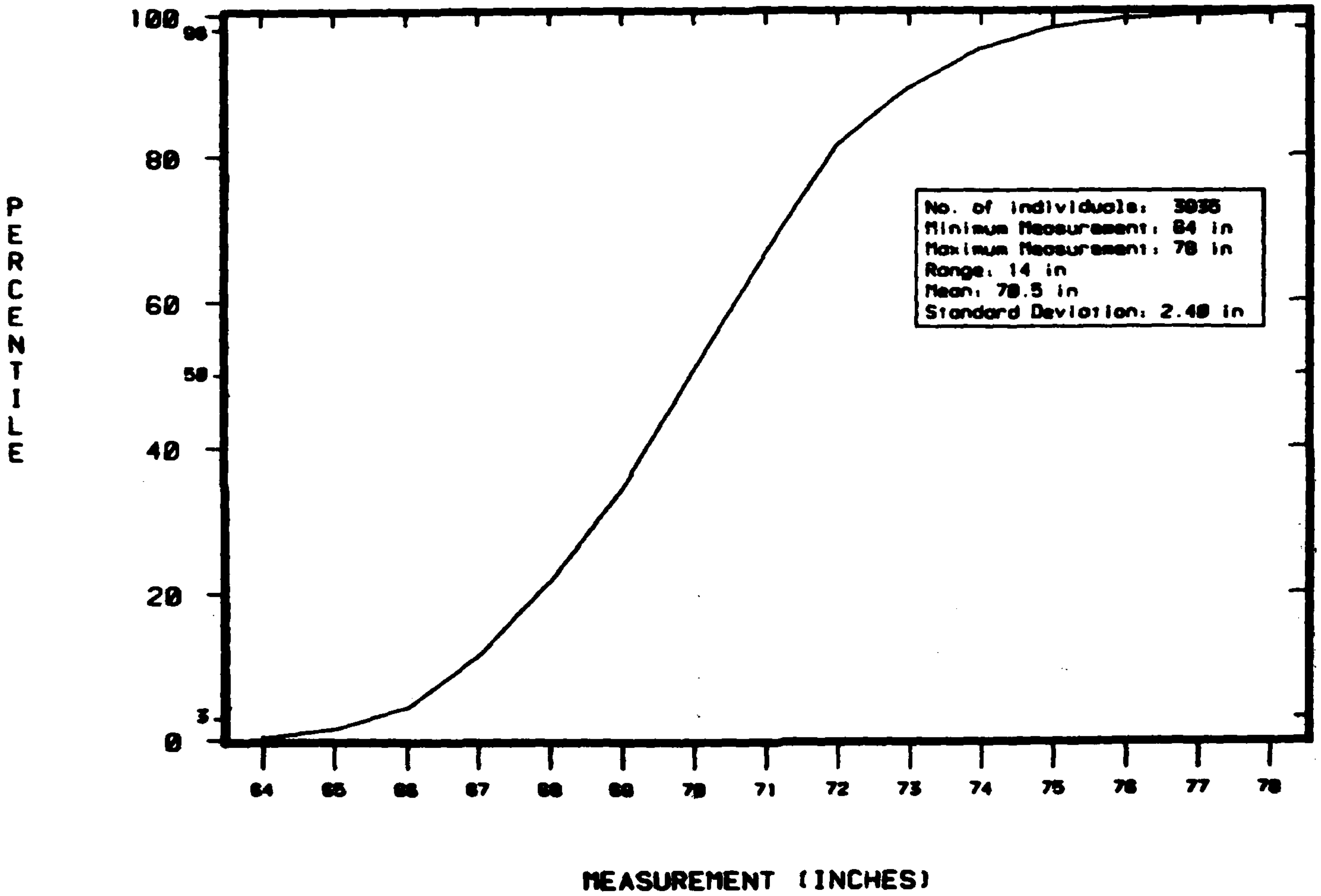


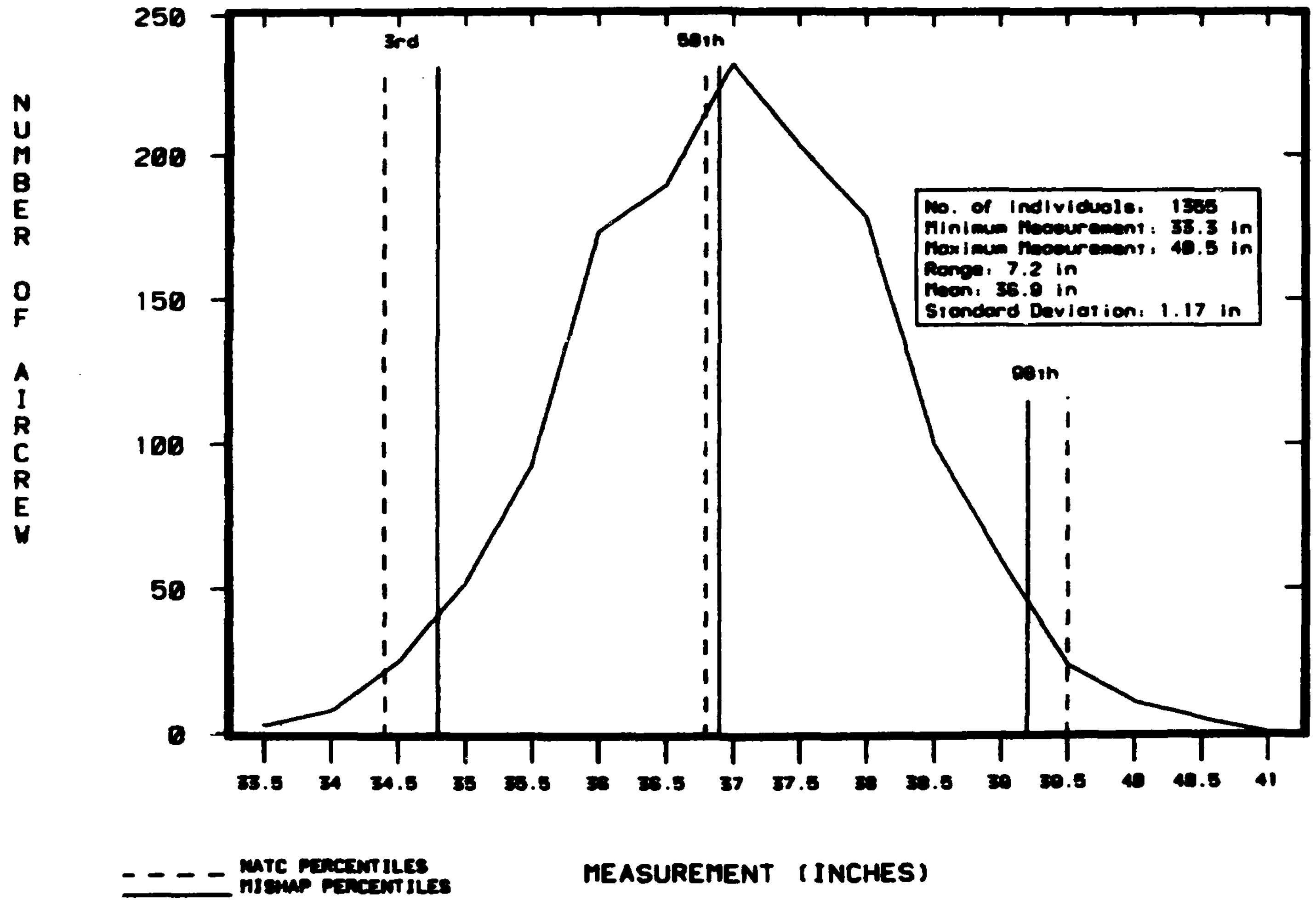
Figure A-15

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
STATURE
1 JANUARY 1980 THROUGH MID 1982



No. of individuals: 3035
Minimum Measurement: 64 in
Maximum Measurement: 78 in
Range: 14 in
Mean: 70.5 in
Standard Deviation: 2.40 in

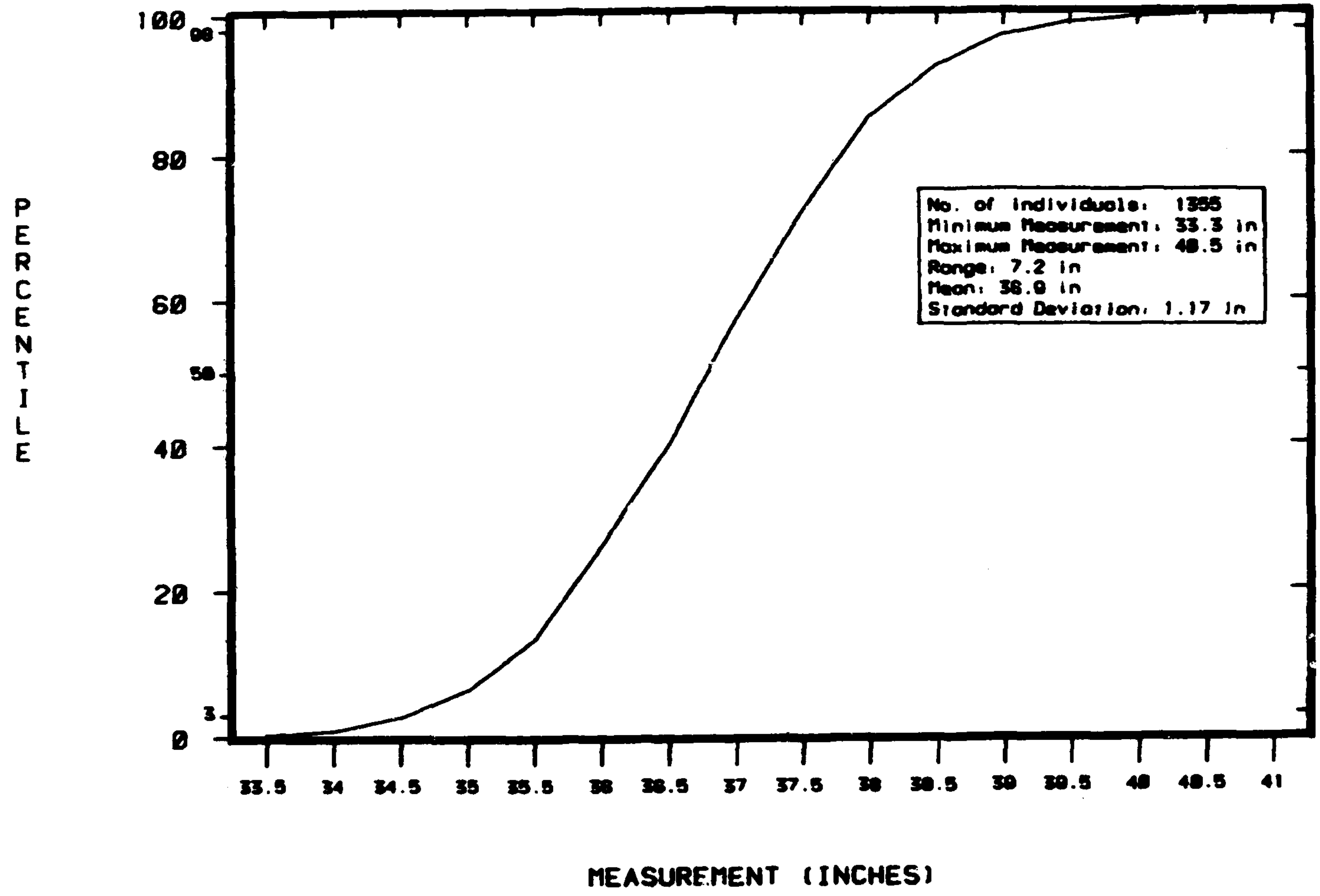
Figure A-16



U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982

Figure A-17

U.S. NAVY AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982



No. of individuals: 1355
Minimum Measurement: 33.3 in
Maximum Measurement: 40.5 in
Range: 7.2 in
Mean: 36.9 in
Standard Deviation: 1.17 in

Figure A-18

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1980 THROUGH MID 1982

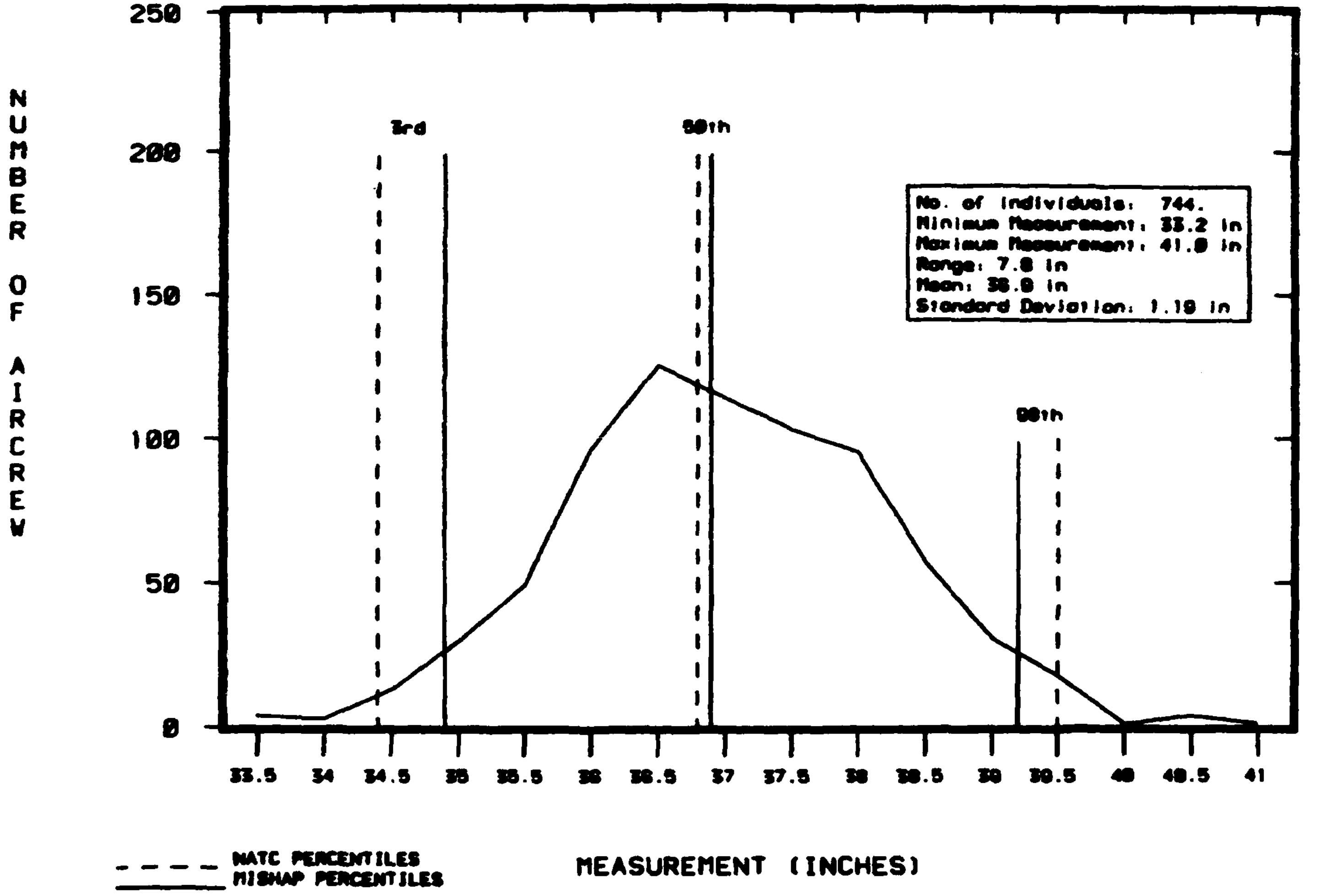


Figure A-19

U.S. NAVY AIRCREW - FIXED WING (NON-AAES)
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982

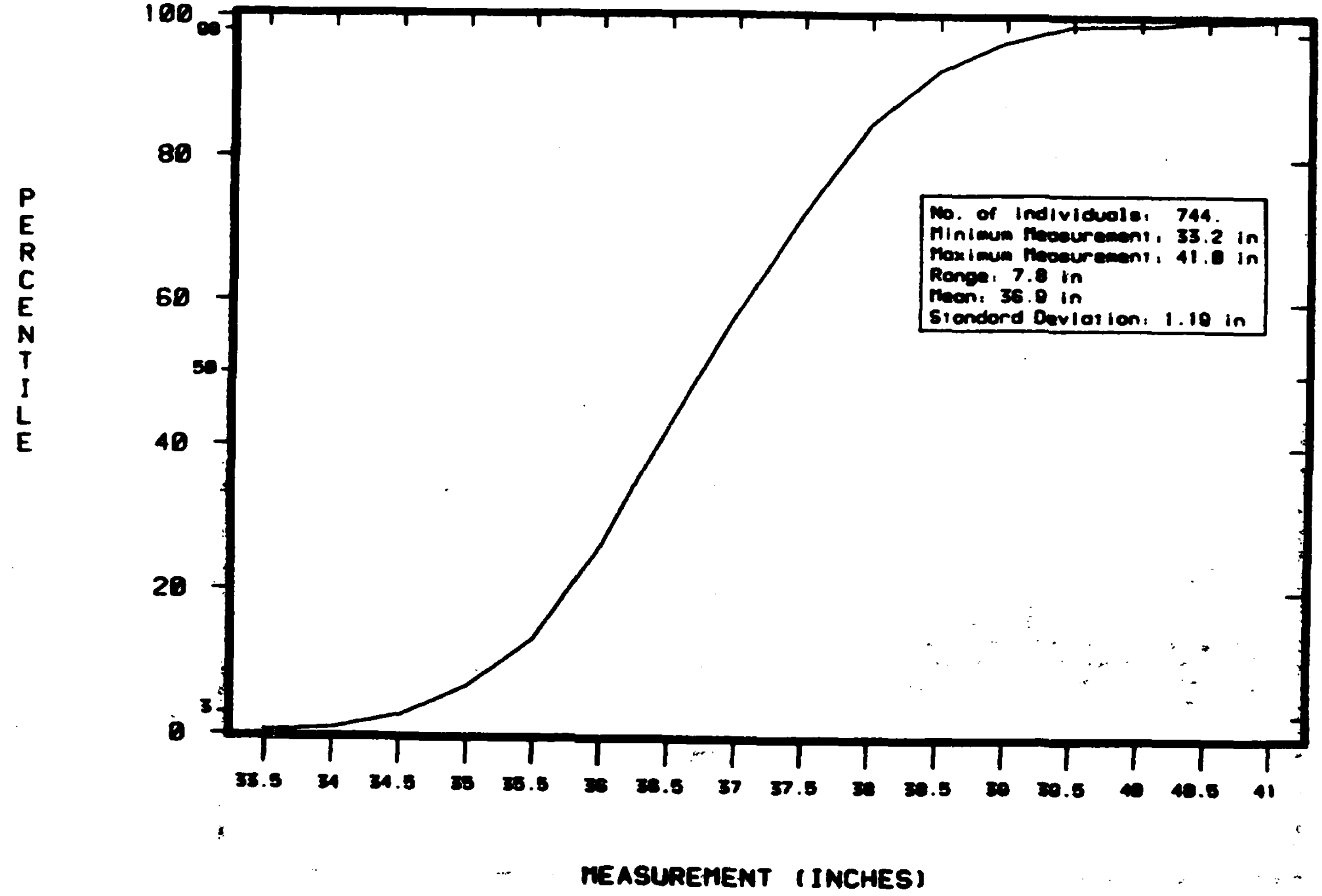


Figure A-20

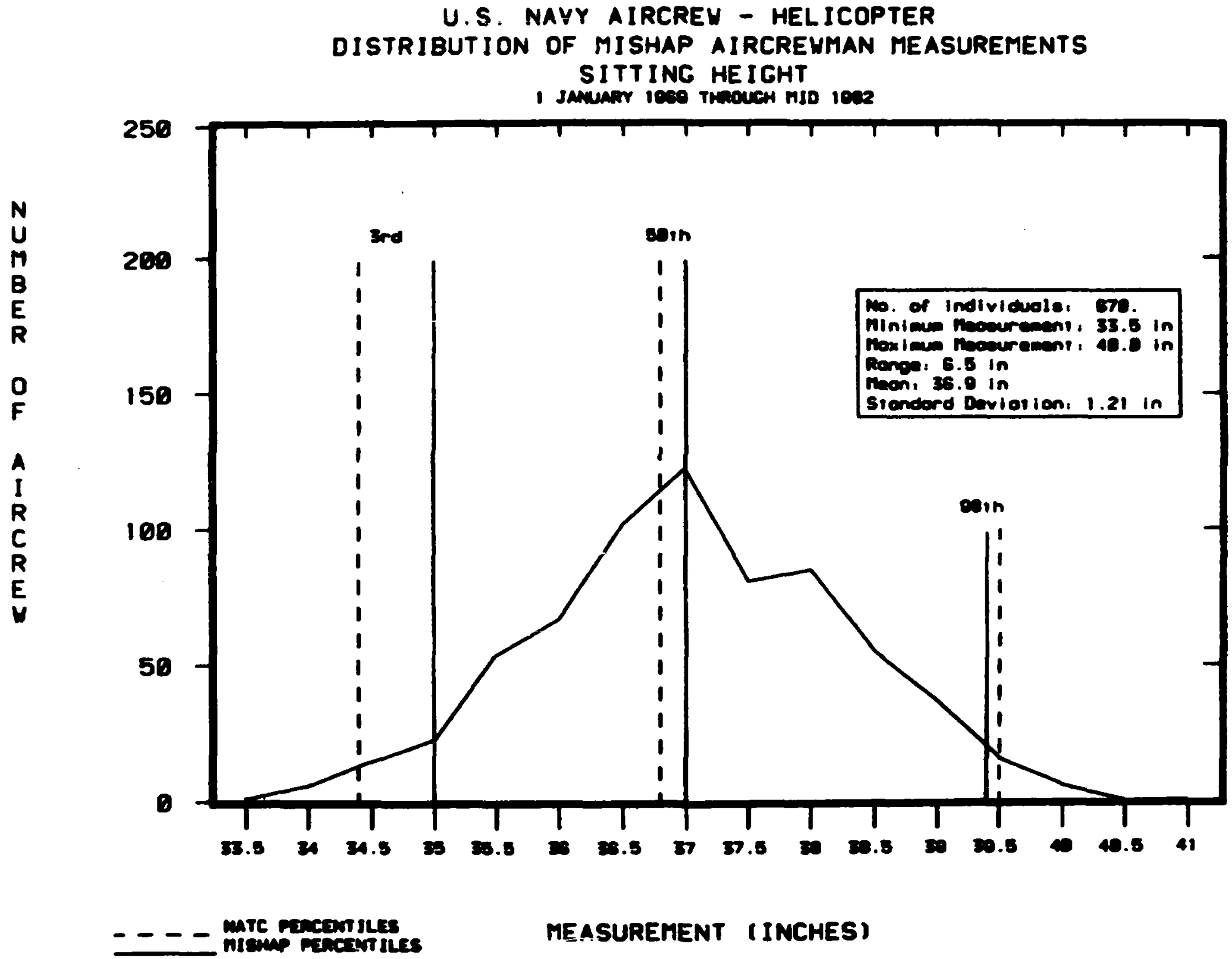

U.S. NAVY AIRCREW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982
NUMBER OF AIRCREW
250
200
150
100
50
0
3rd
50th
98th
No. of individuals: 670.
Minimum Measurement: 33.5 in
Maximum Measurement: 40.0 in
Range: 6.5 in
Mean: 36.9 in
Standard Deviation: 1.21 in
33.5
34
34.5
35
35.5
36
36.5
37
37.5
38
38.5
39
39.5
40
40.5
41
MEASUREMENT (INCHES)
NATC PERCENTILES
MISHAP PERCENTILES

Figure A-21

U.S. NAVY AIRCREW - HELICOPTER
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982

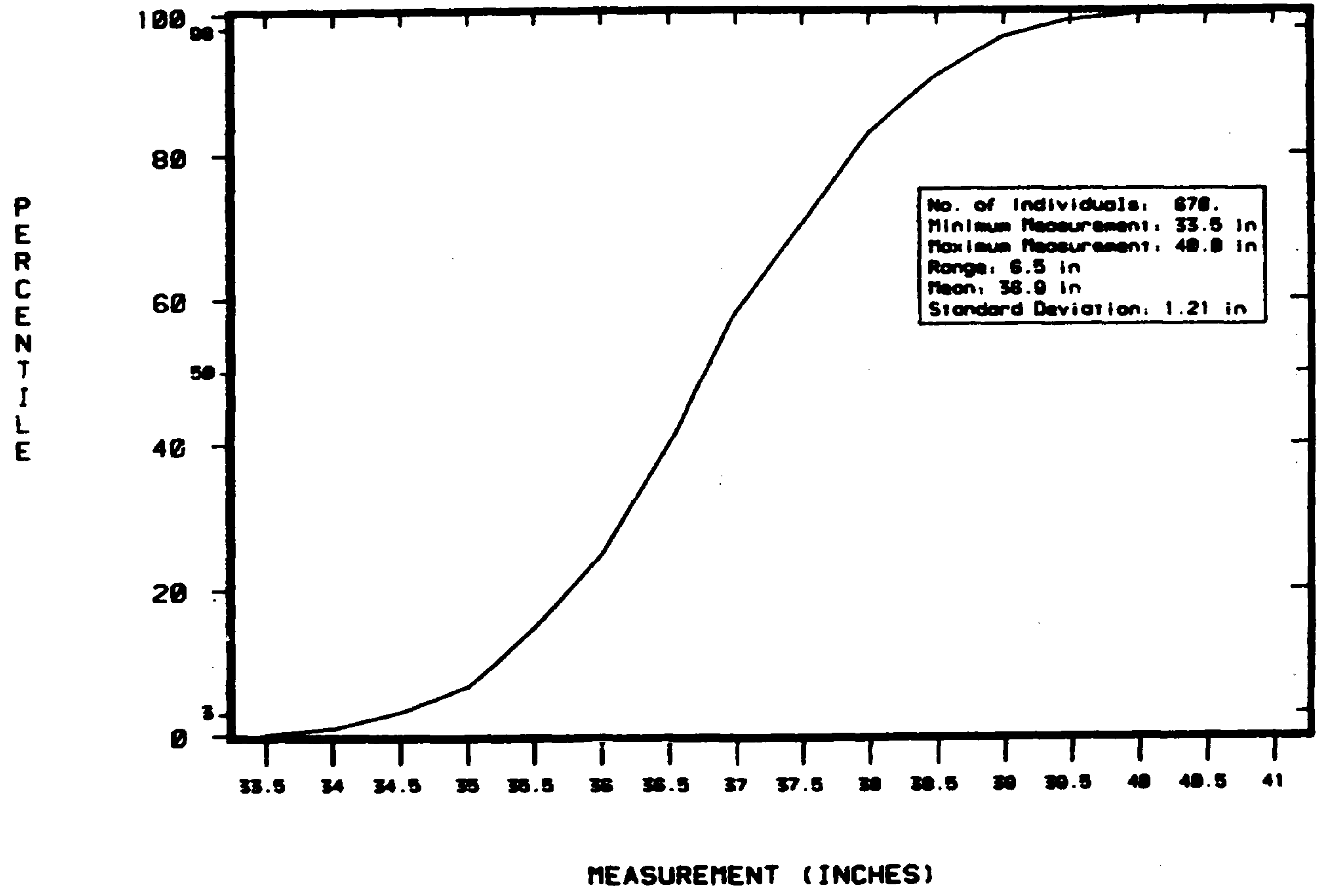


Figure A-22

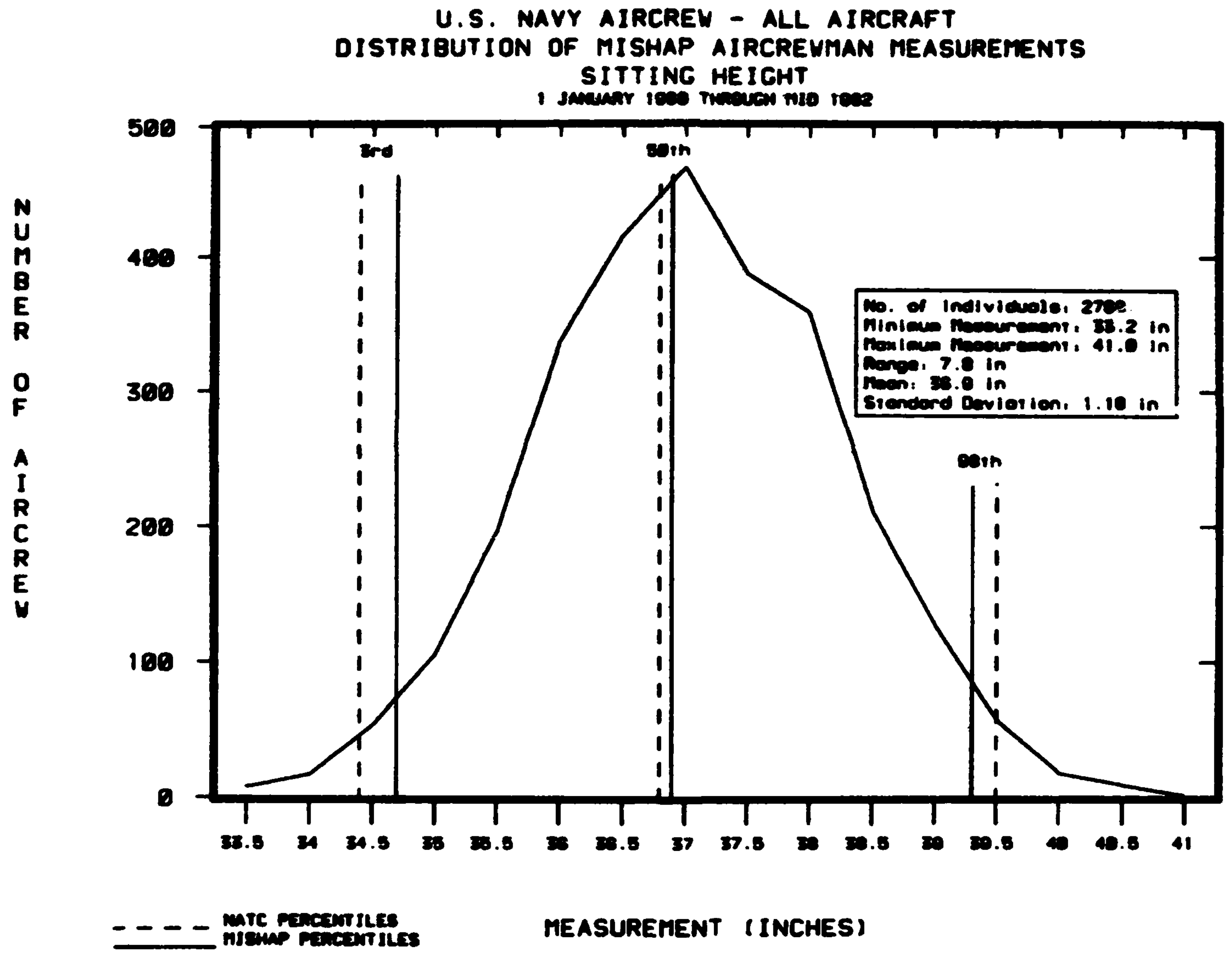
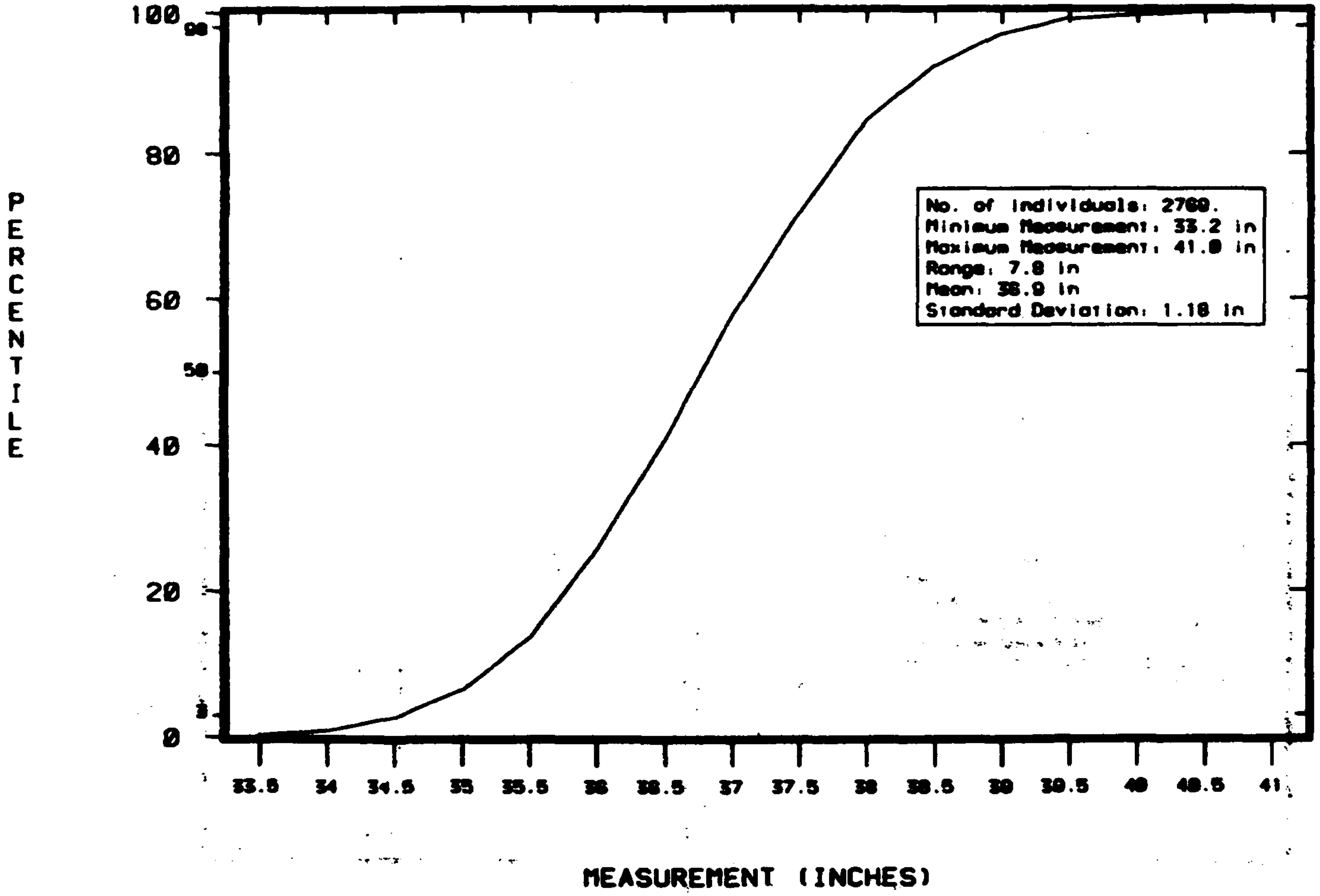

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1980 THROUGH MID 1982
NUMBER OF AIRCREW
500
400
300
200
100
0
3rd
50th
98th
No. of Individuals: 2702
Minimum Measurement: 33.2 in
Maximum Measurement: 41.0 in
Range: 7.8 in
Mean: 36.9 in
Standard Deviation: 1.10 in
33.5
34
34.5
35
35.5
36
36.5
37
37.5
38
38.5
39
39.5
40
40.5
41
MEASUREMENT (INCHES)
NATC PERCENTILES
MISHAP PERCENTILES

Figure A-23

U.S. NAVY AIRCREW - ALL AIRCRAFT
DISTRIBUTION OF MISHAP AIRCREWMAN MEASUREMENTS
SITTING HEIGHT
1 JANUARY 1969 THROUGH MID 1982



No. of Individuals: 2760.
Minimum Measurement: 33.2 in
Maximum Measurement: 41.0 in
Range: 7.8 in
Mean: 36.9 in
Standard Deviation: 1.18 in

Figure A-24

AIRCREW AUTOMATED ESCAPE SYTEMS (AAES) MAINTENANCE CAUSED AIRCREW AND MAINTENANCEMAN FATALITIES AND SEVERE INJURIES

Frederick C. Guill

ABSTRACT

An often ignored problem concerning escape systems is the role of maintenance error in the production of injuries and fatalities among aircrew and groundcrew as well as damage to aircraft and facilities. Reasons for ignoring this problem include the interrelationship between design and maintenance error, the high rate of major escape system component non-recovery, and the lack of appreciation among investigators of the often subtle manner in which such errors can induce malfunctions. Recent examination of investigators' reports revealed a number of potential maintenance error induced system malfunctions during the periods 1961 through 1965 and 1969 through 1979, suggesting the problem has and does exist and may be significantly affecting aircrew safety.

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) MAINTENANCE CAUSED AIRCREW AND MAINTENANCEMAN FATALITIES AND SEVERE INJURIES

Frederick C. Guill

INTRODUCTION

Since the advent of ejection seats in U.S. Navy aircraft in the late 1940's, the Navy has continuously and vigorously sought ways to provide aircrews with means for safe escape from an increasingly greater range of emergency conditions, including, especially, emergencies occurring at low altitudes. This effort largely has been accomplished by automating all of the escape sequence events and functions except those of recognizing the need for escape and initiating escape.

Some of these efforts, as for example the introduction in the middle to late 1950's of the zero delay lanyard (ZDL) which, when connected, pulled the parachute pack actuator arming cable as the seat was ejected to reduce from the basic system operating timing the time until parachute pack opening and the subsequent deployment and filling of the parachute. The zero delay lanyard, however, required aircrew actions such as connecting the lanyard before take-off, disconnecting the lanyard when passing through a prescribed altitude during climbout, and re-connecting the lanyard when passing through a prescribed altitude during the descent for landing. Many aircrew ejected at low altitudes following take-off or while approaching for landing having forgotten to connect the zero delay lanyard; while others ejected at high speeds having failed to disconnect the lanyard as prescribed. Ejection at low levels without the lanyard connected cost precious time for the arming cable then would not be pulled until man and seat had separated a sufficient distance with adequate force. Ejection at high speeds with the lanyard connected resulted in insufficient ejectee deceleration before parachute opening with consequent very high opening shock loads, frequently resulting in considerable damage to the parachute with consequent injury or death of the ejectee as a result of too high speed contact with the surface.

As a consequence, designers sought means for enhancing escape performance without relying upon aircrew pre-manipulation of escape system elements. These efforts, attempting to strike a balance between high speed deceleration requirements and the need for low altitude escape, tended towards designs which projected the seat and man on high, long trajectories and used an assortment of mechanical lanyards, strikers and triprods to initiate the events and functions of the escape sequences or to initiate the ballistic sequencing of these events and functions. These designs shifted a large portion of the burden for assuring escape system proper functioning from the individual aircrewman onto the escape system maintenance personnel, for, if after an ejection seat had been re-installed in the aircraft these same mechanical actuator devices were not reconnected or repositioned, an ejecting aircrewman would not have the ejection sequence events and functions performed automatically. Under these conditions (i.e., failure of automatic sequencing) the ejectee's survival would depend upon the altitude, speed and attitude of the aircraft at ejection (determining time to surface impact of the seat and man) and the ejectee's ability to recognize the situation and to actuate each subsystem manually in proper sequence. On the other hand, should a seat be removed without first disconnecting or repositioning these mechanical actuator devices, the devices and subsequent events and functions would be actuated, often with dire consequences to the maintenance personnel or nearby personnel, as well as to the aircraft and facilities. Compounding this problem was the fact that it was difficult both to reach and connect/disconnect or position and to visually check many of these mechanical actuator devices both during ejection seat installation and afterwards when inspectors checked the quality of the re-installation.

The problem became more severe as the Navy recognized that a large number of ejections were occurring out of the escape systems' performance envelopes and also that many emergencies were occurring outside those envelopes thereby inducing aircrew to attempt to stay with and control the aircraft through its surface impact. Both approaches were producing unacceptable fatality rates. Accordingly, Navy escape system specifications began requiring not only low level, upright escape capability, but also low level, adverse attitude and low level, high descent rate escape capabilities. At the same time, as a consequence of concern regarding both the numbers of ejectees seriously or fatally injured as a consequence of maintenance errors and the numbers of maintenance personnel sustaining serious or fatal injuries while maintaining these complex and necessarily potentially dangerous life saving equipments, the Navy specifications began imposing stringent design, evaluation and test requirements aimed at increasing designer and evaluator consciousness of, and attention to, avoiding these problems.

It is too early in the history of the two ejection seats, SIIIS-3 series and Mk10 series, recently procured under these more stringent requirements, to determine whether major progress in reducing maintenance errors and maintenance error caused injuries and fatalities has resulted from these new and more stringent requirements which were developed and implemented in Navy specifications issued between 1970 (MIL-S-18471D, MIL-E-9426D and AR-49B) and 1978 (MIL-S-18471F, MIL-E-9426F and MIL-STD-2067). However, it is the purpose of this and later papers to document, to the extent possible, the nature of the problems and experiences which led to these increasingly stringent requirements and which, if maintenance errors continue to occur at a significant rate in the newer systems, might require devising even more stringent requirements.

THE DATA

During the period from 1 January 1969 through 31 December 1979 there were a total of thirty (30) proven or highly probable reported serious maintenance errors among 1,457 ejection attempts (Table I).[1] These types of errors of, and by themselves, irrespective of any other factors associated with the ejection attempts, were capable of causing severe (major) or fatal injuries among the ejectees (e.g., if the error prevented catapult firing, the ejectee, unless he succeeded in manually bailing out of the aircraft and subsequently manually deploying and opening his parachute, would sustain fatal injuries in the aircraft crash irrespective of whether the attempt was initiated in or out of the escape system performance envelope). There were 20 serious problems which probably, or definitely, resulted from maintenance errors among 796 overland ejection attmepts (Table II) and 10 reported among 661 overwater ejection attempts (also Table II).

Examination of the records during this period for the most modern of the ejection seats in the U.S. Navy inventory shows:

TABLE III

	TOTAL EJECTIONS	OVERLAND EJECTIONS	OVERWATER EJECTIONS
ESCAPACs, IF-3, IG-2, IG-3, IG-4	5/111 (4.505%)	2/63 (3.175%)	3/48[2] (6.250%)
Mk A7, Mk F7, Mk GRU7, Mk GUEA7, Mk GRU7a, Mk H7	9/589 (1.528%)	7/241 (2.905%)	2/348 (0.575%)

---

[1] An examination of Naval Safety Center, Norfolk, computerized extracts of MOR/FSR data for this period, when confined to (1) searching the codified data and (2) in-envelope ejections, reveals only three serious maintenance errors in AAES. The additional 27 instances of serious, life-threatening potential maintenance error were located by the author through applying personal knowledge of systems' designs and functioning and reviewing both the codified and the narrative synopses available from the Naval Safety Center. Based upon earlier studies conducted by the author, the author believes that careful examination of the original MORs/FSRs for all of the ejection attempts for this period will undoubtedly reveal additional cases; cases detectable only as a consequence of exercising considerable in-depth detailed knowledge of each system when examining the records. Often the reporting officers have found and recorded extremely clear evidence of such malfunctions but have lacked the requisite knowledge and experience with the systems and their components, their functioning and their normal post-usage appearance and condition, to properly interpret their data.

[2] Several of these were witnessed by wingmen or reported by the affected crewmember by radio and appear to have involved the failure of a segment of the seat-canopy-seat interfaces, in A-4 series aircraft, blocking escape

In addition, following one mishap during this period in which it is believed that no ejection attempt was made, a serious maintenance error which would have caused serious injury or more probably, fatal injuries had ejection been initiated, was discovered in the retrieved portions of the escape system.

Serious maintenance errors in escape systems are not new. During the 5 year period from 1 January 1962 through 31 December 1966, an investigation of the mishap records reveals a total of 31 serious problems which probably, or definitely, resulted from maintenance errors among the 1962, 1963, 1964, 1965, and 1966 ejection attempts.

Table IV presents for these two separate periods brief narrative accounts of each of the ejection attempts in which a serious problem with a high potential of being, or proven to be, a maintenance error interfered with the correct functioning, or had the ejection sequence not been interrupted by surface impact, would have interfered with one or more critical elements and functions of the escape sequence. Each mishap description has been annotated by this author to illustrate the severity of the problem/error. In the earlier period one type of serious maintenance error, not fully documented in Table IV, due to the difficulty of identifying the mishaps from the manner in which the mishap data is filed, involved the many occasions in which seats raised up partially or totally fell out of the aircraft during catapult launch, negative G manuevers or inverted flight. This particular problem caused the loss of lives and aircraft. The particular seats had been in Navy inventory for several years and had been maintained by squadrons for several years before the problem emerged, but when it emerged, it did so rapidly and in significant quantities, necessitating an extremely urgent design change to reduce its potential for recurring (it is not believed to have recurred since completion of the retrofit and production incorporation of the change).

DISCUSSION

An important and oft forgotten aspect of any discussion of aircrew automated escape systems (AAES), including discussion of serious maintenance error occurrence/non-occurrence, is that, as illustrated in Figure 1, an AAES is comprised of more than just an ejection seat and that the proper functioning of each of these additional components of the AAES can be, and generally is, just as critical to the safety of the would be ejectee as is the proper functioning of the ejection seat itself. Figures (2) through (10) illustrate for several specific cases the general location of the problems reported to have been experienced. In each of these instances, as well as in very many others, these problem locations when, as is possible in many instances, associated with both the histories of the systems, observed results and investigative results, provide strong evidence that the problem in fact was induced by maintenance error, not design nor manufacturing error.

(^{2} cont.) system functioning. Obtaining this information in these ways has been unique and alters the data for overwater escapes from the normal pattern.

Another factor often forgotten in counting escape statistical aspects, such as the frequency of occurrence of serious maintenance errors, is the large quantity of ejection seats and other AAES elements never retrieved and hence never inspected. This problem is especially acute among overwater escape attempts which occur with great frequency (there have been very few exceptions with respect to the loss of AAES following overwater ejections since usually the probable location is not known with any reasonable precision and the cost of retrieval when the location is known with some precision generally is very high) and which generally tend to show a lower rate of occurrence for a given seat than its overland rate of occurrence, suggesting that probably many maintenance errors and, unfortunately, many of their victims were lost into Davy Jone's locker. The problem also occurs following overland ejections, however, the data reported do not permit an estimation of the ratio of recovered to lost ejection seats following overland ejection. (Examination of ESCAPACs IF-3, IG-2, IG-3, and IG-4 records at first appears to refute the trend. Further examination however, as footnoted (footnote 2), reveals that the problems were concentrated in the A-4 series aircraft and, from comments of wingmen and aircrew futilely attempting to eject, a major consideration in these failures has involved the complex seat-canopy-seat signal interfacing required, since due to the location of structural beams in the canopy, the pilot has always been unable to resort to through-the-canopy ejection. These several mechanisms' designs have required extra care and careful adjustment during maintenance and have lacked redundancy capable of by-passing sequence event blockage induced by maintenance error or by any other cause.) Even in the case of the ECAPACs then, when the seat-canopy-seat interfacing issue is removed, the trend is greater reportage of serious maintenance errors for overland than overwater ejections, but the numbers are low.

Yet another factor which influences the discovery and reportage of maintenance errors following usage of an AAES, let alone serious maintenance errors, is partially addressed in footnote 1; the knowledge and experience of the investigator concerning the AAES and its many components, their collective and individual functioning, and their collective and individual appearance and condition after usage, as well as their proclivity to sustain damage upon impacting the surface. Compounding this factor is the potential that an activity might be unwilling to "put itself on report" by indicating the presence of serious maintenance errors, especially if a life has been lost and their resultant willingness, consciously or not, to accept any other seemingly plausible explanation which can be obtained. Further complications arise from the simple fact that in many of the instances in which maintenance errors occurred or were believed to have occurred, further examination often revealed that the design of the component(s) and/or subsystem(s) involved were especially susceptible to maintenance error -- they could be termed as being "overly human dependent" in their design. Although such design susceptibility to, or even in some instance tendancy to encourage or promote, errors in maintenance is important and requires addressal by all personnel involved in the AAES acquisition process (requirements formulators, estimators of cost and schedule, planners of evaluations and tests, designers, design evaluators, design testers, manuals and training requirements formulaters, writers of manuals and training syllabi, evaluators of manuals and training syllabi, and program managers), the specific issue at hand is: "was there a maintenance error committed on the AAES being investigated and, if so, exactly what was it and which components were involved?" Only then does the next issue arise: "Is the design of the affected/involved component(s) and subsystem(s) a contributing or causal factor of the maintenance error(s) and, if so, in what manner?" Why is this important? A maintenance error, especially one in which design is a contributing or causal factor, is a problem with an often high potential for recurrence as a perusal of Table IV will reveal. Just as there is a potential tendancy for not "putting oneself on report" by identifying a problem as a maintenance error, there is the corresponding, conscious or otherwise, desire among designers and those involved in acquiring an AAES to identify problems as "isolated incidents", i.e., incidents which are not likely to recur. Thus, to a degree, the entire AAES community is uncomfortable when confronted with an AAES problem which is potentially or, perhaps, unavoidably identifiable as a maintenance error.

Based upon the data presented herein and the preceding discussion, it is believed that for the period from 1 January 1969 through 31 December 1979, the reported thirty (30) incidents of serious, life-threatening maintenance errors in AAES (Table IV) is a conservatively low estimate. Similarly, the thirty-one incidents reported in the earlier period are also believed to represent conservatively low estimates of occurrence.

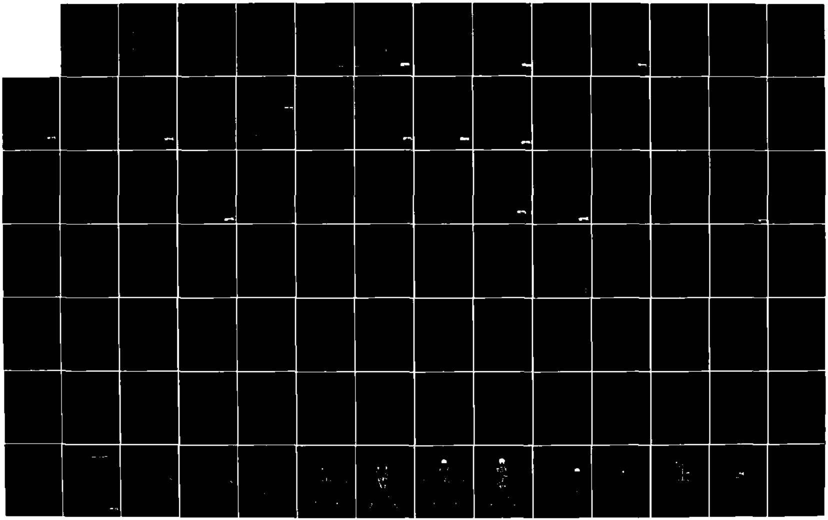
CONCULSION

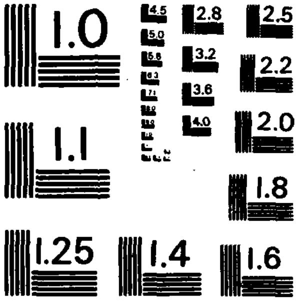
Maintenance errors in AAES are presently and will continue to be a problem; one that has, is now and will cost aircrew and maintenance personnel lives. It is suspected, also, that as a consequence of the factors discussed and others, that the incidence of maintenance errors will remain underreported. Where this underreportage in fact is deliberate; an attempt to avoid "putting oneself on report", a grave disservice to the aviation community, both present and future, is committed for it helps hide from the AAES community the presence of the problem, its cause(s) and the need for remedial action(s) both in in-service and future systems. Efforts are continuing under the Aircrew Automated Escape Systems (AAES) and Aircrew Life Support Systems (ALSS) Equipments In-Service Usage Data Analysis Report to identify AAES design aspects particularly susceptible to serious maintenance errors so that remedial actions can be initiated as appropriate. Most of the Navy's current inventory of ejection seat type escape systems' designs and evaluations predate the stringent requirements that originated with the issuance of the D revisions of MIL-S-18471 (design) and MIL-E-9426 (test) and with the issuance of MIL-STD-2067 (R/M) and which were imposed upon the most recent escape system acquisitions now in service: AV-8A/SIIIS-3 and F-18/Mk US10S. These more stringent requirements were also imposed upon the soon to be introduced A-7/SIIIS-3ER. Unfortunately, it is too soon, in view of the small quantities of these escape systems in active Navy inventory and the to-date short total service lives involved, to evaluate the success or failure of these design, design analyses and design test and evaluation efforts in reducing the problem of serious maintenance errors occurring among in-service AAES.

ADA134833

AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE
USAGE DATA ANALYSES VO..(U) NAVAL WEAPONS ENGINEERING
SUPPORT ACTIVITY WASHINGTON DC C W STOKES ET AL.
UNCLASSIFIED 05 NOV 83 NAVWESA-1-83-VOL-1 F/G 1/3 NL

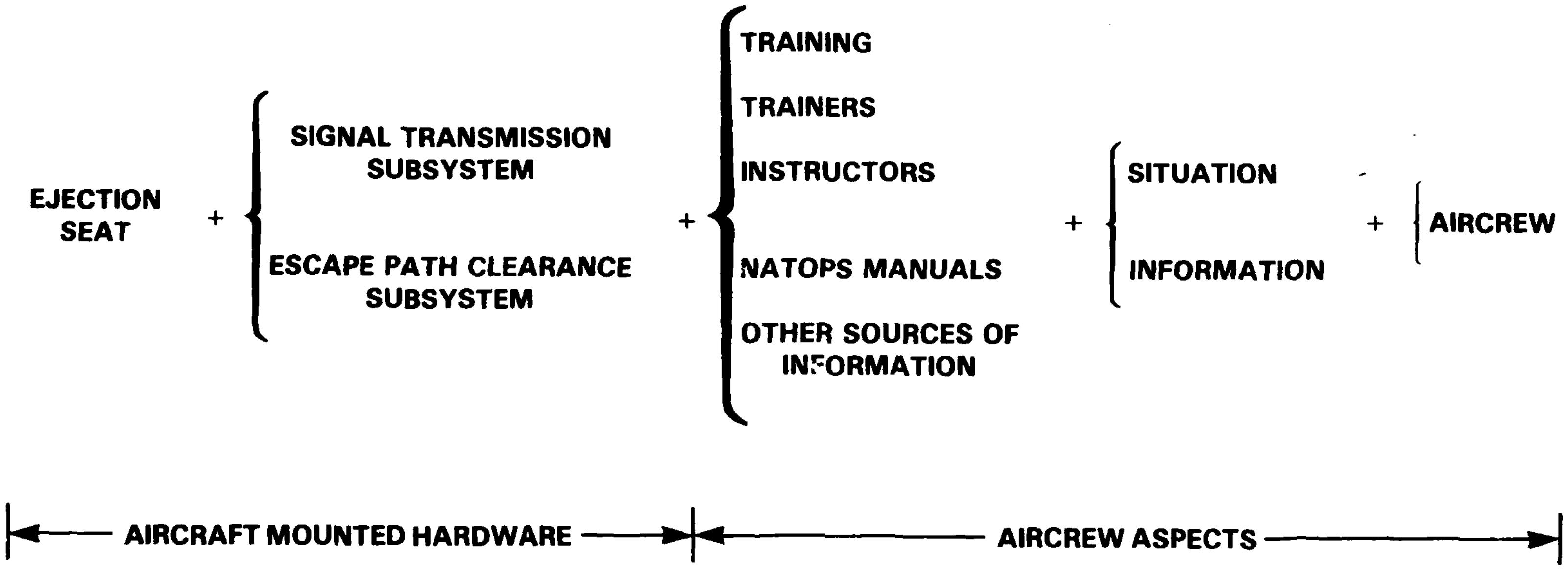
5/6





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COMPONENTS OF COMPLETE AIRCREW AUTOMATED ESCAPE SYSTEM



EJECTION SEAT

+

SIGNAL TRANSMISSION SUBSYSTEM

ESCAPE PATH CLEARANCE SUBSYSTEM

+

TRAINING

TRAINERS

INSTRUCTORS

NATOPS MANUALS

OTHER SOURCES OF INFORMATION

+

SITUATION

INFORMATION

+

AIRCREW

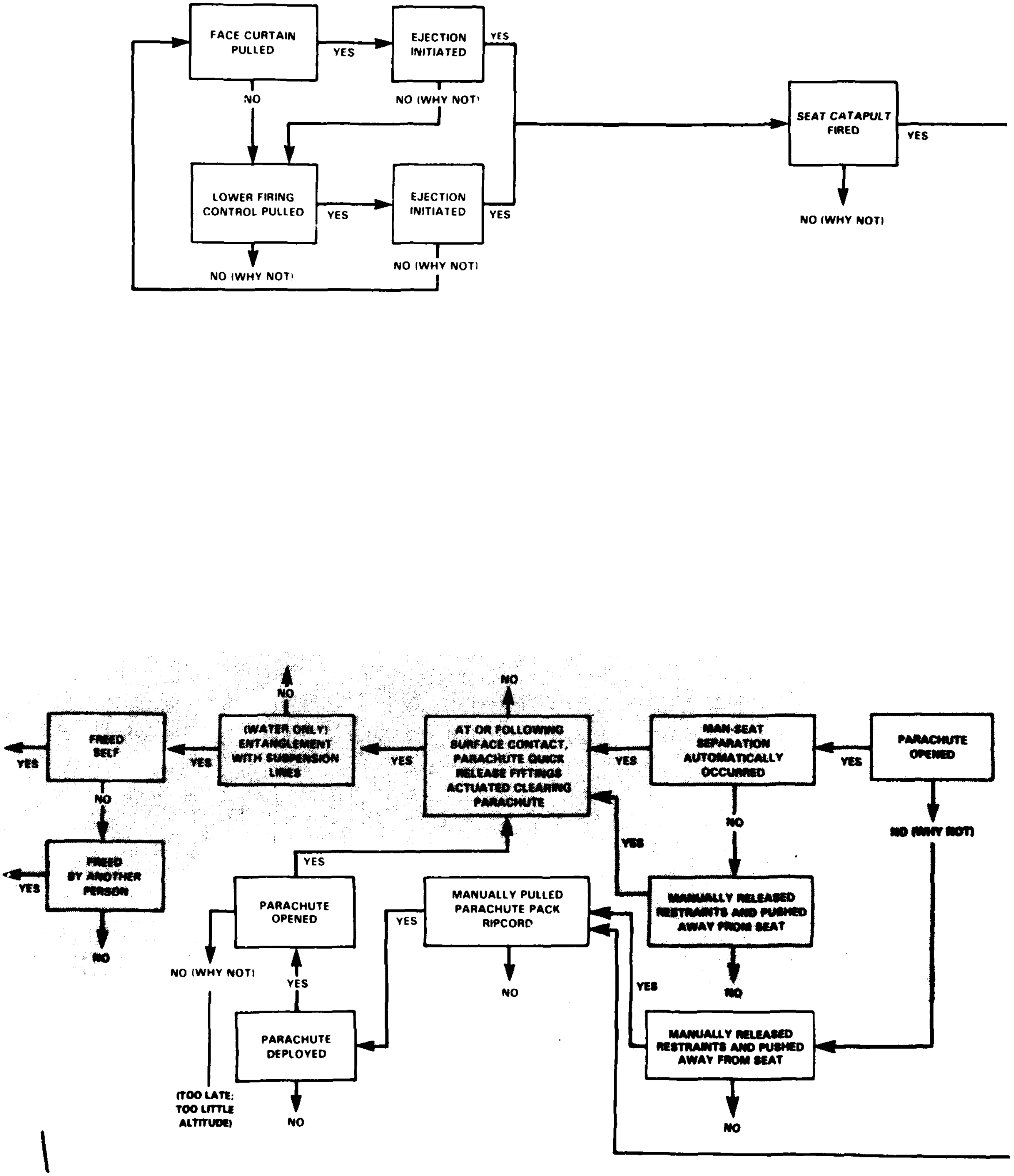
AIRCRAFT MOUNTED HARDWARE

AIRCREW ASPECTS

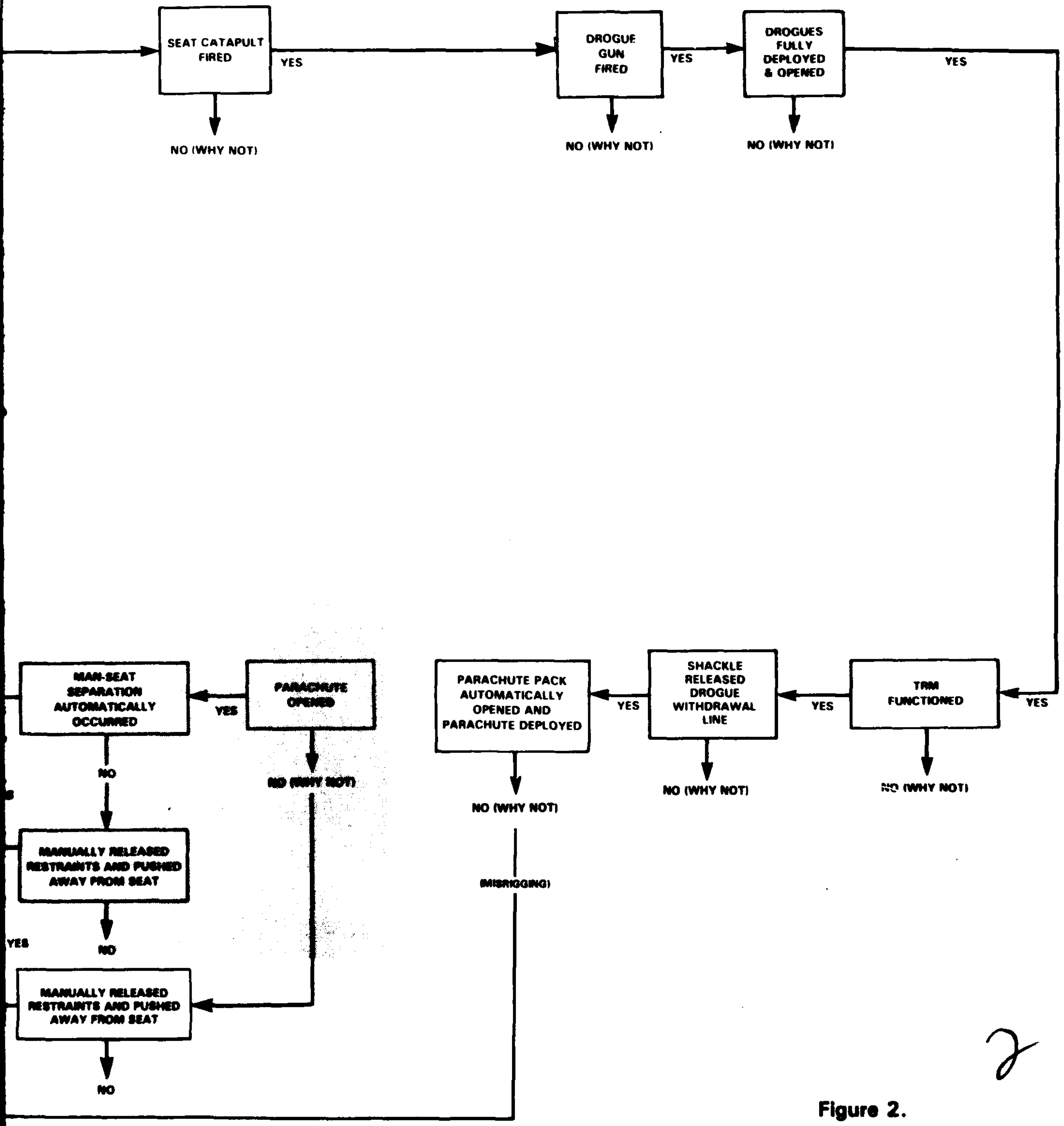
Figure 1

REF. NO. 82

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-6/
(SEATS ARE INDEPENDENTLY ACTIVATED E



NCE FLOW DIAGRAM FOR A-6/MK GRU5 ESCAPE SYSTEM
ARE INDEPENDENTLY ACTIVATED BY EACH CREWMAN)

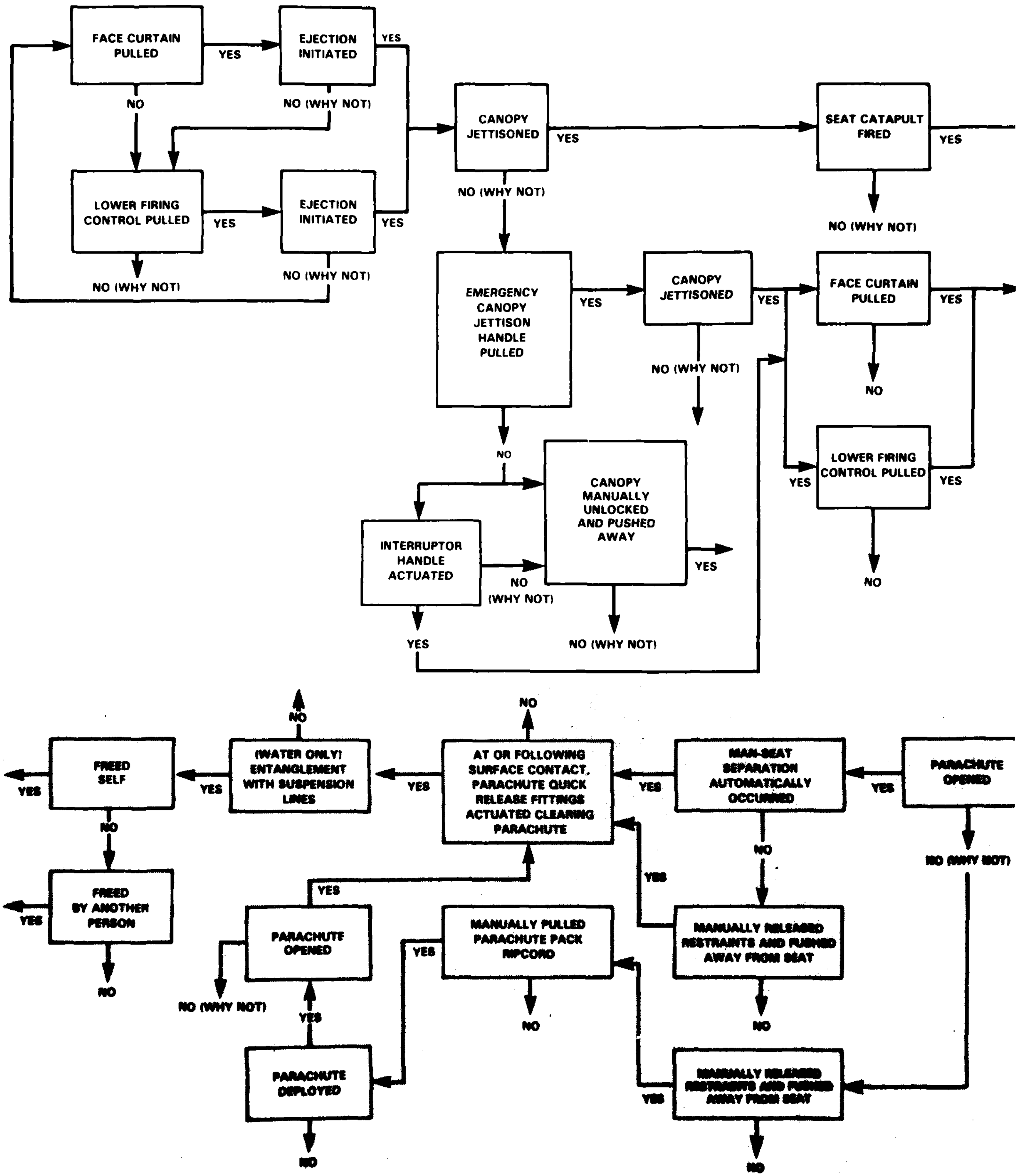


2

Figure 2.

ESCAPE SEQUENCE FLOW DIAGRAM FOR F-8

REF. NO. 113



LOW DIAGRAM FOR F-8/MK F7 ESCAPE SYSTEM

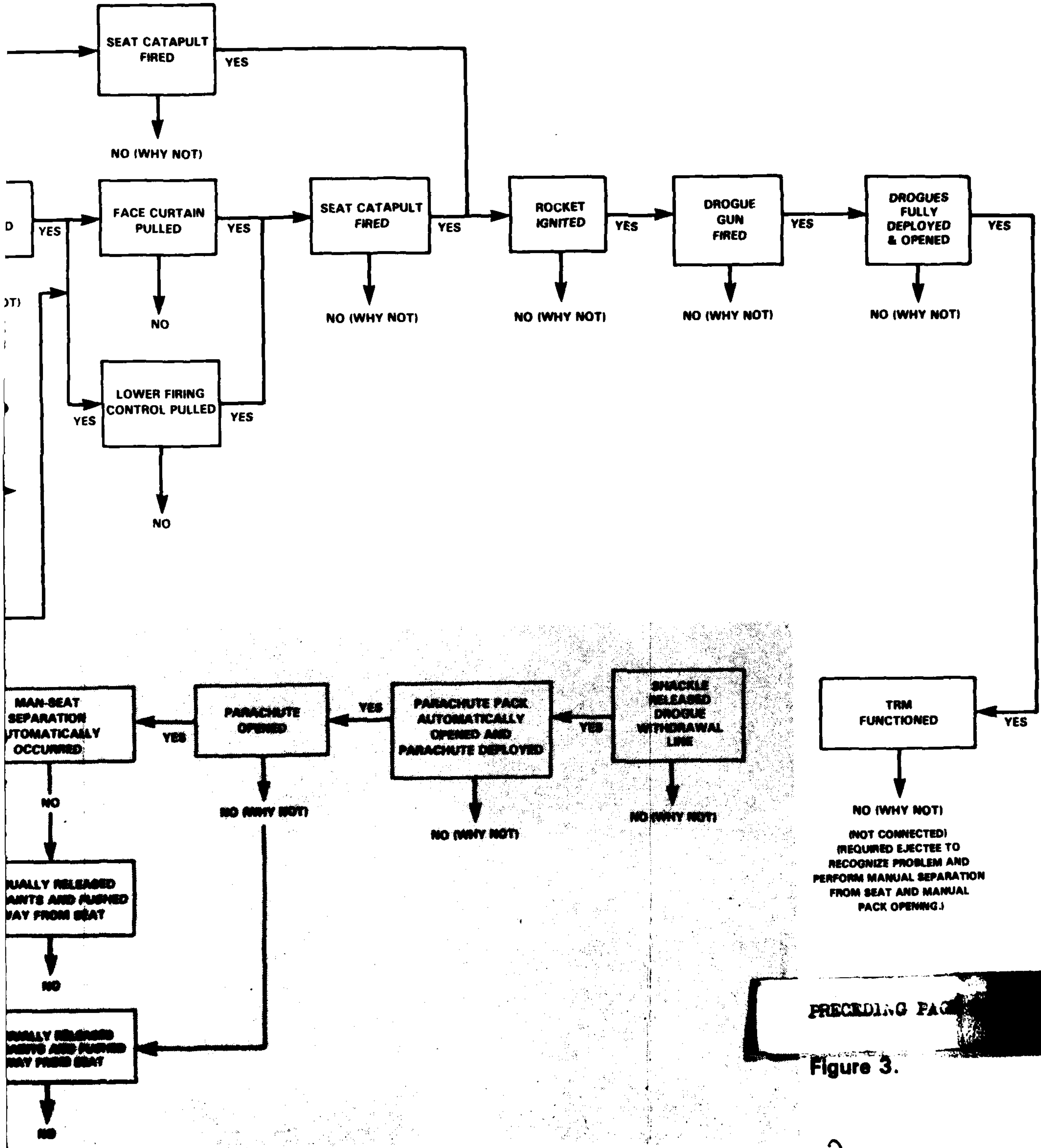


Figure 3.

2

REF. NO. 128

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-4 ESC

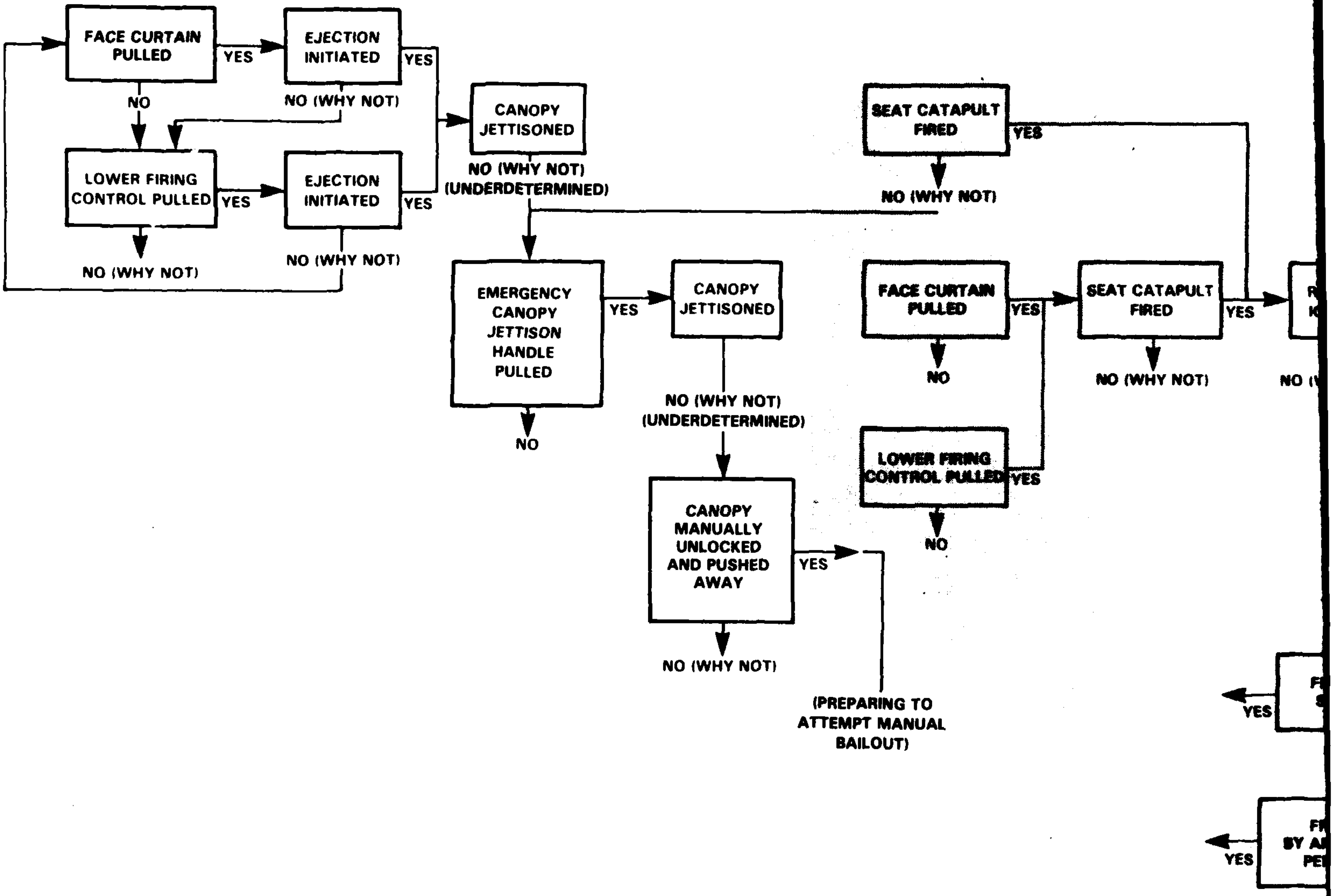


Figure 4.

AM FOR A-4 ESCAPACs ESCAPE SYSTEMS

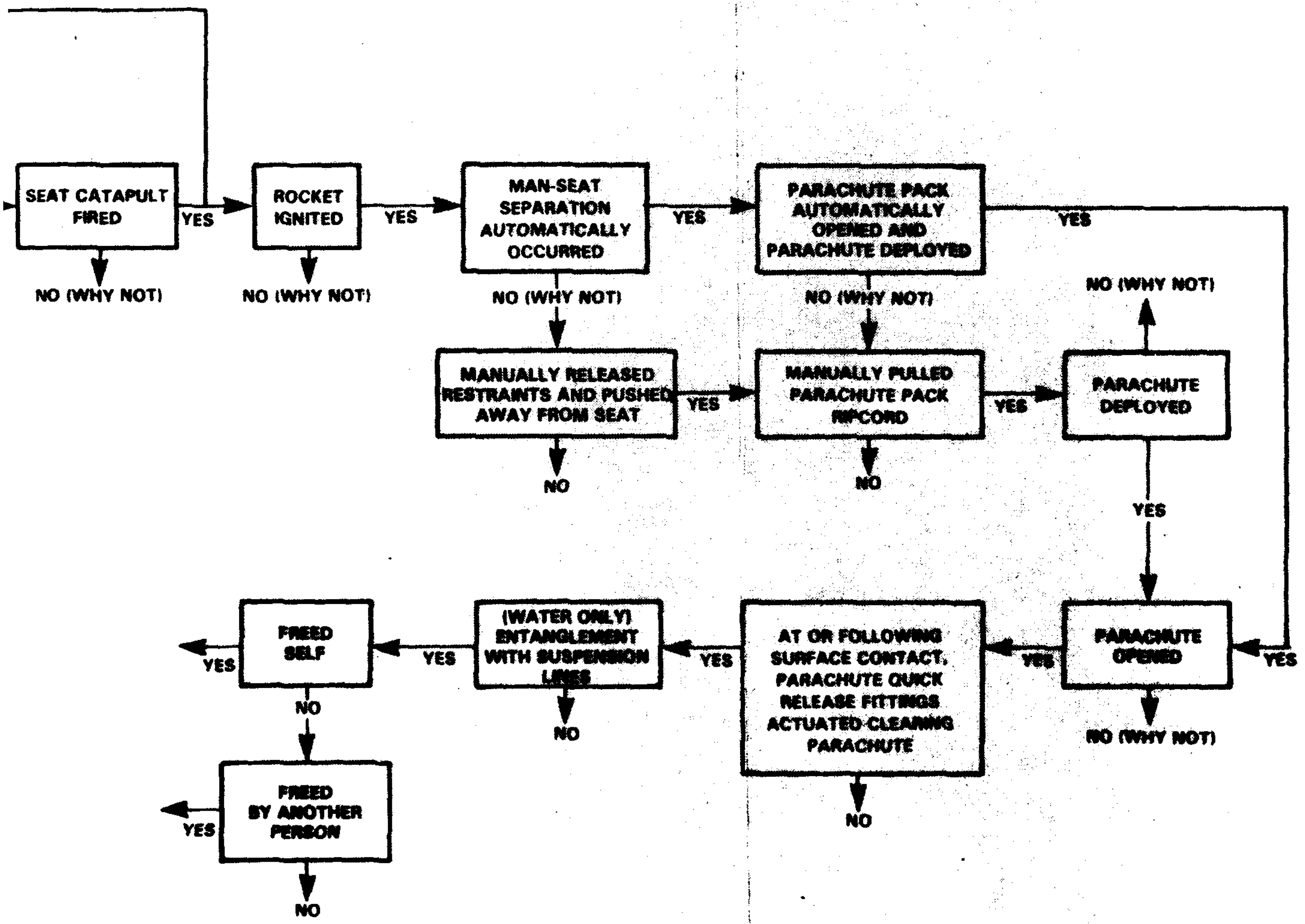
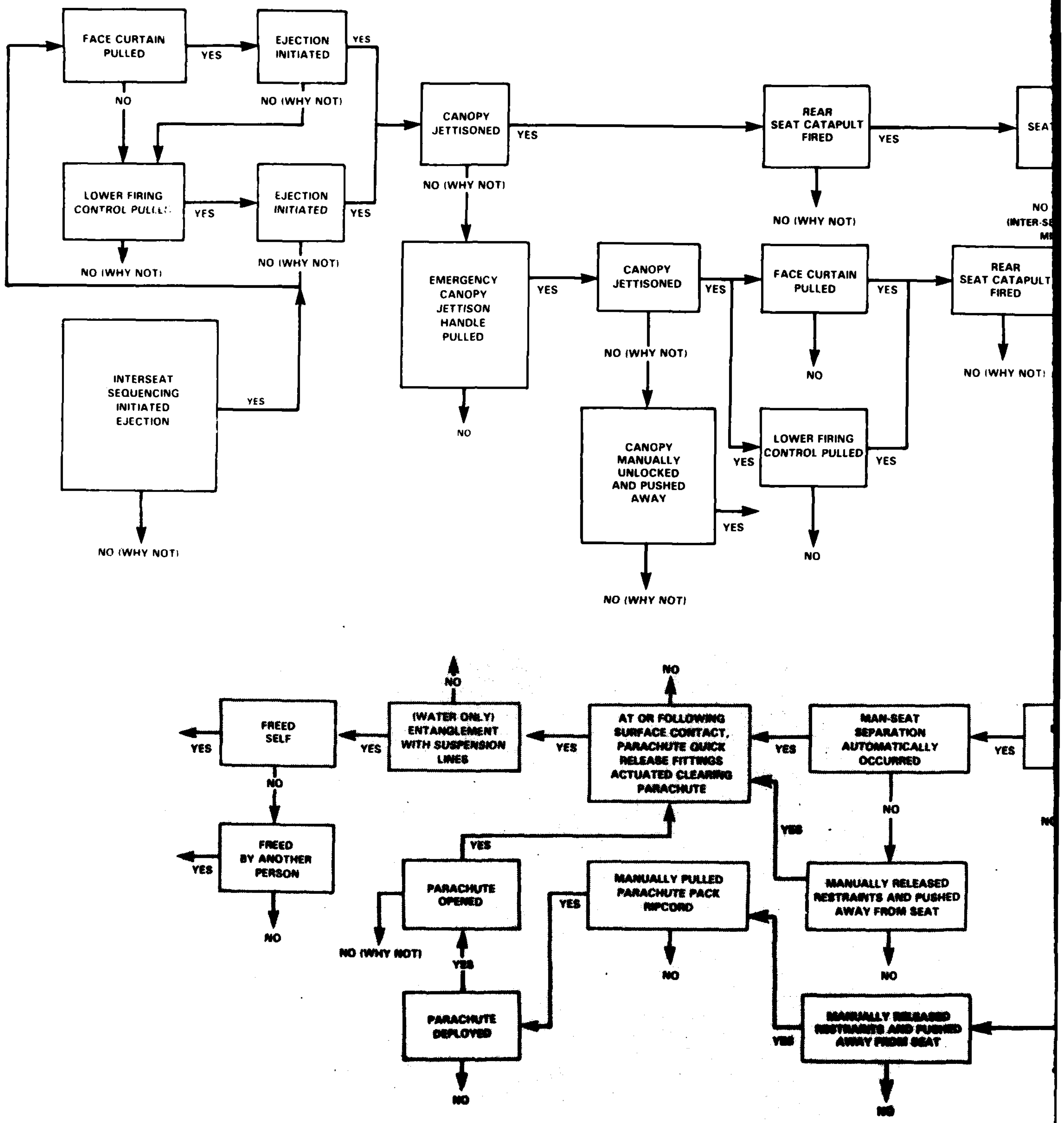


Figure 4.

2

REF. NO. 334

ESCAPE SEQUENCE FLOW DIAGRAM FOR F-4/MK



OR F-4/MK H7 ESCAPE SYSTEM

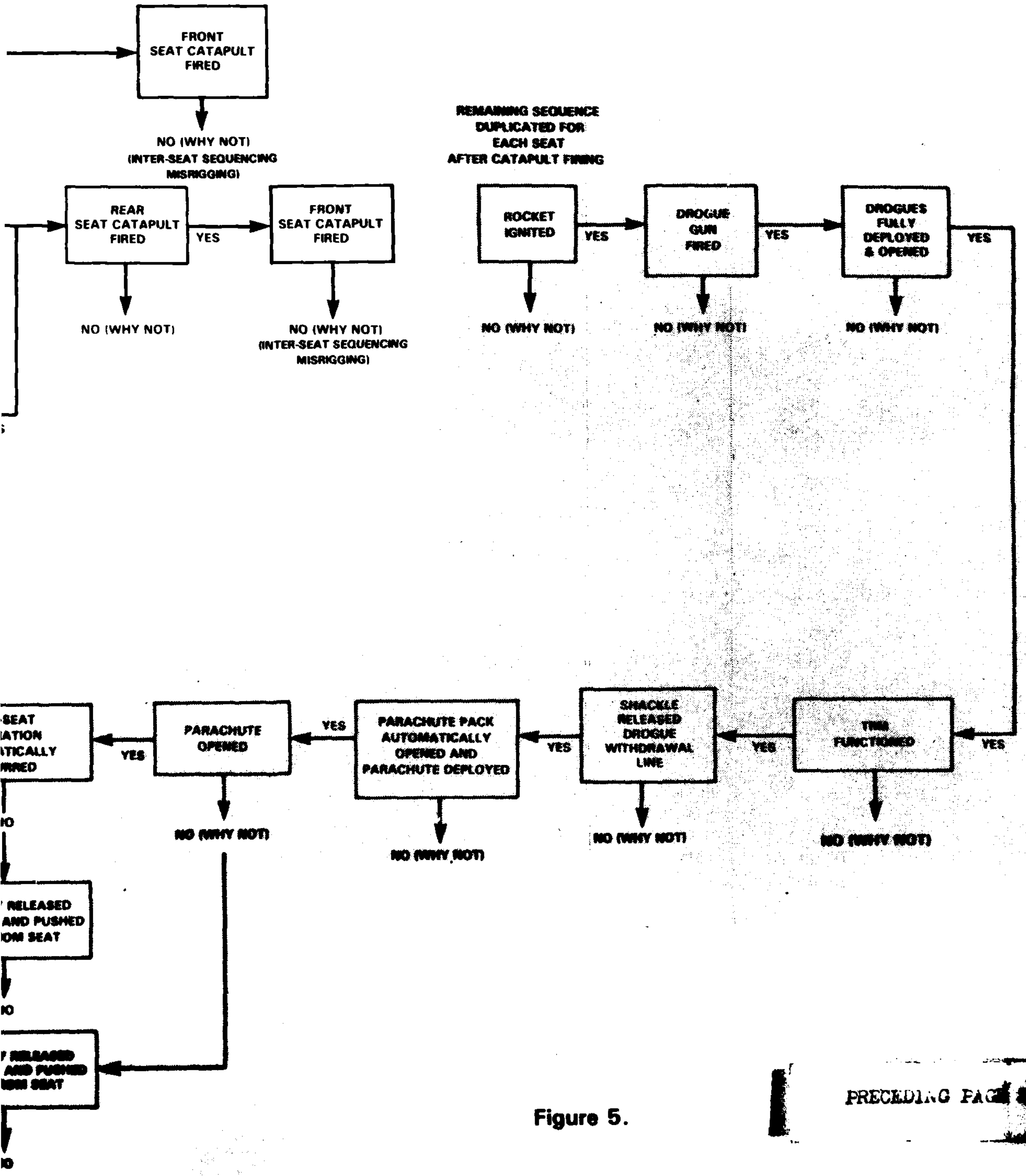


Figure 5.

2

REF. NOS. 398, 776, 1243

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-4 E

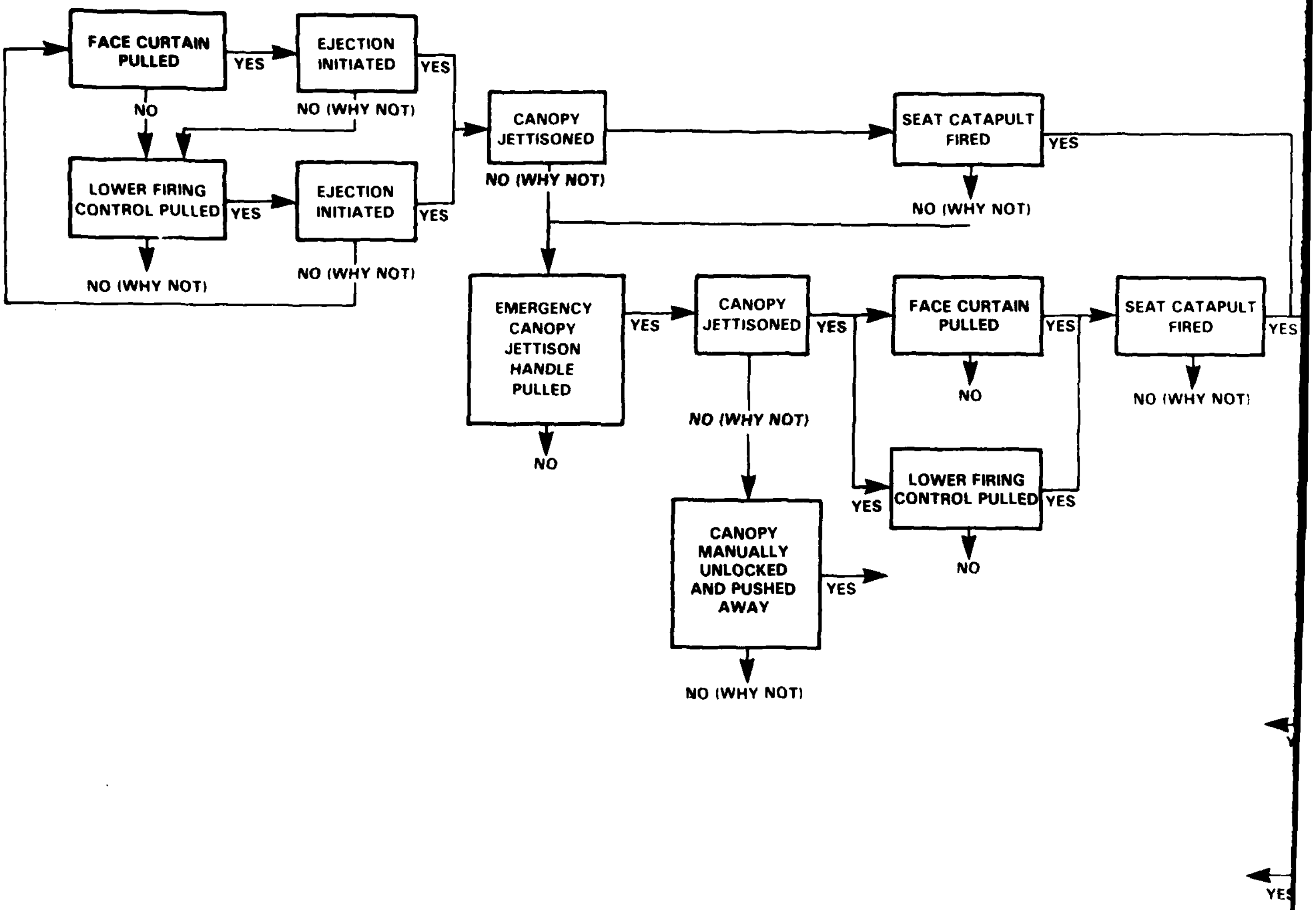


Figure 6.

IAGRAM FOR A-4 ESCAPACs ESCAPE SYSTEMS

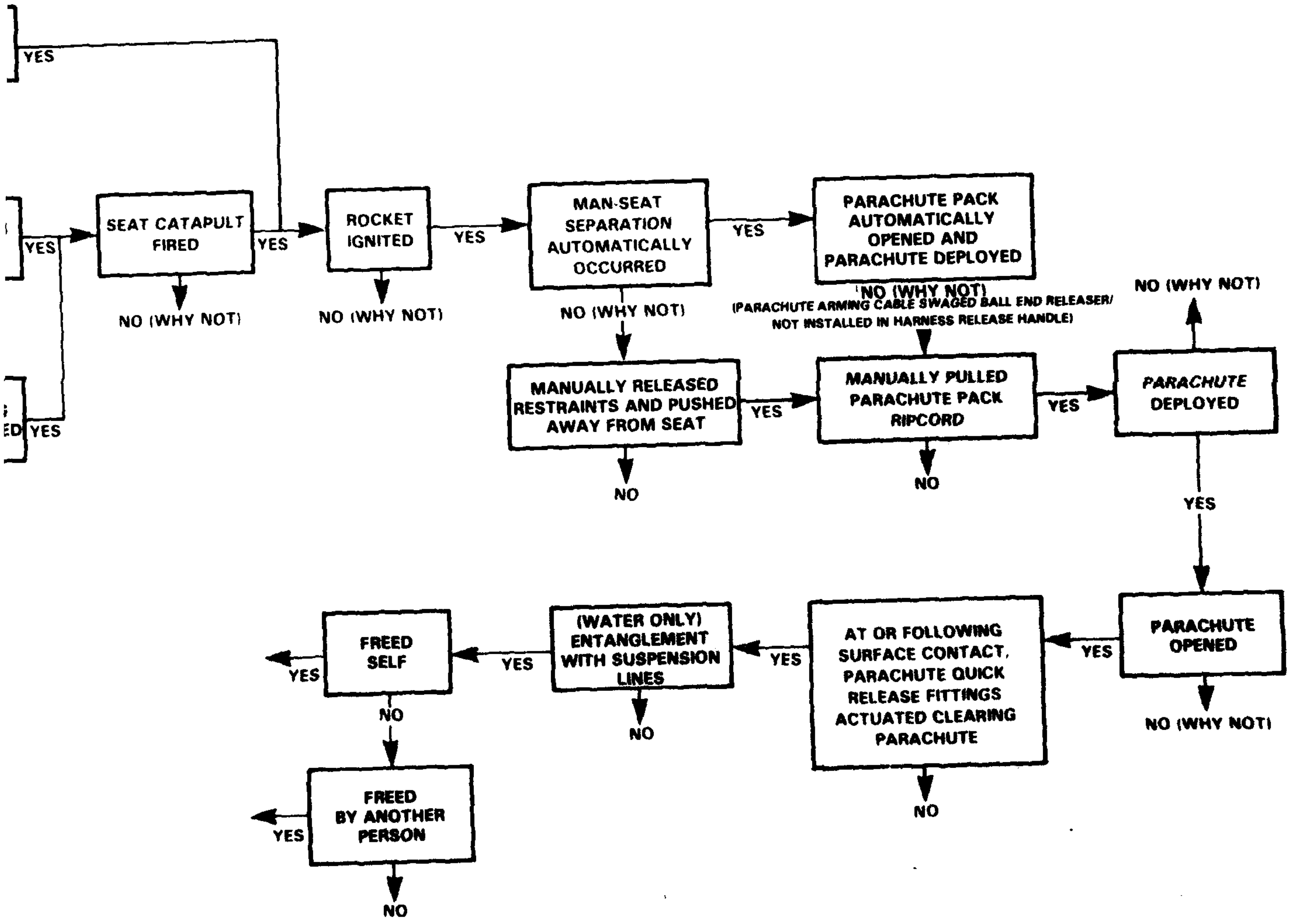
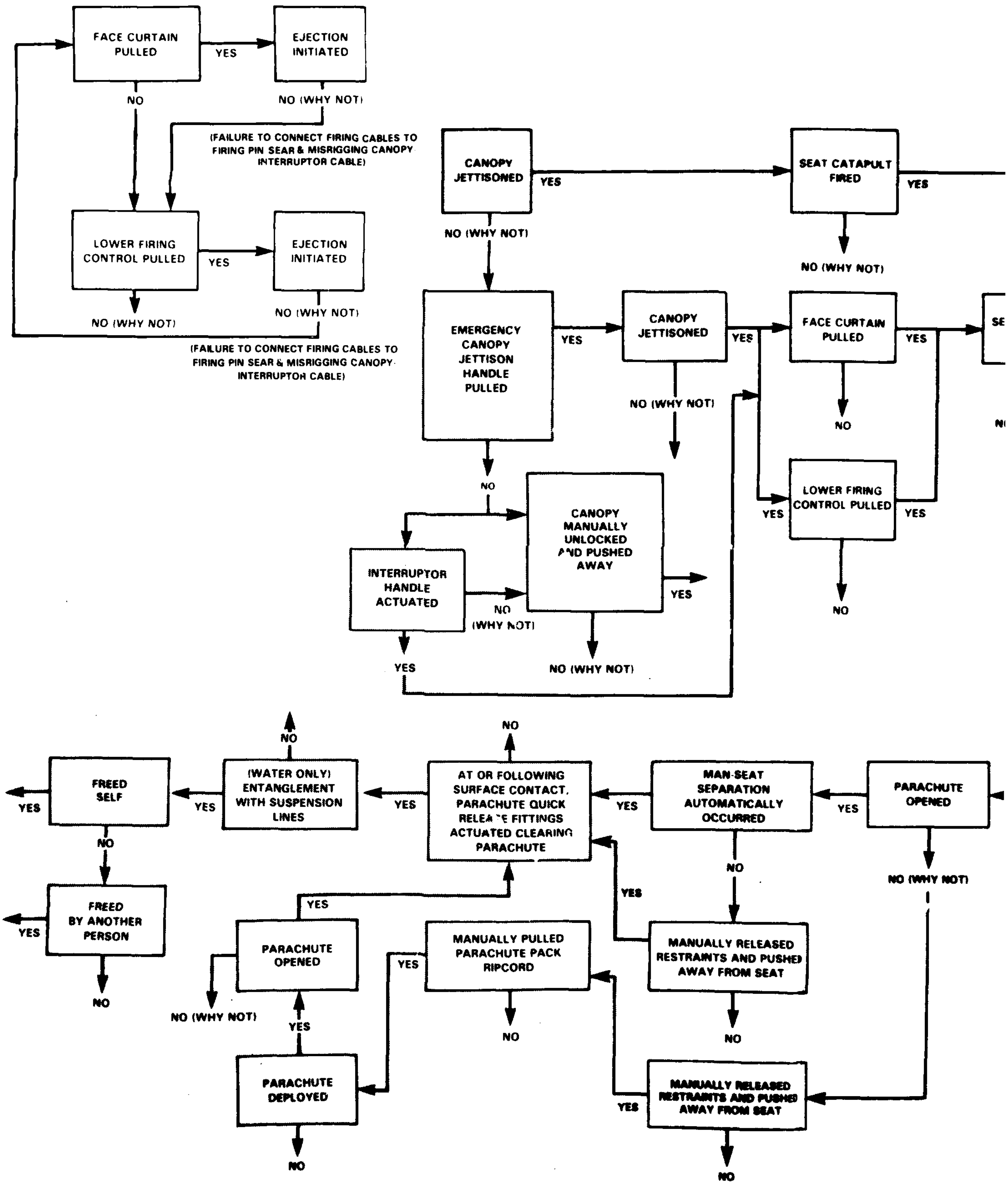


Figure 6.

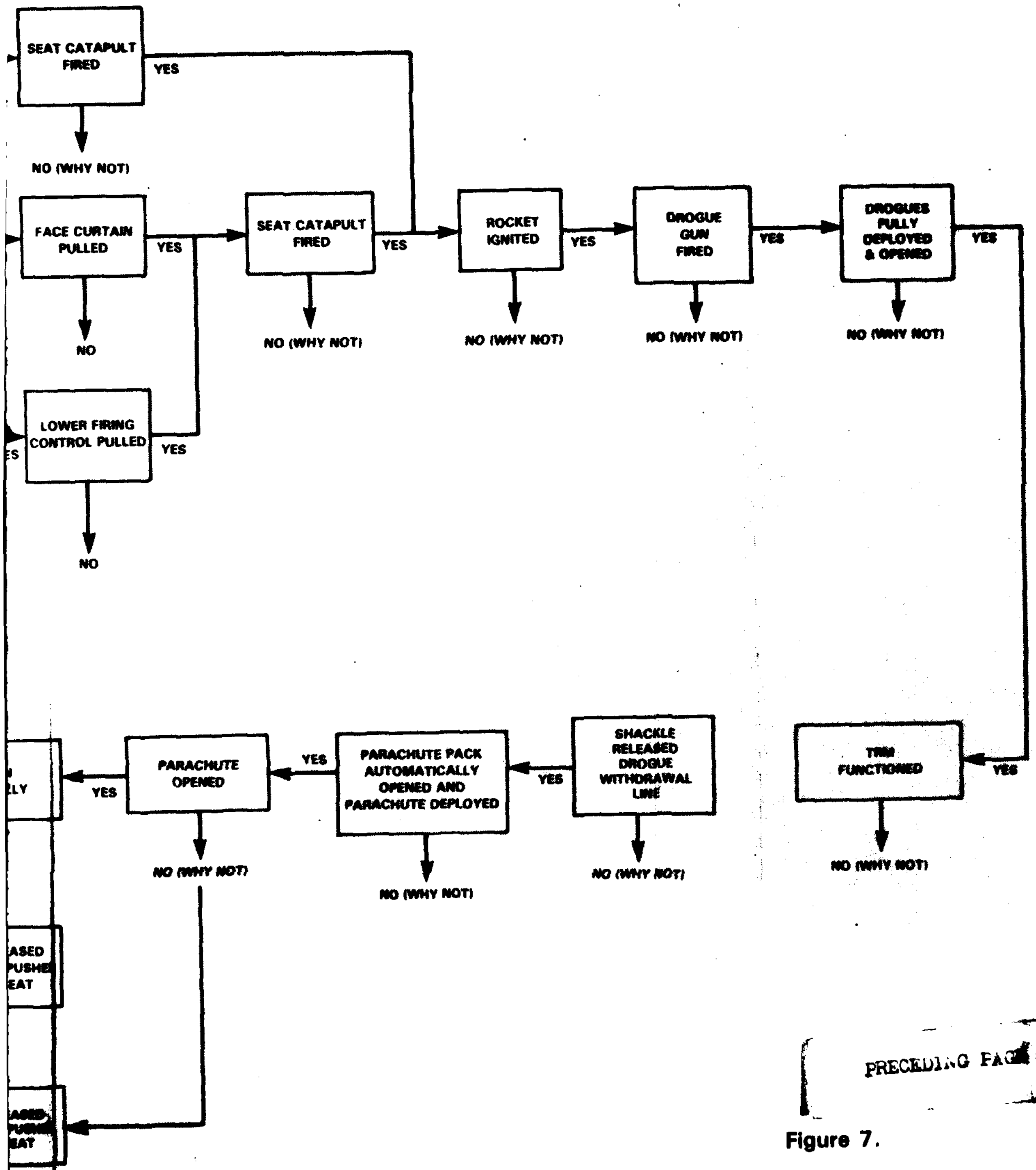
2

REF. NO. 782

ESCAPE SEQUENCE FLOW DIAGRAM FOR F-8/M



IAGRAM FOR F-8/MK F7 ESCAPE SYSTEM



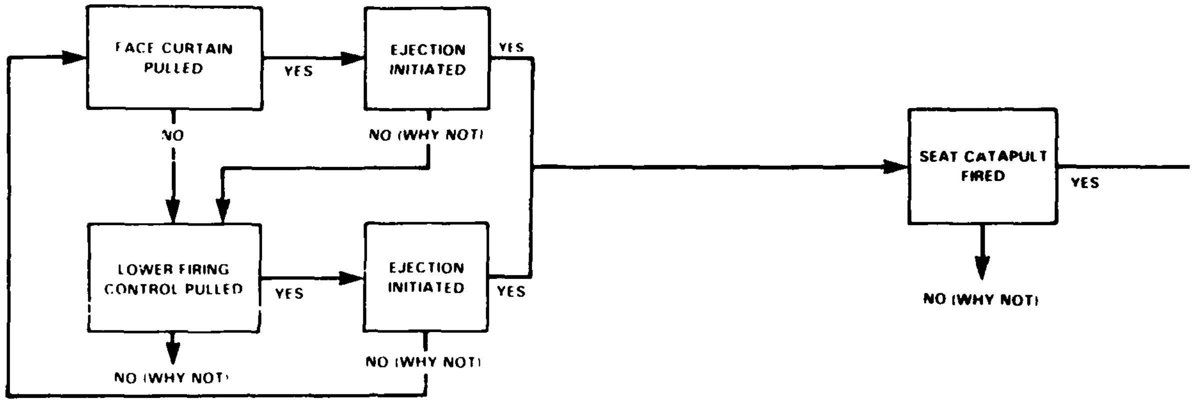
PRECEDING PAG

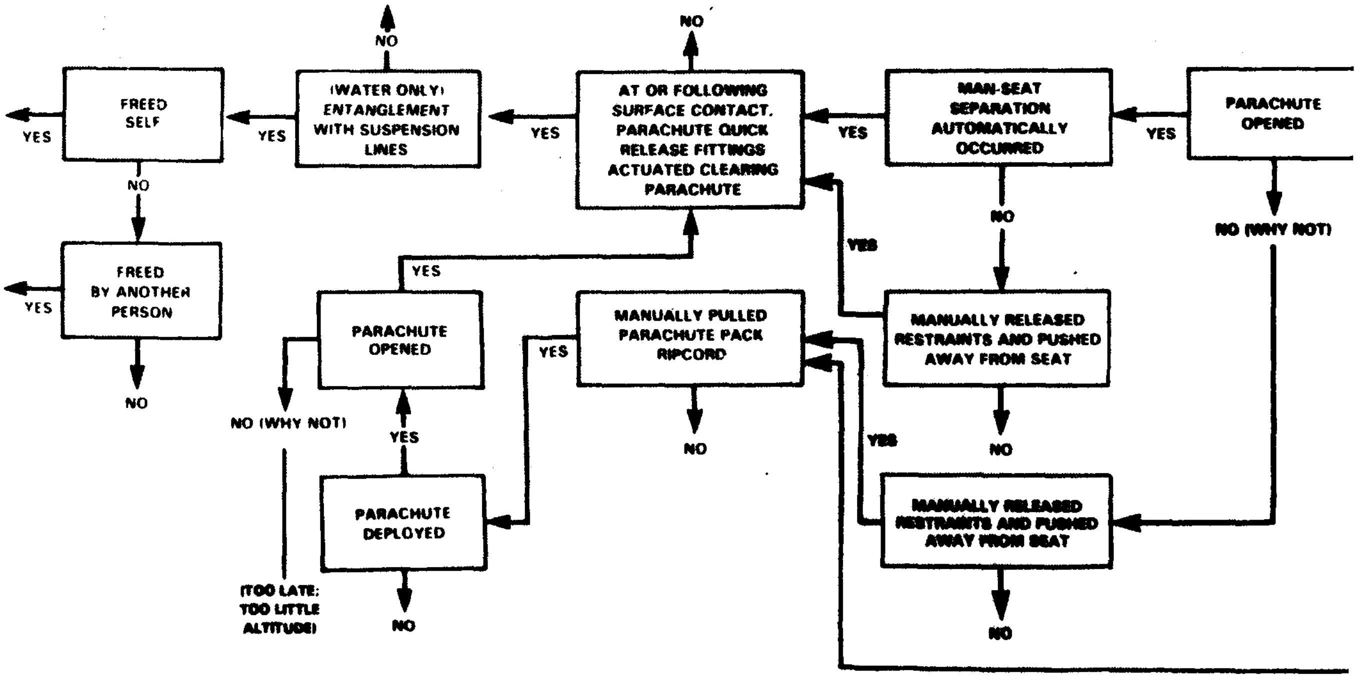
Figure 7.

2

REF. NO. 892

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-6
(SEATS ARE INDEPENDENTLY ACTIVATED





AGRAM FOR A-6/MK GRU7 ESCAPE SYSTEM
ENTLY ACTIVATED BY EACH CREWMAN)

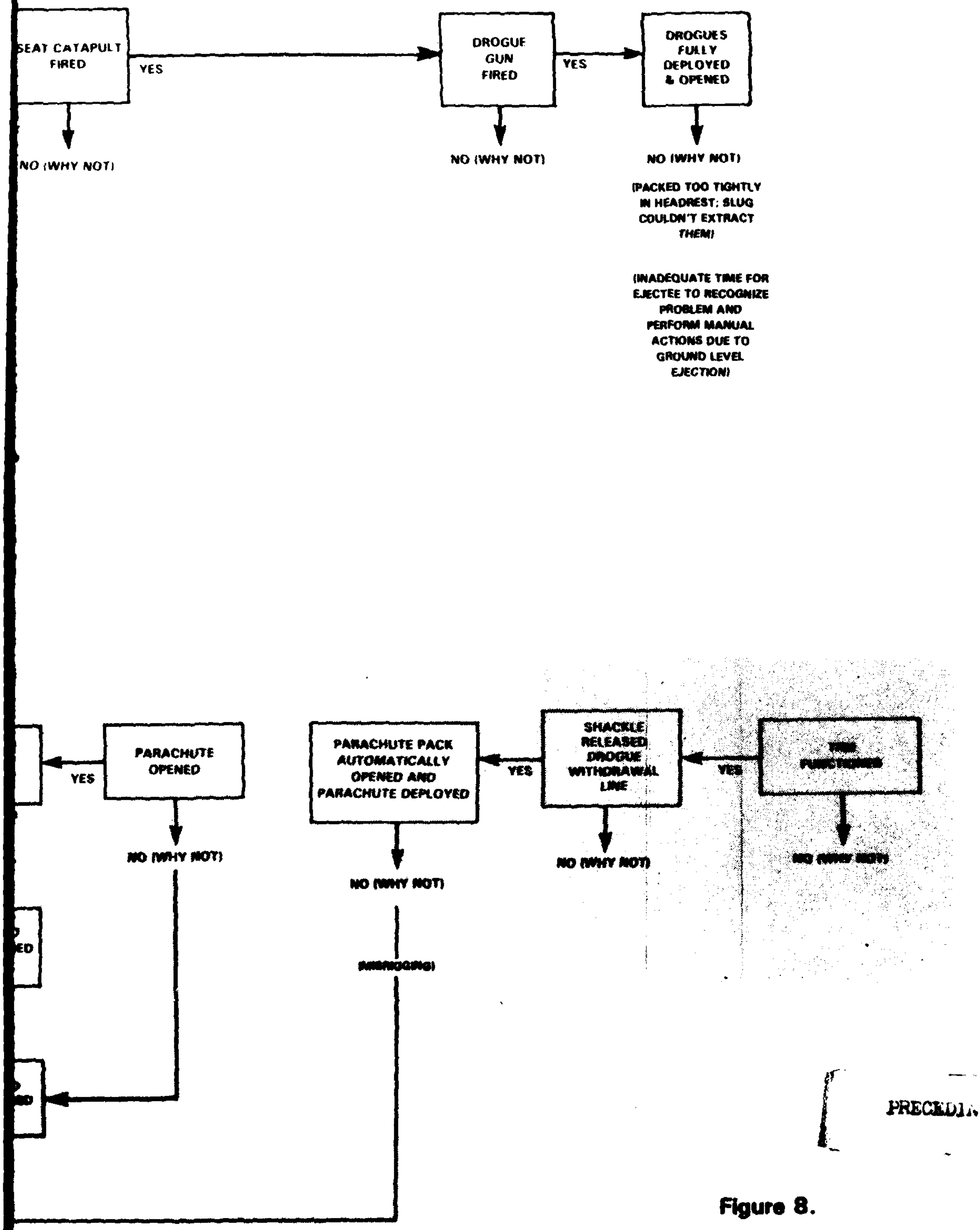


Figure 8.

2

REF. NO. 895

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-7 ES(

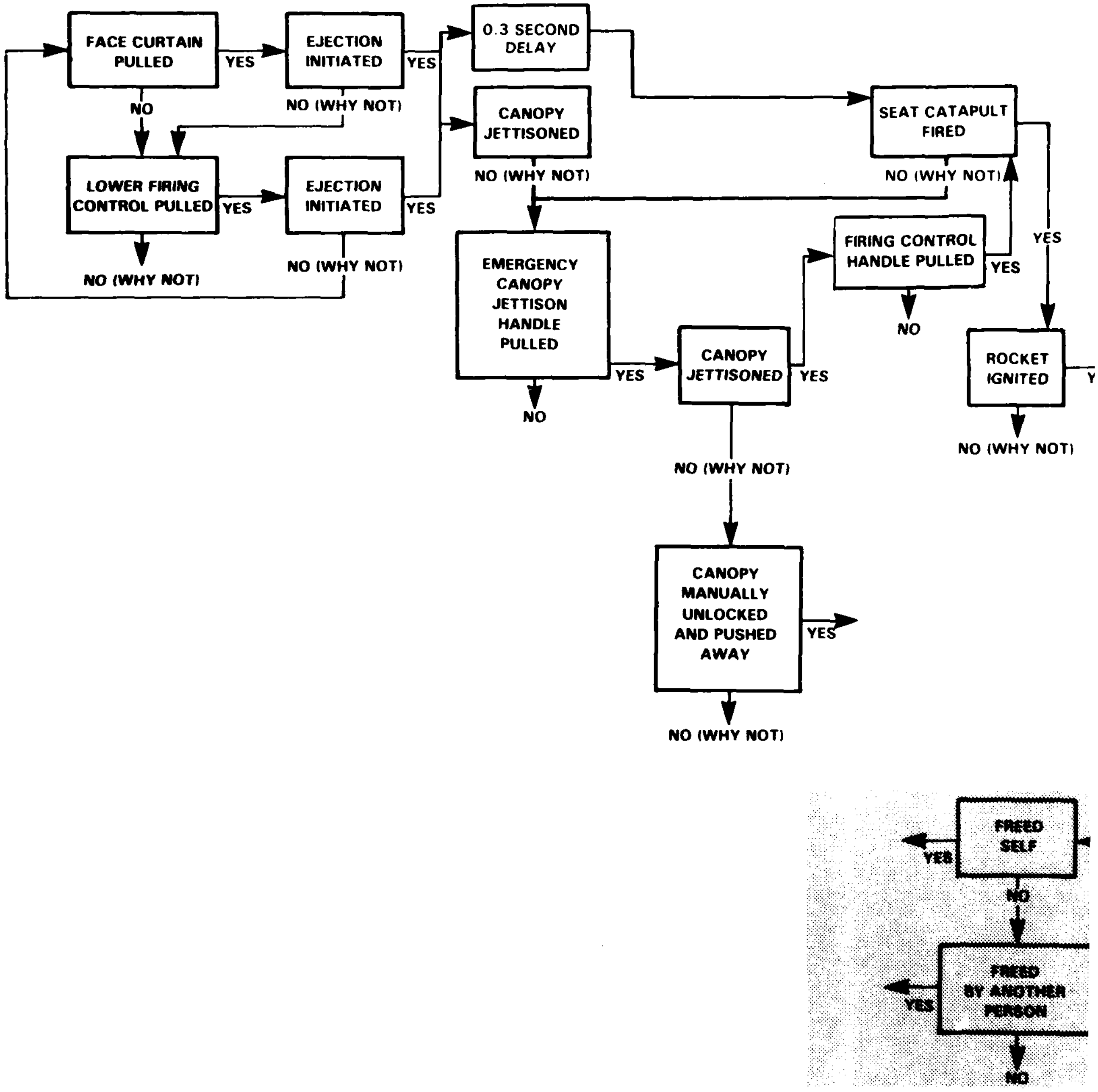


Figure 9.

DIAGRAM FOR A-7 ESCAPAC IC-2 SYSTEM

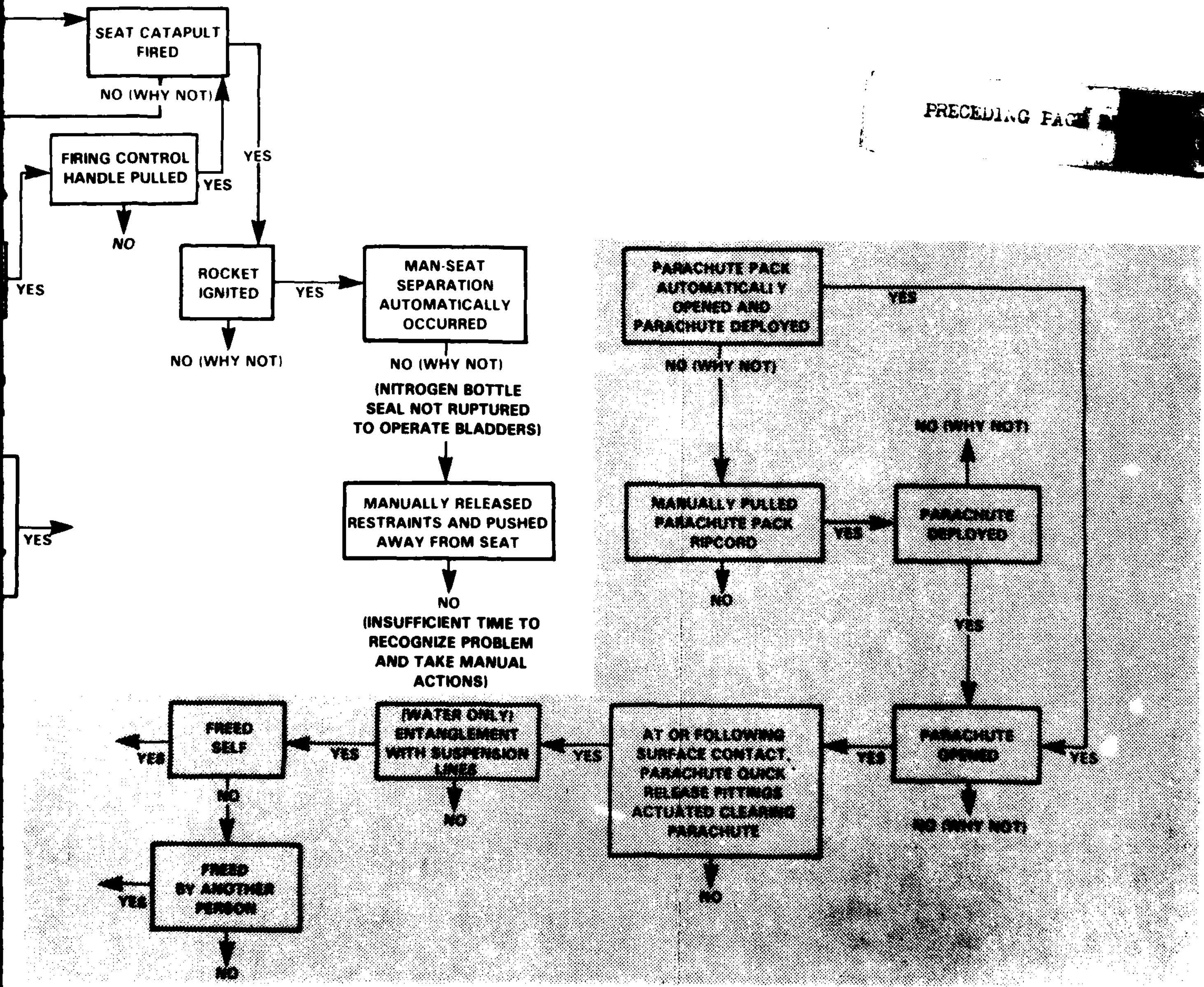


Figure 9.

REF. NO. 1682

ESCAPE SEQUENCE FLOW DIAGRAM FOR A-4

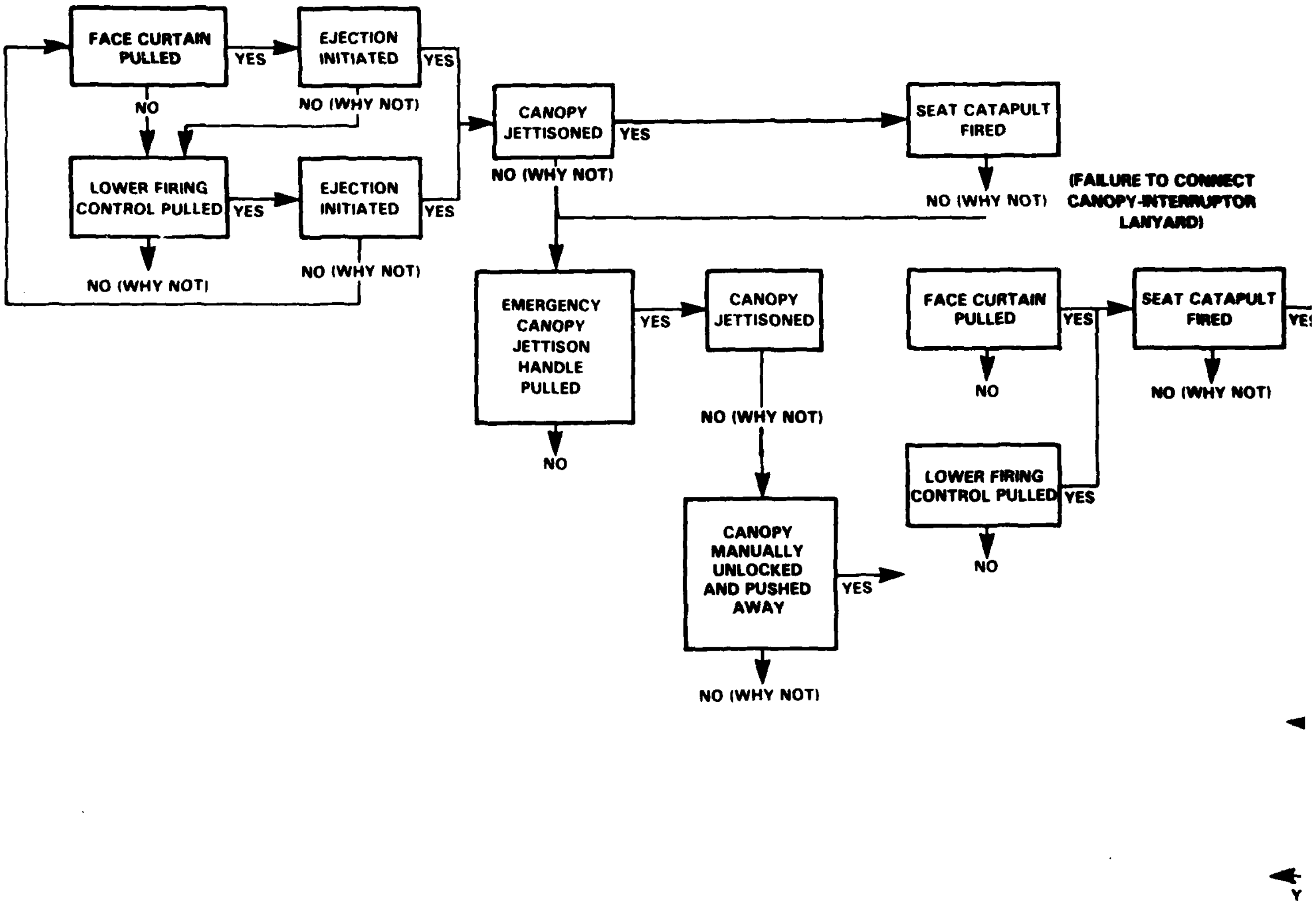


Figure 10.

RAM FOR A-4 ESCAPACs ESCAPE SYSTEMS

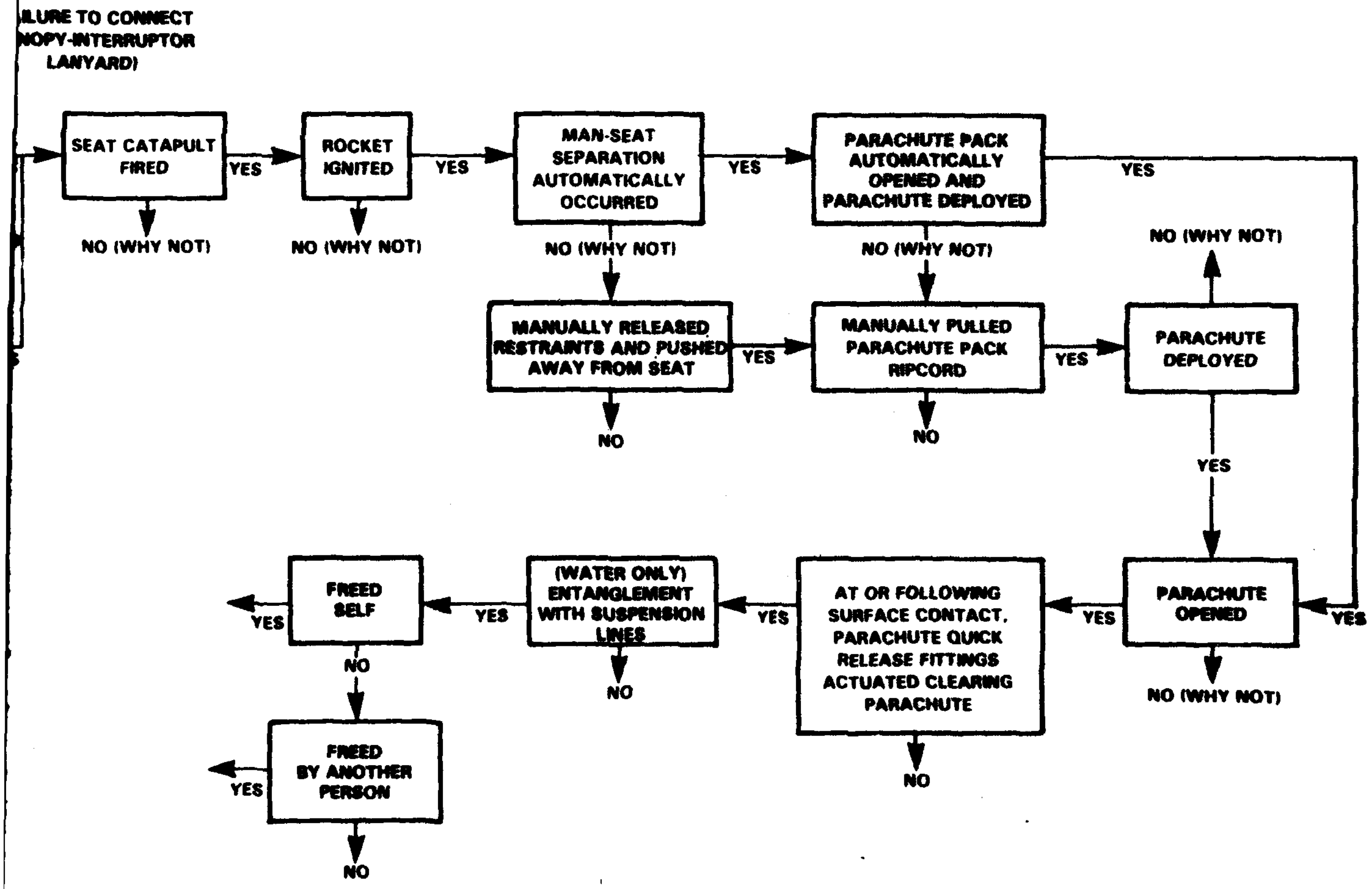


Figure 10.

2

ARE TWO TYPES OF EJECTION SEATS IN ONE AIRCRAFT SERIES IN ONE SQUADRON A SERIOUS OPERATIONAL HAZARD?

Frederick C. Guill

ABSTRACT

A potential problem of concern to aircrew automated escape systems (AAES) managers during any major upgrading of an escape system, especially involving the replacement of major elements such as ejection seats, has been the duration of the transition period, particularly the duration of the transition period in any single operational unit. The concern arises from the potential introduce for aircrew and groundcrew confusion concerning the performance, safety, handling, and maintenance aspects if they must ride in or work with two different systems in one aircraft. An attempt was made to assess the significance of the problem of two types of ejection seats in one aircraft series by examining the escape records preceding, during and following transition periods. Limitations in data access currently in effect, preclude adequate examination of the recent pre-transition periods, but the available data is presented for consideration.

ARE TWO TYPES OF EJECTION SEATS IN ONE AIRCRAFT SERIES IN ONE SQUADRON A SERIOUS OPERATIONAL HAZARD?

Frederick C. Guill

INTRODUCTION

For many years the personnel of the Crew Systems Branch, Naval Air Systems Command, and its predecessor organizations, have been concerned regarding the potential confusion hazards likely to confront aircrew during periods when aircraft are being retrofitted with new ejection seats or other major escape system elements. The concern has been that aircrew switches from one system to the other and back again repeatedly as might happen during the transition period when a squadron's aircraft were equipped with two different systems might result in confusion concerning the capabilities, initiating characteristics and mode of operation of that system in which the crewmember is riding when an emergency occurs requiring ejection. Such confusion, it was feared, might result in increased fatality rates and increased incidence of serious injuries among ejectees.

In the past though, the potential for a squadron retaining two types of seats in its aircraft or for aircrew transferring between similarly aircraft equipped squadrons often encountering two different types of seats was, deliberately a short term problem due to actions taken to ensure rapid changeovers in each squadron. Thus the trade-off between the risks attendant to an overlap or transition between seats and ultimately enhancing aircrew escape capability was believed worthwhile and, most importantly, the risk during the transition period minimal. Recently, however, senior management has suggested that for various reasons it would be politically/economically desirable to institute procedures which would result in many squadrons and aircrew being faced repeatedly on a more permanent basis with this problem of flying in one seat and then another type of different performance, characteristics and functions.

The question raised then is: Are there any data which might aid in resolving the safety issue; an issue which, at least at present, can only be discussed in abstract theory? This paper presents approaches being pursued to develop and analyze the data for evaluating this issue, the problems encountered and the plans for surmounting them, and the progress achieved. This paper then, is an outline of the plan and a progress report concerning the execution of that plan.

THE PROBLEM IN ASSESSING THIS ISSUE

The issue of aircrew safety when those aircrew are flying different types of ejection seats is not easily addressed. For one thing it is at this late date difficult to identify the installation dates of each of the major ejection seat upgradings. Secondly, it is even more difficult at this date to ascertain how long a period was required for each squadron to transition from new to upgraded ejection seats and what policies possibly were promulgated and implemented at the local level to mitigate the potentially adverse safety effects of the transition upon both aircrew and groundcrew personnel. What can be addressed at this time is the overlap (or gap) between the first ejection using a given upgraded escape system and the last ejection using the system being replaced (Table 1 and Figures (1) through (4)). These data however, are not at present available on a squadron basis and even if they were, the quantities of ejections per squadron during the usually deliberately short duration transition should be few. Another critical problem which is being addressed is the need to examine the escape attempt record for the seat being replaced. In many instances, to acquire sufficient data requires examination of pre-1969 escape attempt records.

APPROACH FOR ASSESSING THIS ISSUE

As shown in Figure 1, the first step was to examine the data for the period from 1 January 1969 through 31 December 1979 for ejections evidencing periods of seat transitions in aircraft. With the cooperation of the Naval Air Systems Command Change Control Board (CCB) Secretariat, records dating back to the early 1960's have been examined to identify the subject matter and to identify numbers for CCB's and IBCC's (Intra-Bureau Change Control, the predecessor form) affecting aircrew automated escape systems (AAES). It is intended to attempt to recall each document and its associated ECP (Engineering Change Proposal) and to extract the essence of the change and its applicability for use in these analyses. Subsequently, the appropriate BACSEBS (BUWEPS Aviation Clothing and Survival Equipment Bulletins), AFC's (Air Frame Changes) and ACC's (Aircrew Systems Changes) will be identified to permit identification of the dates of issuance, priority and such information as might aid in identifying the presence or absence of each change in each ejection seat used in an escape attempt. (In some instances, it should be noted that the latter information is presented in the original MORs/FSRs (Medical Officer's Reports/Flight Surgeon's Reports).) Until these configuration data have been acquired and carefully entered into the Naval Weapons Engineering Support Activity's Aircrew Automated Escape System (AAES) and Aircrew Life Support System (ALSS) Equipment In-service Usage Data Analysis project data banks, the data presented in Figures (1) through (4) will be the only available data for defining the transition periods occurring between 1 January 1969 through 31 December 1979. (An earlier set of transition periods occurred during the replacement of the so-called "standard" or "NAMC Type I" and "NAMC Type II" catapult ejection seats with the Martin-Baker Mk 5 Series ejection seats and, in A-4 series aircraft only, the "RAPEC I" type ejection seats. The data for examining this earlier set of transitions lies entirely in the computerized log of U.S. Navy pre-1969 ejections now being created and will be examined upon completion of that log.)

With the present limited available data, the ejection histories of each of the Table I listed escape systems is being examined first in three separate periods: (1) for a one year period preceding the first recorded ejection in the upgraded escape system, (2) for the period between the first recorded ejection in the upgraded escape system and the last reported ejection using the escape system being replaced, and (3) for a one year period following the last reported ejection using the escape system being replaced. The one year periods are arbitrary, while the ejection transition period is identified by the records and included in Table I. These data will be examined for potentially significant changes in ejection success rate as well as major rates and the cases will be carefully examined on a case-by-case basis using the original MORs/FSRs. Based on the information contained in Table I a number of the mishaps to be examined in this effort will be identified through use of the newly developed computer logs. The second approach being employed is to examine the escape attempt records for (1) the 25, the 50, and the 100 ejection attempts immediately preceding the transition period, (2) the ejection attempts occurring during the transition period, and (3) the 25, the 50, and the 100 ejection attempts immediate following the transition period. These approaches are illustrated in Figures (1) through (4).

In addition, there have been several historic ejections in which a CAG (Carrier Air Group) commander or similar senior officer prided himself in being qualified in a multitude of the aircraft operating from his ship and eventually ejected and demonstrated less than satisfactory knowledge concerning the escape system he used. Enough so that in several instances, the reporting medical officers felt compelled to address this problem and to suggest limiting the numbers of aircraft an individual could be considered currently qualified to fly. Finding these cases for the information they contain is expected to be a major task, but an attempt will be made using the computerized ejection logs recently developed and still being upgraded and then searching original MORs.

CONCLUSION

At this stage, the data available is insufficient to permit assessment of the risks of having two types of seats in one series aircraft in one squadron, largely as a result of so much pre-transition data required to established baseline success rates is in the pre-1969 period. In addition a similar, earlier period of transitioning from older ejection seats to upgraded capability seats occurred between 1958 and 1962. All of the necessary data for examining the earlier is, by definition, pre-1969 data. As indicated earlier, efforts are continuing to develop that pre-1969 data and it is anticipated that the risk assessments can be made within the next year.

Note: Data was prepared by Mr. Tom Henke.

TABLE I

EJECTION SEAT UTILIZATION 1969-1979 DURING TRANSITION TO UPGRADED SEATS

AIRCRAFT SERIES	SEAT (SEAT BEING REPLACED LISTED FIRST, REPLACEMENT SEAT SECOND)	RECORD OF EJECTIONS DEFINING THE TRANSITION PERIOD		TRANSITION DURATION (BASED ON EJECTIONS) (MONTHS)	NUMBER OF EJECTIONS DURING TRANSITION PERIOD
		INITIAL	LAST		
TF-9J	MK A5	2/18/69	11/20/70		
TF-9J	MK A7	5/17/71	7/30/73	0	0
F-8	MK F5	1/14/69	9/9/70		15
F-8	MK F7	4/8/69	8/30/77	17	33
A-6	MK GRU5	2/12/69	4/7/77		31
A-6	MK GRU7	5/27/72	12/29/79	59	22
EA-6B	MK GRUEA5	3/30/71	11/16/71		
EA-6B	MK GRUEA7	1/13/75	9/28/78	0	0
F-4	MK H5	1/20/69	6/10/71		15*
F-4	MK H7	4/27/68	12/19/79	38	125*
A-5	HS-1	2/19/69	9/12/73		1
A-5	HS-1A	4/21/73	8/13/74	5	3
T-2	LS-1	1/11/69	6/6/78		
T-2	LS-1A	7/27/79	10/23/79	0	0
A-4	IA-1	1/26/69	8/14/79		90*
A-4	IC-3	1/20/69	4/25/77	127*	132*
A-4	IC-3	1/20/69	4/25/77		49
A-4	IF-3	7/28/72	8/17/77	57	16
A-4	IF-3	7/28/72	8/17/77		15
A-4	IG-3	3/5/74	12/22/79	41	21
A-4	IC-3	1/20/69	4/25/77		18
A-4	IG-3	3/5/74	12/22/79	37	17
A-7	IC-2	1/8/69	8/30/76		8
A-7	IG-2	4/6/75	12/14/79	16	10

*POST 1/1/69 DATA

EJECTION SEAT USAGE
DURATION OF U.S. NAVY EJECTION SEATS TRANSITION PERIODS WHEN UPGRADING
(1 JANUARY 1968 THROUGH 31 DECEMBER 1979)

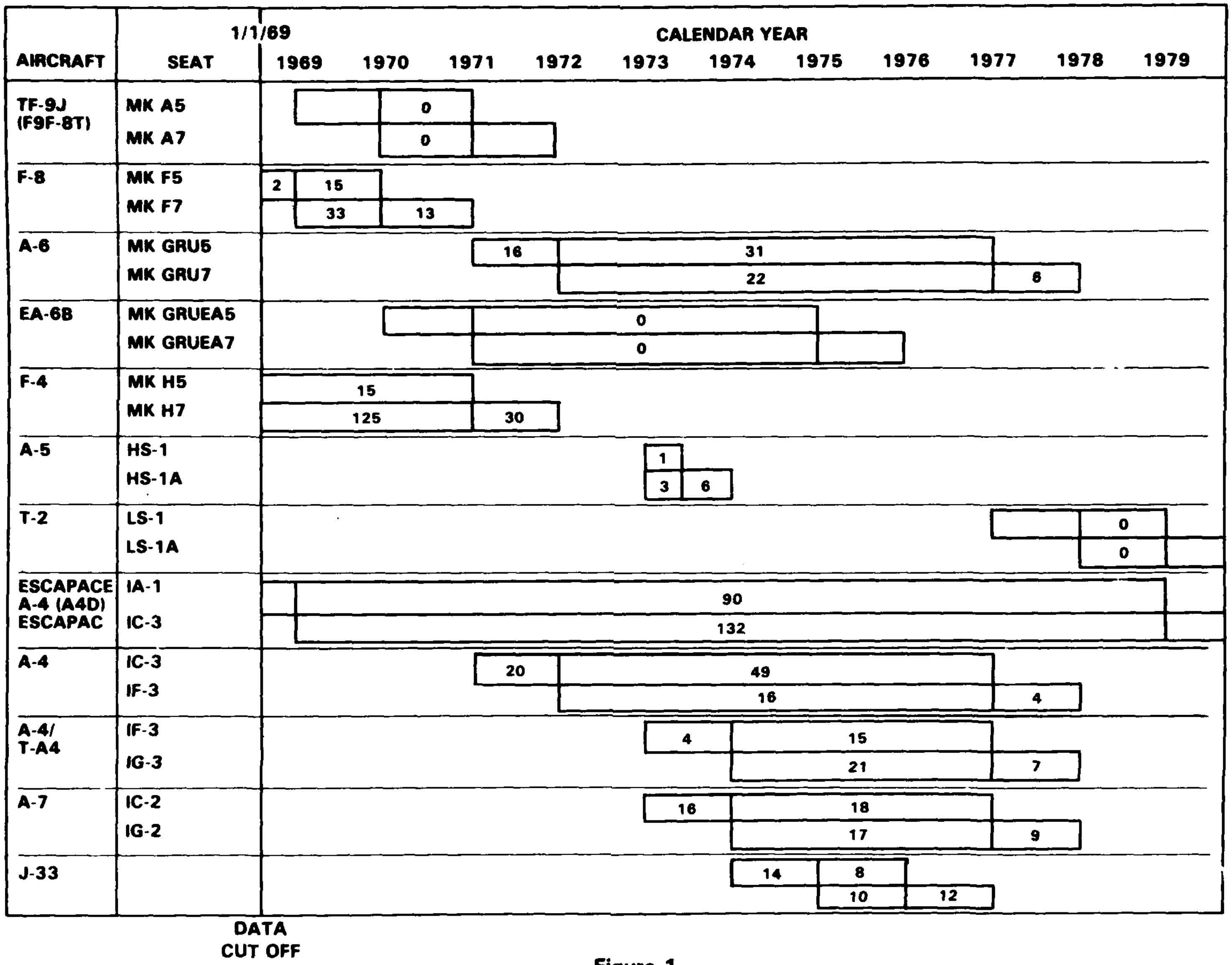


Figure 1

EJECTION SEAT USAGE
DURATION OF U.S. NAVY EJECTION SEATS TRANSITION PERIODS WHEN UPGRADING
(1 JANUARY 1968 THROUGH 31 DECEMBER 1979)

AIRCRAFT	SEAT	25 PRECEDING	TRANSITION	25 FOLLOWING
TF-9J (F9F-8T)	MK A5		0	
	MK A7		0	
F-8	MK F5	2 TOT/1 OTHER/1 FAT	15 TOT/1 MAJ/11 OTHER/3 FAT	
	MK F7		33 TOT/2 MAJ/30 OTHER/1 FAT	25 TOT/2 MAJ/18 OTHER/5 FAT
A-6	MK GRU5	16 TOT/1 MAJ/9 OTHER/6 FAT	31 TOT/8 MAJ/14 OTHER/9 FAT	
	MK GRU7		22 TOT/6 MAJ/10 OTHER/6 FAT	25 TOT/5 MAJ/20 OTHER
EA-6B	MK GRUEA5		0	
	MK GRUEA7		0	
F-4	MK H5		15 TOT/4 MAJ/10 OTHER/1 FAT	
	MK H7		125 TOT/10 MAJ/96 OTHER/19 FAT	25 TOT/4 MAJ/19 OTHER/2 FAT
A-5	HS-1		1 TOT/1 MAJ3 TOT/3 OTHER	
	HS-1A		24 TOT/3 MAJ/16 OTHER/5 FAT	6 TOT/1 MAJ/3 OTHER/2 FAT
T-2	LS-1		0	
	LS-1A		0	
ESCAPACE A-4 (A4D) ESCAPAC	IA-1		90 TOT/12 MAJ/64 OTHER/14 FAT	
	IC-3		132 TOT/21 MAJ/94 OTHER/17 FAT	
A-4	IC-3	25 TOT/5 MAJ/18 OTHER/2 FAT	49 TOT/5 MAJ/33 OTHER/11 FAT	
	IF-3		16 TOT/4 MAJ/9 OTHER/3 FAT	4 TOT/3 OTHER/1 FAT
A-4/ T-A4	IF-3	5 TOT/2 MAJ/3 OTHER	15 TOT/2 MAJ/9 OTHER/4 FAT	
	IG-3		21 TOT/5 MAJ/13 OTHER/3 FAT	25 TOT/4 MAJ/15 OTHER/6 FAT
A-7	IC-2	25 TOT/1 MAJ/17 OTHER/7 FAT	18 TOT/3 MAJ/11 OTHER/4 FAT	
	IG-2		17 TOT/1 MAJ/13 OTHER/3 FAT	25 TOT/8 MAJ/11 OTHER/6 FAT
J-33		25 TOT/6 MAJ/18 OTHER/1 FAT	8 TOT/1 MAJ/7 OTHER	
			10 TOT/1 MAJ/7 OTHER/2 FAT	25 TOT/5 MAJ/12 OTHER/8 FAT

Figure 2

EJECTION SEAT USAGE
DURATION OF U.S. NAVY EJECTION SEATS TRANSITION PERIODS WHEN UPGRADING
(1 JANUARY 1968 THROUGH 31 DECEMBER 1979)

AIRCRAFT	SEAT	50 PRECEDING	TRANSITION	50 FOLLOWING
TF-9J (F9F-8T)	MK A5		0	
	MK A7		0	
F-8	MK F5		15 TOT/1 MAJ/11 OTHER/3 FAT	
	MK F7		33 TOT/2 MAJ/30 OTHER/1 FAT	50 TOT/3 MAJ/42 OTHER/5 FAT
A-6	MK GRU5	50 TOT/12 MAJ/32 OTHER/6 FAT	31 TOT/8 MAJ/14 OTHER/9 FAT	
	MK GRU7		22 TOT/6 MAJ/10 OTHER/6 FAT	16 TOT/1 MAJ/9 OTHER/6 FAT
EA-6B	MK GRUEA5		0	
	MK GRUEA7		0	
F-4	MK H5		15 TOT/4 MAJ/10 OTHER/1 FAT	
	MK H7		125 TOT/10 MAJ/96 OTHER/19 FAT	50 TOT/11 MAJ/34 OTHER/5 FAT
A-5	HS-1		1 TOT/1 MAJ	
	HS-1A		3 TOT/3 OTHER	6 TOT/1 MAJ/3 OTHER/2 FAT
T-2	LS-1		0	
	LS-1A		0	
ESCAPACE A-4 (A4D) ESCAPAC	IA-1		90 TOT/12 MAJ/64 OTHER/14 FAT	
	IC-3		132 TOT/21 MAJ/94 OTHER/17 FAT	
A-4	IC-3	50 TOT/12 MAJ/34 OTHER/4 FAT	49 TOT/5 MAJ/33 OTHER/11 FAT	
	IF-3		16 TOT/4 MAJ/9 OTHER/3 FAT	4 TOT/3 OTHER/1 FAT
A-4/ T-A4	IF-3		15 TOT/2 MAJ/9 OTHER/4 FAT	
	IG-3		21 TOT/5 MAJ/13 OTHER/3 FAT	28 TOT/4 MAJ/18 OTHER/6 FAT
A-7	IC-2	50 TOT/4 MAJ/37 OTHER/9 FAT	18 TOT/3 MAJ/11 OTHER/4 FAT	
	IG-2		17 TOT/1 MAJ/13 OTHER/3 FAT	32 TOT/8 MAJ/18 OTHER/6 FAT
J-33		50 TOT/9 MAJ/36 OTHER/5 FAT	8 TOT/1 MAJ/7 OTHER	
			10 TOT/1 MAJ/7 OTHER/2 FAT	31 TOT/6 MAJ/17 OTHER/8 FAT

Figure 3

EJECTION SEAT USAGE
DURATION OF U.S. NAVY EJECTION SEATS TRANSITION PERIODS WHEN UPGRADING
(1 JANUARY 1968 THROUGH 31 DECEMBER 1979)

AIRCRAFT	SEAT	100 PRECEDING	TRANSITION	100 FOLLOWING
TF-9J (F9F-8T)	MK A5		0	
	MK A7		0	
F-8	MK F5		15 TOT/1 MAJ/11 OTHER/3 FAT	
	MK F7		33 TOT/2 MAJ/30 OTHER/1 FAT	58 TOT/4 MAJ/49 OTHER/5 FAT
A-6	MK GRU5	54 TOT/12 MAJ/34 OTHER	8 TOT/8 MAJ/14 OTHER/9 FAT	
	MK GRU7		22 TOT/6 MAJ/10 OTHER/6 FAT	16 TOT/1 MAJ/9 OTHER/6 FAT
EA-6B	MK GRUEA5		0	
	MK GRUEA7		0	
F-4	MK H5		15 TOT/4 MAJ/10 OTHER/1 FAT	
	MK H7		125 TOT/10 MAJ/96 OTHER/19 FAT	100 TOT/14 MAJ/74 OTHER/12 FAT
A-5	HS-1		1 TOT/1 MAJ	
	HS-1A		3 TOT/3 OTHER	6 TOT/1 MAJ/3 OTHER/2 FAT
T-2	LS-1		0	
	LS-1A		0	
ESCAPACE A-4 (A4D) ESCAPAC	IA-1		90 TOT/12 MAJ/64 OTHER/14 FAT	
	IC-3		132 TOT/21 MAJ/94 OTHER/17 FAT	
A-4	IC-3	83 TOT/16 MAJ/61 OTHER/6 FAT	49 TOT/5 MAJ/33 OTHER/11 FAT	
	IF-3		16 TOT/4 MAJ/9 OTHER/3 FAT	4 TOT/3 OTHER/1 FAT
A-4/ T-A4	IF-3		15 TOT/2 MAJ/9 OTHER/4 FAT	
	IG-3		21 TOT/5 MAJ/13 OTHER/3 FAT	28 TOT/4 MAJ/18 OTHER/6 FAT
A-7	IC-2	100 TOT/16 MAJ/71 OTHER/13 FAT	18 TOT/3 MAJ/11 OTHER/4 FAT	
	IG-2		17 TOT/1 MAJ/13 OTHER/3 FAT	32 TOT/8 MAJ/18 OTHER/6 FAT
J-33		100 TOT/15 MAJ/72 OTHER/13 FAT	8 TOT/1 MAJ/7 OTHER	
			10 TOT/1 MAJ/7 OTHER/2 FAT	31 TOT/6 MAJ/17 OTHER/8 FAT

Figure 4

U.S. NAVY EXPERIENCE WITH SIDE-BY-SIDE UNSEQUENCED ESCAPE IN A-6 SERIES AIRCRAFT, LESSONS TO BE LEARNED
(1 JANUARY 1969 THROUGH 31 DECEMBER 1979)

Frederick C. Guill

ABSTRACT

U.S. Navy A-6 series two-place aircraft are unique among current Navy escape system equipped aircraft in that crew escape is initiated independently by each crewmember and not automatically sequenced upon the initiaton of escape by one of the crew. The reasons for this difference are discussed and the consequences examined.

U.S. NAVY EXPERIENCE WITH SIDE-BY-SIDE UNSEQUENCED ESCAPE IN A-6 SERIES AIRCRAFT LESSONS TO BE LEARNED

(1 January 1969 through 31 December 1979)

Frederick C. Guill

BACKGROUND

As the U.S. Navy upgraded its Mk5 Series (groundlevel escape at take-off and landing speeds) Martin-Baker ejection seats to Mk7 Series (zero/zero escape capability), interseat sequencing was incorporated in two place tandem cockpit aircraft such as the F-4 series and the TF-9J. Sequencing already had been incorporated in several other two place tandem cockpit aircraft such as the T-2 and A-5 series with different types of ejection seats. Sequencing in tandem cockpit aircraft equipped with rocket motor propelled ejection seats was deemed necessary to assure that the front seat would not pass over the rear seat crewmember, subjecting him to direct impingement of the seat propulsion rocket blast, and, in view of the potential difficulty in communicating between cockpits in an emergency, to ensure that both crewmen could be ejected when necessary by one crewmember in the minimum time consistent with precluding collisions or other detrimental post-ejection interactions with jettisoned canopies, seats or ejectees.

For the two place side-by-side A-6 series aircraft, there was not the potential for direct impingement of rocket blast upon a rear crewman and it was the opinion of Navy escape systems experts, fleet personnel, and the contractor that crew cockpit discipline would ensure the rapid egress of both crewmembers when the situation demanded ejection for crew survival.

SCOPE OF STUDY

Recently, reports for each individual A-6 aircraft mishap occurring during the eleven year period from 1 January 1969 through 31 December 1979 were examined to ascertain whether any improvements in the present system were required or highly desirable. Since the issue of incurring the added expense of sequencing for side-by-side two place aircraft or, alternatively, relying upon crew cockpit discipline may be encountered in future designs, this paper is limited to discussing only that one issue. Discussions of other aspects of the A-6 escape system design, e.g., the effects of the fore-and-aft centerline canopy structural beam on through-the-canopy ejection, which might also be faced in future two place side-by-side aircraft are discussed in another paper.

THE DATA

The data examined concern two place A-6 series aircraft (i.e., no EA-6B four place aircraft) mishaps occurring between 1 January 1969 through 31 December 1979 and involve two types of ejection seats: Mk GRU5 which provided groundlevel escape capability at take-off and landing speeds, although without providing safe escape during brief close-to-the-ground phases of each of those evolutions due to aircraft attitude and sinkrate, and Mk GRU7 which provided a zero/zero escape capability and coverage for those take-off and landing phases which had been outside the capability of the Mk GRU5 ejection seat. During the period examined, as depicted in Figure 1, there were 95 A-6 Series aircraft (excluding EA-6B) mishaps involving 188 aircrewmen and of those, 133 aircrewmen attempted ejection. Of those 133 attempting ejection, 104 did so successfully and 29 were fatalities. Twenty-four (24) of the ejection attempts were reported to have occurred outside the envelope. Among these 24 were 7 in which the other crewmember ejected within the envelope, one was believed probably to have ejected out of envelope, twelve (both crewmembers) were reported to have ejected outside the system's performance envelope (one of whom survived), and three appear to have crashed with the aircraft. In six instances among 55 non-attempts, the other crewmember ejected within the envelope. In each of these latter instances, had interseat sequencing been installed, the data suggest that both crewmembers would have been ejected within the escape system's performance envelope.

As a consequence of the ongoing efforts to create computerized ejection and bailout logs for the period from August 1949 through 31 December 1968, it is expected that the A-6 dual crew mishap data base will be significantly expanded during the next year. These earlier A-6 mishaps all involved aircraft equipped with the Mk GRU5 ejection seat, but, nonetheless, can be expected to further clarify and define many of the problems resulting from reliance upon crew cockpit discipline to ensure that all crewmembers safely escape.

PROBLEMS EXPERIENCED WITH NON-SEQUENCED, "COCKPIT DISCIPLINE" ESCAPE IN THE SIDE-BY-SIDE CONFIGURATION

Many of the A-6 ejections and non-ejections examined involved a breakdown in inter-crew communications and/or crew cockpit discipline. In several instances one crewmember, recognizing the developing situation, unduly risked his own life by delaying his own ejection in an attempt to induce the other crewmember to eject, situations which could have been avoided were the seats sequenced allowing initiation of both seat ejections with the actuation of one seat's firing control.

During the period studied, 1 January 1969 through 31 December 1979, there were eleven such instances as follows.

Case 1

FRP raised the nose and rolled inverted. The nose fell through and when there was no attempt to recover, the instructor ordered the pilot to pull out. There was no response from the pilot. The aircraft was in a nose down inverted attitude and the instructor pilot ejected. He sustained major injuries.... The FRP ejected just prior to impact, but outside envelope.

Case 2

Pilot told B/N three times to eject. When B/N failed to comply, pilot reached for face curtain. B/N then reached for his.

Case 3

After night catapult launch, aircraft began to settle and impacted the water. B/N, who had his hand on the face curtain ejected himself at moment of impact and was rescued with minor injuries. The pilot apparently made no attempt to eject and was lost with the aircraft.

Case 4

At the onset of the emergency the aircraft was in the safe ejection envelope. Pilot was not wearing his oxygen mask; pilot inability to communicate (due to lack of oxygen mask) the seriousness of the rapidly developing situation to B/N possibly explains delay of ejection until outside the envelope.

Case 5

Aircraft became uncontrollable - pilot ejected at 200 ft and was not injured. B/N did not eject - fatally injured.... Pilot delayed ejection after aircraft was beyond recovery and did not inform B/N of his intention to eject.

Case 6

B/N ejected immediately after impact at 430 KIAS. At impact the left wing broke off on ridgetop and fuselage was slapped down on ground, sliding over ridgetop. B/N reached for lower ejection handle with difficulty because the rotational acceleration force threw him to right. First pull of lower ejection handle was not forceful enough. Second pull was successful.... Pilot had no right side support, as B/N had, during rotational acceleration and may have been pushed too far right, preventing him from reaching ejection handle.

Case 7

B/N ejected at estimated 25 ft, 350 KIAS, nose down, 45 degrees left bank with aircraft rolling left, and with high sink rate. Pilot followed at much lower altitude, possibly inverted and impacted water immediately after parachute opening shock. Pilot breathed emergency oxygen underwater, surfaced, inflated and boarded raft.

Case 8

B/N, realizing extremis, told pilot to eject and then ejected himself. B/N was rescued with major injuries. Pilot did not eject and sustained massive injuries on impact.

Case 9

On night combat launch, radar became dislodged during catapult stroke. The radar was forced against control stick causing uncontrolled flight. B/N ejected and was rescued with minor injuries. Pilot apparently did not attempt to eject and was lost with aircraft.

Case 10

Pilot ejected at 12,000 ft, 250 KIAS - B/N at 1500 ft, 400 KIAS. Aircraft snap rolling. Negative G's. B/N forced up in cockpit, unable to reach lower handle, pulled face curtain around shoulder to initiate ejection.

Case 11

The pilot of an out of control A-6 at low altitude ordered the B/N to eject and finally struck him on the chest to induce him to eject. The B/N delayed even though the canopy had just been jettisoned to put on his flight gloves. Even though both escapes were successful, they were unnecessarily marginal. The delay caused by the B/N donning his flight gloves could have been eliminated by a sequencing subsystem.

In addition, in this year (1983) there recently occurred yet another documented case wherein breakdown in crew discipline resulted in delayed ejections, the B/N's delayed ejection proved fatal and the pilot was saved when his parachute snagged in tree tops. With both engines shut down and the aircraft out of control, the B/N asked whether he should eject and was firmly told "Eject. Eject." Nonetheless until the pilot struck him and shook his fist in his face the B/N did not initiate his escape. His delay nearly proved fatal for both crewmembers.

There are additional cases with no survivors in which there is sufficient information concerning the circumstances and the crew's character to suggest that in several out of envelope ejection and several non-ejection mishaps, that lack of inter-seat sequencing might have caused the fatal delay or non-ejection.

CONCLUSION

There now exists, after more than a decade of A-6 mishaps recorded in the available portion of the Naval Safety Center's mishap record files, a considerable body of evidence suggesting that a major step which could and should be taken to enhance aircrew survival from disabled A-6 and future two-place side-by-side aircraft would be to replace the present reliance on crew cockpit discipline with a simple inter-seat sequencing system.

Data prepared by Messrs. Robert Cox and Tom Henke.

TWO PLACE A-6 SERIES AIRCRAFT MISHAPS EJECTIONS vs. NON-EJECTIONS

1 JANUARY 1969 THROUGH 31 DECEMBER 1979

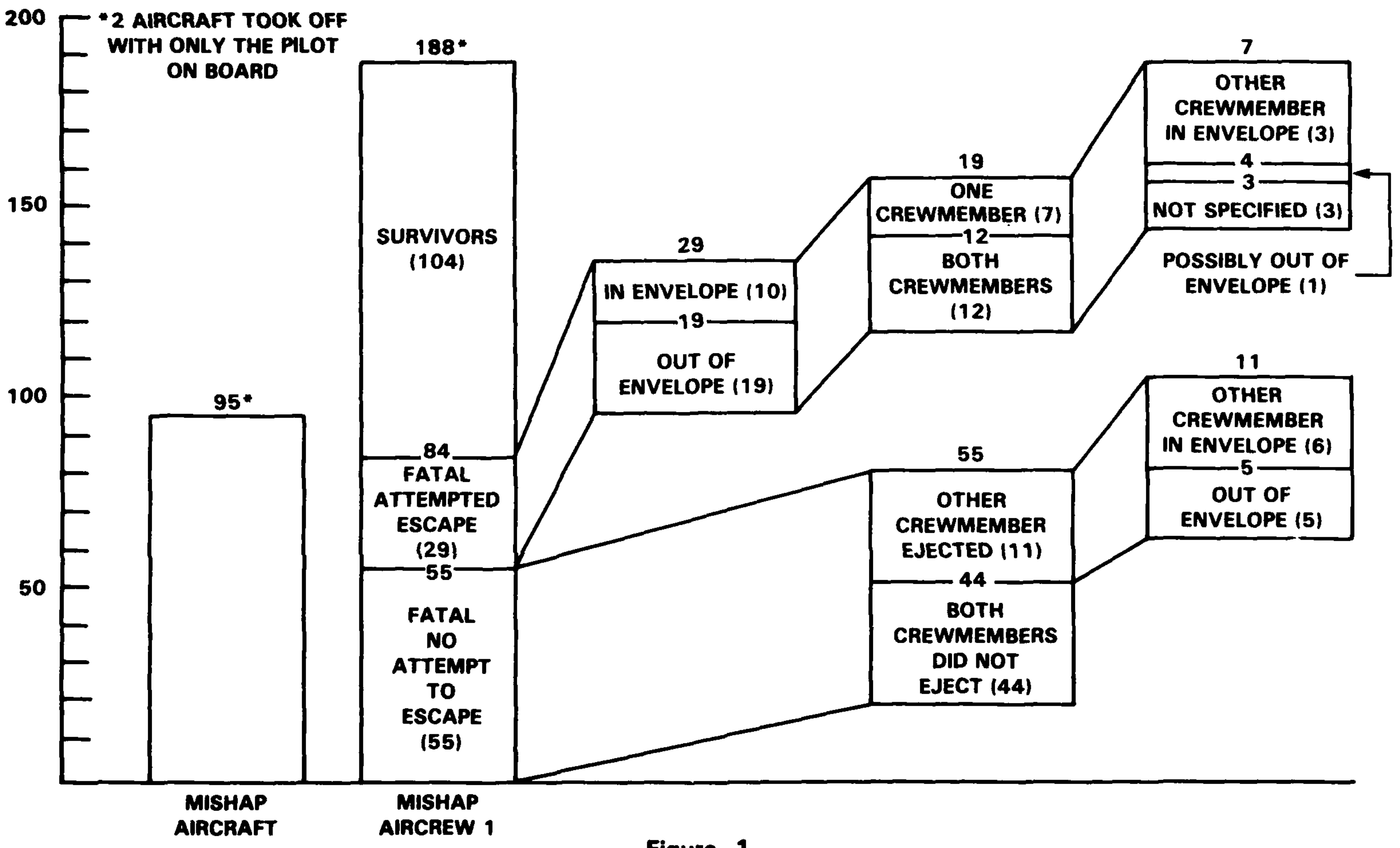


Figure 1

AIRCREW LIFE SUPPORT SYSTEMS (ALSS) EQUIPMENT PRESENCE, USAGE AND DAMAGE DURING U.S. NAVY A-6 SERIES AIRCRAFT EJECTIONS: A PRELIMINARY STUDY

(1 JANUARY 1969 THROUGH 1 DECEMBER 1972)

Frederick C. Guill

ABSTRACT

Of critical interest to the escape system designer and to the designer of survival type life support equipments is whether such equipments sustain damage during escape which impairs equipment functioning in a manner which may lead to aircrew injury or loss. In a pilot study to evaluate the value of acquiring from original reports listings of equipments used by ejectees, 64 A-6 ejectee life support equipment configurations were obtained. These data provided for these 64 ejectees equipment factor vs. usage rate data and, in addition suggested that at least for some equipments the damage incurred frequently is not reported. A conceptual means for examining these data for unreported damage has been proposed, is being examined and is briefly discussed.

AIRCREW LIFE SUPPORT SYSTEMS (ALSS) EQUIPMENT PRESENCE, USAGE AND DAMAGE DURING U.S. NAVY A-6 SERIES AIRCRAFT EJECTIONS A PRELIMINARY STUDY

(1 January 1969 through 31 December 1972)

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INTRODUCTION

In an earlier paper[1] an enumeration was made in several formats of the various factors cited for combinations of aircrew automated escape systems (AAES) and aircrew life support systems (ALSS) equipments involved in escape attempts during the period from 1 January 1969 through 31 December 1979. The enumeration was based upon the data contained in the Naval Safety Center, Norfolk, MOR/FSR (Medical Officer's Report/Flight Surgeon's Report) computer tapes. For many reasons ALSS equipments were included in these computer tapes generally only if in the original MOR/FSR one or more factors considered noteworthy with respect to its availability, usage, usefulness, and/or performance (e.g., lost, caused injury, prevented injury, failed to function, useful in locating survivor, etc.) had been noted. Furthermore, due to the need to codify the information to simplify the data storage, retrieval, and general analyses, the information contained on the computer tapes, necessarily lacked detail; detail which often would be considered significant or, in some cases crucial, by those formulating requirements and/or attempting to ascertain whether to, or who to have, undertake remedial action and, if action is to be taken, what type(s) of action to initiate.

Thus, as discussed in the earlier paper, the available data could not be ranked readily in terms of frequency of occurrence and/or severity of the problem or consequences of occurrence; information especially critical in justifying funding requests for remedial actions to correct problems discovered in in-service AAES and for allocating the available scarce AAES and ALSS resources for optimal impact on aircrew safety.

PILOT PROGRAM

In April 1983, as a trial effort, data were extracted from the original MORs for 64 A-6 crewmembers concerning the ALSS each wore, carried or otherwise had available during the reported emergency. In addition, when available in these documents, information was extracted concerning the exact configuration (model numbers, part numbers, Aircrew Systems Changes incorporated, etc.) and recovered condition (marks, strains, cuts, tears, rips, broken parts, non-functioning elements, etc.) of these equipments. Limited resources and time available for extracting these data and the time required to locate each mishap and extract the data accurately, limited the period researched to 1 January 1969 through 31 December 1972.

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[1] Aircrew Life Support Systems (ALSS) Equipment Aspects of U.S. Navy Ejections, 1 January 1969 through 31 December 1979 by Frederick C. Guill presented at the 20th Annual SAFE Symposium, December 1982

Following the extraction of the data, Naval Weapons Engineering Support Activity, Washington, D.C., personnel encoded the ALSS equipment lists employing the same codification system used by the Naval Safety Center, Norfolk, and then verified their accuracy; a task only recently completed both because of the complexity of the task and the requirement to continue to pursue a multitude of other projects as well as the primary program objectives with limited staff. No effort has as yet been initiated to computerize the ALSS equipment recovered condition information which was acquired at the same time for some of these cases. This effort was undertaken as a pilot program to ascertain the potential value of, and probable cost and time required for reviewing all aviation mishap MORs/FSRs and extracting these data for all mishap crewmembers. This pilot program was piggybacked onto another effort then underway to identify more completely and define A-6 series aircraft escape problems. Time, funding and staffing limitations constrained the effort so that only the data for 64 crewmembers were recorded.

THE DATA

As shown in Table I, the ALSS equipment data contained in this particular sampling of MORs was very complete. (So complete that it far exceeded this researcher's most optimistic expectations.) Table I also depicts the onboard and the not available status for these same equipments as listed in the Naval Safety Center MOR/FSR computer tapes.

These newly extracted data studied permit, for example, a determination that among these 64 mishap aircrewmen exactly five wore anti-exposure suits (four ejecting over and descending upon land and one over and into water). In most cases, however, these data, while not permitting such precise determination of the numbers of equipments actually present/available during these 64 mishaps, did vastly reduce the uncertainty associated with the MOR/FSR computer tapes as to how many articles were actually worn or available. For example, the data show that at least 48 CS/FRP summer flying coveralls were worn whereas the MOR/FSR computer tape for these same cases referenced only one use. Tables II through XVI provide several individual case comparisons between the two sources of data to illustrate the variability in the completeness of ALSS equipment coverage of both sources.

One of the more interesting findings has been the comparison of certain injuries (body part injured and the type and severity of the injury) and the reportage of damage to the ALSS equipments located over the site of injury. In the case of lacerations, punctures, perforations, and similar types of injuries, for example, occurring at a site beneath a flight suit or other garment, it would seem highly unlikely that the garment could escape damage. Nonetheless, many such injuries inexplicably are not accompanied with reports of such garment damage. Table XVII provides several examples illustrating this problem.

FUTURE PLANS

The results of this pilot survey suggest strongly that acquisition of the MOR/FSR listed equipment will be difficult and lengthy, but will provide information in sufficient quantity and quality to enhance our understanding of ALSS equipment failures and successes, deleterious interactions between some elements of certain AAES and some ALSS equipments, as well as aiding in the ranking of equipment problems and adverse interactions with AAES. This improved understanding could enhance (1) future ALSS and AAES design requirements, (2) identification and improved definition of ALSS problems and adverse interactions between ALSS and AAES, (3) decision making concerning the allocation of the scarce ALSS and AAES funds and other resources to resolve problems occurring with current ALSS and AAES equipments, and (4) aid in justifying requests for additional resources required for resolving these identified problems. Accordingly, a formal request has been made to the Naval Safety Center, Norfolk, by the Naval Weapons Engineering Support Activity, Washington, D.C., for permission to extract these data for all aviation mishap aircrew to permit fuller definition and better ranking of ALSS equipment problems.

Consideration is also being given within this program to developing a tool for use by both activities for assessing the probable location and nature of ALSS equipment damage to enable the medical officer responsible for the preparation of the FSR to be queried early, hopefully before materials are lost, in the event damage has not been reported in his FSR, yet other furnished information such as injury data suggest that damage in fact was highly likely to have occurred. As presently envisioned, that tool would be the computer reading of the injury markings displayed on OPNAV form 3752/4, page 3 (Figure 1), to which will be added the crew anthropometric data and the ALSS equipment identified as worn, carried or present during the mishap (Figures 2 through 8) to automatically compare the injury type and location to the equipments to suggest equipment areas which might have sustained damage during the production of the injury (Figures 9 through 12). This not only will permit querying the FSR author(s) concerning the condition of suspect equipments, but will also aid in the generation of equipment damage/potential damage patterns which might enable determination of damage/injury causation mechanisms which might otherwise not be detected or recognized as being significantly frequent in occurrence, defined or resolved.

CONCLUSION

This limited feasibility study has demonstrated that greater detail than that normally available from Naval Safety Center, Norfolk, computerized extracted MOR/FSR data concerning the ALSS equipments involved in mishaps exists for many of these mishaps. It also has demonstrated that ALSS equipment problems are probably being underreported in the original documentation, thereby reducing the quantity and the quality of the data normally available from the Naval Safety Center MOR/FSR computer tapes. It appears feasible to develop a system which by identifying some of the potential ALSS equipment damage, might bring about a reduction in this underreportage. Unfortunately, this feasibility effort, clearly identified that closing the existing ALSS equipment usage and problem knowledge gap will require considerable time and, as yet, unidentified resources. Accordingly, no estimate can be made at this time as to if, and when, such detailed records can be created and evaluated.

Data was prepared by Mr. Tom Henke

TABLE I

TRIAL SAMPLE COMPARISON

Report Date : 09/12/83
Program: MORVSOPN

Personal, Survival, and Escape Equipment Counts
MOR Equipment Page (OPNAV Form 3750.8E) vs. NAVSAFECEN Computerized Data
FOR A-6 SERIES EJECTIONS
ALL TERRAINS --- (64 EJECTEES)

Data From 1 Jan '69 - 31 Dec '72
PAGE 1 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION		OPNAV Form 3750.8E Counts	MOR Master File Counts	
		ABOARD	ABOARD	NOT ABOARD
0101	CS/FPP-1 Summer Flying Coverall	48	01	00
0103	CWU-1/P Intermediate Flying Coverall	02	00	00
0197	Other - NEC Flight Suit	01	00	00
0198	Non-Regulation Flight Suit	01	00	00
0199	Type flight suit not specified	09	00	00
0301	MK-2 Coverall	04	01	01
0302	MK-2A Cutaway Coverall	19	00	00
0399	Type anti-G suit not specified	07	00	02
0402	MK-5A Anti-exposure suit (Complete Suit)	05	03	02
0404	MK-5A Anti-exposure Insulation-ventilation liner	02	00	00
0405	MK-5A Anti-exposure gloves	01	00	00
0501	APH-6A Helmet	23	04	00

NOTE : arrows indicate zero counts

TABLE I (Continued)

Report Date : 09/12/83
Program: MCRVSOPN

Personal, Survival, and Escape Equipment Counts
MOR Equipment Page (OPNAV Form 3750.8E) vs. NAVSAFECEN Computerized Data

Data From 1 Jan '69 - 31 Dec '72
PAGE 2 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION	OPNAV Form 3750.8E Counts	MOR Master File Counts	
	ABOARD	ABOARD	NOT ABOARD
0602 APH-6B Helmet	06	02	00
0603 APH-6C Helmet	20	11	00
0605 APH-6 Helmet (MOD not specified)	09	02	00
0699 Other helmet type not specified	03	02	00
0705 Single visor	08	05	01
0706 Dual visor	17	05	00
0798 Other Helmet Accessories	02	00	00
0801 Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	48	12	05
0898 Gloves---Other	04	00	01
0899 Gloves--Type not specified	04	00	00
0901 Boot, flying(MIL-B-21408) steel toe	60	15	00
0902 Boot/shoe, steel toe, other than flying	02	00	00
0999 Shoes/Boots--Type not specified	02	00	00

NOTE : arrows indicate zero counts

TABLE I (Continued)

ENCLOSURE (1)

```
Report Date : 09/12/83              Personal, Survival, and Escape Equipment Counts              Data From 1 Jan '69 - 31 Dec '72
Program: MORVSOPN          MOR Equipment Page (OPNAV Form 3750.3E) vs. NAVSAFECEN Computerized Data          PAGE  3 OF  9
*******************************************************************************************************************************

                                        ........................................
                                        .                                      .
                                        .   EQUIPMENTS SHOWN ARE ONLY THOSE CITED  .
                                        .                                      .
                                        ........................................

   EQUIPMENT CODE & DESCRIPTION                                OPNAV Form 3750.3E Counts          MOR Master File Counts
   ----------------------------                               --------------------------         ----------------------
                                                              /          ABOARD          \       / ABOARD    NOT ABOARD \
                                                                         ------                    ------    --- ------

 1004  Thermal underwear                                                   16                        00          00

 1093  Clothing--Other                                                     14                        00          00

 1201  A-13A                                                               57                        14          00

 1205  Sierra 756                                                          02                        00          00

.................................................................................................................
 1293  Mask--Other                                                         03                        00          00

 1299  Mask--Type not specified                                            00                        01          00

 1302  Bendix, mini-reg                                                    13                        00          00

 1303  Robertshaw Fulton, mini-reg                                         02                        00          00

.................................................................................................................
 1304  Mini-reg, Type not specified                                        04                        00          00

 1305  Seat mounted regulator                                              07                        00          00

 1393  Other (oxygen regulators)                                           20                        00          00

 1399  Type oxygen regulator not specified                                 02                        00          00

.................................................................................................................
 1405  Oxygen hose                                                         00                        01          00

                                             NOTE : arrows indicate zero counts
```

TABLE I (Continued)

[illegible]
[illegible]

Personnel, Survival, and Escape Equipment Counts
[illegible] Equipment Code (OPNAV Form 3750.35) vs. NAVSAFECEN Computerized Data

Data From 1 Jan '69 - 31 Dec '72
PAGE 4 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION	OPNAV Form 3750.35 Counts	MOR Master File Counts	
	ABOARD	ABOARD	NOT ABOARD
1498 Other (Oxygen Systems/Supply/Components)	00	01	00
1601 LPA-1	31	13	01
1602 LPA-1A	04	00	00
1603 LPA-2	04	01	00
1604 MK-3C	19	00	00
1699 Type life vest not specified	01	00	00
1701 LR-1	46	10	00
1702 LR-1 (Special Helo Configuration)	02	00	00
1797 Pararaft Life Raft, PK-2 (ESA)	02	00	00
1798 Other-N.E.C. (life raft)	06	00	00
1799 Type life raft not specified	04	00	00
1306 PRC-49	01	00	01
1307 PRC-63	39	05	02

NOTE : arrows indicate zero counts

TABLE I (Continued)

Report Date : [illegible]/12/[illegible] Personnel, Survival, and Escape Equipment Counts Data From 1 Jan '69 - 31 Dec '72
Program: [illegible] [illegible] Equipment Page (OPNAV Form 3750.88) vs. NAVSAFECEN Computerized Data Page 5 of 5

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION	OPNAV Form 3750.88 Counts	MOR Master File Counts	
	ABOARD	ABOARD	NOT ABOARD
1303 PRC-90	16	02	00
1314 URT-33	28	03	03
1315 RT-60	06	02	00
1399 Type survival radio not specified	00	00	01
1901 Flaregun, MK 79 MOD 0	34	06	01
1902 Signal light, strobe SDU-5/E	54	05	01
1904 Distress signal, day/night, MK13 MOD 0	50	18	00
1905 Signal mirror	49	01	00
1906 Dye marker	25	06	00
1907 Whistle	42	02	00
1908 Pistol (with tracers or signal cartridges)	01	00	00
1909 Penlight	02	00	00
1910 Hand generated flashlight (in multi-place raft onl	04	00	00

NOTE : arrows indicate zero counts

TABLE I (Continued)

```
Report Date : 08/12/83                Personal, Survival, and Escape Equipment Counts                        Data From 1 Jan '69 - 31 Dec '72
Program: MORVSOPN          MOR Equipment Page (OPNAV Form 3750.6E) vs. NAVSAFECEN Computerized Data                     PAGE  6 OF  9
***************************************************************************************************************************************
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ENCLOSURE(1)

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                                         ..............................................
                                         .                                            .
                                         .    EQUIPMENTS SHOWN ARE ONLY THOSE CITED   .
                                         .                                            .
                                         ..............................................

 EQUIPMENT CODE & DESCRIPTION                           OPNAV Form 3750.6E Counts         MOR Master File Counts
 ----------------------------                           -------------------------         ----------------------
                                                       /         ABOARD          \       / ABOARD    NOT ABOARD \
                                                                 ------                    ------    --- ------

1911  Flashlight                                                   04                        02          01
.................................................................................................
1912  Signal panel, flag, etc.                                     04                        02          00
1998  Other signalling devices/lights                              25                        00          00
1999  Signalling equipment type not specified                      05                        00          00
2002  Wrist compass                                                05                        00          00
.................................................................................................
2003  Water bottle, 4 oz.                                          16                        00          00
2004  Suspension line cutter                                       37                        05          00
2005  Survival knife                                               42                        03          00
2006  Shark repellant                                              04                        00          00
.................................................................................................
2007  SEEK-2                                                       32                        00          00
2008  SRU-31/P                                                     03                        00          02
2009  "Space" blanket, lightweight                                 03                        01          00
2010  Personnel lowering device                                    02                        00          00
.................................................................................................

                                   NOTE : arrows indicate zero counts
```

TABLE I (Continued)

Report Date : [illegible] Personally Survival and Escape Equipment Counts Data From 1 Jan '69 - 31 Dec '72
Program: [illegible] [illegible] (OPNAV Form 3750.6E) vs. NAVSAFECEN Computerized Data PAGE 7 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION	OPNAV Form 3750.6E Counts	MOR Master File Counts	
	/ ABOARD \	/ ABOARD	NOT ABOARD \
2012 SV-2A Survival vest	29	05	01
2014 Gun/Pistol	05	01	00
2015 Pocket compass	09	00	00
2016 Water storage bag	02	00	00
2017 Pocket knife	04	00	00
2019 First aid kit	02	00	00
2021 "Space" blanket (other than 2009)	02	00	00
2097 SV-2 Survival Vest, Type not specified (ESA)	05	00	00
2095 Other survival equipment-miscellaneous	55	00	00
2113 SP-1A Seat Pan	04	00	00
2197 Parachute Survival Kit, PK-2 (ESA)	02	00	00
2195 Survival Kit, Other (ESA)	01	00	00
2199 Type seat survival kit not specified	02	01	00

NOTE : arrows indicate zero counts

TABLE I (Continued)

Report Date : 03/12/83 Personal, Survival, and Escape Equipment Counts Data From 1 Jan '69 - 31 Dec '72
Program: MORVSOPN MOR Equipment Page (OPNAV Form 3750.8E) vs. NAVSAFECEN Computerized Data PAGE 3 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION		OPNAV Form 3750.8E Counts	MOR Master File Counts	
		ABOARD	ABOARD	NOT ABOARD
2501	Lap belt	35	01	00
2502	Shoulder harness/inertia reel	26	00	00
2506	Leg restraint	40	03	01
2508	Torso garment MA-2	17	02	00
2509	Torso garment MA-2P	01	00	00
2510	Leg restaint (dual garter)	06	00	00
2596	Torso Garment, Type not specified (ESA)	17	00	00
2599	Other restraints	01	00	00
2631	MBEU 5027	16	00	00
2634	MBEU (other/unk)	37	22	00
2633	NES-14A	02	02	00
2699	Parachute, Other/Unknown	03	00	00
2705	Manual D-ring	03	01	00

NOTE : arrows indicate zero counts

TABLE I (Continued)

Report Date : [illegible]
Program: [illegible]

Personal, Survival, and Escape Equipment Counts
MOR Equipment File (OPNAV Form 3750.8E) vs. NAVSAFECEN Computerized Data

Data From 1 Jan '69 - 31 Dec '72
PAGE 9 OF 9

ENCLOSURE(1)

EQUIPMENTS SHOWN ARE ONLY THOSE CITED

EQUIPMENT CODE & DESCRIPTION		OPNAV Form 3750.8E Counts	MOR Master File Counts	
		ABOARD	ABOARD	NOT ABOARD
2793	Other parachute opening devices/miscellaneous	30	00	00
2799	Parachute Opening Device Unknown	02	00	00
2301	Koch fitting - upper	43	15	00
2306	Harley buckle	09	05	00
2393	Other canopy/harness releases	05	00	00
3402	Life raft lanyard	00	03	00
3501	Life vest inflator	00	01	00
9999	General equipment	00	06	00

Data summarized under column entitled "OPNAV Form 3750.8E Counts" was extracted from each original MOR (Medical Officer's Report) for A-6 series mishaps occurring during the period 1 January 1969 through 31 December 1972. Data summarized in the column entitled "MOR Master File Counts" was extracted from NAVSAFECEN supplied computerized MOR data tapes for each of the cases represented in the first column and includes equipments cited for their absence. Data presented above represents that presented in both data sources for 64 A-6 series mishap aircrewmen, including 53 classified as ejection codes 1 or 5.

TABLE I (Continued)

```
Report Date : 05/12/83        EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)
                                          EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT       For 54 A-5 Series Ejections From 1 Jan '69 - 31 Dec '72
********************************************************************************************************

                  INTERPRETIVE LIST OF INJURY SEVERITY & PHASE CODES
                  --------------------------------------------------

                    PHASE                              SEVERITY
                    -----                              --------

                  A - Accident                       9 - Unknown
                  D - Descent                        A - Fatal
                  E - Escape/Egress                  B - Major
                  L - Landing                        F - Minor
                  R - Rescue                         M - Minimal
                  S - Survival
```

ENCLOSURE(2)

****

TABLE II

****

Report Date : 08/12/83

EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)
EQUIPMENT FACTORS AND INJURIES (PART 2)
For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72

ENCLOSURE(2)

Programs: IATATIME & INJ/FACT

Record 5 of 64

REFERENCE NUMBER - 0084   A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E	MOR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0706	Dual visor	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	X		
0901	Boot, flying(MIL-B-21406) steel toe	X		
1604	Thermal underwear	X		
1201	A-13A	X	X	
1302	Bendix, mini-reg	X		
1405	Oxygen hose		X	
1498	Other (Oxygen Systems/Supply/Components)		X	
1608	MK-3C	X		
1699	Type life vest not specified	X		
1798	Other-N.E.C. (life raft)	X		
1807	PRC-63	X		
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
1905	Signal mirror	X		
1907	Whistle	X		
2003	Water bottle, 4 oz.	X		
2004	Suspension line cutter	X		
2005	Survival knife	X		
2007	SEEA-2	X		
2098	Other survival equipment-miscellaneous	X		
2501	Lap belt	X		
2502	Shoulder harness/inertia reel	X		
2506	Leg restraint	X		
2604	MBEU (other/unk)	X	X	
2798	Other parachute opening devices/miscellaneous	X		
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE II (Continued)

REFERENCE NUMBER - 0084   A/C   A006A

EQUIPMENT INFORMATION

Code	Description	Factors
1201	A-13A	25 Improper use (other)
1405	Oxygen hose	06 Damaged-major
1498	Other (Oxygen Systems/Supply/Components)	17 Release/disconnect failure 06 Damaged-major
2604	PBEU (other/unk)	10 Failed to operate (radio, actuator, 49 Maintenance/Installation error 45 Equipment problem (loss, failure, et

INJURY INFORMATION

Injury Classification = A - Fatal

Body Part		Diagnoses	Sev	Ph
Posterior	2nd Cervical Vertebra	Transection	A	L
Unknown	Face	Compound comminuted	9	L
Left	Leg, lower	Fracture, simple	9	L

************ *** TABLE III ***

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**
EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 9 of 64

****

REFERENCE NUMBER - 0204 A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E	MOR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0399	Type Anti-G suit not specified	X		
0601	APH-6A Helmet	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	X	X	
0901	Boot, flying(MIL-B-21408) steel toe		X	
0999	Shoes/Boots--Type not specified	X		
1201	A-13A	X		
1399	Other (oxygen regulators)	X		
1608	MK-3C	X		
1701	LR-1	X	X	
1614	URT-33			X
1901	Flaregun, MK 79 MOD 0	X		
1902	Signal light, strobe SDU-5/E	X	X	
1904	Distress signal, day/night, MK13 MOD 0		X	
1905	Signal mirror	X		
1907	Whistle	X	X	
1998	Other signalling devices/lights	X		
2003	Water bottle, 4 oz.	X		
2312	SV-2A Survival vest	X		
2099	Other survival equipment-miscellaneous	X		
2098	Other survival equipment-miscellaneous	X		
2197	Pararaft Survival Kit, PK-2 (ESA)	X		
2506	Leg restraint	X		
2508	Torso garment MA-2	X		
2604	MEEU (other/unk)	X		
2798	Other parachute opening devices/miscellaneous	X		
2601	Koch fitting - upper	X		
2606	Harley buckle	X	X	

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE III (Continued)

REFERENCE NUMBER - 0204   A/C   A006A

EQUIPMENT INFORMATION

Code	Description	Factors	
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	44	Prevented/minimized injury
0901	Boot, flying(MIL-B-21408) steel toe	25	Improper use (other)
		60	Other (specify)
1701	LR-1	04	Lost
		24	Restraints/attachments not used prop
		60	Other (specify)
1814	URT-33	02	Not available-left behind
		49	Maintenance/Installation error
		60	Other (specify)
1902	Signal light, strobe SDU-5/E	42	Aided in location/rescue
		11	Operated partially
		60	Other (specify)
1904	Distress signal, day/night, MK13 MOD 0	42	Aided in location/rescue
1907	Whistle	42	Aided in location/rescue
2806	Harley buckle	60	Other (specify)

INJURY INFORMATION

Injury Classification = B - Major

Body Part		Diagnoses	Sev	Ph
Right	Ankle	Fracture, simple	8	L

Body Part		Diagnoses	Sev	Ph
Bilateral	Hand, include fingers	Burn, thermal	9	L

Body Part		Diagnoses	Sev	Ph
Anterior	Thorax	Contusion	9	L

************. *** TABLE IV ***

Report Date : 09/12/83 EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**
EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 11 of 64

****

REFERENCE NUMBER - 0258 A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E	MDR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0601	APH-6A helmet	X		
0602	APH-6B Helmet		X	
0706	Dual visor	X		
0898	Gloves---Other	X		
0901	Boot, flying(MIL-B-21408) steel toe	X	X	
1201	A-13A	X		
1603	MK-3C	X		
1701	LR-1	X		
1814	URT-33	X		
1901	Flaregun, MK 79 MOD 0	X		
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
1907	Whistle	X		
2005	Survival knife	X		
2007	SEEK-2	X		
2015	Pocket compass	X		
2017	Pocket knife	X		
2098	Other survival equipment-miscellaneous	X		
2501	Lap belt	X		
2502	Shoulder harness/inertia reel	X		
2604	M2EU (other/unk)	X	X	
2798	Other parachute opening devices/miscellaneous	X		
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE IV (Continued)

REFERENCE NUMBER - 0258 A/C A006A

EQUIPMENT INFORMATION

Code	Description	Factors
0602	APH-6B Helmet	44 Prevented/minimized injury
0301	Boot, flying(MIL-B-21408) steel toe	44 Prevented/minimized injury
2604	MBEU (other/unk)	06 Damaged-major 60 Other (specify)

INJURY INFORMATION

Injury Classification = 8 - Major

Body Part		Diagnoses	Sev	Ph
Left	Leg, upper	Comminuted	8	L

Body Part		Diagnoses	Sev	Ph
Right	Knee	Dislocation	9	E

Body Part		Diagnoses	Sev	Ph
Right	Arm, lower	Laceration	9	E

TABLE V

Report Date : 08/12/83 — EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)

EQUIPMENT FACTORS AND INJURIES (PART 2)

Programs: IATATIME & INJ/FACT — For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72

ENCLOSURE(2)

Record 22 of 64

REFERENCE NUMBER - 0485 A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E CITATIONS	MDR Master File CITATIONS	
Code	Description	ABOARD	ABOARD	NOT ABOARD
0101	CS/FRP-1 Summer Flying Coverall	X		
0302	MK-2A Cutaway Coverall	X		
0603	APH-6C Helmet	X	X	
0706	Dual visor		X	
0801	Gloves, flying(MIL-G-81188) fire resistant(NOMEX)	X	X	
0901	Boot, flying(MIL-B-21408) steel toe	X	X	
1004	Thermal underwear	X		
1201	A-13A	X		
1305	Seat mounted regulator	X		
1608	MK-3C	X		
1701	LR-1	X		
1807	PRC-63	X	X	
1814	URT-33	X		
1901	Flaregun, MK 79 MOD 0	X		
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
1905	Signal mirror	X		
1906	Dye marker	X		
1907	Whistle	X		
2003	Water bottle, 4 oz.	X		
2005	Survival knife	X	X	
2009	"Space" blanket, lightweight	X		
2012	SV-2A Survival vest	X	X	
2098	Other survival equipment-miscellaneous	X		
2501	Lap belt	X	X	
2502	Shoulder harness/inertia reel	X		
2506	Leg restraint	X		
2305	Harley buckle	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE V (Continued)

REFERENCE NUMBER - 0485 A/C A006A

EQUIPMENT INFORMATION

Code	Description
0503	APH-6C Helmet
0706	Dual visor
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)
0901	Boot, flying(MIL-B-21408) steel toe
1807	PRC-63
2005	Survival knife
2012	SV-2A Survival vest
2501	Lap belt

Factors

44 Prevented/minimized injury
04 Lost
60 Other (specify)
25 Improper use (other)
60 Other (specify)

04 Lost

05 Damaged-minor
44 Prevented/minimized injury

04 Lost

04 Lost
23 Restraint/attachment inadequacy

06 Damaged-major
36 Design deficiency

36 Design deficiency
23 Restraint/attachment inadequacy
60 Other (specify)

INJURY INFORMATION

Injury Classification = B - Major

Body Part		Diagnoses	Sev	Ph
Posterior	1st Lumbar Vertebra	Compression	8	E

Body Part		Diagnoses	Sev	Ph
Left	Knee	Contusion	9	E

Body Part		Diagnoses	Sev	Ph
Total (Refers to Body Part)	Skull (Cranium)	Contusion	9	E

TABLE V (Continued)

Body	Body	Diagnoses	Sev	Ph
Right	Elbow	Laceration	9	E

Body	Part	Diagnoses	Sev	Ph
Left	Hand, include fingers	Contusion	9	E

**************. .************************************ **TABLE VI** **

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) ENCLOSURE(2)
EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 23 of 64

****

REFERENCE NUMBER - 0547 A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E	MOR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0302	MK-2A Cutaway Coverall	X		
0601	APH-6A Helmet	X	X	
0706	Dual visor	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	X		
0901	Boot, flying(MIL-B-21408) steel toe	X	X	
1201	A-13A	X	X	
1305	Seat mounted regulator	X		
1601	LPA-1	X	X	
1701	LR-1	X		
1807	PRC-63	X	X	
1901	Flaregun, MK 79 MOD 0	X	X	
1902	Signal light, strobe SDU-5/E	X		
1905	Signal mirror	X		
1907	Whistle	X		
2005	Survival knife	X	X	
2007	SEEK-2	X		
2012	SV-2A Survival vest	X	X	
2014	Gun/Pistol	X	X	
2017	Pocket knife	X		
2113	SP-1A Seat Pan	X		
2506	Leg restraint	X	X	
2508	Torso garment MA-2	X		
2601	MSEU 5027	X		
2798	Other parachute opening devices/miscellaneous	X		
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE VI (Continued)

REFERENCE NUMBER - 0547 A/C A006A

EQUIPMENT INFORMATION

Code	Description	Factors
0601	APH-5A Helmet	04 Lost 33 Poor fit 45 Equipment problem (loss, failure, et 44 Prevented/minimized injury
0901	Boot, flying(MIL-B-21408) steel toe	04 Lost
1201	A-13A	18 Inadvertent release/disconnect 60 Other (specify)
1601	LPA-1	10 Failed to operate (radio, actuator,
1807	PRC-63	04 Lost
1901	Flaregun, MK 79 MOD 0	04 Lost
2005	Survival knife	35 Material deficiency 05 Damaged-minor
2012	SV-2A Survival vest	04 Lost
2014	Gun/Pistol	44 Prevented/minimized injury
2506	Leg restraint	

INJURY INFORMATION

Injury Classification = B - Major

Body Part		Diagnoses	Sev	Ph
Right	Knee	Derangement	8	E

Body Part		Diagnoses	Sev	Ph
Left	Arm, lower	Fracture, simple	9	E

TABLE VI (Continued)

Left	Arm, lower	Fracture, simple		E
Body Part		Diagnoses	Sev	Ph
Right	Elbow	Laceration	9	E
Body Part		Diagnoses	Sev	Ph
Left	Face	Laceration	9	E
Body Part		Diagnoses	Sev	Ph
Right	Knee	Perforation	9	E

TABLE VII

ENCLOSURE(2)

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)
EQUIPMENT FACTORS AND INJURIES (PART 2)
Record 25 of 64

Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72

REFERENCE NUMBER - 0569 A/C A006A

EQUIPMENTS		OPNAV Form 3750.8E	MOR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0301	MK-2 Coverall	X		X
0605	APH-6 Helmet (MOD not specified)	X		
0705	Single visor	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)			X
0901	Boot, flying(MIL-B-21408) steel toe	X		
1201	A-13A	X		
1302	Bendix, mini-reg	X		
1601	LPA-1	X		
1701	LR-1	X		
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
2005	Survival knife	X		
2098	Other survival equipment-miscellaneous	X		
2301	Lap belt	X		
2302	Shoulder harness/inertia reel	X		
2506	Leg restraint	X		
2604	MEBU (other/unk)	X		
2798	Other parachute opening devices/miscellaneous	X		
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE VII (Continued)

REFERENCE NUMBER - 0569 A/C A006A

EQUIPMENT INFORMATION

Code	Description	Factors
0301	PK-2 Coverall	02 Not available-left behind
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	02 Not available-left behinu

INJURY INFORMATION

Injury Classification = 6 - Minimal Inju

TABLE VIII

ENCLOSURE(2)

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************  ******************************************              ****************************************************
Report Date : 08/12/83        EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)
                                         EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT       For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72                 Record 28 of 64
******************************************************************************************************************************

                                                 REFERENCE NUMBER - 0630     A/C   A006C
                                                 -----------------------     ------------

     EQUIPMENTS                                                OPNAV Form 3750.8E              MDR Master File
     ----------                                                ----- ---- -------              --- ------ ----
  Code  Description                                               CITATIONS                      CITATIONS
  ----  -----------                                               ---------                -----------------------
                                                                 / ABOARD \                / ABOARD     NOT ABOARD \
                                                                   ------                    ------     --- ------

  0101  CS/FRP-1 Summer Flying Coverall                              X
  0603  APH-6C Helmet                                                X                         X
  0801  Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)            X
  0901  Boot, flying(MIL-B-21408) steel toe                          X                         X
  1201  A-13A                                                        X
  1304  Mini-reg, Type not specified                                 X
  1601  LPA-1                                                        X                         X
  1701  LR-1                                                         X                         X
  1807  PRC-63                                                       X
  1806  PRC-90                                                       X                         X
  1814  URT-33                                                       X
  1901  Flaregun, MK 79 MOD 0                                        X
  1902  Signal light, strobe SDU-5/E                                 X                         X
  1904  Distress signal, day/night, MK13 MOD 0                       X
  1905  Signal mirror                                                X
  1906  Dye marker                                                   X
  1907  Whistle                                                      X
  2004  Suspension line cutter                                       X                         X
  2005  Survival knife                                               X
  2007  SEEK-2                                                       X
  2012  SV-2A Survival vest                                          X                         X
  2098  Other survival equipment-miscellaneous                       X
  2501  Lap belt                                                     X
  2502  Shoulder harness/inertia reel                                X
  2506  Leg restraint                                                X
  2604  MBEU (other/unk)                                             X                         X
  2801  Koch fitting - upper                                         X                         X

                                                     NOTE
                                                     ----

                              An equipment with code ending in '98', '99', ect. may be listed
                              two or more times as these codes are often 'catch-alls' for
                              unspecified or unknown equipments.
```

TABLE VIII (Continued)

REFERENCE NUMBER - 0630 A/C A006C

EQUIPMENT INFORMATION

Code	Description
0603	APH-6C Helmet
0301	Boot, flying(MIL-B-21408) steel toe
1601	LPA-1
1701	LR-1
1808	PRC-90
1902	Signal light, strobe SDU-5/E
2004	Suspension line cutter
2012	SV-2A Survival vest
2604	MBEU (other/unk)
2801	Koch fitting - upper

Factors

42 Aided in location/rescue

05 Damaged-minor

32 Discomfort/bulkiness
30 Other equipment interfered

03 Discarded

12 Difficulty locating
30 Other equipment interfered

30 Other equipment interfered
42 Aided in location/rescue

12 Difficulty locating
30 Other equipment interfered
30 Other equipment interfered

40 Dragging (parachute only)
39 Entanglement (parachute suspension l

16 Release/disconnect difficulty
30 Other equipment interfered

INJURY INFORMATION

Injury Classification = F - Minor

Body Part		Diagnoses	Sev	Ph
Left	Shoulder	Strain	F	E

Body Part		Diagnoses	Sev	Ph
Bilateral	Leg, upper	Hematoma	9	E

TABLE VIII (Continued)

Bilateral	Leg, upper	Hematoma		E
Body Part		Diagnoses	Sev	Ph
Left	Hand, include fingers	Laceration	9	E

TABLE IX

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********  ******************************************   TABLE IX   ******************************************  *******
Report Date  08/12/83       EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)   ENCLOS  E(a)
                                          EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT       For 54 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72                 Record 31 of 64
*************************************************************************************************************************

                                          REFERENCE NUMBER - 0648      A/C   A006A
                                          -----------------------      ------------

      EQUIPMENTS                                                 OPNAV Form 3750.8E            MDR Master File
      ----------                                                 ----- ---- -------            --- ------ ----
  Code  Description                                                  CITATIONS                     CITATIONS
  ----  -----------                                                  ---------              ----------------------
                                                                    / ABOARD \               / ABOARD     NOT ABOARD \
                                                                      ------                   ------     --- ------

  0101  CS/FRP-1 Summer Flying Coverall                                  X
  0603  APH-6C Helmet                                                    X
  0801  Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)                X
  0901  Boot, flying(MIL-B-21408) steel toe                              X
  1201  A-13A                                                            X
  1304  Mini-reg, Type not specified                                     X
  1601  LPA-1                                                            X                       X
  1701  LR-1                                                             X                       X
  1807  PRC-63                                                           X
  1808  PRC-90                                                           X                       X
  1814  URT-33                                                           X
  1901  Flaregun, MK 79 MOD 0                                            X
  1902  Signal light, strobe SDU-5/E                                     X                       X
  1304  Distress signal, day/night, MK13 MOD 0                           X
  1905  Signal mirror                                                    X
  1306  Dye marker                                                       X                       X
  1907  Whistle                                                          X
  1911  Flashlight                                                                               X
  2004  Suspension line cutter                                           X                       X
  2005  Survival knife                                                   X
  2007  SEEK-2                                                           X
  2012  SV-2A Survival vest                                              X                       X
  2098  Other survival equipment-miscellaneous                           X
  2501  Lap belt                                                         X
  2502  Shoulder harness/inertia reel                                    X
  2506  Leg restraint                                                    X
  2604  MEEU (other/unk)                                                 X                       X
  2801  Koch fitting - upper                                             X                       X

                                              NOTE
                                              ----

                      An equipment with code ending in '98', '99', ect. may be listed
                      two or more times as these codes are often 'catch-alls' for
                      unspecified or unknown equipments.
```

TABLE IX (Continued)

REFERENCE NUMBER - 0648 A/C A006A

EQUIPMENT INFORMATION

Code	Description	Factors
1501	LPA-1	25 Improper use (other)
1701	LR-1	19 Inadvertent actuation
1808	PRC-90	10 Failed to operate (radio, actuator,
1902	Signal light, strobe SDU-5/E	42 Aided in location/rescue
1906	Dye marker	19 Inadvertent actuation 42 Aided in location/rescue
1911	Flashlight	42 Aided in location/rescue
2004	Suspension line cutter	36 Design deficiency 11 Operated partially 60 Other (specify) 32 Discomfort/bulkiness
2012	SV-2A Survival vest	
2604	MBEU (other/unk)	38 Entanglement (parachute suspension l 40 Dragging (parachute only)
2801	Koch fitting - upper	16 Release/disconnect difficulty 12 Difficulty locating

INJURY INFORMATION

Injury Classification = G - Minimal Inju

Body Part		Diagnoses	Sev	Ph
Right	Wrist	Contusion	M	5

Body Part	Diagnoses	Sev	Ph

TABLE X

```
**********  ****************************************  TABLE X  ****************************************************

Report Date : 08/12/93        EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)   ENCLOSURE(2)
                                          EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT       For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72                  Record 38 of 64

***************************************************************************************************************************

                                          REFERENCE NUMBER - 0745       A/C  KA006D
                                          -----------------------       ------------

       EQUIPMENTS                                           OPNAV Form 3750.8E                   MOR Master File
       ----------                                           ----- ---- -------                   --- ------ ----
   Code  Description                                            CITATIONS                            CITATIONS
   ----  -----------                                            ---------                   ----------------------
                                                             / ABOARD  \                    / ABOARD       NOT ABOARD \
                                                               ------                         ------       --- ------

   0101  CS/FRP-1 Summer Flying Coverall                          X
   0302  MK-2A Cutaway Coverall                                   X
   0601  APH-6A Helmet                                            X                             X
   0801  Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)        X                             X
   0901  Boot, flying(MIL-B-21408) steel toe                      X                             X
   1201  A-13A                                                    X
   1398  Other (oxygen regulators)                                X
   1508  MK-3C                                                    X
   1799  Type life raft not specified                             X
   1807  PRC-63                                                   X
   1808  PRC-90                                                   X
   1901  Flaregun, MK 79 MOD 0                                    X
   1902  Signal light, strobe SDU-5/E                             X
   1905  Signal mirror                                            X
   1906  Dye marker                                               X
   1907  Whistle                                                  X
   1912  Signal panel, flag, etc.                                 X
   2005  Survival knife                                           X
   2007  SEEK-2                                                   X
   2010  Personnel lowering device                                X
   2012  SV-2A Survival vest                                      X
   2015  Pocket compass                                           X
   2098  Other survival equipment-miscellaneous                   X
   2099  Other survival equipment-miscellaneous                   X
   2506  Leg restraint                                            X
   2596  Torso Garment, Type not specified   (ESA)                X
   2604  MBEU (other/unk)                                                                       X
   2806  Harley buckle                                                                          X
   3402  Life raft lanyard                                                                      X

                                                       NOTE
                                                       ----

                                   An equipment with code ending in '98', '99', ect. may be listed
                                   two or more tires as these codes are often 'catch-alls' for
                                   unspecified or unknown equipments.
```

TABLE X (Continued)

REFERENCE NUMBER - 0745   A/C KA006D

EQUIPMENT INFORMATION

Code	Description	Factors
0601	APH-6A Helmet	44 Prevented/minimized injury
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	44 Prevented/minimized injury
0901	Boot, flying(MIL-B-21408) steel toe	05 Damaged-minor 44 Prevented/minimized injury
2604	MBEU (other/unk)	39 Entanglement (parachute suspension l
2806	Harley buckle	14 Connection/closure difficulty 30 Other equipment interfered
3402	Life raft lanyard	14 Connection/closure difficulty 30 Other equipment interfered

INJURY INFORMATION

Injury Classification = G - Minimal Inju

Body Part		Diagnoses	Sev	Ph
Bilateral	Thorax	Abrasion	M	E

Body Part		Diagnoses	Sev	Ph
Left	Arm, lower	Abrasion	M	E

Body Part		Diagnoses	Sev	Ph
Right	Leg, lower	Hematoma	M	E

Body Part		Diagnoses	Sev	Ph

** **TABLE XI** **

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**
EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 40 of 64

****

REFERENCE NUMBER - 0772 A/C KA006D

EQUIPMENTS		OPNAV Form 3750.8E	MOR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0603	APH-6C Helmet	X		
0699	Other helmet type not specified		X	
0705	Dual visor	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)			X
0901	Boot, flying(MIL-B-21408) steel toe	X	X	
1004	Thermal underwear	X		
1058	Clothing--Other	X		
1058	Clothing--Other	X		
1201	A-13A	X	X	
1601	LPA-1	X	X	
1701	LR-1	X		
1807	PRC-63	X		
1809	PRC-90	X		
1814	URT-33	X		
1901	Flaregun, MK 79 MOD 0	X		
1902	Signal light, strobe SDU-5/E		X	
1904	Distress signal, day/night, MK13 MOD 0		X	
1911	Flashlight	X		
1998	Other signalling devices/lights	X		
2007	SEEK-2	X		
2014	Gun/Pistol	X		
2019	First aid kit	X		
2098	Other survival equipment-miscellaneous	X		
2098	Other survival equipment-miscellaneous	X		
2199	Type seat survival kit not specified		X	
2501	Lap belt	X		
2510	Leg restaint (dual garter)	X		
2601	MSEU 5027	X		
2604	MSEU (other/unk)		X	
2801	Koch fitting - upper	X	X	
2606	Marley buckle	X		

An equipment with code ending in '98', '99', ect. may be listed
two or more times as these codes are often 'catch-alls' for
unspecified or unknown equipments.

TABLE XI (Continued)

REFERENCE NUMBER - 0772   A/C KA006D

EQUIPMENT INFORMATION

Code	Description	Factors
0699	Other helmet type not specified	42 Aided in location/rescue
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	02 Not available-left behind
0901	Boot, flying(MIL-B-21408) steel toe	05 Damaged-minor 44 Prevented/minimized injury
1201	A-13A	03 Discarded
1601	LPA-1	20 Actuation difficulty
1902	Signal light, strobe SDU-5/E	42 Aided in location/rescue
1904	Distress signal, day/night, MK13 MOD 0	42 Aided in location/rescue
2199	Type seat survival kit not specified	03 Discarded
2604	MBEU (other/unk)	38 Entanglement (parachute suspension l
2801	Koch fitting - upper	16 Release/disconnect difficulty

INJURY INFORMATION

Injury Classification = G - Minimal Inju

************ ** **TABLE XII** **

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**

EQUIPMENT FACTORS AND INJURIES (PART 2)

Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 42 of 64

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REFERENCE NUMBER - 0778 A/C A0066

EQUIPMENTS Code	Description	OPNAV Form 3750.8E CITATIONS ABOARD	MOR Master File CITATIONS ABOARD	MOR Master File CITATIONS NOT ABOARD
0101	CS/FRP-1 Summer Flying Coverall	X		
0302	MK-2A Cutaway Coverall	X		
0602	APH-6B Helmet	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	X		
0901	Boot, flying(MIL-B-21408) steel toe	X		
1201	A-13A	X		
1398	Other (oxygen regulators)	X		
1608	MK-3C	X		
1701	LR-1	X		
1899	Type survival radio not specified			X
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X	X	
1905	Signal mirror	X		
1906	Dye marker	X	X	
1907	Whistle	X		
1998	Other signalling devices/lights	X		
2012	SV-2A Survival vest	X		
2098	Other survival equipment-miscellaneous	X		
2506	Leg restraint	X		
2503	Torso garment MA-2	X		
2604	MB2U (other/unk)	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE XII (Continued)

REFERENCE NUMBER - 0776 A/C A006B

EQUIPMENT INFORMATION

Code	Description	Factors
1899	Type survival radio not specified	02 Not available-left behind 66 Not available - Needed
1904	Distress signal, day/night, MK13 MOD 0	42 Aided in location/rescue
1906	Dye marker	42 Aided in location/rescue

INJURY INFORMATION

Injury Classification = F - Minor

Body Part		Diagnoses	Sev	Ph
Posterior	Back	Strain	F	E

Body Part		Diagnoses	Sev	Ph
Left	Shoulder	Contusion	9	E

TABLE XIII

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MOR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**
EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72 Record 43 of 64

REFERENCE NUMBER - 0785 A/C A006A

EQUIPMENTS Code	 Description	OPNAV Form 3750.8E CITATIONS / ABOARD \	MOR Master File CITATIONS / ABOARD	 NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0103	CWU-1/P Intermediate Flying Coverall	X		
0603	APH-6C Helmet	X		
0706	Dual visor	X		
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	X	X	
0901	Boot, flying(MIL-B-21408) steel toe	X		
1004	Thermal underwear	X		
1098	Clothing--Other	X		
1201	A-13A	X		
1398	Other (oxygen regulators)	X		
1603	MK-3C	X		
1701	LR-1	X		
1807	PRC-63	X		
1814	URT-33	X		
1901	Flaregun, MK 79 MOD 0	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
1905	Signal mirror	X		
1906	Dye marker	X		
1907	Whistle	X		
2003	Water bottle, 4 oz.	X		
2005	Survival knife	X		
2007	SESK-2	X		
2008	SRU-31/P	X		
2009	"Space" blanket, lightweight	X		
2012	SV-2A Survival vest	X		
2098	Other survival equipment-miscellaneous	X		
2501	Lap belt	X		
2510	Leg restaint (dual garter)	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE XIII (Continued)

REFERENCE NUMBER - 0785 A/C A006A

EQUIPMENT INFORMATION

Code	Description		Factors
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	04 Lost	

INJURY INFORMATION

Injury Classification = B - Major

Body Part		Diagnoses	Sev	Ph
Right	Shoulder	Comminuted	8	E
Right	Knee	Laceration	9	E
Left	Knee	Strain	9	L
Right	Elbow	Contusion	9	E
Right	Hand, include fingers	Contusion	9	E

************. **

TABLE XIV

.*****

Report Date : 08/12/83 EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1) **ENCLOSURE(2)**

EQUIPMENT FACTORS AND INJURIES (PART 2)

Programs: 1ATATIME & INJ/FACT For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72

Record 46 of 64

****

REFERENCE NUMBER - 0877 A/C KA006D

EQUIPMENTS		OPNAV Form 3750.8E	MDR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0101	CS/FRP-1 Summer Flying Coverall	X		
0302	MK-2A Cutaway Coverall	X		
0605	APH-6 Helmet (MOD not specified)	X		
0706	Dual visor	X	X	
0601	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)			X
0901	Boot, flying(MIL-B-21408) steel toe	X		
1205	Sierra 756	X		
1305	Seat mounted regulator	X		
1606	MK-3C	X		
1701	LR-1	X		
1807	PRC-63	X		
1808	PRC-90	X		
1902	Signal light, strobe SDU-5/E	X		
1904	Distress signal, day/night, MK13 MOD 0	X		
1905	Signal mirror	X		
1998	Other signalling devices/lights	X		
2004	Suspension line cutter	X		
2012	SV-2A Survival vest	X		
2098	Other survival equipment-miscellaneous	X		
2501	Lap belt	X		
2510	Leg restaint (dual garter)	X		
2596	Torso Garment, Type not specified (ESA)	X		
2699	Parachute, Other/Unknown	X		
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE XIV (Continued)

REFERENCE NUMBER - 0877   A/C KA006D

EQUIPMENT INFORMATION

Code	Description	Factors
0786	Dual visor	06 Damaged-major
0801	Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)	02 Not available-left behind

INJURY INFORMATION

Injury Classification = G - Minimal Inju

Body Part		Diagnoses	Sev	Ph
Right	Shoulder	Contusion	M	E

Body Part		Diagnoses	Sev	Ph
Left	Leg, lower	Contusion	M	E

****

TABLE XV

*** *******

```
Report Ca     03/12/33        EQUIPMENT COMPARISON BETWEEN MOR/FSR  TAIL AND COMPUTER RECORDS DETAIL (PART 1)   ENCLOSL..2(a)
                                            EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT        For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72                 Record 51 of 64
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****

REFERENCE NUMBER - 0892   A/C   A006E

EQUIPMENTS		OPNAV Form 3750.8E	MDR Master File	
		CITATIONS	CITATIONS	
Code	Description	/ ABOARD \	/ ABOARD	NOT ABOARD \
0161	CS/FRP-1 Summer Flying Coverall	X		
0603	APH-6C helmet	X		
0381	Boots, flying(MIL-B-21408) steel toe	X		
1098	Clothing--Other	X		
1298	Mask--Other	X		
1303	Robertshaw Fulton, mini-reg	X		
1601	LPA-1			X
1701	LR-1	X		
1807	PRC-63			X
1814	URT-33			X
1901	Flaregun, MK 79 MOD 0			X
1902	Signal light, strobe SDU-5/E			X
1911	Flashlight			X
2012	SV-2A Survival vest			X
2199	Type seat survival kit not specified	X		
2506	Leg restraint			X
2510	Leg restaint (dual garter)	X		
2633	NES-14A	X	X	
2801	Koch fitting - upper	X		

NOTE

An equipment with code ending in '98', '99', ect. may be listed two or more times as these codes are often 'catch-alls' for unspecified or unknown equipments.

TABLE XV (Continued)

REFERENCE NUMBER - 0892 A/C A006E

EQUIPMENT INFORMATION

Code	Description	Factors	
1601	LPA-1	02	Not available-left behind
1807	PRC-63	02	Not available-left behind
1814	URT-33	02	Not available-left behind
1301	Flaregun, MK 79 MOD 0	02	Not available-left behind
1302	Signal light, strobe SDU-5/E	02	Not available-left behind
1911	Flashlight	02	Not available-left behind
2012	SV- Survival vest	02	Not available-left behind
2506	Leg restraint	02	Not available-left behind
2633	HES-14A	10 45	Failed to operate (radio, actuator, Equipment problem (loss, failure, et

INJURY INFORMATION

Injury Classification = A - Fatal

Body Part		Diagnoses	Sev	Ph
Left	Thorax	Rupture	A	E

Body Part		Diagnoses	Sev	Ph
Total (Refers to Body Part)	Thorax	Pneumo/Hemothorax	5	E

TABLE XV (Continued)

```
    --    ----                                                    ---------                                --
Posterior                       4th Thoracic Vertebra           Fracture, simple                      9      E

     Body Part                                                     Diagnoses                          Sev    Ph
     ---- ----                                                     ---------                          ---    --
Total (Refers to Body Part)    Multiple body parts              Fracture, simple                      9      E

     Body Part                                                     Diagnoses                          Sev    Ph
     ---- ----                                                     ---------                          ---    --
Total (Refers to Body Part)    Multiple body parts              Injury, internal                      9      E
```

TABLE XVI

ENCLOSURE(2)

```
***********.******************************************  TABLE XVI  ****************************************************

Report Date : 08/12/83        EQUIPMENT COMPARISON BETWEEN MDR/FSR DETAIL AND COMPUTER RECORDS DETAIL (PART 1)
                                             EQUIPMENT FACTORS AND INJURIES (PART 2)
Programs: 1ATATIME & INJ/FACT       For 64 A-6 Series Ejections From 1 Jan '69 - 31 Dec '72                   Record 57 of 64

*************************************************************************************************************************

                                                  REFERENCE NUMBER - 0979       A/C   A005A
                                                  -----------------------       -----------

      EQUIPMENTS                                                   OPNAV Form 3750.8E                MOR Master File
      ----------                                                   ----- ---- -------                --- ------ ----
   Code  Description                                                  CITATIONS                         CITATIONS
   ----  -----------                                                  ---------               -------------------------
                                                                    / ABOARD  \               / ABOARD      NOT ABOARD \
                                                                      ------                    ------      --- ------

   0197  Other - NEC Flight Suit                                         X
   0302  MK-2A Cutaway Coverall                                          X
   0605  APH-6 Helmet (MOD not specified)                                X                        X
   0801  Gloves, Flying(MIL-G-81188) fire resistant(NOMEX)               X
   0901  Boot, flying(MIL-B-21406) steel toe                             X
   1201  A-13A                                                           X
   1356  Other (oxygen regulators)                                       X
   1603  LPA-2                                                           X
   1701  LR-1                                                            X
   1807  PRC-63                                                          X
   1808  PRC-90                                                          X
   1814  URT-33                                                          X
   1902  Signal light, strobe SDU-5/E                                    X
   1904  Distress signal, day/night, MK13 MOD 0                          X
   1905  Signal mirror                                                   X
   1998  Other signalling devices/lights                                 X
   2005  Survival knife                                                  X
   2098  Other survival equipment-miscellaneous                          X
   2098  Other survival equipment-miscellaneous                          X
   2501  Lap belt                                                        X
   2502  Shoulder harness/inertia reel                                   X
   2505  Leg restraint                                                   X
   2596  Torso Garment, Type not specified   (ESA)                       X
   2601  MBEU 5027                                                       X
   2798  Other parachute opening devices/miscellaneous                   X
   2801  Koch fitting - upper                                            X

                                                          NOTE
                                                          ----

                                 An equipment with code ending in '98', '99', ect. may be listed
                                 two or more times as these codes are often 'catch-alls' for
                                 unspecified or unknown equipments.
```

TABLE XVI (Continued)

REFERENCE NUMBER - 0979   A/C   A006A

EQUIPMENT INFORMATION

Code	Description
0605	APH-6 Helmet (MOD not specified)

Factors

05 Damaged-minor
44 Prevented/minimized injury

INJURY INFORMATION

Injury Classification = F - Minor

Body Part		Diagnoses	Sev	Ph
Right	Legs upper	Contusion	F	A

Body Part		Diagnoses	Sev	Ph
Left	Legs upper	Laceration	9	A

TABLE XVII

LIMITED SAMPLE OF A-6 MISHAP AIRCREW GARMENTS WHICH, BASED UPON ONLY SPECIFIC REPORTED INJURIES (EXCLUDING MULTIPLE EXTREME) PROBABLY SUSTAINED DAMAGE NOT REPORTED IN MOR (BASED UPON 64 A-6 MISHAP AIRCREWMEN) DURING THE PERIOD 1 JANUARY 1969 – 31 DECEMBER 1972

CASE	TYPE & LOCATION OF INJURY	GARMENT(S) PROBABLY AFFECTED (DAMAGED)	CITED PHASE OF INJURY OCCURRENCE
1	LACERATION POSTERIOR SHOULDER	CS/FRP-1 SUMMER FLYING COVERALL	(LANDING)
2	SIMPLE FRACTURE RIGHT ANKLE	SHOES/BOOTS – TYPE NOT SPECIFIED[1]	(LANDING)
3	LACERATION LOWER RIGHT ARM	CS/FRP-1 SUMMER FLYING COVERALL	(EGRESS)
4	CONTUSION RIGHT FOOT, INCLUDING TOES	BOOT, FLYING (MIL-B-21408) STEEL TOE	(EGRESS)
5	LACERATION RIGHT ELBOW	CS/FRP-1 SUMMER FLYING COVERALL	(EGRESS)
6	LACERATION RIGHT ELBOW PERFORATION RIGHT KNEE	CS/FRP-1 SUMMER FLYING COVERALL	(EGRESS)
7	LACERATION LEFT HAND, INCLUDING FINGERS	GLOVES, FLYING (MIL-G-81188) FIRE RESISTANT (NOMEX)	(EGRESS)
8	LACERATION OF MULTIPLE BODY PARTS	[2]	(EGRESS)
9	LACERATION LOWER RIGHT ARM	CS/FRP-1 SUMMER FLYING COVERALL	(EGRESS)
10	LACERATION RIGHT KNEE	CS/FRP-1 SUMMER FLYING COVERALL	(EGRESS)
11	LACERATION LEFT UPPER LEG	OTHER – NEC[3] FLIGHT SUIT MK 2A CUTAWAY COVERALL	(AFTER)
12	DISLOCATION RIGHT FOOT, INCLUDING TOES	BOOT, FLYING (MIL-B-21408) STEEL TOE	(EGRESS)
13	LACERATION LEFT ELBOW	TYPE FLIGHT SUIT NOT SPECIFIED	(EGRESS)
14	LACERATION LEFT HAND, LANDING INCLUDING FINGERS	GLOVES, FLYING (MIL-G-81188) FIRE RESISTANT (NOMEX)	(EGRESS)

NOTES

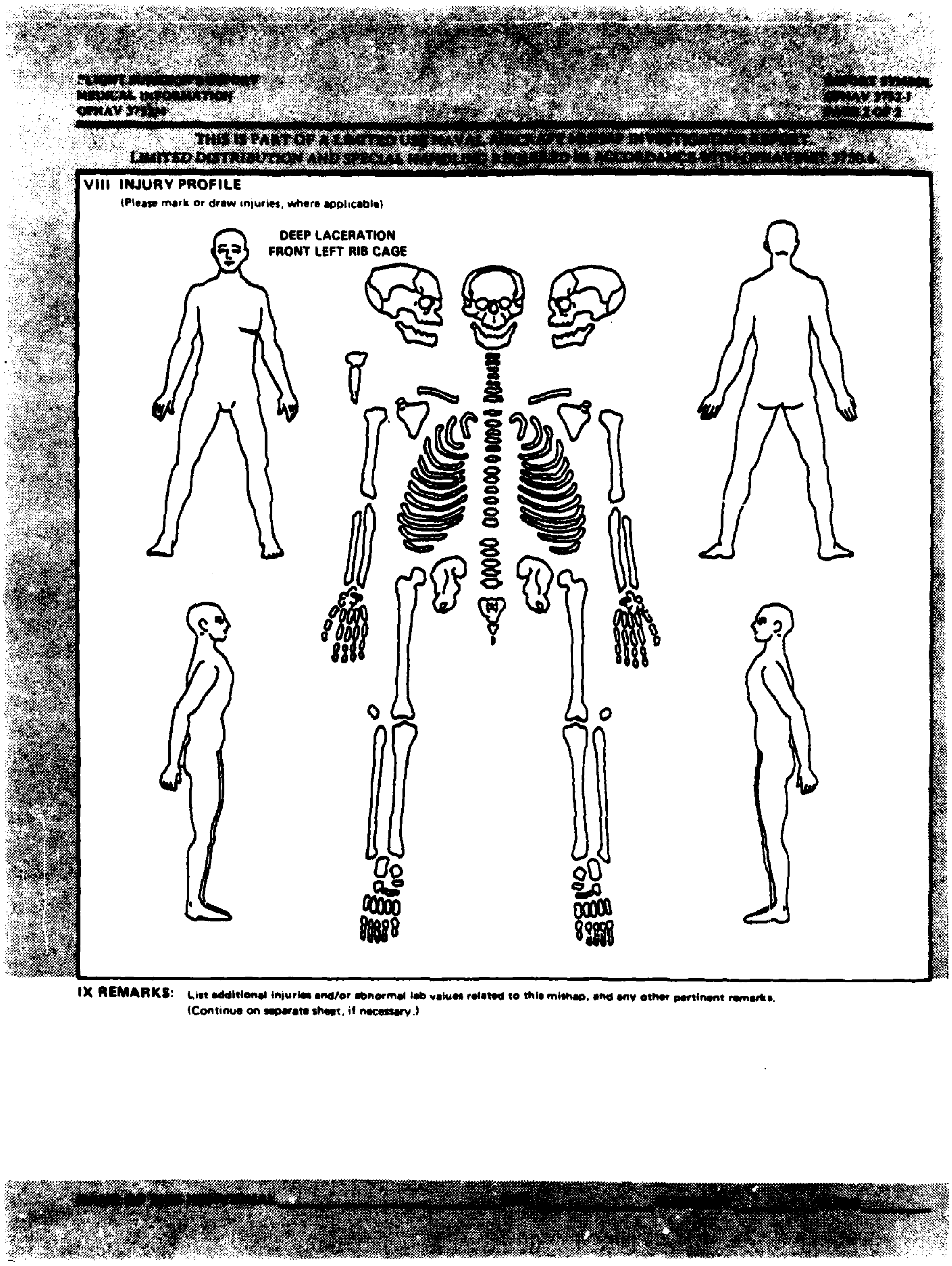
[1] IN CASE NUMBER 2, THE MOR/FSR COMPUTER TAPE CITES "IMPROPER USE (OTHER) FOR "BOOT, FLYING (MIL–B-21408) STEEL TOE".

[2] IN CASE NUMBER 8, LOCATION(S) OF THE MULTIPLE BODY PARTS LACERATED WERE NOT SPECIFIED, MAKING INFEASIBLE ESTIMATING WHICH GARMENTS WORN MIGHT HAVE BEEN AFFECTED.

[3] NEC (NOT ELSEWHERE CODED – TERM USED IN THE MOR/FSR DATA TAPES).

[4] IN ONE 1971 CASE, THE MOR/FSR COMPUTER TAPE REPORTED "DAMAGED-MINOR" TO CS/FRP-1 SUMMER FLYING COVERALL WITH A "LACERATION RIGHT KNEE".

[5] IN ONE 1972 CASE, THE MOR/FSR COMPUTER TAPE REPORTED "DAMAGED-MINOR" TO "MK 2 COVERALL". NO COMMENT CONCERNING POTENTIAL DAMAGE TO CS/FRP-1 SUMMER FLYING COVERALL REPORTED BY THE ORIGINAL MOR TO ALSO HAVE BEEN WORN.



FLIGHT [illegible] REPORT [illegible]
MEDICAL INFORMATION
OPNAV 37[illegible]

REPORT SYMBOL
OPNAV 3750-1
PAGE 2 OF 2

THIS IS PART OF A LIMITED USE NAVAL AIRCRAFT MISHAP INVESTIGATION REPORT.
LIMITED DISTRIBUTION AND SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 3750.6.

VIII INJURY PROFILE

(Please mark or draw injuries, where applicable)

DEEP LACERATION
FRONT LEFT RIB CAGE

IX REMARKS: List additional injuries and/or abnormal lab values related to this mishap, and any other pertinent remarks. (Continue on separate sheet, if necessary.)

Figure 1. MOR Page

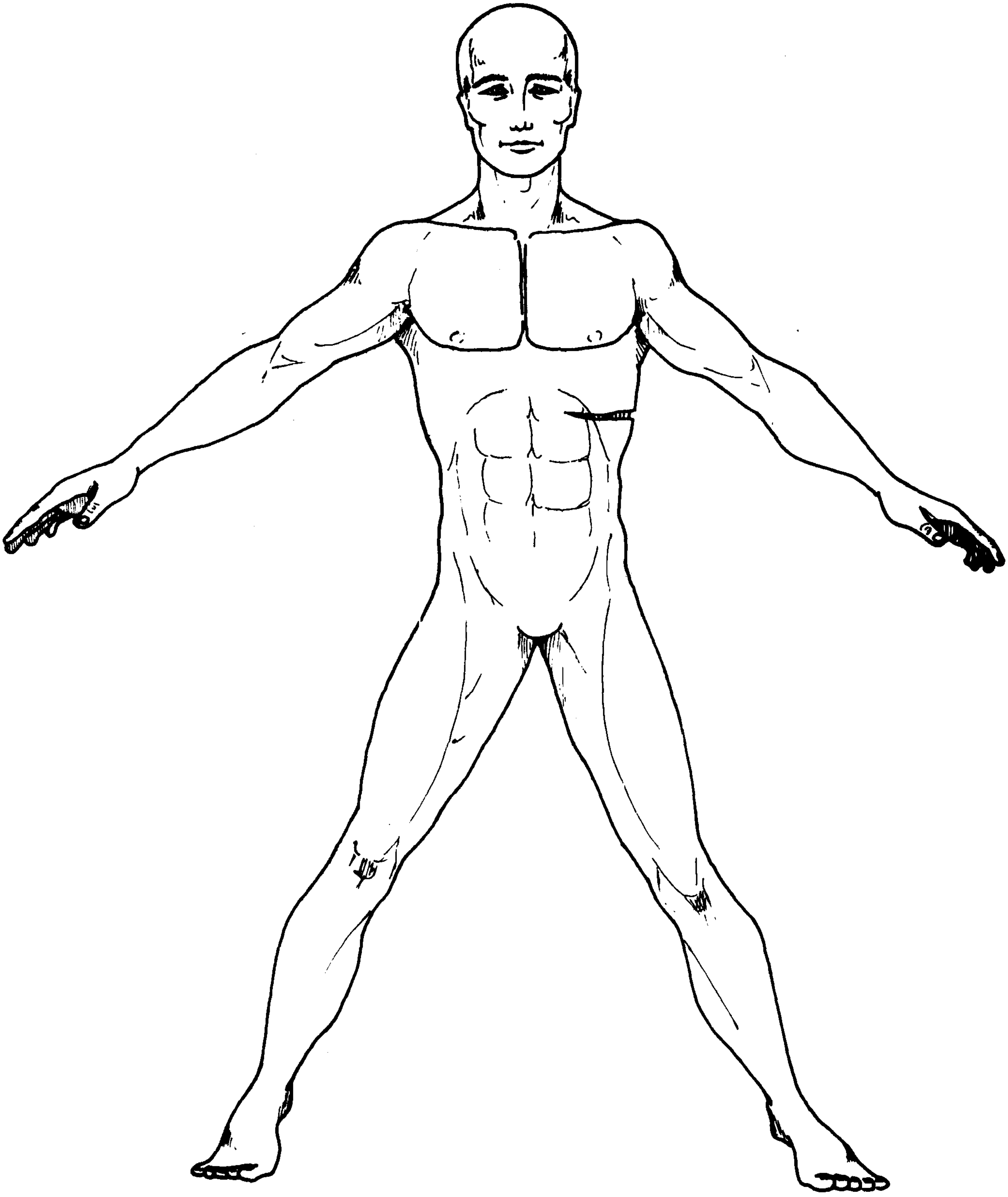


Figure 2. Expanded View of Body

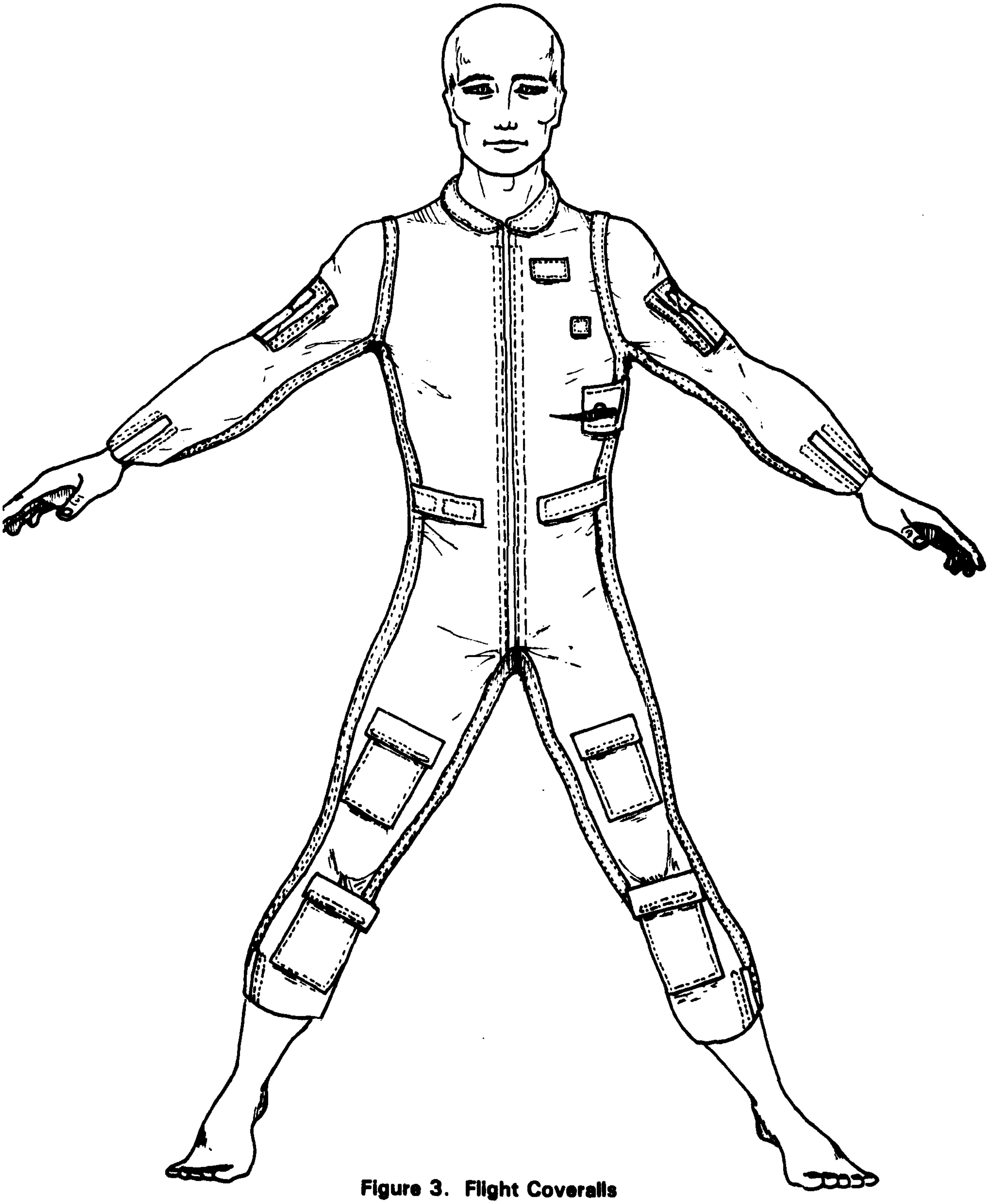


Figure 3. Flight Coveralls

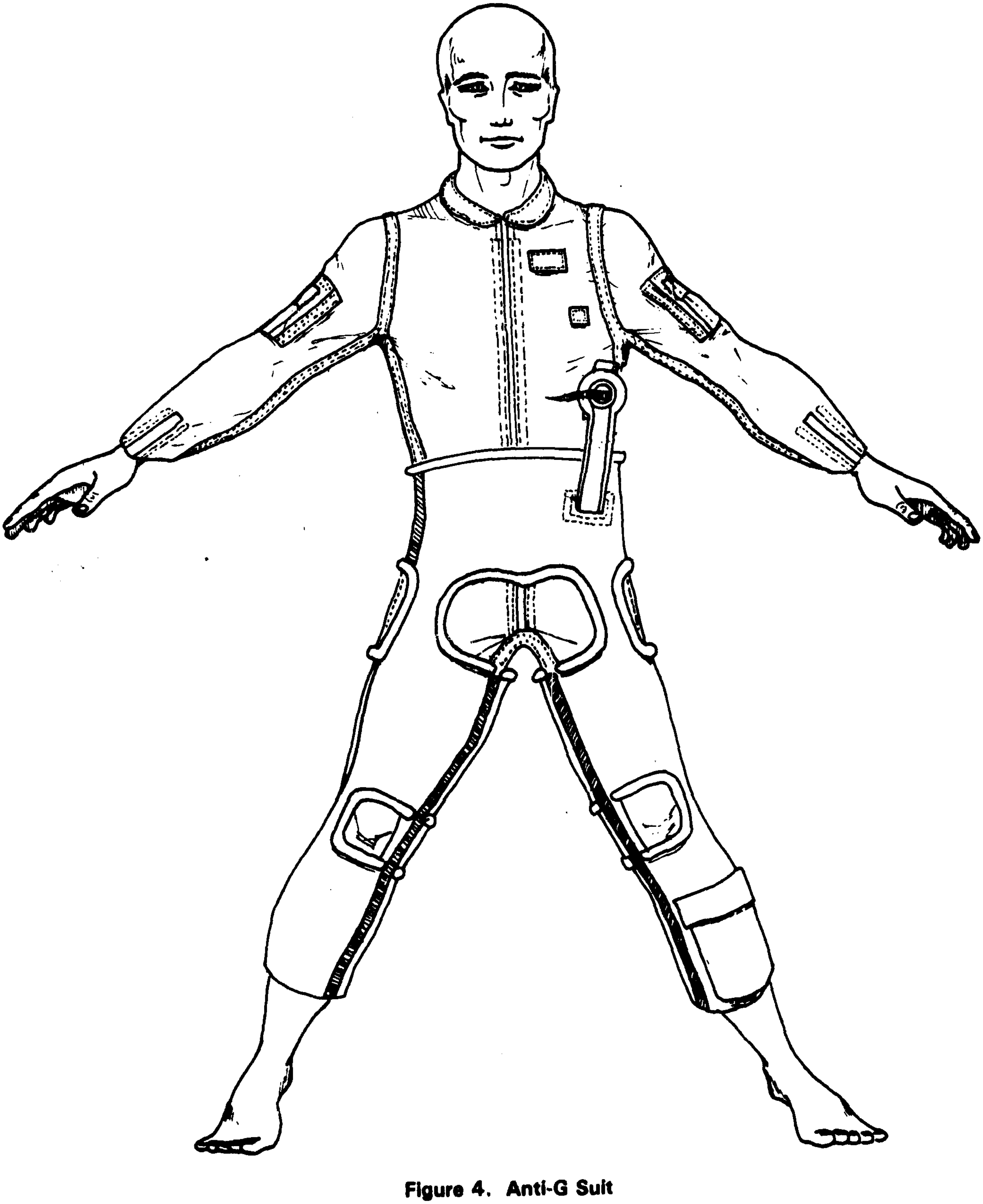


Figure 4. Anti-G Suit

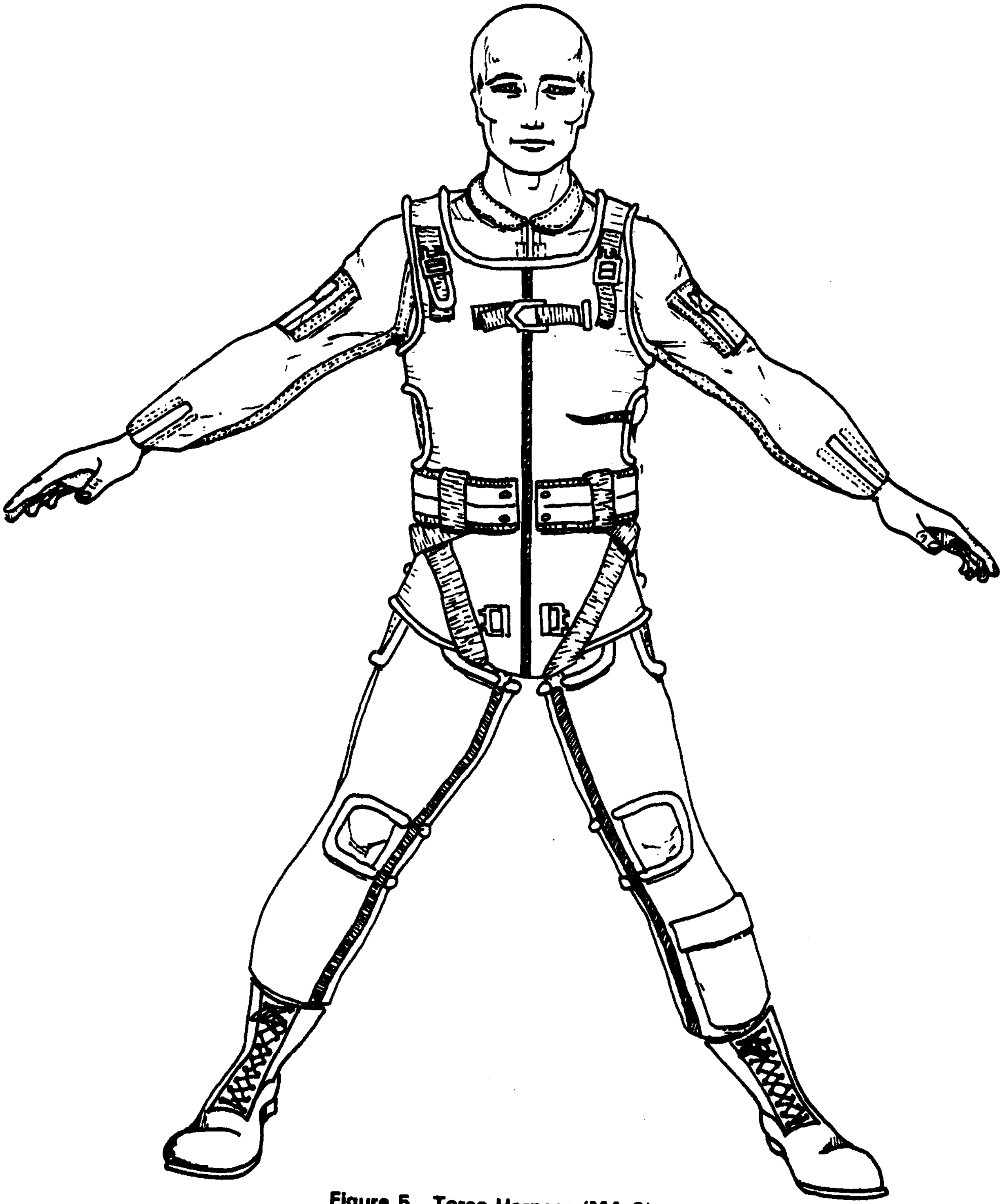


Figure 5. Torso Harness (MA-2)

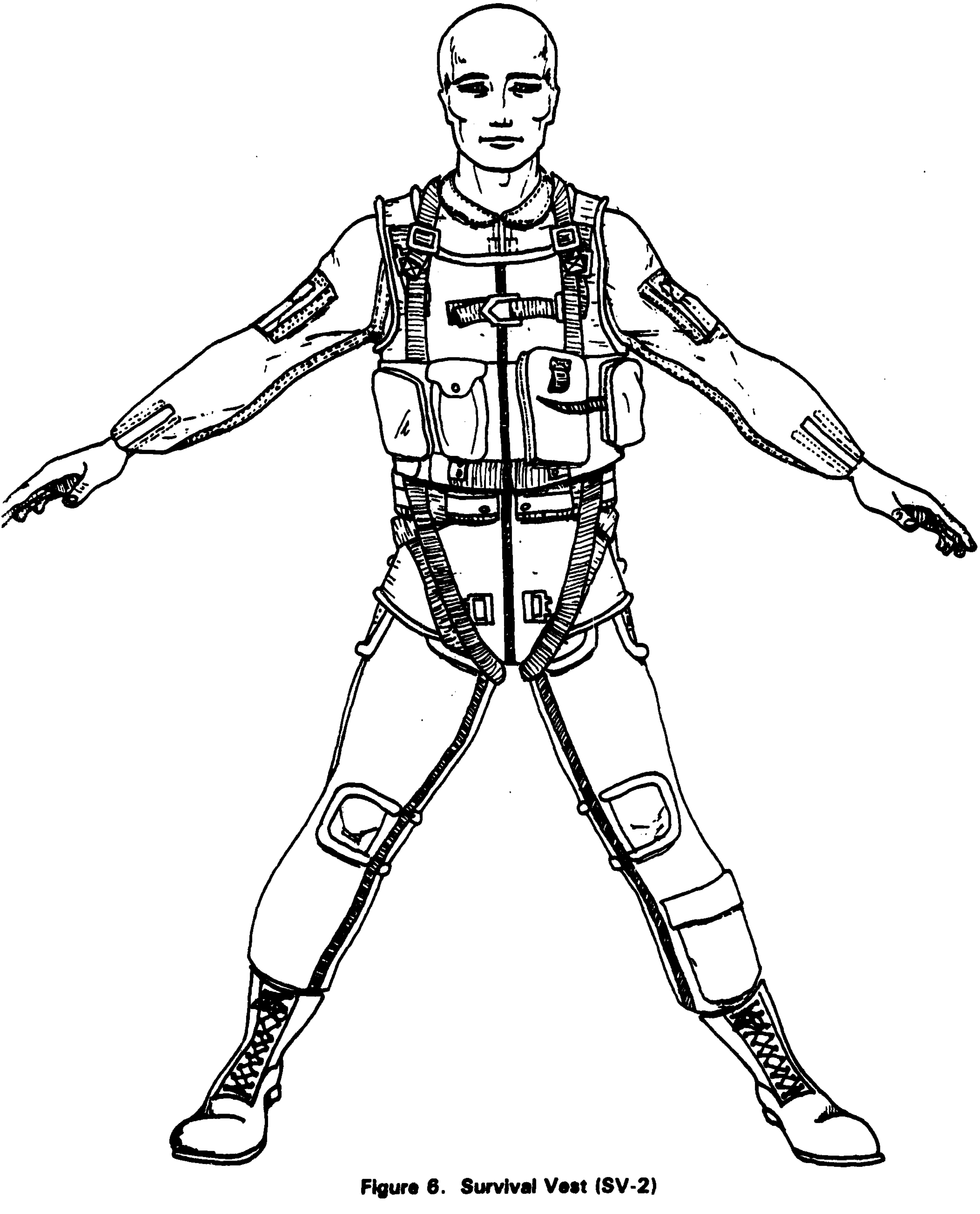


Figure 6. Survival Vest (SV-2)

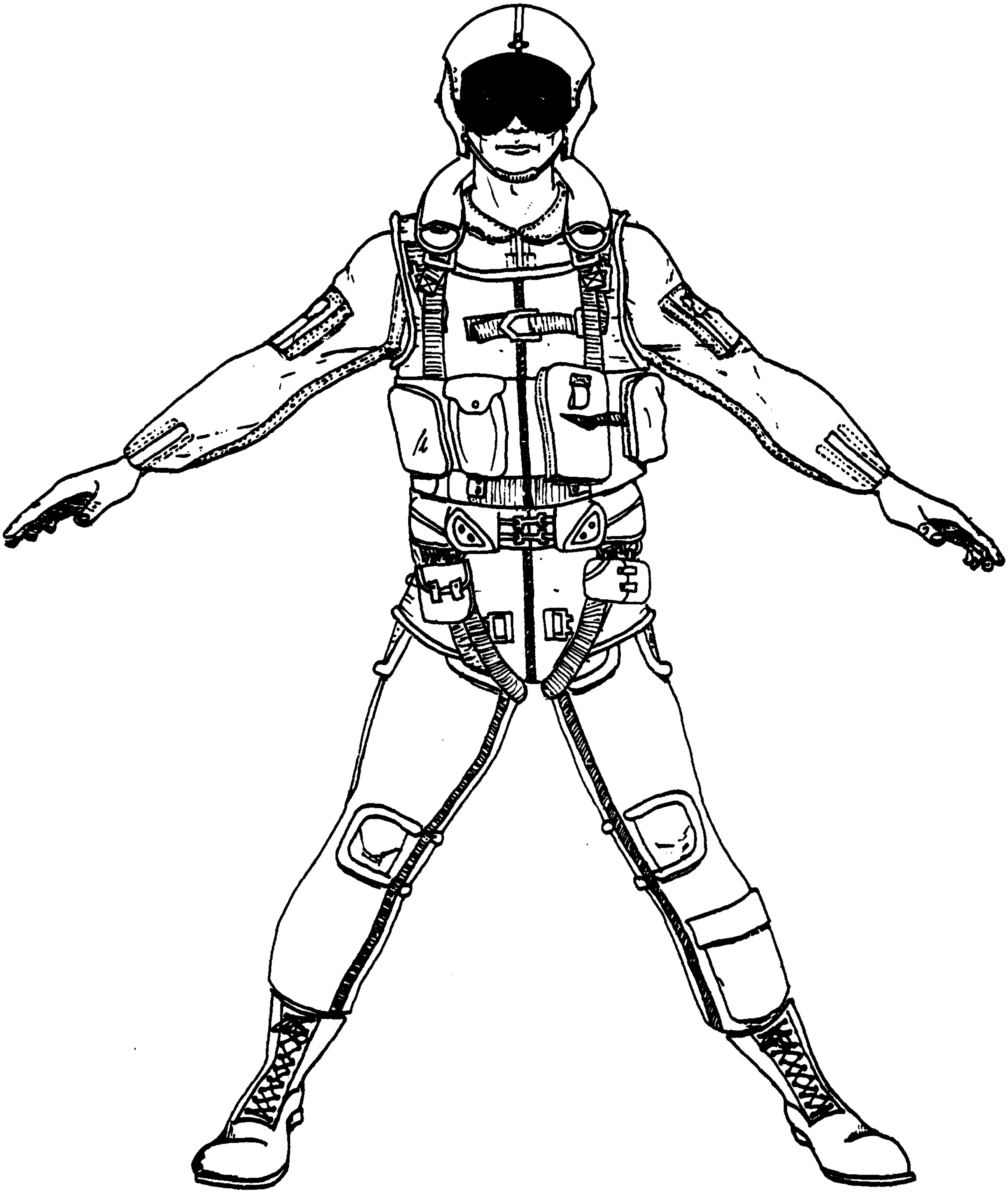


Figure 7. Personnel Flotation (LPA)

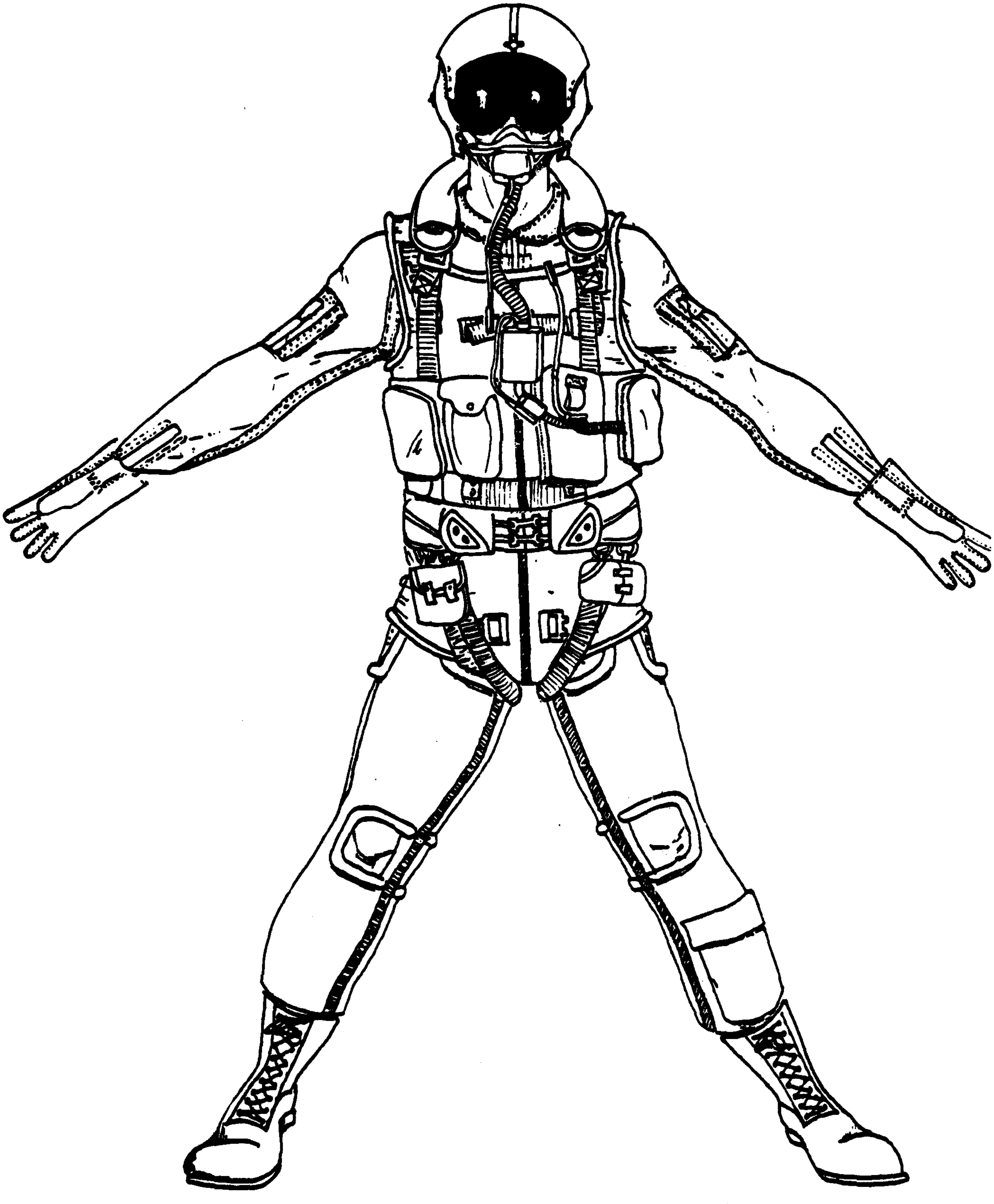


Figure 8. Boots, Helmet, Oxygen Mask and Hose, Gloves

ARTICLES WORN NOT LIKELY TO HAVE BEEN DAMAGED AS A CONSEQUENCE OF INJURY PRODUCTION

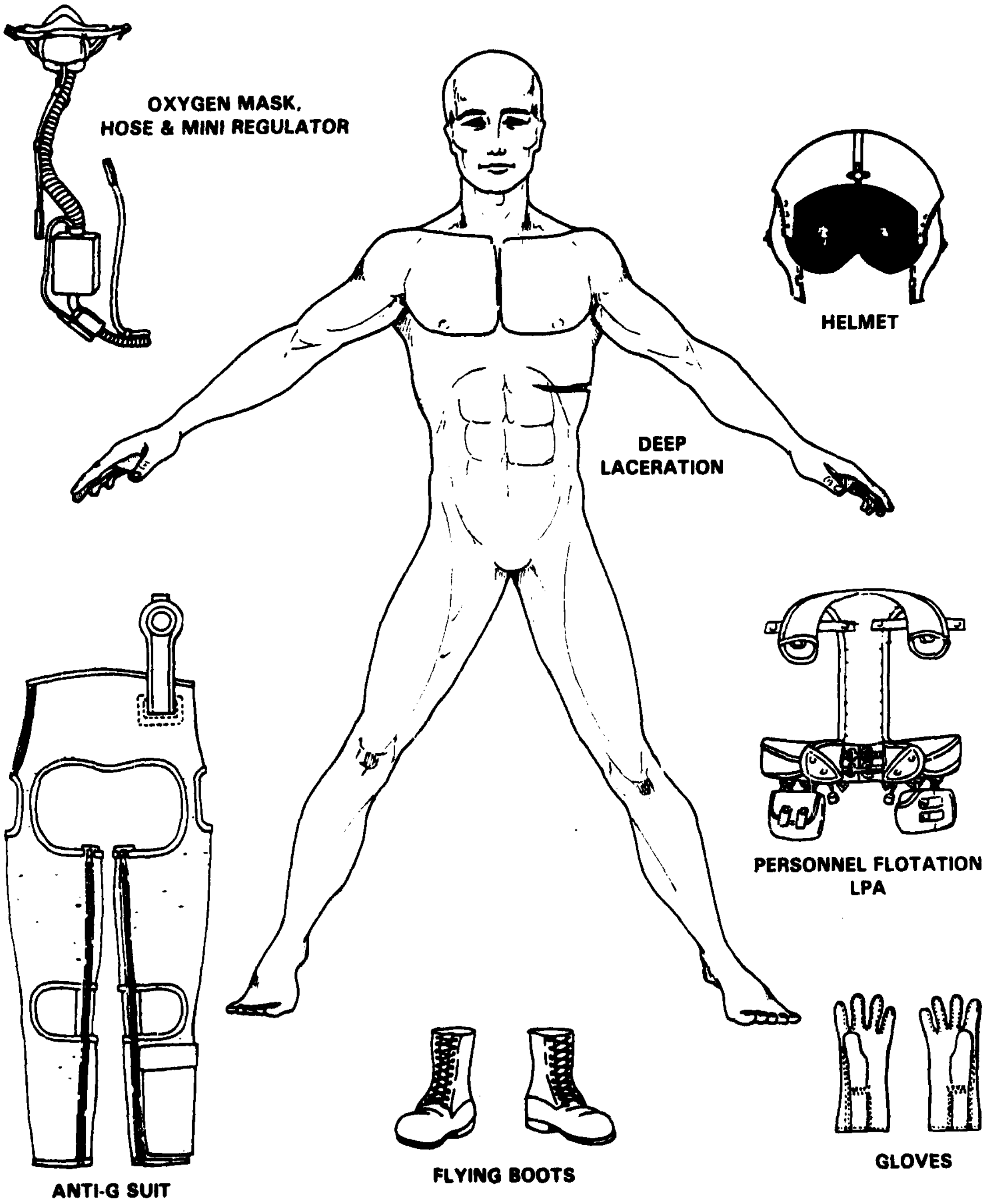


Figure 9

ARTICLES WORN LIKELY TO HAVE SUSTAINED DAMAGE DURING INJURY PRODUCTION

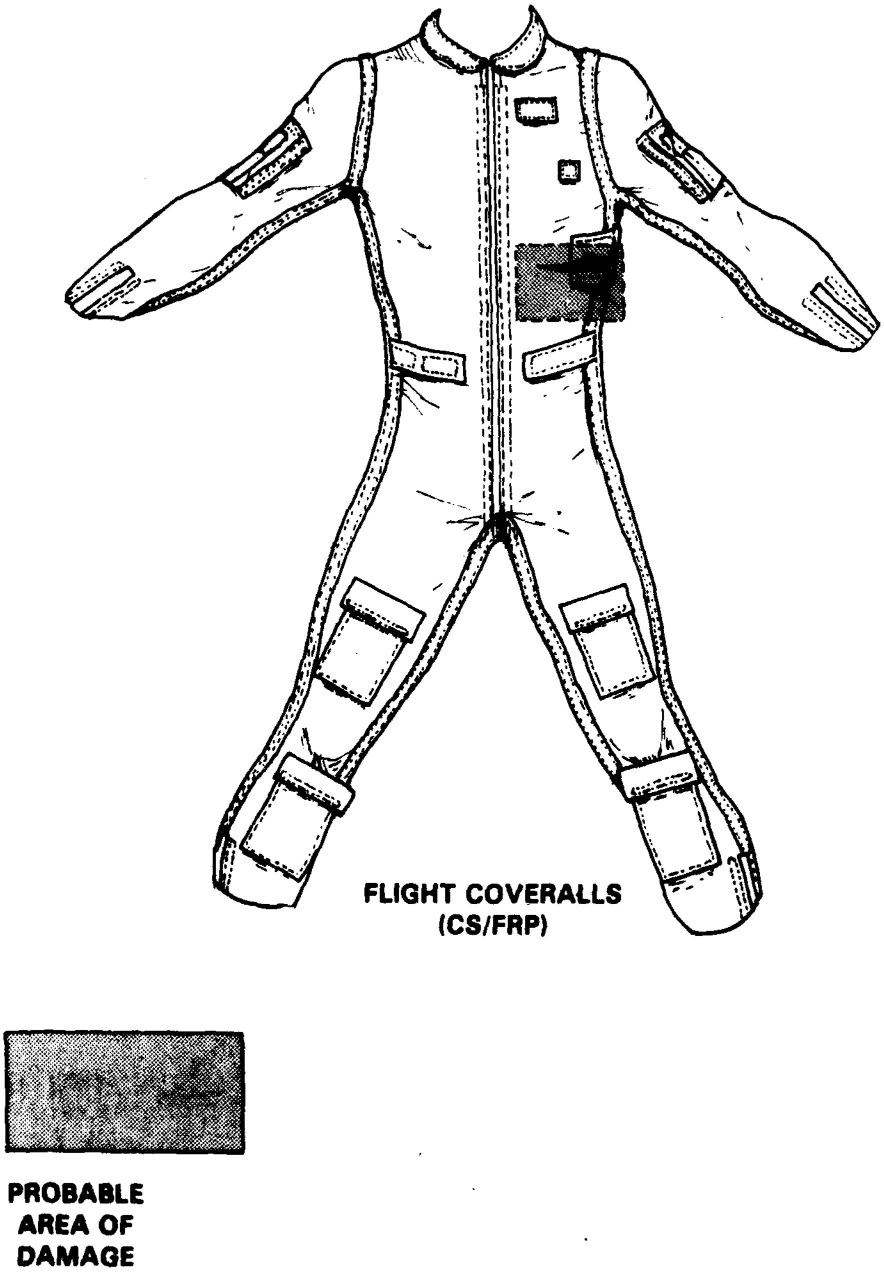
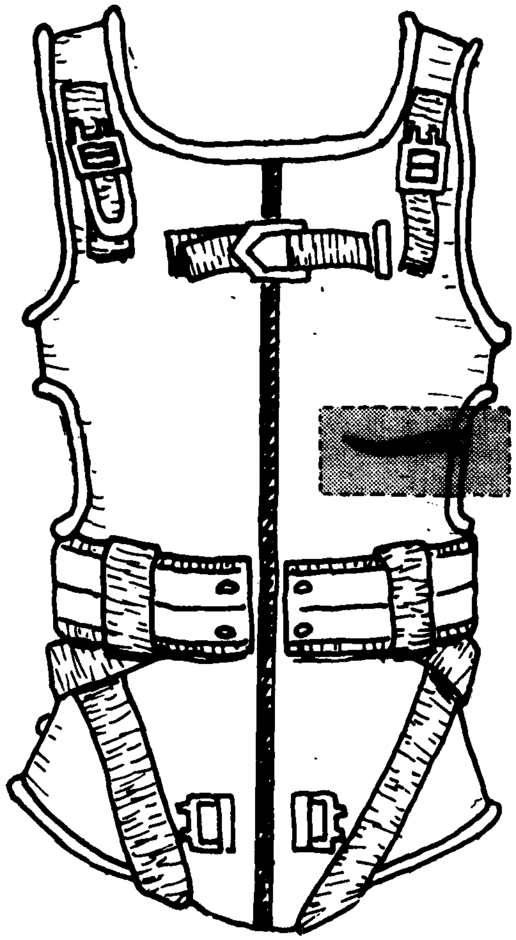


Figure 10

ARTICLES WORN LIKELY TO HAVE SUSTAINED DAMAGE DURING INJURY PRODUCTION

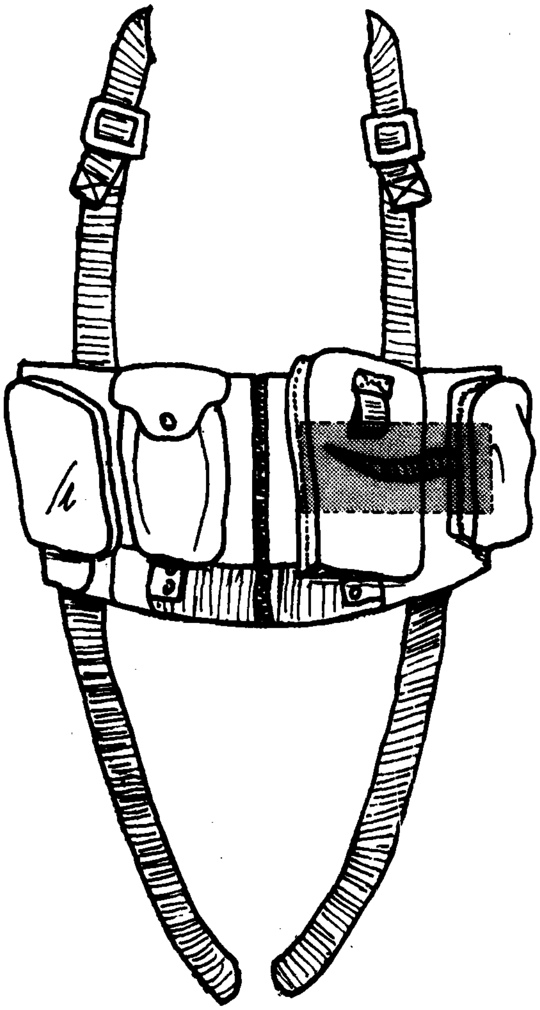


TORSO HARNESS (MA-2)

▨ **PROBABLE AREA OF DAMAGE**

Figure 11

ARTICLES WORN LIKELY TO HAVE SUSTAINED DAMAGE DURING INJURY PRODUCTION



SURVIVAL VEST (SV-2)

▨ PROBABLE AREA OF DAMAGE

Figure 12

COMPARATIVE SERIOUS NON-FATAL INJURY PATTERNS AND SERIOUS AIRCREW LIFE SUPPORT SYSTEMS (ALSS) DAMAGE PATTERNS ASSOCIATED WITH THROUGH-THE-CANOPY EJECTIONS FROM TWO PLACE SIDE-BY-SIDE A-6 SERIES AIRCRAFT AND FROM OTHER U.S. NAVY THROUGH-THE-CANOPY EJECTION AIRCRAFT; 1 JANUARY 1969 THROUGH 31 DECEMBER 1979

Frederick C. Guill

ABSTRACT

Concern has long been held concerning the effects of the A-6 canopy centerline fore-and-aft beam upon ejectee safety. Ejection data recently were examined in order to ascertain whether significant injuries occur more frequently on the inboard side of ejectees and, if so, whether the pattern was different from that sustained by ejectees from other types of aircraft. Several minor suggestions injury patterns were found, however, also found was an ambiguity in the terminology employed to describe injury locations concerning employed to describe injury locations concerning an ejectee's limbs. Use of terms such as anterior and posterior without identifying whether the particular limb was the right or the left limb and the term bilateral which in some instances referred to both right and left limbs while in other instances may simply have been referring to both sides of one limb, preclude establishing or disproving the correctness of the injury expectations. This does, however, clearly indicate a need for specific use of the terms left and right to identify the injured limb.

AD-A134833 AIRCREW AUTOMATED ESCAPE SYSTEMS (AAES) IN-SERVICE USAGE DATA ANALYSES VO..(U) NAVAL WEAPONS ENGINEERING SUPPORT ACTIVITY WASHINGTON DC C W STOKES ET AL. 6/6

UNCLASSIFIED 05 NOV 83 NAVWESA-1-83-VOL-1 F/G 1/3 NL

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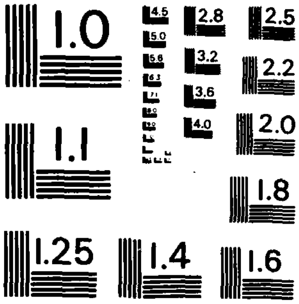
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2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

COMPARATIVE SERIOUS NON-FATAL INJURY PATTERNS AND SERIOUS AIRCREW LIFE SUPPORT SYSTEMS (ALSS) DAMAGE PATTERNS ASSOCIATED WITH THROUGH-THE-CANOPY EJECTIONS FROM TWO PLACE SIDE-BY-SIDE A-6 AIRCRAFT AND FROM OTHER U.S. NAVY THROUGH-THE-CANOPY EJECTION AIRCRAFT

1 January 1969 through 31 December 1979

Frederick C. Guill

INTRODUCTION

For many years there has been great concern and considerable controversy concerning through-the-canopy ejection with many designers and users strongly preferring jettisoned canopy ejection. A long term and strong concern has been the belief that through-the-canopy ejectees sustain lacerations, punctures and similar injuries with associated significant damage to vital aircrew life support systems (ALSS) equipments more frequently and with a greater severity than do jettisoned-canopy ejectees. A more recent and stronger concern, has been the seemingly greater risk of sustaining fatal injuries when ejecting through-the-canopy than when ejecting after jettisoning of the canopy.[1] As in so many real world cases, the choice between these two canopy modes has not been one easily resolved for despite the apparent increased risks of injury there are several valuable benefits to be derived by ejecting through-the-canopy as opposed to ejecting after the canopy has been jettisoned.[2]

The issues are important to aircrew ease of mind and to their trust of their escape systems and, ultimately therefore, to the safety and survival of many aircrewmen. The U.S. Navy has had the largest quantity of through-the-canopy ejectees and, in addition, has had a number of systems in which the ejectee had the option to select the mode of canopy when ejecting thereby creating a body of data which, when fully compiled, might permit case-by-case comparisons of virtually identical escape conditions, equipment configurations and final terrain for identical ejection seats.

---

[1] This latter concern was fully addressed in the papers Investigation of Fatality Rates for Different Canopy Modes by Dr. Ronald Herd presented at the 20th Annual Safe Symposium, December 1982, and the earlier one An Analysis of the Fatality Rate Data From "Jettison-Canopy" and "Through-Canopy" Ejections From Automated Airborne Escape Systems by John E. Vetter presented at the 19th Annual SAFE Symposium, December 1981.

[2] Briefly discussed in Preliminary Generalized Thoughts Concerning Jettisoned vs. Through-the-Canopy Ejection Escape Systems by Frederick C. Guill presented at the 19th Annual SAFE Symposium, December 1981.

Progress in fully compiling that data is being made, in the form of an ejection log covering the period from August 1949 through 31 December 1968. The Naval Safety Center, Norfolk, computerized MOR/FSR (Medical Officer's Report/Flight Surgeon's Report) data is available for the period from 1 January 1969 to the present. In addition, plans are being developed to compile data with which to assess the frequency and severity of ALSS equipment damage associated with through-the-canopy ejection and jettisoned-canopy ejection. Both of these efforts are underway, but, due to staffing and funding constraints as well as higher priority tasks, are progressing at a slow rate.

One other set of data bearing upon this issue is available and that is the A-6 series aircraft through-the-canopy ejection data versus data for other aircraft through-the-canopy ejections and for jettisoned-canopy ejections during the period from 1 January 1969 through 31 December 1979. This study compares the two place side-by-side A-6 through-the-canopy ejection data with that data collected for other U.S. Navy through-the-canopy ejections with respect to injuries and ALSS equipment damage probably induced by contact with shards of canopy plexiglass.

THE A-6 CANOPY DESIGN

The A-6 canopy is unique among aircraft cockpit canopies through which ejections occur. The canopy plexiglass is manufactured in two halves, one righthand and one lefthand; and when installed in the canopy frame the two halves are joined and reinforced by a structural fore-and-aft centerline beam. The plexiglass adjacent to the centerline beam is approximately horizontal whereas that at the outer sides of the canopy frame is nearly vertical. The general concept of the design is illustrated in Figure 1.

Clearance between this fore-and-aft centerline canopy beam and the ejection seats' inboard sides and, if properly positioned laterally, their occupants' inboard limbs is minimal. As the headrest, parachute pack and ejectee shoulders pass through and break the canopy, horizontal shards of plexiglass are retained by the centerline beam forming sharp small cantilevered beams highly resistive to deflection and therefore likely to cause ejectee injury and equipment damage. Based upon the injury patterns examined and discussed below, these shards can and do inflict serious injury (one is known to have been fatal--involving arterial damage) and potentially life threatening damage to critical ALSS equipments. In addition, as discussed below, it is clear that several crewmembers while ejecting have suffered severe injuries through direct, solid contact with the fore-and-aft centerline canopy beam.

DATA PROBLEMS

Injury type and location data were developed for pilots and for B/Ns (bombardeer/navigators) of two place A-6 series aircraft for both jettisoned-canopy and through-the-canopy in-envelope ejections accomplished clear of the aircraft, for all other through-the-canopy ejections, and for all other jettisoned canopy jettisoned canopy ejections. These data were then separated into two sections for each of the above groupings: (a) injuries to the head and neck areas, and (b) injuries to body locations below the neck. The latter sections of the data groupings were examined first since one of the specific issues of interest was the effect, if any, of the fore-and-aft centerline canopy beam upon ejectee injury/non-injury. These sections of the data groupings are depicted in Tables I through LXXXVIII for comparative information.

An immediate problem affecting the ability to assess the affect of the fore-and-aft centerline canopy beam on ejectee safety is apparent upon examining the data presented in these tables concerning the location of injuries to the ejectee limbs: the use of the terms "bilateral", "posterior" and "anterior" without an identification as to whether the injury affected the right, the left or both limb segments described as the body part injured. Until this aspect of the data is resolved through the examination of the original MORs/FSRs the effect of the fore-and-aft centerline canopy beam upon ejectee injury patterns cannot be assessed. Efforts have been initiated to examine each MOR and FSR for which the computerized injury description employs any of the three listed terms.

EJECTEE INJURY PATTERNS

As noted in the preceding comments, due to the nature of the data concerning limb injuries, it is difficult to develop an analysis of comparative A-6 crewmember injury patterns versus those of other groupings of ejectees. Nonetheless there emerged a few teasers, one being injuries to ejectee hands. Among the 963 jettisoned canopy ejectees it appears that the right hand is more likely to sustain injury than the left, although fractures occurred more frequently to left hands:

TABLE LXXXIX
HAND INJURIES SUSTAINED BY JETTISONED CANOPY EJECTEES

	left	right	bilateral	anterior	posterior
abrasion	2	10	1	1	0
contusion	1	4	0	0	0
laceration	3	7	0	0	0
all fractures	3	1	0	0	0
TOTALS	9	22	1	1	0

Two place A-6 aircraft B/Ns ejecting in envelope through-the-canopy sustained one fracture each of left shoulder, left upper leg, left wrist and right lower arm and 8 lacerations on their left sides versus 6 on their right sides with one limb laceration described as bilateral, while abrasions were equally distributed at 4 for each side with one limb abrasion described as bilateral. Contusions sustained by these B/Ns were concentrated 13 on the left side to 2 on the right side with 3 contusions of limbs described as bilateral. The B/Ns' left side is his inboard side the side closest to the fore-and-aft centerline beam.

Among two place A-6 aircraft pilots ejecting in-envelope through-the-canopy, there were 3 fractures of right shoulders, 1 each of right lower leg and of right ankle, 1 lower lower leg, and 1 bilateral upper arm (i.e., believed in this case to mean both the right and left upper arm, but the issue will be checked). Lacerations were concentrated 11 on the right side against 1 on the left side with 3 lacerations of limbs described as bilateral, while abrasions were 7 on the right side, 5 on the left side and 3 limb abrasions described as bilateral. Contusions, similarly were nearly balanced, with 14 right side, 11 left side and 5 limb contusions described as bilateral. In the case of the pilot, the right side is his inboard side.

Thus, even with the presence of ambiguous injury location descriptions, the data suggest at least a slight tendancy for several types of injuries to occur more frequently on the two place A-6 ejectee's inboard limbs and side than on his outboard side. Specifically, these injury types include all classifications of fractures for both pilots and B/Ns, lacerations for pilots, and contusions for B/Ns.

CONCLUSION

Due to ambiguities in injury location descriptions, it is pre-mature to compare the two-place in envelope through-the-canopy ejectee injury patterns with those sustained by in-envelope through-the-canopy or jettisoned-canopy ejectees from other aircraft. Efforts have been initiated to resolve these ambiguities and the results will be reported as soon as they are available.

Data was prepared by Mr. Robert Cox

TABLE I
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: SHOULDER

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19		2						
A-6 B/N	TC	47	16								
OTHER	TC	88	24			1					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	6	6	13					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE II
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	5	1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE III
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, LOWER

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1	1						
A-6 PILOT	JC	12	2		1						
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	5	6					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE IV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE V
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16	1							
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	2	6					1

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE VI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2		1					
A-6 B/N	TC	47	16		1						
OTHER	TC	88	24								
A-6 PILOT	JC	12	2	1							
A-6 B/N	JC	6	2								
OTHER	JC	963	206	5	3	8					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE VII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ARM, LOWER

INJURY DIAGNOSIS:ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16		1						
OTHER	TC	88	24	1							
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	3	1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE VIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:WRIST

INJURY DIAGNOSIS:ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19		1	1					
A-6 B/N	TC	47	16	1							
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE IX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1		1					
A-6 B/N	TC	47	16	2	1	1					
OTHER	TC	88	24	3	2	1					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	10	2	1	1				

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE X
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: KNEE

INJURY DIAGNOSIS: ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1	2						
A-6 B/N	TC	47	16								
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	7	5	5					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XI

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ELBOW

INJURY DIAGNOSIS:ABRASION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	3							
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	6	3	1					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:SHOULDER

INJURY DIAGNOSIS:CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1	2	1					
A-6 B/N	TC	47	16	1	1						
OTHER	TC	88	24	3	4	5					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2	1							
OTHER	JC	963	206	15	19	24	3		1		1

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2	4	2					
A-6 B/N	TC	47	16		3	2					
OTHER	TC	88	24	5		2		2			1
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	17	9	14		4			

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XIV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, LOWER

INJURY DIAGNOSIS:CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1	1	1					
A-6 B/N	TC	47	16								1
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2		1						
OTHER	JC	963	206	10	9	14					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	4	7	1					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16		2						
OTHER	TC	88	24		1	1					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	5	9	4		1			1

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	4		2					
A-6 B/N	TC	47	16		2						
OTHER	TC	88	24	3	1	1					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	5	1	2					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ARM, LOWER

INJURY DIAGNOSIS:CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19		1						
A-6 B/N	TC	47	16		2						
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2							

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:WRIST

INJURY DIAGNOSIS:CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	1						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2	2						
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	4	1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXI

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:KNEE

INJURY DIAGNOSIS:CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1	1						
A-6 B/N	TC	47	16		2						
OTHER	TC	88	24	1							
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	8	4	2					1

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXII

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: CONTUSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2							
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	2						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: SHOULDER

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16					1			
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXIV

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16		3						
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	1	1					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, LOWER

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16	1							
OTHER	TC	88	24	1	1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	6							

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR

P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS:LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1		1					
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2		1					
A-6 B/N	TC	47	16								
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ARM, LOWER

INJURY DIAGNOSIS:LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16	2	1						
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	2						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXXI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1		1					
A-6 B/N	TC	47	16	3	2	1					
OTHER	TC	88	24	1	1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	7	3						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXXII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:KNEE

INJURY DIAGNOSIS:LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	2							
A-6 B/N	TC	47	16		2						
OTHER	TC	88	24		1			1			
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	1						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ELBOW

INJURY DIAGNOSIS:LACERATION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	3	1						
A-6 B/N	TC	47	16								
OTHER	TC	88	24		1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XXXIV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: SHOULDER

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, LOWER

INJURY DIAGNOSIS:COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XXXIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ARM, UPPER

INJURY DIAGNOSIS:COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XL
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:ARM, LOWER

INJURY DIAGNOSIS:COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:HAND, INCLUDING FINGERS

INJURY DIAGNOSIS:COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE XLIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: KNEE

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLIV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: COMPRESSION

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: SHOULDER

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, LOWER

INJURY DIAGNOSIS:COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1							

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE XLIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS:COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE L
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, LOWER

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LIV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: KNEE

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1							

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: COMPOUND COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:SHOULDER

INJURY DIAGNOSIS:COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16		1						
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	2						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LVII

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, UPPER

INJURY DIAGNOSIS:COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16		1						
OTHER	TC	88	24	2							
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, LOWER

INJURY DIAGNOSIS:COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		2						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LVIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXI

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206			1					

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, LOWER

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16		1						
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXIV

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:KNEE

INJURY DIAGNOSIS:COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: COMMINUTED

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: SHOULDER

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXVIII

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, UPPER

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1	1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, LOWER

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	1						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206			1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXIII

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, LOWER

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1							

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXIV

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS:COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: KNEE

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: COMPOUND

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206								

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXVIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:SHOULDER

INJURY DIAGNOSIS:SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1							
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	6	1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXIX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED:LEG, UPPER

INJURY DIAGNOSIS:SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24			2					
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	1						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXX
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: LEG, LOWER

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1	1						
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1	1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	5	5						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXXI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ANKLE

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19	1							
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1	3						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2	1							
OTHER	JC	963	206	2	2						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXXII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: FOOT, INCLUDING TOES

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1	1						
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	5						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXXIII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, UPPER

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19			1					
A-6 B/N	TC	47	16								
OTHER	TC	88	24	1							
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	3	6						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXXIV

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ARM, LOWER

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19		1						
A-6 B/N	TC	47	16	1							
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	1	1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXXV
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: WRIST

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206			1					

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXXVI
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: HAND, INCLUDING FINGERS

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	1	3						

INJURY LOCATIONS

R – RIGHT	P – POSTERIOR
L – LEFT	M – MEDIAL
B – BILATERAL	T – TOTAL BODY
A – ANTERIOR	U – UNKNOWN

TABLE LXXXVII
COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: KNEE

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206	2	2						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

TABLE LXXXVIII

COMPARTIVE SERIOUS INJURY PATTERNS FOR EJECTEES ACCOMPLISHING EJECTIONS CLEAR OF THE AIRCRAFT WITHIN THE AAES PERFORMANCE CAPABILITY ENVELOPE

(BODY LOCATION SHOULDER AND BELOW)

BODY PART INJURED: ELBOW

INJURY DIAGNOSIS: SIMPLE

	CANOPY MODE	TOTAL AIRCREW	TOTAL AIRCREW SUSTAINING INJURIES	INJURY LOCATION							
				R	L	B	A	P	M	T	U
A-6 PILOT	TC	42	19								
A-6 B/N	TC	47	16								
OTHER	TC	88	24								
A-6 PILOT	JC	12	2								
A-6 B/N	JC	6	2								
OTHER	JC	963	206		1						

INJURY LOCATIONS

R – RIGHT
L – LEFT
B – BILATERAL
A – ANTERIOR
P – POSTERIOR
M – MEDIAL
T – TOTAL BODY
U – UNKNOWN

GENERAL CONCEPTUAL DESIGN SKETCH OF A-6 SERIES (NON-EA-6B) AIRCRAFT COCKPIT CANOPY AND EJECTION SEAT PLACEMENT

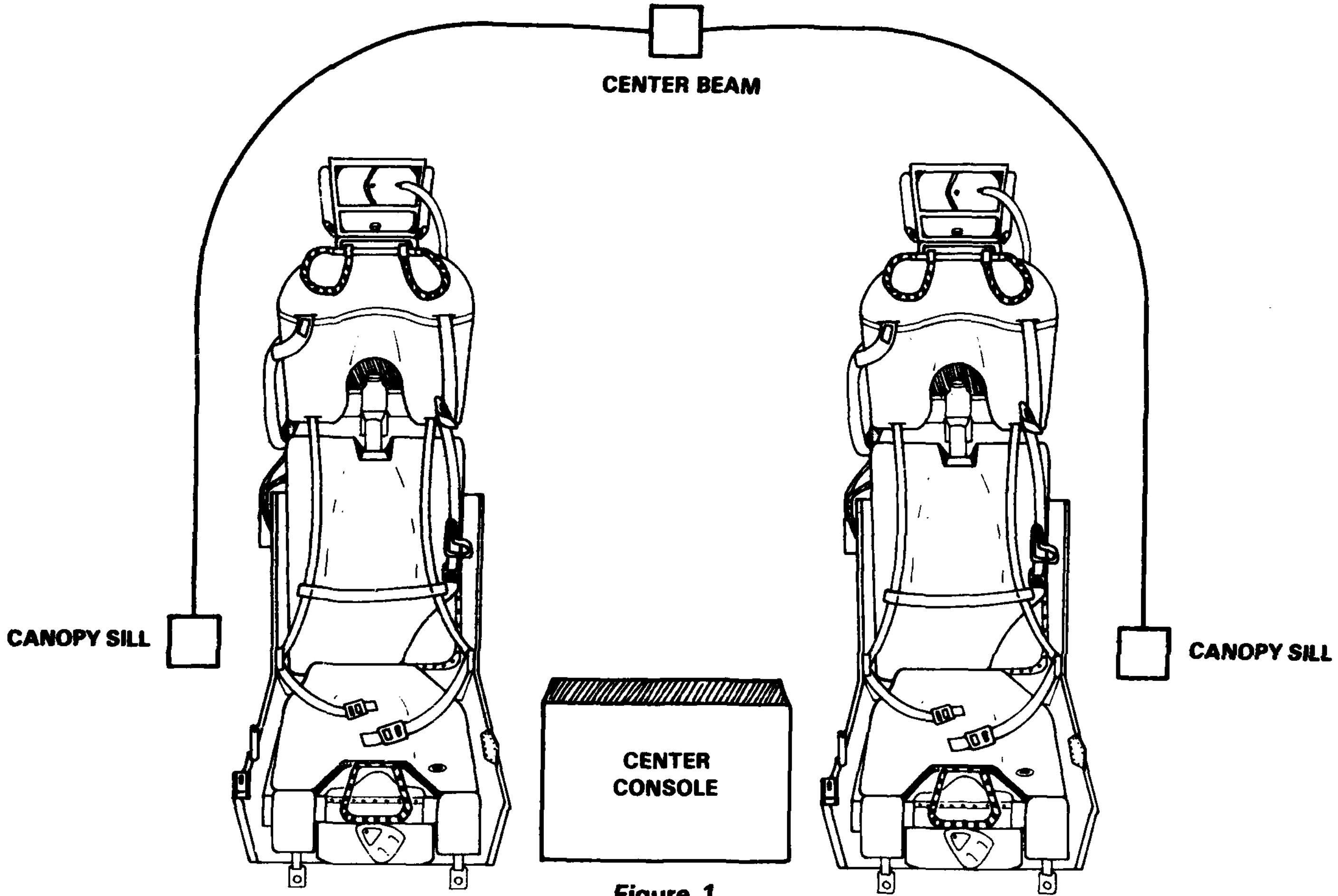

Figure 1.

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