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P-3 PILOT ERRORS. A CONCEPTUAL APPROACH.(U)
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⑥ P-3 PILOT ERRORS: A CONCEPTUAL APPROACH

By

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EXECUTIVE SUMMARY

Chapter I - Introduction. The basic thrust of this study is to improve our understanding of pilot errors by examining pilots' attitudes toward, and perceptions of, errors in a way never attempted before. Background information on a recent study of the game of "Eight Ball" is provided in this chapter since the "Eight Ball" study was used as a guide in the examination of pilot errors. Computer programs for cluster analysis, multidimensional scaling and discriminant analysis were utilized in this exploratory research project.

Chapter II - Method. This chapter describes the methodology used to examine pilot behaviors as pretested on 23 Newport area P-3 pilots. Sixty P-3 pilot behaviors were typed on 3x5 cards, and each of the pilots was asked to sort the cards into two or more piles as they perceived the behaviors related to one another. The respondents' sortings were subjected to cluster analysis, and the solution resulted in three major clusters that seemed to fit logically within the realm of P-3 piloting. The clusters are briefly described and depicted in three dimensional representations. Since there was a patterning of P-3 pilot behaviors, it was thought that there would be patterning among P-3 pilot errors.

Chapter III - The First Fleet Pilot Study. This chapter describes the first round of interviews that were conducted with 51 P-3 pilots stationed at a major P-3 patrol squadron base. These pilots were asked to sort 60 cards, on which were typed P-3 pilot errors, into more than two piles, as they perceived the errors went together. These pilots were also asked to sort the same 60 errors into seven slots in a box ranging from "most serious" to "least serious". Seriousness is discussed in Chapter VI. The clustering solutions of "Acceptable," "Unacceptable", and "Runway Environment Technique" errors were depicted and discussed. Multidimensional scaling solutions were depicted to show the dimensions of the clusters as named by the author. These dimensions give us clues as to how pilots view the errors thus leading us to a better understanding of pilots' perceptions.

Chapter IV - The Second Fleet Pilot Study. This chapter follows the same format as the preceding chapter in describing the second study of 52 P-3 pilots accomplished at another major patrol squadron base. These pilots were interviewed in the same manner as the first group except that they were also asked to rank order 13 preselected errors on four attributes: Career, Rattle, Embarrassment and Fun. Results of these rankings are discussed in Chapter VII. The clustering solution for the second group of pilots, although much the same as the first group's cluster solution, has some differences that are discussed along with possible reasons for the differences. Also, as in the preceding chapter, multidimensional scaling solutions for each cluster are provided.

Chapter V - The Combined Results. The data for all 103 pilots were aggregated and subjected to cluster analysis and multidimensional scaling. Results are treated in this chapter in the same format as the two preceding chapters. The concept that the respondents have views of a "pilot" that differ from views of an "aviator" is discussed as a possible reason for the clustering of Acceptable Errors and Runway Environment Technique Errors. As in the preceding chapters, multidimensional scaling solutions are provided.

Chapter VI - Seriousness. This chapter treats the results of the seriousness scaling. The pilots were divided into groups of low (40-799 hrs), medium (800-1499 hrs) and high (over 1500 hrs) P-3 flight hours. Using this grouping and grouping by base location, a discriminant analysis program could predict group membership fairly accurately, based on how the respondent sorted the errors. The idea that some pilots in the "high" group sort errors in the same manner as the pilots in the "low" group (or vice versa) is discussed along with possible implications and applications for the future. Tables are presented for the discriminant analysis findings and the seriousness ranking.

Chapter VII - Attributes. This chapter contains a brief discussion of the results of the ranking of the 13 preselected errors along the four attributes of Career, Rattle, Embarrassment and Fun. A table depicts the mean rankings, and discussion centers on the finding that some errors are perceived as career wreckers, embarrassing, likely to rattle and not much fun, but these are errors that are not likely to cause much damage or bring about loss of life. On the other hand, there are some errors that are perceived to have an element of fun that are high risk errors, and the possibility for loss of life and aircraft damage is high when these errors occur.

Chapter VIII - Conclusion, New Directions. This chapter summarizes what has been learned from the study. The points covered are that:

a. It is possible to use clustering techniques to make explicit certain implicit patterning of pilot errors.

b. Multidimensional scaling can identify significant dimensions of the error space and these dimensions may give us directions for the future study of errors.

c. There are differences in the way pilots view the seriousness of errors and these differences might suggest areas for further study.

d. A subset of errors, more manageable in size, might model the total error space.

e. Scaling of errors on certain attributes might give us clues as to what changes in pilots' attitudes to strive for to achieve a safer flying environment.

ACKNOWLEDGMENTS

I am indebted to many people who took time from their busy schedules to provide me advice and data. This project is solely the product of the original thinking of Professor John M. Roberts, the Andrew Mellon Professor for Anthropology at the University of Pittsburgh. His dynamic and innovative thinking is the impetus behind this study. The assistance in methodology, computer programming, and data analysis provided by Gary E. Chick, a graduate student at the University of Pittsburgh, was also invaluable to the completion of this study. Acknowledgment must also be made to Professor Roy G. D'Andrade who generously allowed the authors to use his U-Clust program before its publication. The advice and encouragement of my faculty advisor, Captain D.F. Parker, has kept the project moving toward a timely completion. Also the guidance and backing provided by Professor Hugh Nott of the Center for Advanced Research and Lieutenant Colonel Gerry Keller, USMC, are greatly appreciated.

Most of all, I am indebted to the pilots of the Patrol Squadrons who gave freely of their time and knowledge in an active demonstration of their concern for, and their dedication to, the improvement of flight safety.

This report has been submitted to fulfill the requirements of the Center for Advanced Research. Analysis of the data is continuing, and further reports co-authored by Professor Roberts and Gary Chick will be submitted for publication.

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CHAPTER I

INTRODUCTION

> Man's miscalculations--of inches or feet, seconds or minutes, thickness, width, solidity and a dozen other factors--have induced great suffering throughout history.[1]

Human error continues to plague the aviation community at a time when great strides are being made in designing safety features into aircraft. Aviation accident rates have tumbled in the last two decades, yet the percentage of accidents attributed to human error has remained fairly stable.[2] Human error research must therefore go on, and improved understanding is required if there is to be a drastic reduction in pilot error accidents. We must find the "why" of human error.

Background--The Roberts/Chick Study

In 1977 John M. Roberts and Gary E. Chick conducted a study of a league of "Eight Ball" players in Western Pennsylvania.[3] This exploratory study was an attempt to construct a model of the behavioral array of actions associated with the play of the pool-type game of "Eight Ball." In this study an informed judge listed sixty "Eight Ball" behaviors, good and bad, important and unimportant, interesting and uninteresting, which he felt represented the full behavioral array found in "Eight Ball." Examples of these behaviors are: CHALKING THE CUE STICK, RACKING THE BALLS and CALLING THE POCKET. The selection of behaviors was only an ethnographic judgment, but the judge was a long-term player who was completely familiar with the game and the league. The sixty behaviors he identified constituted, then, a model of "Eight Ball" behavioral space. Expressions commonly used for the sixty behaviors by most "Eight Ball" players were entered on 3 by 5 cards. Forty-five experienced members of the league were given the cards, and each player sorted them into piles, based on the similarities which he determined the various behaviors had to each other. An aggregate similarity matrix based on sorting was then clustered.

Clustering refers to a number of related statistical classification techniques that take data units (in this case "Eight Ball" behaviors) and ideally group them into clusters so that elements within a cluster have a high degree of natural association among themselves, while the clusters are relatively distinct from one another. The extent to which a procedure results in such clusters depends upon the structuring inherent in the data based upon an aggregation of the clusters of each participant. Hierarchical clustering techniques produce representations of the data units that are roughly analogous to the taxonomies of descriptive semantics.

Each of the main clusters was treated as a domain, and the behaviors within the domain were subjected in turn to multidimensional scaling. Roberts and Chick determined that both the clusters and dimensions produced by these procedures have ethnographic import. Stated somewhat differently, the clusters and dimensions must be understood if people are to understand the play of the game as it actually occurs.

Finally, the attitudinal study of a small sample of experts and a small sample of more ordinary players was conducted. All of the players scaled all of the behaviors associated with actual play in terms of the fun they experienced when they performed them. Players also scaled their estimates of the amount of concentration that a set of behaviors required and the degree to which their concentration was broken when they practiced certain behaviors.

The total analysis therefore, dealt with a sample of actual behaviors occurring in the space on and around the pooltable in the course of the play of "Eight Ball" and the conceptual space into which the players place this play. Then, to a degree, attitudes towards concentration and fun were "mapped" within the described space.[4] The total description gained from such mapping leads to a better understanding of the play of the game, and the authors believe that it will also give clues as to the factors that determine why some players are better than others.

Research Objectives

Until technology produces an automated flying machine with no pilot aboard, we must continually strive to reduce human errors in aviation. The Navy invests heavily in training and safety programs in order to produce a competent, safe pilot. Following the lead of the Roberts/Chick study, it seems reasonable that an understanding of pilots' attitudes toward errors might furnish insights and suggest new dimensions for effort in the field of training and safety. This study is, therefore, an exploratory attempt to discover more about pilot errors and to search for a new way to view the space of errors for the purpose of achieving a fuller understanding of them.

Employing the methodology used in the Roberts/Chick study a "new look" at pilot errors was attempted. Because the author is a qualified P-3 pilot with more than 2800 pilot hours in the P-3 ORION anti-submarine patrol aircraft, the study is focused on P-3 pilots.

CHAPTER II

METHOD

Preliminary Testing at the Naval War College

The author selected sixty of the numerous behaviors relating to all aspects of P-3 piloting and typed these behaviors on 3 by 5 cards. The behaviors selected were those normally accomplished by the pilot and represent actions which occur in all phases of P-3 operations. The sixty behaviors are listed in Table I.

The initial feasibility of mapping similarity matrices for the clustering was obtained by giving the shuffled card deck to P-3 pilots stationed at the Naval War College or in the Newport area and asking them to sort the cards into two or more piles on the basis of the similarity which the behaviors had for each other. The minimum and maximum numbers of piles obtained through this procedure were two and eleven. The sorting task was accomplished by twenty-three P-3 pilots with varying fleet experience and currency in the aircraft. The twenty-three similarity matrices were then summed to produce the aggregate matrix which was entered into the clustering program. This aggregate matrix was clustered using the U-statistic clustering technique.[1] This technique is a non-parametric method of hierarchical clustering which groups on the basis of the best mean rank of proximity scores

TABLE I

SIXTY P-3 PILOT BEHAVIORS

PERFORM A NO FLAP LANDING
EXTEND THE LANDING GEAR WITHOUT ELECTRICAL POWER
NULL OUT AN ENGINE DUE TO TD SYSTEM MALFUNCTION
GIVE THE COMMAND TO 'E' HANDLE AN ENGINE FOR LOW OIL PRESSURE
PERFORM A THREE ENGINE FERRY TAKEOFF
STOP THE AIRCRAFT DUE TO BRAKE FIRE
PERFORM AN ACTUAL THREE ENGINE LANDING
LAND THE AIRCRAFT WITH A FLAT TIRE ON THE MAIN MOUNT
FLY ACTUAL INSTRUMENTS ON PARTIAL PANEL
ABORT THE TAKEOFF AT 80 KNOTS
LAND THE AIRCRAFT DOWNWIND
LAND THE AIRCRAFT ON A SHORT RUNWAY
LAND THE AIRCRAFT ON AN ICY RUNWAY
LAND THE AIRCRAFT AT NIGHT
LAND THE AIRCRAFT IN A CROSSWIND
POST FLIGHT THE AIRCRAFT
FILL OUT THE YELLOW SHEET
SECURE ALL THE RADIOS
SET THE PARKING BRAKE IN THE CHOCKS
PUT CREW IN DITCHING STATIONS FOR TAKEOFF
CHECK THE FLAPS SET FOR TAKEOFF
CHECK THE TRIM TABS SET FOR TAKEOFF
CHECK BRAKES DURING TAXI
CHECK THE TURN INDICATORS AND COMPASSES ON TAXI
CHECK FLIGHT CONTROLS FOR FREEDOM DURING TAXI
INSURE THAT THE TAKEOFF CHECK LIST IS COMPLETE
SET YOUR RADIOS AND HSI TO CARRY OUT YOUR CLIMBOUT
SET YOUR SEAT BELT AND SHOULDER HARNESS
ADJUST YOUR SEAT
CALL FOR THE BEFORE START CHECK LIST
CALL FOR THE AFTER START CHECK LIST
SIGNAL "CHOCKS OUT" TO THE LINEMAN
OBSERVE ENGINE START TEMPERATURES AND RPM'S
PREFLIGHT THE AIRCRAFT
BRIEF THE CREW BEFORE DEPARTING ON MISSION
FIT THE PARACHUTE AND STOW IT
CALL FOR GEAR UP
CALL FOR MAX POWER
MAINTAIN DIRECTIONAL CONTROL ON TAKEOFF ROLL
ADVANCE THE POWER LEVERS TO BEGIN THE TAKEOFF
ROTATE THE AIRCRAFT DURING TAKEOFF
ESTABLISH THE CLIMB
LINE UP THE AIRCRAFT ON RUNWAY CENTERLINE FOR TAKEOFF
CALL FOR NTS CHECK
BRIEF COCKPIT CREW ON LANDING PROCEDURE
CALL FOR DESCENT CHECK LIST
CHECK ALTIMETER SETTING AND READ BACK BEFORE DESCENT
OBTAIN LANDING WEIGHT AND SPEEDS
CHECK THE BRAKES AFTER GEAR DOWN ON FINAL
CALL FOR LANDING FLAPS
CALL FOR APPROACH FLAPS
SHOOT AN ACTUAL GCA
TRANSITION FROM INSTRUMENTS TO VISUAL WHEN CONTACT
REVERSE THE PROPS ON LANDING ROLL
EASE THE POWER AS LANDING FLARE IS ESTABLISHED
MAINTAIN DIRECTIONAL CONTROL ON ROLLOUT BY VARYING REVERSE
TURN OFF THE RUNWAY
SWITCH LEFT HAND FROM YOKE TO NOSEWHEEL STEERING ON ROLL OUT
RESET POWER AFTER DESCENT TO VECTOR ALTITUDE
REDUCE POWER FOR DESCENT

connecting potential clusters. The hierarchical clustering solution obtained from the computer is depicted in Figure 1.

Next, a small number of P-3 pilots examined the clustering solution presented in Figure 1 and agreed that the clustering seemed logical and it fitted their experience in P-3 flying.[2]

Three major clusters were accordingly identified, agreed to by the experts and titled:

I. Difficulty Cluster

II. Assurance/Checking Cluster

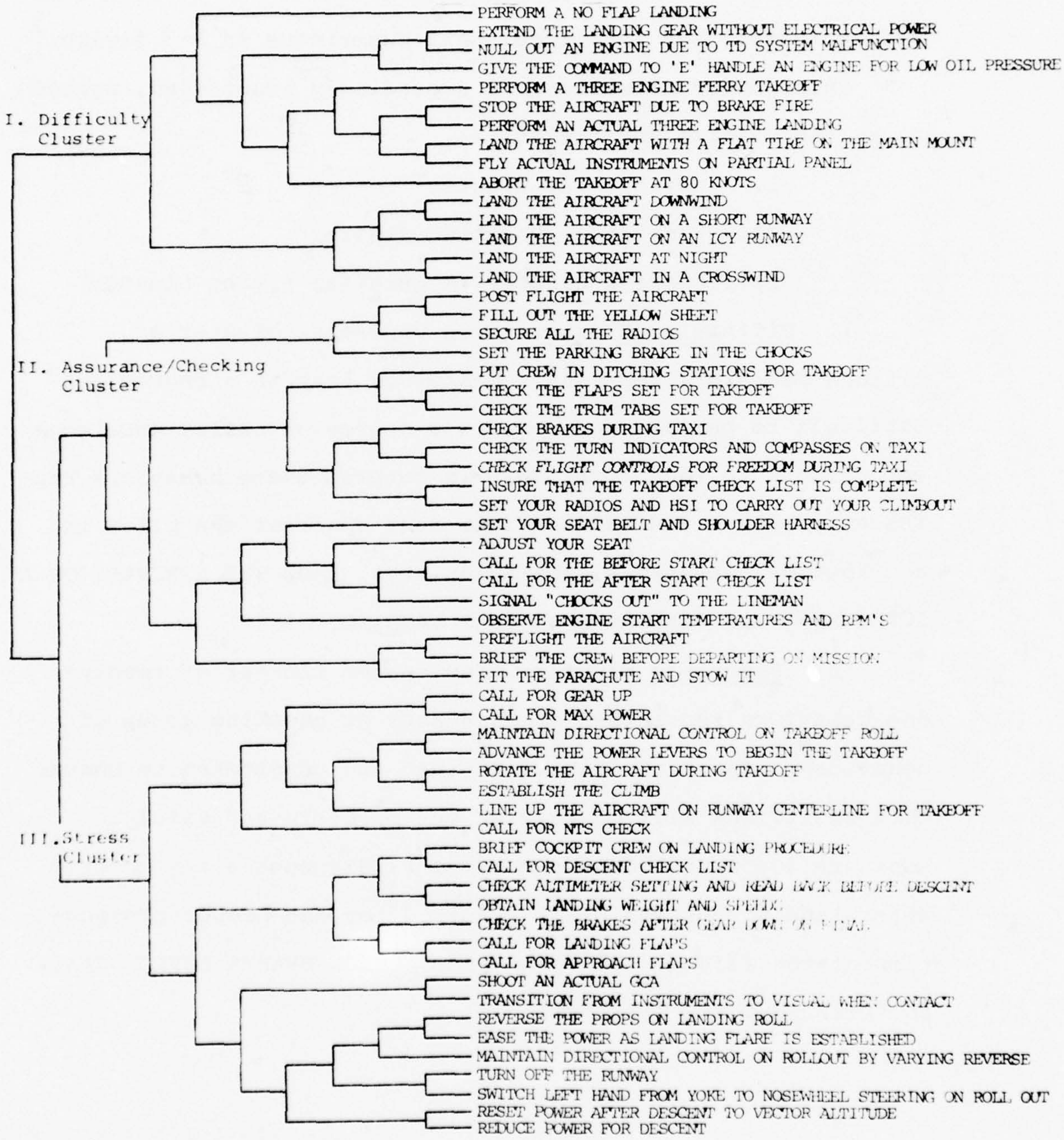
III. Stress Cluster (Sequential Flying Cluster)

I. Difficulty Cluster. The uppermost cluster of fifteen behaviors represents behaviors that to a degree are difficult to perform and require a degree of skill, knowledge and airmanship to accomplish. In general these behaviors represent problems and malfunctions that confront the pilot in non-routine situations. Examples are: LAND THE AIRCRAFT ON AN ICY RUNWAY and PERFORM A NO FLAP LANDING.

II. Assurance Cluster. The center cluster of twenty-one behaviors represents an assurance or checking group of behaviors. These are behaviors that are undertaken to ensure that the flight will be carried out properly and safely. Most are accomplished before takeoff, although a few occur after landing but are still required for the proper prosecution of the flight. Examples are: CHECK BRAKES DURING TAXI and PREFLIGHT THE AIRCRAFT.

FIGURE 1

NEWPORT AREA P-3 PILOTS CLUSTERING OF BEHAVIORS



III. Stress Cluster. The lower cluster of twenty-four behaviors is sequential in nature and appears to proceed from takeoff to landing. Most of the behaviors in this cluster have to do with normal flying, involving manipulation of the controls, changing the status of the aircraft or giving the orders for manipulation of the controls. The sequential nature of the cluster provoked further speculation that any flight produces stress that increases from takeoff to landing. Consequently, this grouping was also tentatively labeled a stress cluster. Examples are: ROTATE THE AIRCRAFT DURING TAKEOFF, ESTABLISH THE CLIMB, CALL FOR DESCENT CHECKLIST and TURN OFF THE RUNWAY.

Subclusters within a major cluster can be identified, such as landing cluster of five behaviors at the bottom of the Difficulty Cluster (Figure 1, lines 11 through 15). These subclusters were not examined closely in this preliminary testing, however, and will require further analysis in subsequent studies.

Since the three major clusters defined an overall pattern that seemed to make sense to P-3 pilots, the 60 behavior as sorted by the pilots were next subjected to multidimensional scaling to search for the structure or domain of the clusters.[3] Figures 2, 3 and 4, with accompanying Tables II, III, and IV, show the results of this scaling in three-dimensional interpoint distance representation. Separate figures and tables for each cluster were drawn to show a less cluttered representation of the clusters within the space of the total sixty behaviors. An examination of each of the three figures shows that the behaviors do cluster, each group occupying its own "space" within the total space. The key for the letters appearing in Figure 2 is given in Table II. A similar usage holds for Figures 3 and 4 where the keys appear in Tables III and IV.

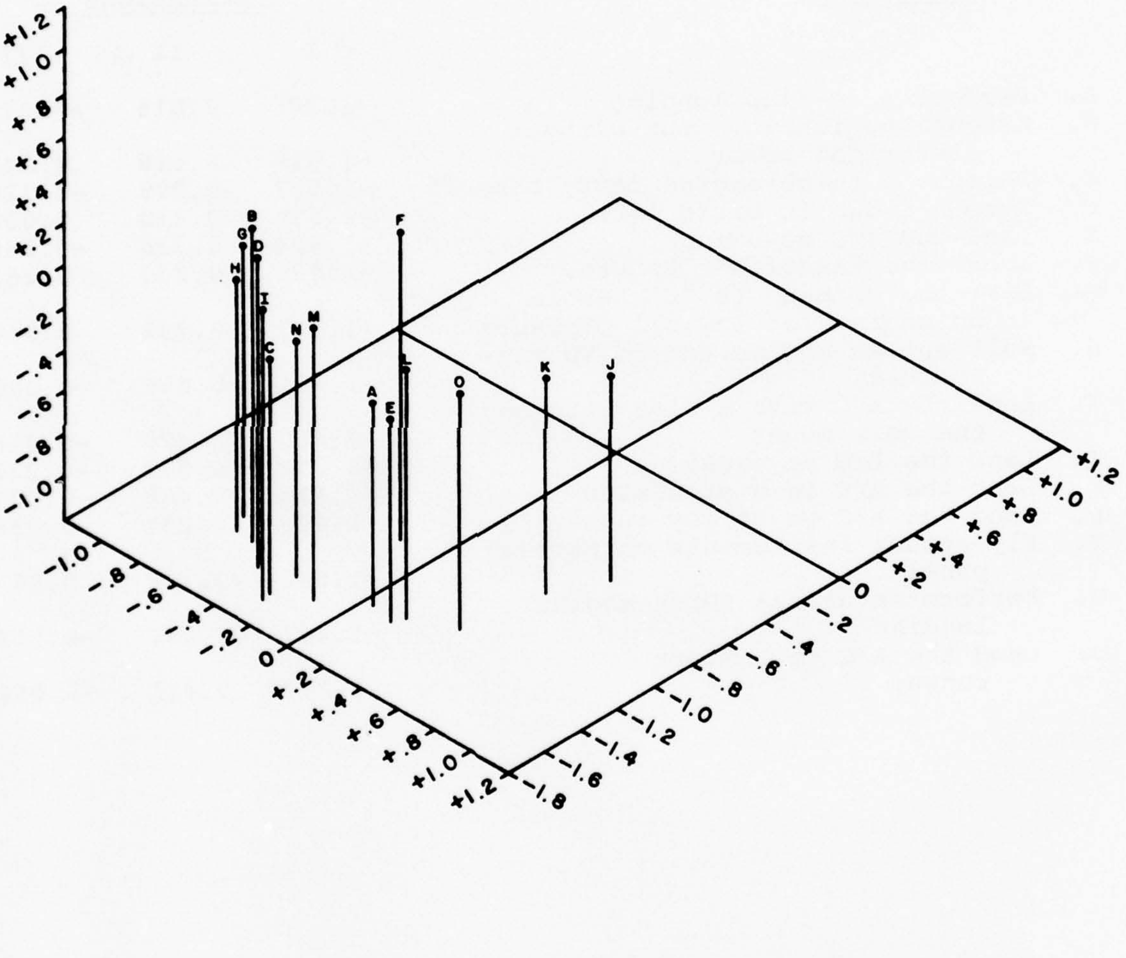
Each cluster was then multidimensionally scaled separately, and certain dimensions were identifiable but will not be treated here since further research centering on errors was desired.

The sorting accomplished by the initial twenty-three War College/Newport Pilots served as a pre-testing experiment and demonstrated that the sixty behaviors were meaningful to all, and since they had form and structure, they were cognitively mapped within the pilots' minds. This information indicated that further probing in the more narrow field of errors was possible.

To prepare for field testing, an array of seventy errors was compiled from a Naval Safety Center statistical printout of pilot factor accidents and incidents, and from the author's flying experience. The change from sixty to seventy errors represented an attempt to increase the number in the action space, allowing more opportunity for definitive clustering.

The seventy errors were pre-tested on seven War College P-3 pilots in much the same manner as before, except that the

Figure 2



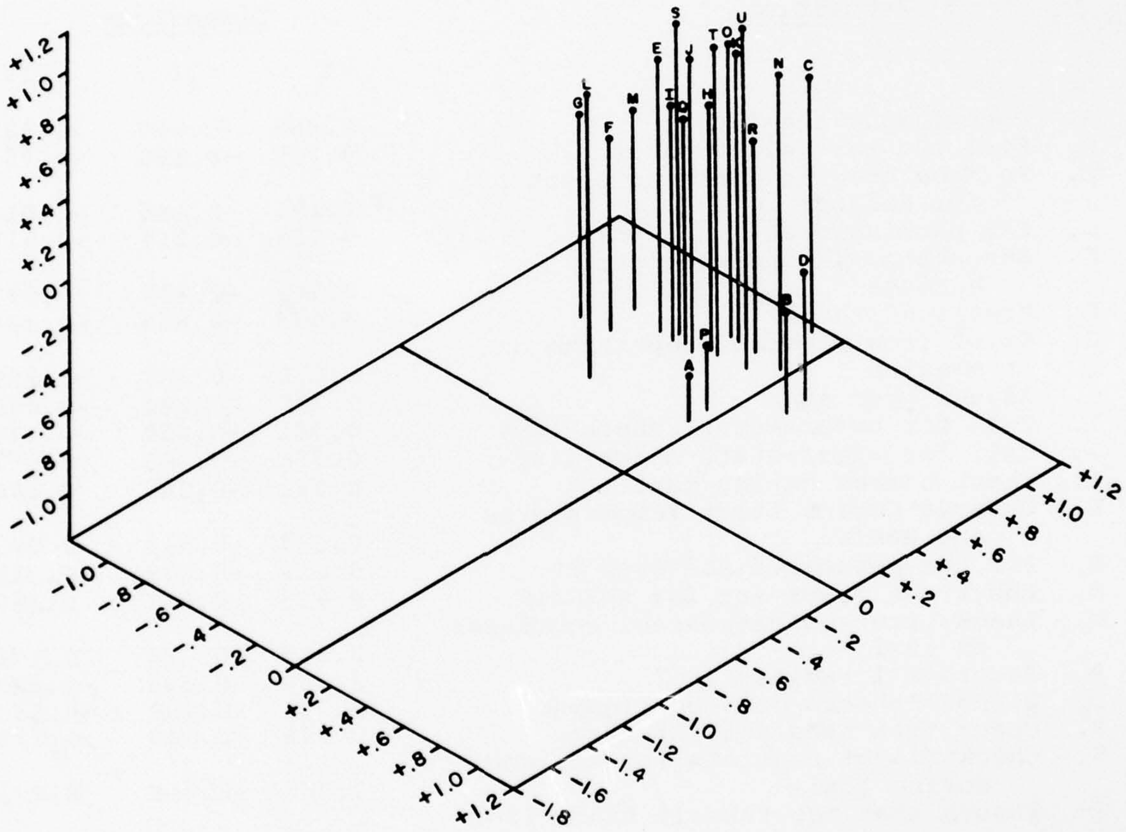
Three-dimensional representation of interpoint distances of the 15 Difficulty behaviors in the 60 behavior space.

TABLE II

DIFFICULTY CLUSTER

Behaviors		Dimensions		
		I	II	III
A.	Perform a no-flap landing	-1.385	0.014	-0.274
B.	Extend the landing gear without electrical power	-1.396	-0.616	0.248
C.	Perform a three-engine ferry takeoff	-1.582	-0.299	-0.120
D.	Stop A/C due to brake fire	-1.539	-0.410	0.034
E.	Land the A/C downwind	-1.404	0.230	-0.266
F.	Abort the takeoff at 80 kts.	-1.084	-0.233	0.263
G.	Give the command to "E" handle an engine for low oil pressure	-1.317	-0.742	0.066
H.	Null out an engine due to TD malfunction	-1.401	-0.646	-0.005
I.	Land the A/C with a flat tire on the main mount	-1.660	-0.320	-0.016
J.	Land the A/C at night	-0.594	0.573	-0.237
K.	Land the A/C in a crosswind	-0.813	0.468	-0.209
L.	Land the A/C on an icy runway	-1.423	0.235	-0.058
M.	Fly actual instruments on partial panel	-1.542	-0.178	0.067
N.	Perform an actual three-engine landing	-1.447	-0.297	-0.114
O.	Land the A/C on a short runway	-1.297	0.421	-0.088

Figure 3



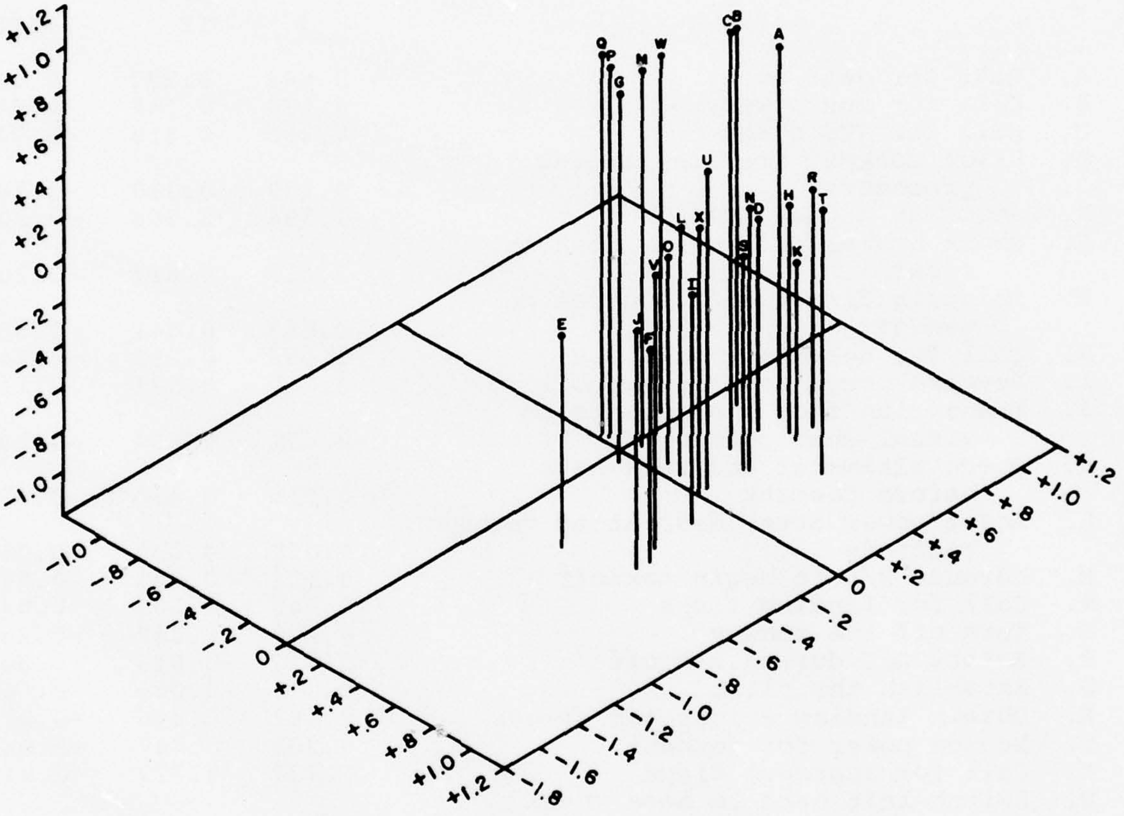
Three-dimensional representation of interpoint distances of the 21 Assurance/Checking behaviors in the 60 behavior space.

TABLE III

ASSURANCE/CHECKING CLUSTER

	Behaviors	Dimensions		
		I	II	III
A.	Post-flight the A/C	0.405	-0.060	-0.927
B.	Fill out the yellow sheet	0.710	-0.190	-0.757
C.	Put the crew in ditching stations for takeoff	1.195	-0.164	-0.012
D.	Set parking brake in chocks	0.798	0.237	-0.617
E.	Set seat belt and shoulder harness	0.763	-0.490	0.097
F.	Preflight the A/C	0.638	-0.660	-0.325
G.	Brief crew prior to departing on mission	0.618	-0.786	-0.239
H.	Adjust your seat	0.797	-0.282	-0.055
I.	Call for before-start check list	0.731	-0.459	-0.129
J.	Call for after-start check list	0.756	-0.363	-0.057
K.	Check brakes during taxi	0.912	-0.249	0.146
L.	Observe engine start temperatures and RPM's	0.334	-0.513	0.093
M.	Fit the parachute and stow it	0.819	-0.719	-0.322
N.	Check the flaps set for takeoff	0.933	-0.012	0.180
O.	Check turn indicators and compasses on taxi	0.918	-0.333	0.174
P.	Secure all radios	0.532	-0.048	-0.880
Q.	Signal "chocks out" to lineman	0.734	-0.400	-0.133
R.	Check trim tabs set for takeoff	0.878	-0.143	0.213
S.	Check flight controls for freedom during taxi	0.768	-0.468	0.235
T.	Insure that the takeoff check list is complete	0.768	-0.283	0.210
U.	Set radios and HSI to carry out climbout	0.780	-0.137	0.351

Figure 4



Three-dimensional representation of interpoint distances of the 24 Stress behaviors in the 60 behavior space.

TABLE IV

STRESS CLUSTER (SEQUENTIAL FLYING CLUSTER)

Behaviors		Dimensions		
		I	II	III
A.	Call for gear up	0.602	0.277	0.532
B.	Call for max power	0.534	0.155	0.571
C.	Call for NTS check	0.265	0.318	0.747
D.	Brief cockpit crew on landing procedure	0.459	0.310	-0.202
E.	Shoot an actual GCA	-0.584	0.368	-0.205
F.	Check brakes after gear down on final	0.410	0.627	-0.209
G.	Maintain directional control on takeoff	-0.053	0.041	0.539
H.	Call for descent check list	0.559	0.385	-0.140
I.	Reverse props on landing roll	-0.015	0.574	0.115
J.	Transition from instruments to visual when contact	-0.471	0.634	-0.081
K.	Check altimeter and read back before descent	0.516	0.454	-0.373
L.	Reset power after descent to vector altitude	0.058	0.339	-0.050
M.	Advance P/L to begin takeoff	0.111	0.029	0.545
N.	Call for landing flaps	0.240	0.505	0.046
O.	Turn off the runway	0.178	0.262	-0.255
P.	Rotate A/C during takeoff	0.032	-0.013	0.500
Q.	Establish the climb	0.006	0.066	0.565
R.	Obtain landing weight and speeds	0.587	0.446	-0.096
S.	Reduce power for descent	0.201	0.449	-0.042
T.	Call for approach flaps	0.436	0.727	0.041
U.	Switch left hand to nose wheel steering on rollout	0.067	0.455	0.295
V.	Maintain directional control on roll-out by varying reverse	-0.348	0.554	0.079
W.	Line up A/C on runway centerline for takeoff	0.304	-0.107	0.496
X.	Ease the power as flare is established	0.002	0.468	0.046

pilots were asked to return more than two piles, to get greater definition. Some of these pilots had sorted the first sixty behaviors, and some were unfamiliar with the procedure. In addition, the seven pilots were asked to sort an identical card deck into seven slots in a box, ranking the errors from "most serious" to "least serious." Cards already slotted could be seen by the sorter and could be changed to another slot if desired. The seventy errors did show distinct clusters, and the seriousness ranking seemed sufficiently promising to justify field testing. It was decided, however, that the increase from sixty to seventy errors made the task prohibitively cumbersome, and a decision was made to employ only sixty errors. The ten errors dropped were selected because they were very similar to an error already in the deck or because they were very general in nature.

CHAPTER III

THE FIRST FLEET PILOT STUDY

Fifty-one P-3 pilots ranging in age from 24 to 43 and in P-3 pilot hours from 40 to 4000 were surveyed at a major patrol squadron base in February 1978. As in the preliminary error study, the pilots were asked to sort the errors into more than two piles, based upon their perception of how the errors related to each other.

No time limit was imposed nor was there a limit on the number of piles a respondent could make. The pilots were assured anonymity and told only that the sorting was for a survey related to aviation safety. They were also asked to sort the same 60 errors into seven slots in a box, ranging from "most serious" to "least serious."

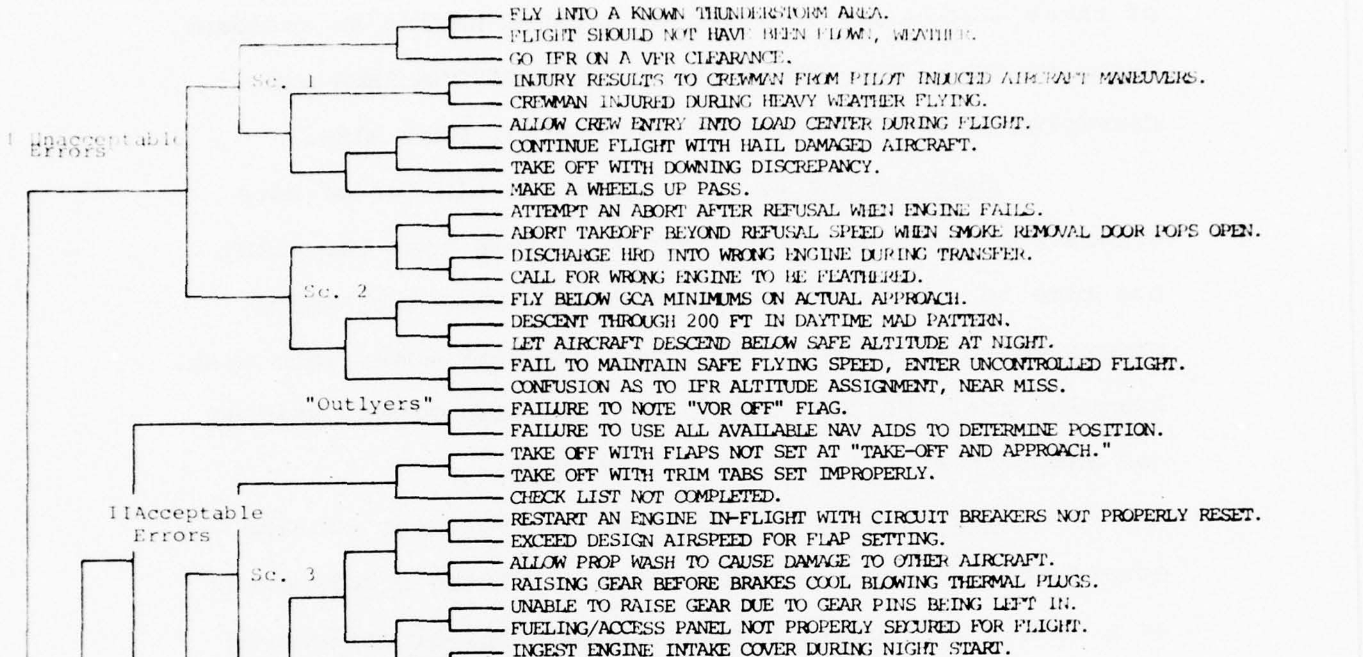
The clustering solution for the errors sorted by the 51 pilots is shown in Figure 5. This solution was examined by several War College P-3 pilots who aided in naming the major clusters and sub-clusters. The three major clusters were titled:

I. Unacceptable Errors
II. Acceptable Errors
III. Runway Environment Technique Errors

I. Unacceptable Errors. The uppermost cluster of 18 errors is a grouping of errors that are "killers." These errors are highly unacceptable to most pilots, even though

FIGURE 5

FIRST FLEET PILOT STUDY CLUSTERING OF ERRORS



most pilots will admit to having committed at least some of these errors and survived or escaped having an accident. Examples are: FLY INTO A KNOWN THUNDERSTORM AREA and CONFUSION AS TO IFR ALTITUDE ASSIGNMENT, NEAR MISS.

Sub-cluster 1. The upper sub-cluster of nine errors that are deliberate errors, errors that the pilot has time to ponder before committing. They are, then, errors where a judgment factor or headwork comes into play. Examples are: FLIGHT SHOULD NOT HAVE BEEN FLOWN, WEATHER and TAKE OFF WITH A DOWNING DISCREPANCY.

Sub-cluster 2. The lower sub-cluster of nine errors are spur-of-the-moment errors. These errors occur as a result of necessarily rapid decisions or actions on the part of the pilot. Judgment is less a factor here than reaction to stimuli or fast moving events. Examples are: CALL FOR THE WRONG ENGINE TO BE FEATHERED and ATTEMPT AN ABORT AFTER REFUSAL WHEN ENGINE FAILS.

II. Acceptable Errors. The center cluster of 25 errors is a grouping of errors that are more acceptable to pilots. These errors are more common and occur more frequently. They are expected from less experienced pilots and watched for and anticipated by senior pilots in the instructor role. Many pilots have committed these errors or witnessed the commission thereof. In some cases, these errors have occurred and escaped detection by supervisory authority when no damage or injury resulted from the error.

Examples are: TAKE OFF WITH PITOT COVERS LEFT ON and SECURE AN ENGINE IN-FLIGHT PRIOR TO DETERMINING IF ACTUAL MALFUNCTION EXISTS.

Sub-cluster 3. The upper sub-cluster of 17 errors appears to be a grouping of inattention or distraction errors. These are items that a pilot should have detected, but through inattention, temporary distraction, stress, fatigue or a break in habit pattern, the occurrence is missed or the pilot errs in the action required by the event. Examples are: CHECK LIST NOT COMPLETED and TAKE OFF WITH PITOT COVERS LEFT ON.

The first two errors of this sub-cluster, FAILURE TO NOTE "VOR OFF" FLAG and FAILURE TO USE ALL AVAILABLE NAV AIDS... are "outlyers" i.e., although joined with each other at the first level, they are not joined in another grouping until the seventh level. It is difficult to determine the reason for this unless the errors were semantically segregated by reason of the first word, "FAILURE."

Sub-cluster 4. This sub-cluster of eight errors appears to involve a lack of knowledge of the aircraft systems. Pilots may also feel that the responsibility for these errors lies at least partially with other crew members such as the Flight Engineer or the Co-pilot; clearly though, these errors relate to aircraft systems knowledge. Examples are: IMPROPER USE OF DEICING EQUIPMENT and ATTEMPT TO START A DECOUPLED ENGINE.

III. Runway Environment Technique Errors. The lower major cluster of 17 errors is a grouping of errors that occur in the runway environment and are mostly technique errors on the part of the pilot. Most of these errors reflect hands-on operation of the aircraft controls and occur in the action of changing the status of the aircraft, i.e., a change from airborne status to on-the-ground operation or vice versa. Examples are: FLARE TOO HIGH and RAISE THE LANDING GEAR PREMATURELY.

Sub-cluster 5. This upper sub-cluster of nine errors represents a group of errors wherein an outside influence, such as wind, snow, lack of daylight, or shortness of runway, contributes to the occurrence of the error. In these cases, then, there are other than routine factors that are involved or contribute to the occurrence of the error. Examples are: TAXI THE AIRCRAFT INTO A SNOW BANK and ALLOW PROP TO CONTACT RUNWAY DURING CROSSWIND LANDING. As in sub-cluster 3, there are two "outlayers" found in this sub-cluster. The first two errors, SALVAGE A LANDING FROM A POOR APPROACH THAT SHOULD HAVE BEEN A WAVE OFF and ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING, are joined with each other at the first level but do not join again until the seventh level. A possible explanation here is that both these errors have a strong success factor involved in their occurrence, which is to say that if a pilot can skillfully salvage a landing from a poor approach or land an overweight aircraft smoothly, he experiences some positive affect from the action. (The phenomenon of positive affect resulting from an error will be examined further in the Second Fleet Pilot Study.)

Sub-cluster 6. This lower sub-cluster of eight errors is a grouping of motor-skill errors. The pilot technique displayed in committing these errors reflects a lack of hand, eye, and brain coordination. These errors may be associated with pilot experience levels. Examples are: SHIFT HAND TO NOSE WHEEL STEERING TOO SOON and OVER ROTATE ON TAKEOFF.

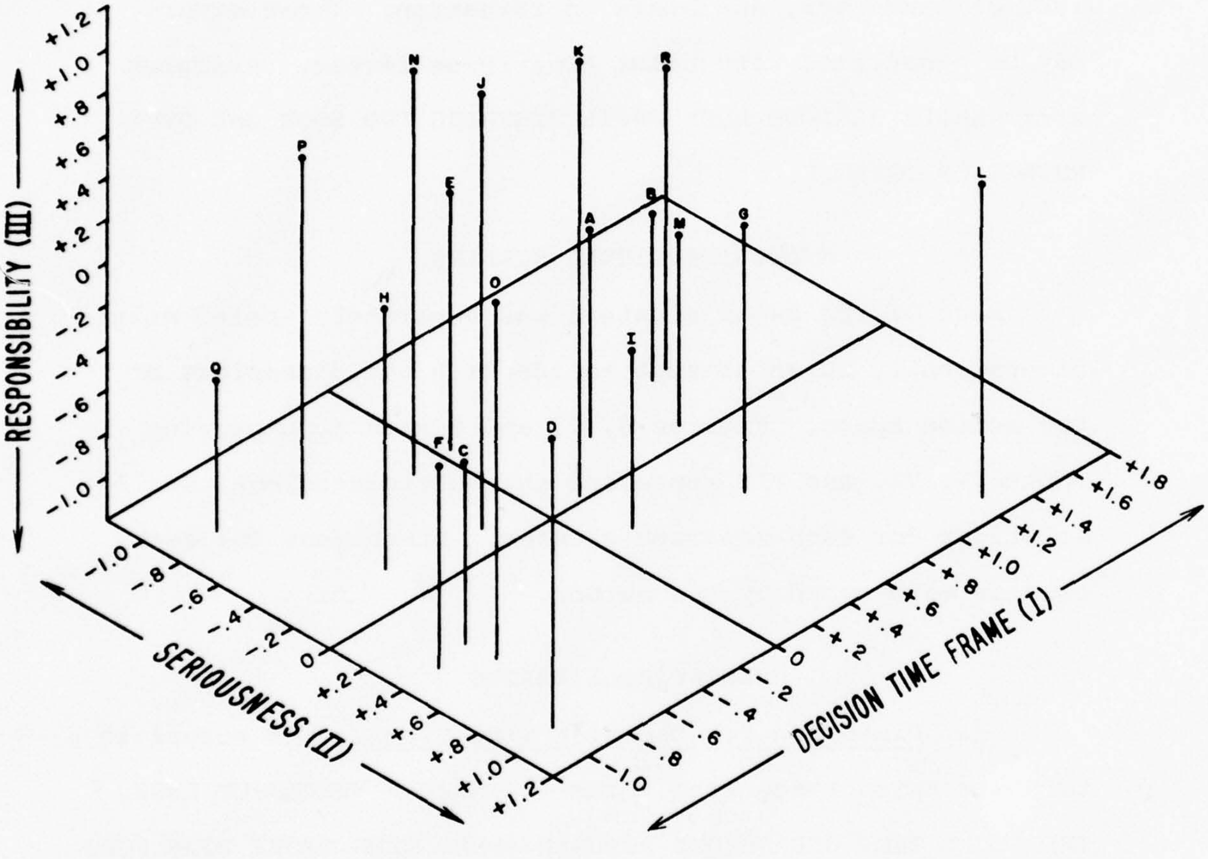
MULTIDIMENSIONAL SCALING

Each of the major clusters was separately scaled multidimensionally in an attempt to identify the dimensions of the action space. Figures 6, 7, and 8 with accompanying Tables V, VI, and VII represent the multidimensional scaling solutions for each separate cluster. Dimensions for each cluster were named by the author.

UNACCEPTABLE ERRORS

Dimension I: Decision Time Frame. The errors in this dimension range from, Item (Q) MAKE A WHEELS UP PASS, (F) ABORT TAKE OFF BEYOND REFUSAL SPEED WHEN SMOKE DOOR POPS OPEN, and (D) DISCHARGE HRD INTO WRONG ENGINE DURING TRANSFER which are rapidly occurring events, to (R) GO IFR ON A VFR CLEARANCE and (B) FLIGHT SHOULD NOT HAVE BEEN FLOWN,

Figure 6



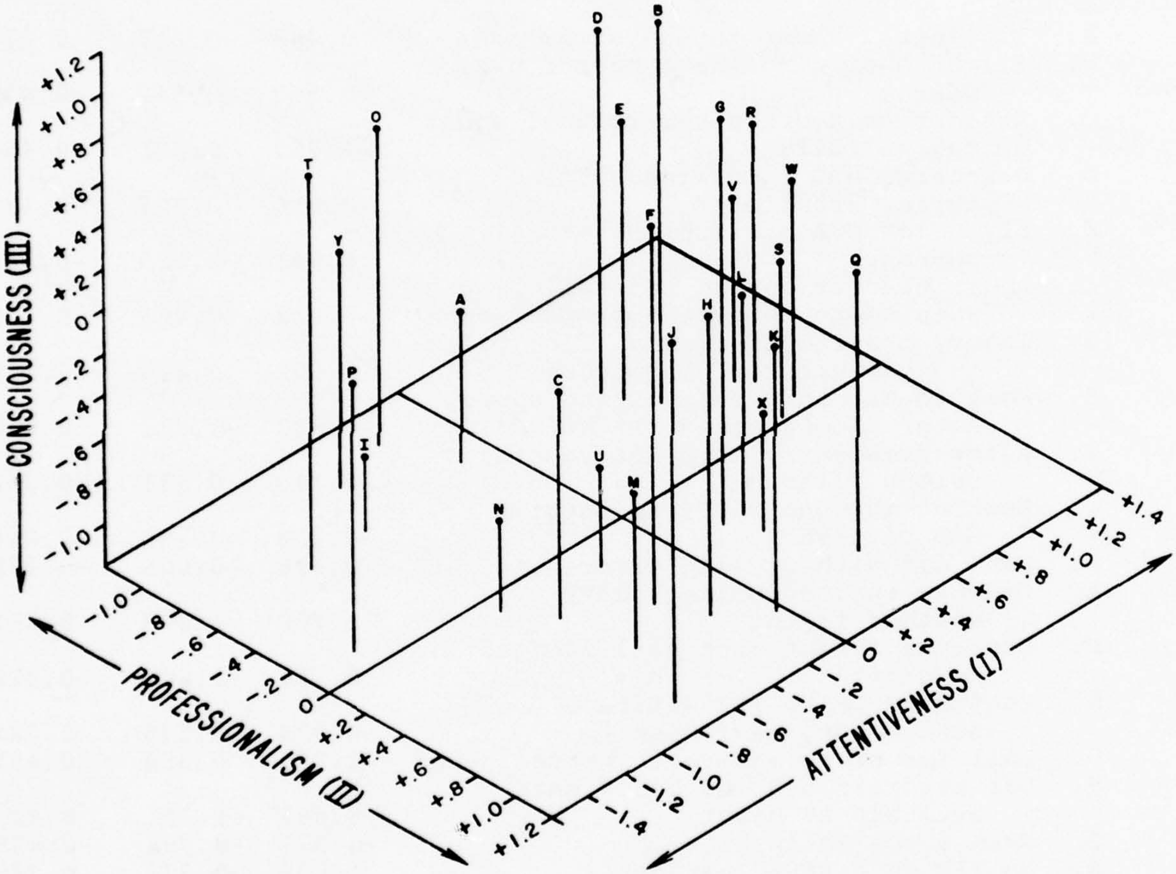
Three-dimensional representation of interpoint distances among the 18 Unacceptable Errors.

TABLE V

UNACCEPTABLE ERRORS

	Errors	Dimensions		
		I	II	III
A.	Fly into a known thunderstorm area	0.448	-0.317	-0.272
B.	Flight should not have been flown, weather	0.963	-0.381	-0.439
C.	Attempt an abort after refusal when engine fails	-0.757	0.371	-0.457
D.	Discharge HRD into wrong engine during transfer	-0.918	0.907	0.172
E.	Fly below GCA minimums on actual approach	0.091	-0.525	-0.018
F.	Abort takeoff beyond refusal speed when smoke removal door pops open	-0.912	0.463	-0.359
G.	Injury results to crewman from pilot-induced aircraft maneuvers	0.602	0.415	0.158
H.	Fail to maintain safe flying speed, enter uncontrolled flight	-0.600	-0.203	0.070
I.	Allow crew entry into load center during flight	0.113	0.316	-0.351
J.	Descent through 200FT in daytime MAD pattern	-0.178	-0.100	0.894
K.	Take off with downing discrepancy	0.198	-0.006	-0.879
L.	Crewman injured during heavy weather flying	1.268	1.075	0.291
M.	Continue flight with hail-damaged aircraft	0.786	-0.042	-0.318
N.	Confusion as to IFR altitude assignment, near miss	-0.094	-0.575	0.725
O.	Call for wrong engine to be feathered	-0.700	0.558	0.451
P.	Let aircraft descend below safe altitude at night	-0.469	-0.791	0.423
Q.	Make a wheels-up pass	-0.873	-0.792	-0.476
R.	Go IFR on a VFR clearance	1.032	-0.374	0.385

Figure 7



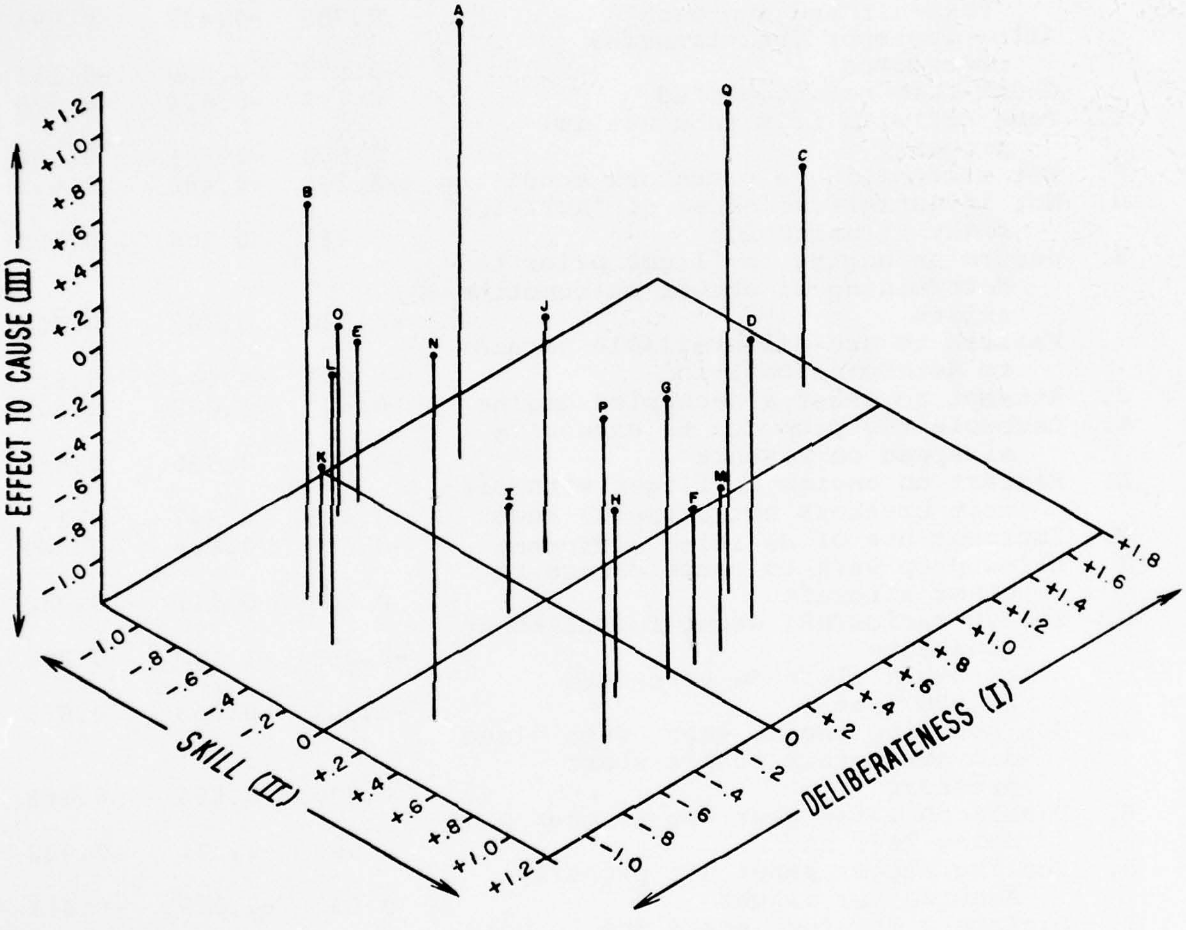
Three-dimensional representation of interpoint distances among the 25 Acceptable Errors.

TABLE VI

ACCEPTABLE ERRORS

	Errors	Dimensions		
		I	II	III
A.	Failure to note "VOR OFF" flag	-0.821	-0.673	-0.490
B.	Take off with flaps not set at "take-off and approach"	0.705	-0.432	0.691
C.	Allow improper fuel transfer procedures	-0.577	0.300	-0.157
D.	Check list not completed	0.498	-0.624	0.526
E.	Take off with trim tabs set improperly	0.500	-0.501	0.136
F.	Not recognizing a pitchlock condition	-0.268	0.486	0.648
G.	Not investigating cause of "ANTI-ICE" light illumination	0.243	0.306	0.695
H.	Secure an engine in-flight prior to determining if actual malfunction exists	-0.220	0.703	0.207
I.	Failure to use all available navaids to determine position	-0.659	-0.644	-0.831
J.	Attempt to start a decoupled engine	-0.674	1.007	0.508
K.	Decouple the prop due to excessive airspeed on restart	-0.008	0.835	0.053
L.	Restart an engine in-flight with circuit breakers not properly reset	0.275	0.347	-0.119
M.	Improper use of de-icing equipment	-0.602	0.669	-0.449
N.	Allow prop wash to cause damage to other aircraft	0.668	0.111	-0.740
O.	Set up radios/HSI wrong for climbout clearance	-0.251	-1.142	0.291
P.	Allow cabin altitude to exceed 10,000 feet	-1.301	-0.053	0.065
Q.	Not securing engine start when bleed did not return to pre-start pressure	0.439	0.855	0.168
R.	Unable to raise gear due to gear pins being left in	0.963	-0.271	-0.030
S.	Fueling/access panel not properly secured for flight	0.832	-0.096	-0.411
T.	Declare a low fuel state due to headwinds	-1.061	-0.598	0.697
U.	Exceed design airspeed for flap setting	-0.303	0.221	-0.688
V.	Ingest engine intake cover during night start	0.907	-0.271	-0.293
W.	Take off with pitot covers left on	1.015	-0.149	0.163
X.	Raising gear before brakes cool blowing thermal plugs	0.247	0.529	-0.594
Y.	Misread altimeter	-0.547	-0.914	-0.048

Figure 8



Three-dimensional representation of interpoint distances among the 17 Runway Environment Technique Errors.

TABLE VII

RUNWAY ENVIRONMENT ERRORS

	Errors	Dimensions		
		I	II	III
A.	Salvage a landing from a poor approach that should have been a wave-off	0.460	-0.881	0.860
B.	Raise the landing gear prematurely	-0.553	-0.639	0.655
C.	Accomplish an unauthorized overweight landing	1.682	-0.300	-0.126
D.	Shift hand to nose wheel steering too soon	0.420	0.643	0.161
E.	Taxi the aircraft into a snow bank	0.020	-1.009	-0.422
F.	Flare too high	0.135	0.717	-0.511
G.	Applying too much brake on landing rollout	-0.006	0.676	0.084
H.	Tap brake while applying rudder on rollout	-0.269	0.626	-0.379
I.	Make a hard landing, "G" meter exceeds 5.2 "G's"	-0.056	-0.003	-0.718
J.	Turn off runway too fast, blow tire	0.242	-0.163	-0.075
K.	Allow prop to contact runway during crosswind landing	-0.581	-0.596	-0.550
L.	Reversing too fast on no-flap landing, pitchlocked prop	-0.742	-0.409	0.048
M.	Over-rotate on takeoff	0.263	0.707	0.419
N.	Induce an autofeather by rapid movement of P/L	-0.809	0.278	0.466
O.	Taxi off the taxiway at night	-0.104	-0.976	-0.314
P.	Overtemp an engine by rapid movement of P/L	-0.553	0.888	0.324
Q.	Retract gear before flaps during a wave-off	0.451	0.441	0.917

WEATHER where the decision to commit these errors is not usually made in a time sensitive environment.

Dimension II: Seriousness. The errors in this dimension range from (Q) MAKE A WHEELS UP PASS and (P) LET AIRCRAFT DESCEND BELOW SAFE ALTITUDE AT NIGHT which are fairly serious errors, to (L) CREWMAN INJURED DURING HEAVY WEATHER FLYING and (D) DISCHARGE HRD INTO WRONG ENGINE DURING TRANSFER which are errors of a lesser seriousness.

Dimension III: Responsibility. The errors in this dimension range from (K) TAKE OFF WITH DOWNING DISCREPANCY and (Q) MAKE A WHEELS UP PASS which are the type errors that would, in the author's opinion, be solely the responsibility of the pilot, to (J) DESCEND THROUGH 200 FT IN DAYTIME MAD PATTERN and (O) CALL FOR THE WRONG ENGINE TO BE FEATHERED, errors that may be momentary oversights, overreaction or overcontrolling and although the pilot is responsible, he may assign some of the responsibility to other people or other occurrences in the flying environment.

ACCEPTABLE ERRORS

Dimension I: Attentiveness. The errors in this dimension range from (P) ALLOW CABIN ALTITUDE TO EXCEED 10,000 FEET and (A) FAIL TO NOTE VOR OFF FLAG both of which require close attention by the pilot not to miss, to (W) TAKE OFF WITH PITOT COVERS LEFT ON and (R) UNABLE TO RAISE GEAR DUE TO GEAR PINS BEING LEFT IN, both of which are easier to discover and prevent from happening.

Dimension II: Professionalism. The errors in this dimension at first seemed to be uninterpretable, ranging from navigation errors at one end to systems knowledge at the other. In the pilots' view, knowledge of aircraft systems is a sign of professionalism and while all these errors are acceptable, the navigational errors are oversights that a pilot, even though very professional, may make. The errors then, range from (O) SET UP RADIOS/HSI WRONG FOR CLIMBOUT CLEARANCE and (Y) MISREAD ALTIMETER to (J) ATTEMPT TO START A DECOUPLED ENGINE and (Q) NOT SECURING ENGINE START WHEN BLEED AIR DID NOT RETURN TO PRE-START PRESSURE.

Dimension III: Consciousness. Although there is a lack of consciousness in making all these errors, the author detects a greater degree of this failing along this dimension. Ranging from (N) ALLOW PROP WASH TO CAUSE DAMAGE TO OTHER AIRCRAFT and (U) EXCEED DESIGN AIRSPEED FOR FLAP SETTING, which seem to show that the pilot was thinking of something else at the time, to (D) CHECK LIST NOT COMPLETE and (F) NOT RECOGNIZING A PITCHLOCK CONDITION, errors that occur as the pilot is dealing with that very situation.

RUNWAY ENVIRONMENT TECHNIQUE ERRORS

Dimension I: Deliberateness. The errors in this dimension range from (C) ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING and (D) SHIFT HAND TO NOSEWHEEL STEERING TOO SOON which are deliberate actions on the part of the pilot, to (N) INDUCE AN AUTOFEATHER BY RAPID MOVEMENT OF P/L and (K) ALLOW PROP TO CONTACT RUNWAY DURING CROSSWIND LANDING which are caused by the pilot but have less an element of deliberate action on his part.

Dimension II: Skill. The errors in this dimension range from (E) TAXI THE AIRCRAFT INTO A SNOW BANK and (O) TAXI OFF THE TAXIWAY AT NIGHT which are errors that are "headwork" type errors and may denote the experience level or lack of skill of the pilot, to (D) SHIFT HAND TO NOSEWHEEL STEERING TOO SOON and (F) FLARE TOO HIGH which are motor-skill type errors that in the pilots' perception do not denote as much a lack of skill as "headwork" errors.

Dimension III: Effect to Cause. The errors in this dimension range from (F) FLARE TOO HIGH and (I) MAKE A HARD LANDING "G" METER EXCEEDS 5.2 "G's" which are,in a way,effects of errors, to (A) SALVAGE A LANDING FROM A POOR APPROACH THAT SHOULD HAVE BEEN A WAVEOFF and (B) RAISE THE LANDING GEAR PREMATURELY which,in a way,are causes.

In summary, these dimensions may be arbitrarily named and interpreted, but still provide us with areas for possible study or themes for training programs in the future.

CHAPTER IV

THE SECOND FLEET PILOT STUDY

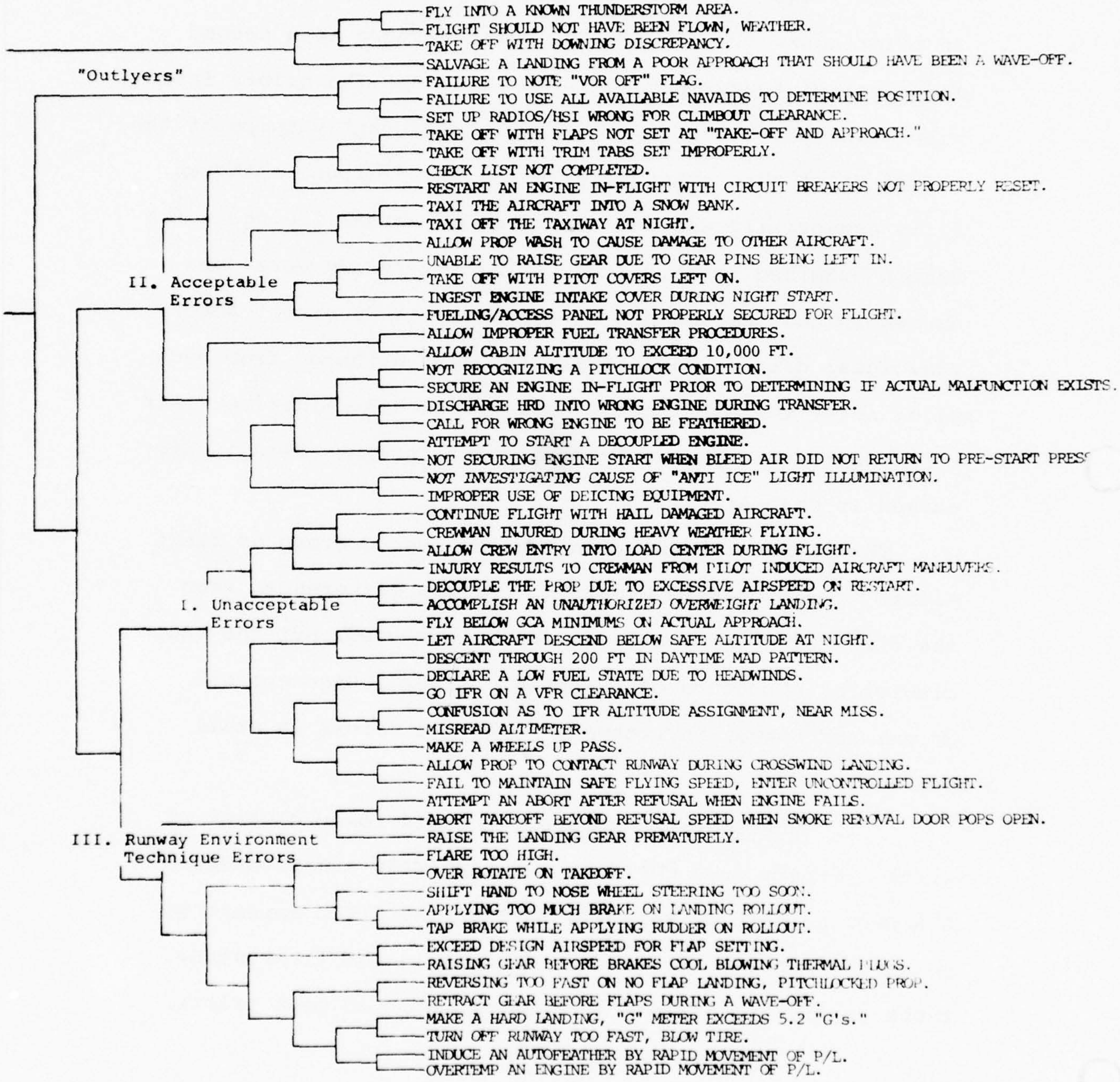
Fifty-two P-3 pilots ranging in age from 23 to 43 and in pilot hours from 50 to 3700 were surveyed at a second major patrol squadron base in April 1978. The pilots interviewed in this study fly a slightly different version of the P-3 aircraft than that flown by the first group, although it is essentially the same in terms of actual flying in the domain examined in this study. The interviews were conducted in the same manner as the first study except that additional data on four attributes were gathered from each pilot after the sorting and seriousness determination tasks were completed. The analysis of the attribute data is discussed in Chapter VII.

The clustering solution for the second group of fleet pilots is depicted in Figure 9. Slight differences from the first group's clustering can be detected, but the basic clustering structure of Acceptable Errors, Unacceptable Errors and Runway Environment Technique Errors is still present.

I. Unacceptable Errors. The mid-lower cluster of sixteen errors from CONTINUE A FLIGHT WITH A HAIL DAMAGED AIRCRAFT to FAIL TO MAINTAIN SAFE FLYING SPEED appears to be an Unacceptable Error Cluster. As in the first study, these errors are killers and unacceptable to most pilots.

FIGURE 9

SECOND FLEET PILOT STUDY CLUSTERING OF ERRORS



The sub-clusters of deliberate errors and spur-of-the-moment errors are not as distinct in the second study as in the first.

II. Acceptable Errors. The Acceptable Error Cluster is the mid-upper cluster of twenty-one errors from TAKE OFF WITH FLAPS NOT SET AT "TAKE-OFF AND APPROACH" to IMPROPER USE OF DEICING EQUIPMENT. As in the first fleet pilot study, the sub-clusters of inattention and systems knowledge errors were present.

III. Runway Environment Technique Errors. The lower cluster of sixteen errors from ATTEMPT AN ABORT AFTER REFUSAL WHEN ENGINE FAILS to OVER TEMP AN ENGINE BY RAPID POWER LEVER MOVEMENT is the Runway Environment Technique Error Cluster. Again the sub-clusters are not as distinct in this group as they were in the first fleet pilot study.

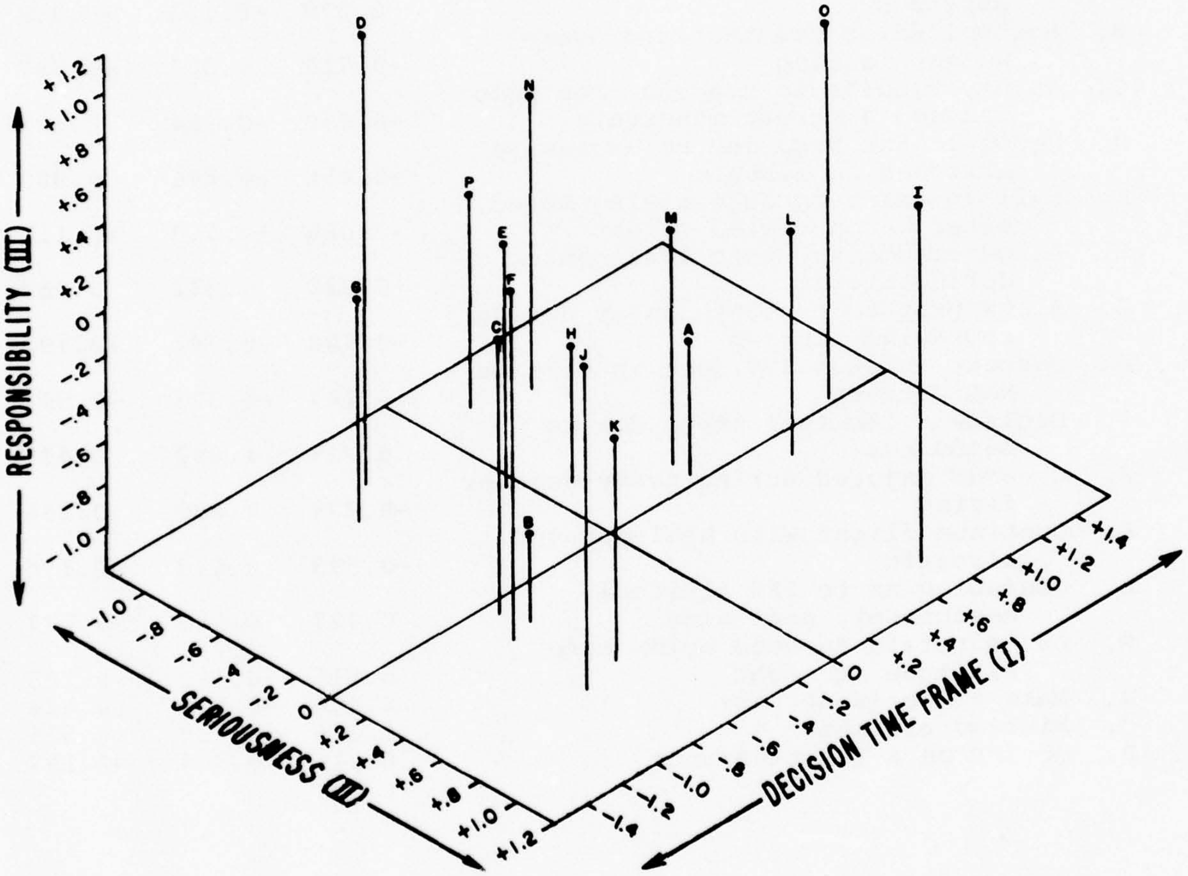
The first two small clusters at the top of the clustering sequence are "outlyers" and contain errors from each of the three major clusters (Acceptable, Unacceptable etc.) of the first study. The occurrence of several major P-3 accidents during the period between the two studies may have influenced the sorting of the second group of pilots; alternative hypotheses, however, involve differences resulting from geographic location, aircraft model differences, differences in deployment sites, command influence and differences in antecedent training.

In summary, the differences in the clusterings of the two groups shows that, notwithstanding the fact that P-3 pilots are a select group, highly trained in very specialized work, they have differences in the way they array errors in their minds. Customarily, cognizant Navy officials at all levels tend to think of a P-3 pilot as "A P-3 pilot," similar in most respects, standardized and differing only in his experience level as measured by how many flight hours he has accumulated. He is treated accordingly and assigned to billets as "A P-3 pilot" with other factors, such as overall performance, determining which P-3 pilot billet he occupies. In contrast to this approach, the subtle differences shown in the clustering of errors may suggest differences in P-3 pilots that should be taken into account, at least in terms of required training and likely safety record of an individual pilot.

The presence of the basic structure of Acceptable, Unacceptable and Runway Environment Technique Errors might indicate, for instance, that some errors are loosely structured in pilots' minds and that if the Navy is striving for a standardized P-3 pilot, some formal training in error structuring which would strengthen these clusters in a desirable fashion might be indicated.

Multidimensional Scaling. Each of the major clusters was separately scaled to attempt to identify the dimensions of the action space. Figures 10, 11, and 12 with accompanying

Figure 10



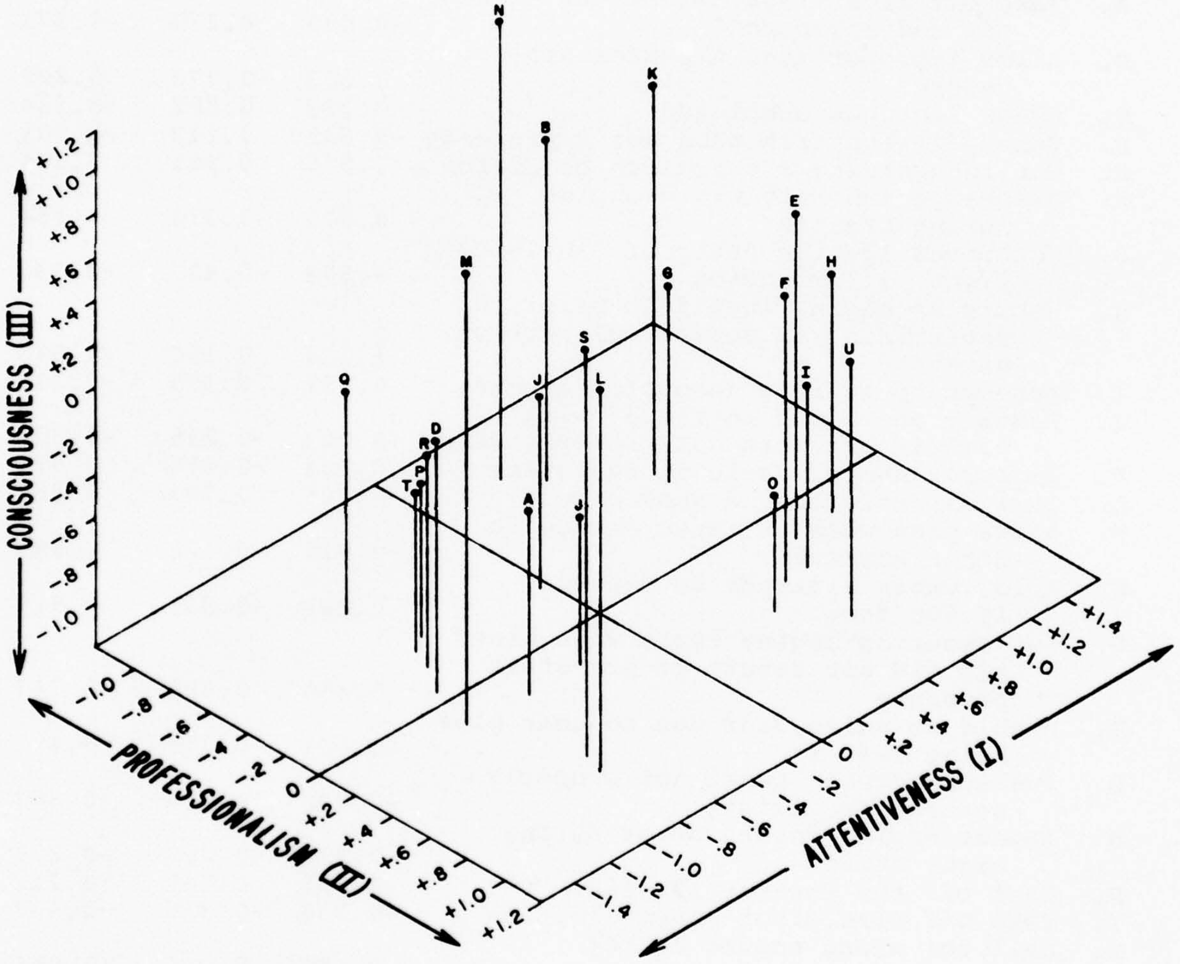
Three-dimensional representation of interpoint distances among the 16 Unacceptable Errors, Second Fleet Pilot Study.

TABLE VIII

UNACCEPTABLE ERRORS--SECOND FLEET PILOT STUDY

	Errors	Dimensions		
		I	II	III
A.	Fly below GCA minimums on actual approach	0.575	-0.123	-0.532
B.	Accomplish an unauthorized overweight landing	-0.712	0.227	-0.797
C.	Injury results to crewman from pilot-induced aircraft maneuvers	-0.750	-0.164	0.123
D.	Decouple the prop due to excessive airspeed on restart	-0.456	-0.846	0.883
E.	Fail to maintain safe flying speed, enter uncontrolled flight	-0.066	-0.563	-0.117
F.	Allow crew entry into load center during flight	-0.822	0.322	0.463
G.	Allow prop to contact runway during crosswind landing	-0.608	-0.747	-0.192
H.	Descent through 200 feet in daytime MAD pattern	0.144	-0.353	-0.591
I.	Declare a low fuel state due to headwinds	0.725	1.002	0.477
J.	Crewman injured during heavy-weather flying	-0.829	0.690	0.368
K.	Continue flight with hail-damaged aircraft	-0.593	0.613	-0.176
L.	Confusion as to IFR altitude assignment, near miss	0.927	0.135	-0.177
M.	Let aircraft descend below safe altitude at night	0.515	-0.192	-0.195
N.	Make a wheels-up pass	0.470	-0.938	0.124
O.	Misread altimeter	1.266	-0.029	0.535
P.	Go IFR on a VFR clearance	0.215	0.964	-0.197

Figure 11



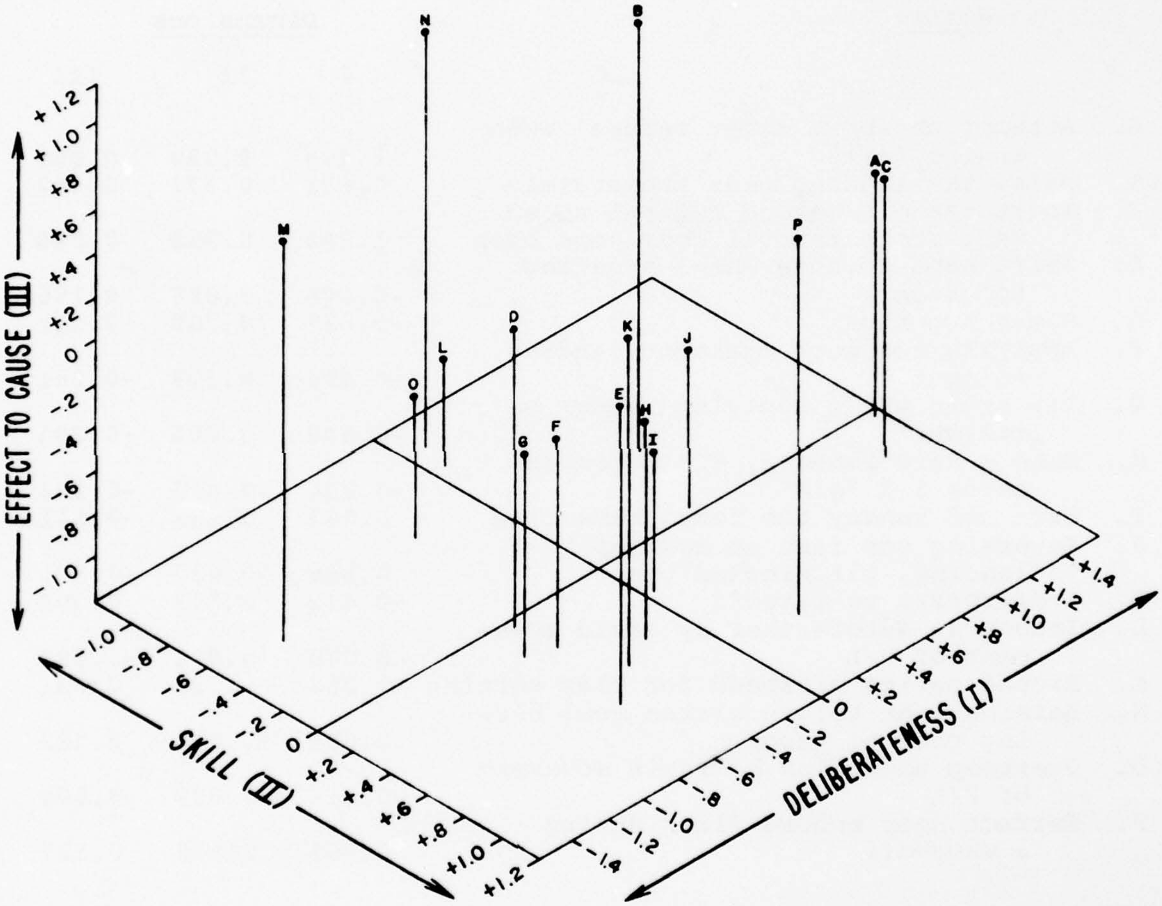
Three-dimensional representation of interpoint distances among the 21 Acceptable Errors, Second Fleet Pilot Study.

TABLE IX

ACCEPTABLE ERRORS--SECOND FLEET PILOT STUDY

	Errors	Dimensions		
		I	II	II
A.	Take off with flaps not set at "take-off and approach""	-0.603	0.273	-0.371
B.	Allow improper fuel transfer procedures	0.503	-0.773	0.299
C.	Check list not completed	-0.333	0.202	-0.524
D.	Take off with trim tabs set improperly	-0.832	-0.113	-0.101
E.	Not recognizing a pitchlock condition	0.876	0.201	0.304
F.	Discharge HRD into wrong engine during transfer	0.675	0.378	0.154
G.	Not investigating cause of "anti-ice" light illumination	0.808	-0.407	-0.337
H.	Secure an engine in-flight prior to determining if actual malfunction exists	1.154	0.190	-0.092
I.	Attempt to start a decoupled engine	0.791	0.395	-0.392
J.	Restart an engine in-flight with circuit breakers not properly reset	-0.023	-0.295	-0.357
K.	Improper use of de-icing equipment	0.844	-0.478	0.574
L.	Taxi aircraft into a snow bank	-0.786	0.793	0.587
M.	Allow prop wash to cause damage to other aircraft	-0.911	0.178	0.866
N.	Allow cabin altitude to exceed 10,000 feet	0.368	-0.861	0.919
O.	Not securing engine start when bleed air did not return to pre-start pressure	0.460	0.485	-0.743
P.	Unable to raise gear due to gear pins being left in	-0.664	-0.358	-0.491
Q.	Fueling/access panel not properly secured for flight	-0.738	-0.733	-0.263
R.	Ingest engine intake cover during night start	-0.772	-0.263	-0.257
S.	Taxi off the taxiway at night	-0.755	0.739	0.711
T.	Take off with pitot covers left on	-0.734	-0.316	-0.420
U.	Call for wrong engine to be feathered	0.672	0.764	-0.065

Figure 12



Three-dimensional representation of interpoint distances among the 16 Runway Environment Technique Errors, Second Fleet Pilot Study.

TABLE X

RUNWAY ENVIRONMENT TECHNIQUE ERRORS--SECOND FLEET PILOT STUDY

	Errors	Dimensions		
		I	II	III
A.	Attempt an abort after refusal when engine fails	1.468	0.050	0.069
B.	Raise the landing gear prematurely	0.632	-0.472	0.702
C.	Abort takeoff beyond refusal speed when smoke removal door pops open	1.382	0.252	0.085
D.	Shift hand to nose wheel steering too soon	-0.546	0.058	0.196
E.	Flare too high	-0.627	0.708	0.119
F.	Applying too much brake on landing rollout	-0.494	0.318	-0.261
G.	Tap brake while applying rudder on rollout	-0.640	0.266	-0.281
H.	Make a hard landing, "G" meter exceeds 5.2 "g's"	-0.234	0.477	-0.202
I.	Turn off runway too fast, blow tire	0.067	0.235	-0.611
J.	Reversing too fast on no-flap landing, pitchlocked prop	0.556	-0.027	-0.531
K.	Over-rotate on takeoff	-0.412	0.515	0.302
L.	Induce an autofeather by rapid movement of P/L	0.079	-0.881	-0.692
M.	Exceed design airspeed for flap setting	-1.262	-0.525	0.631
N.	Raising gear before brakes cool blowing thermal plugs	0.084	-1.047	0.522
O.	Overtemp an engine by rapid movement of P/L	-0.416	-0.607	-0.575
P.	Retract gear before flaps during a wave-off	0.363	0.679	0.527

Tables VIII, IX and X represent the multidimensional scaling solution for each separate cluster. No attempt was made to scale the outlyers since there were too few errors to obtain significantly stressed dimensions. The dimensions of the major clusters appeared to be the same as in the first study and will not be discussed here.

CHAPTER V

THE COMBINED RESULTS

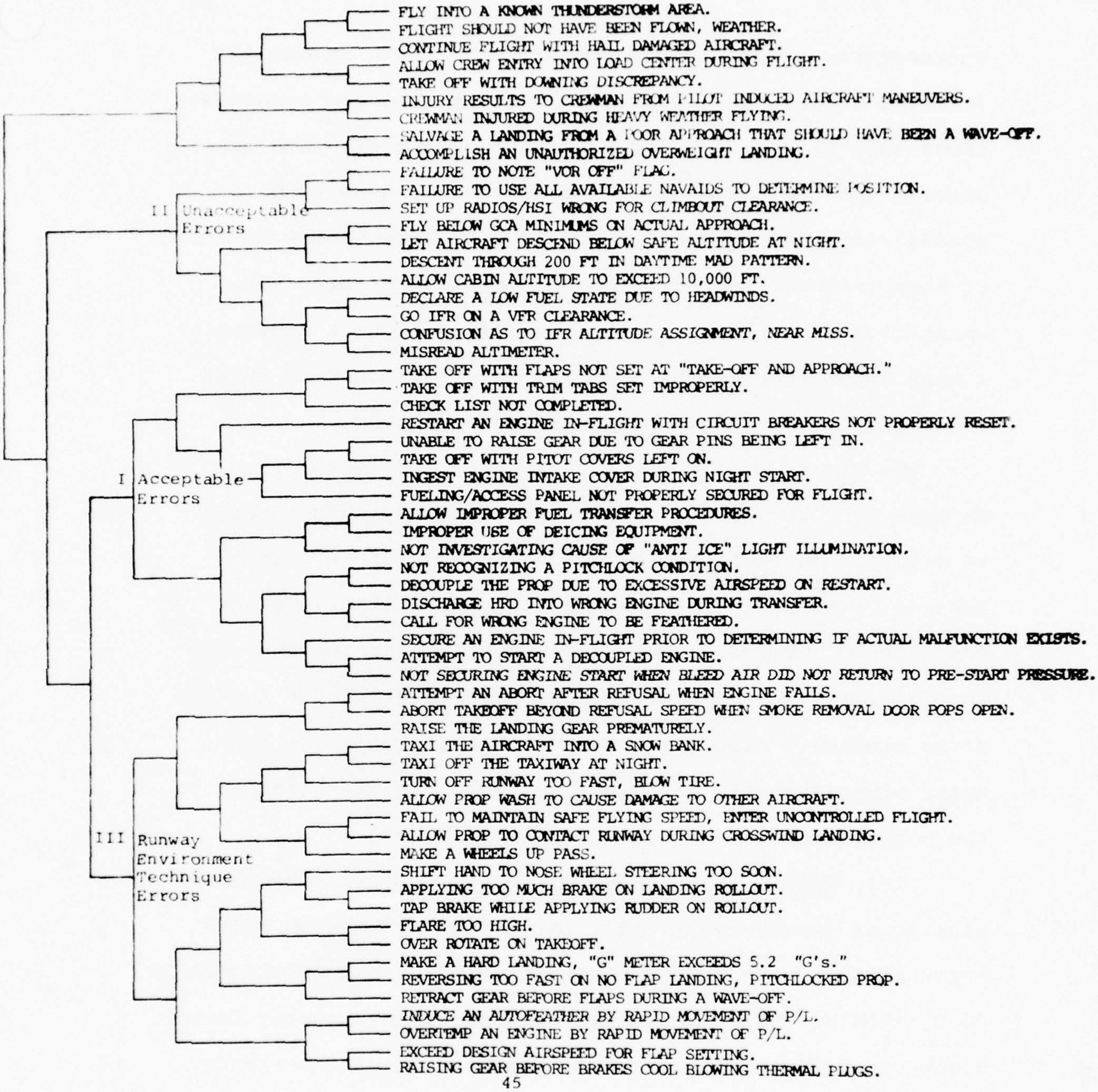
After the Second Fleet pilot study data were analyzed, they were combined with the data from the first study. The resulting data base for all 103 pilots was subjected to the hierarchical clustering program. Although slightly different from each of the individual studies, the combined cluster still retains the basic underlying structure of each of its component parts. Figure 13 is the combined clustering solution for all 103 pilots.

I. Acceptable Errors. The mid-lower cluster of errors listed from TAKE OFF WITH FLAPS NOT SET AT "TAKEOFF AND APPROACH" to NOT SECURING ENGINE START WHEN BLEED AIR DID NOT RETURN TO PRE-START PRESSURE is essentially the Acceptable Error Cluster of the past two studies. The first eight errors form a sub-cluster of check-list or preflight errors, and the next ten errors form a sub-cluster of aircraft systems knowledge errors. In all, these errors are inattention or oversight errors that display a lapse, forgetfulness or a kind of personal shortcoming, and may be said to denote a lack of professionalism on the part of the pilot.

II. Unacceptable Errors. The uppermost cluster of nine errors listed from FLY INTO A KNOWN THUNDERSTORM AREA to ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING is the

FIGURE 13

103 PILOTS COMBINED CLUSTERING



Unacceptable Error Cluster. It is still much an outlyer from the other major clusters showing that these errors are those that pilots find the hardest to associate with other errors. Stated somewhat differently, they seem to be a special class of errors. There is a deliberateness in most of these errors. This may be the factor that sets them apart from the other errors. Instead of being a blunder, a slip or an inadvertant mistake, these errors seem to be conscious, intentional, made-by-decision-errors.

The mid-upper cluster of eleven errors listed from FAILURE TO NOTE VOR OFF FLAG to MISREAD ALTIMETER appears to still be another unacceptable grouping with a slant towards weather or Instrument Flying Rules (IFR) flying. Most errors involve dial or instrument monitoring and most were situated in the Unacceptable Error Clusters in the two prior studies. Also this cluster does not join the other major clusters until the 8th level which is very similar to the position in first fleet pilot study.

III. Runway Environment Technique Errors. The lower cluster of twenty-two errors listed from ATTEMPT AN ABORT AFTER REFUSAL WHEN ENGINE FAILS to RAISING GEAR BEFORE BRAKES COOL, BLOWING THERMAL PLUGS is the Runway Environment Technique Cluster. These errors display a lack of experience and are coordination or motor skill errors. These are errors that involve actual control of the aircraft and, as described below, point out the conception that P-3 pilots may have of differences between an aviator and a pilot. These are the "stick and rudder" pilot errors, as differentiated by P-3 pilots from the aviator errors in the Acceptable Error Cluster.

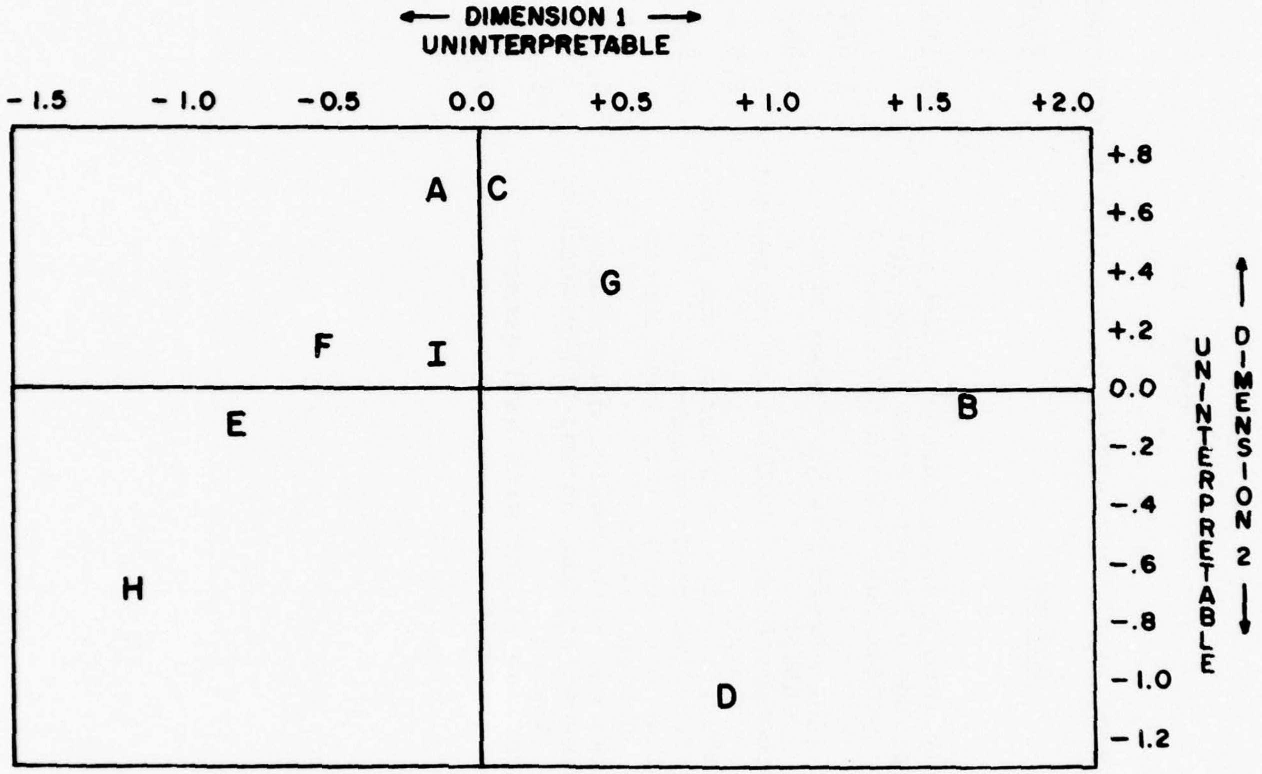
It is the author's opinion that in the subculture of P-3 pilots there is a perceived difference between a "pilot" and an "aviator" (author's terms). The "pilot" may be an accomplished "stick and rudder man," who is a precision flyer in terms of physically handling the aircraft, while at the same time he can be a poor aviator--sloppy in his attention to detail and shallow in his knowledge of aircraft systems. On the other hand, the "aviator" might not be as skilled in precision flying but is more expert in administration, instructing, leadership, and judgment. For instance, a good "pilot" may always land the aircraft precisely on speed at the touchdown point, but he may be prone to overlook an item on the checklist, while an "aviator" might not be as precise in flying the aircraft but would be professional in his supervision of the crew, and unlikely to miss an item on the preflight.

The desired flying officer from a safety point of view is an officer who has the good points of both the "pilot" and the "aviator," and certainly the P-3 aviation community has some of these. However, the segregation of the Acceptable Errors when compared to the Runway Environment Technique Errors seems to bear a relationship to the "pilot/aviator" conception.

In all, the combined clustering represents a smoothed-out or averaged clustering when compared to its components. It tells us that P-3 pilots, although not formally trained in error structuring, do have a basic cognitive mapping of errors. Something in their cultural pattern tells them to structure the errors along three groupings: Acceptable, Unacceptable and Runway Environment Technique areas. More sophisticated research should, however, define more succinctly the nature and limits of these groupings. The combined clustering also tells us that there are certain errors that P-3 pilots find difficulty in grouping within these categories because they appear to be unacceptable while at the same time showing a certain level of wilful deliberateness. Without question, further study of this special group of errors is warranted.

Multidimensional Scaling. Each of the major clusters was separately scaled to attempt to identify the dimensions of the action space. Figures 14, 15, 16 and 17, with accompanying Tables XI, XII, XIII, abd XIV, represent the multidimensional solutions for each separate cluster. The two-dimensional solutions for the Deliberate and IFR clusters were uninterpretable. Although partially changed by errors shifting between clusters, the three-dimensional solutions for the Acceptable and Runway Environment Technique clusters still retained dimensions found in the first two studies.

Figure 14



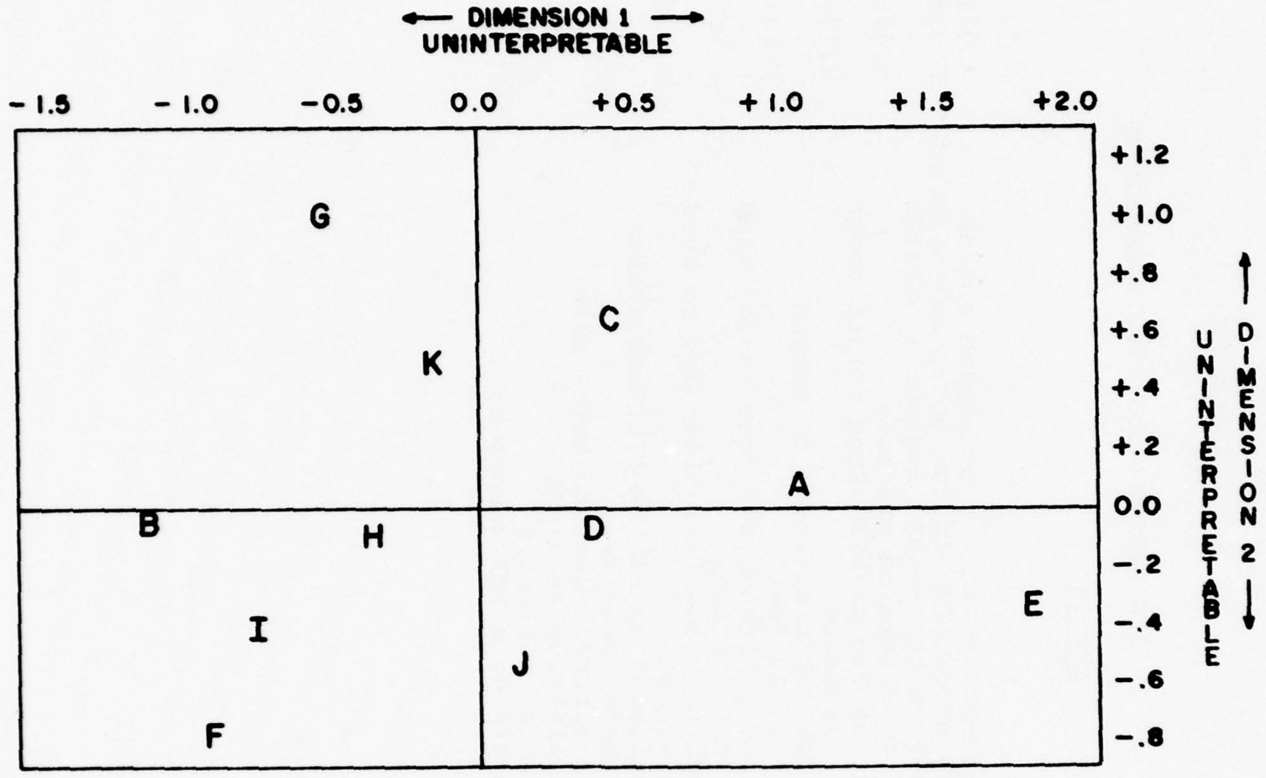
Two-dimensional representation of interpoint distances among the 9 Unacceptable, Deliberate Errors, 103 Pilots Combined.

TABLE XI

UNACCEPTABLE DELIBERATE ERRORS--103 PILOTS COMBINED

	Errors	Dimensions	
		I	II
A.	Fly into a known thunderstorm area	-0.156	0.684
B.	Salvage a landing from a poor approach that should have been a wave-off	1.619	-0.087
C.	Flight should not have been flown, weather	0.067	0.677
D.	Accomplish an unauthorized overweight landing	0.838	-0.086
E.	Injury results to crewman from pilot-induced aircraft maneuvers	-0.834	-0.129
F.	Allow crew entry into load center during flight	-0.559	0.126
G.	Take off with downing discrepancy	0.451	0.379
H.	Crewman injured during heavy-weather flying	-1.277	-0.696
I.	Continue flight with hail-damaged aircraft	-0.148	0.112

Figure 15



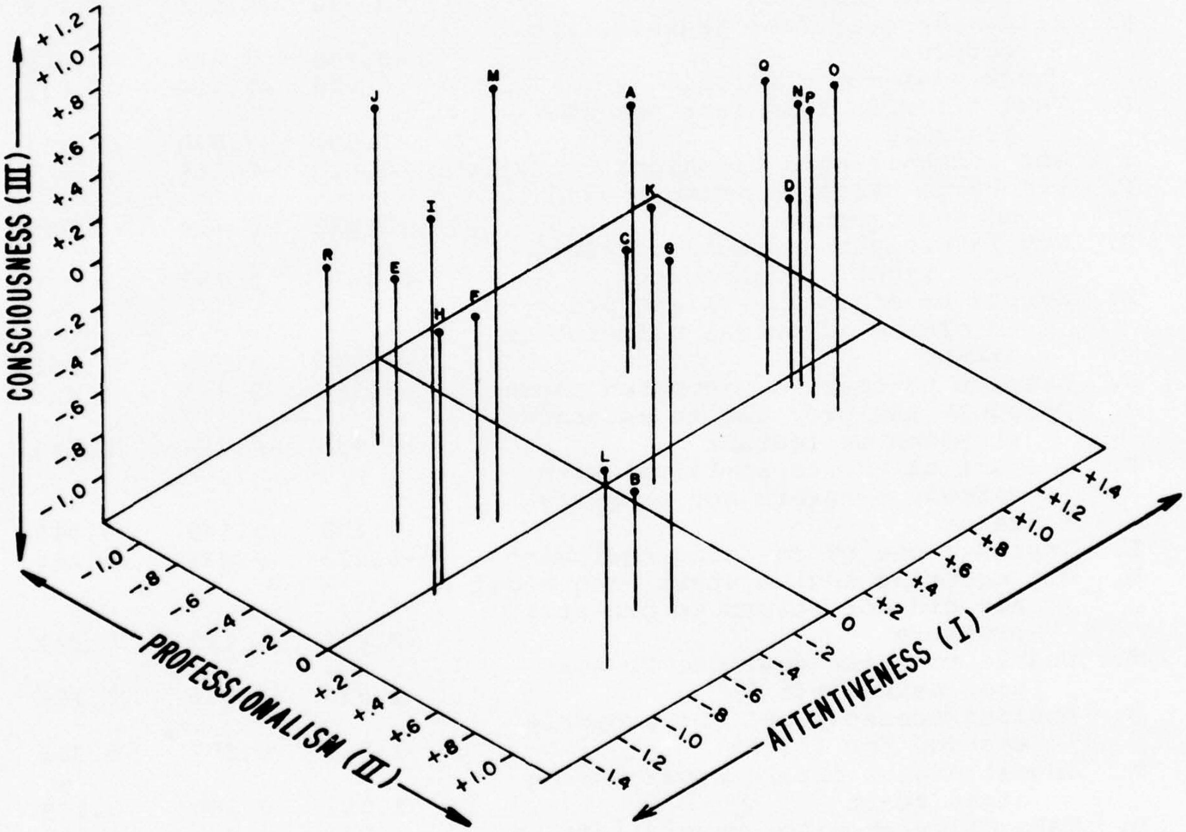
Two-dimensional representation of interpoint distances among the
11 Unacceptable, IFR Errors, 103 Pilots Combined.

TABLE XII

IFR ERRORS--103 PILOTS COMBINED

Errors	I	II
A. Attempt to start a decoupled engine	1.071	0.075
B. Fly below GCA minimum on actual approach	-0.158	-0.002
C. Failure to use all available navaids to determine position	0.426	0.614
D. Set up radios/HSI wrong for climbout clearance	0.377	-0.041
E. Allow cabin altitude to exceed 10,000 feet	1.831	-0.370
F. Descent through 200 feed in day time MAD pattern	-0.920	-0.792
G. Declare a low fuel state due to head-winds	-0.522	1.045
H. Confusion as to IFR altitude assignment, near miss	-0.396	-0.112
I. Let aircraft descend below safe altitude at night	-0.706	-0.428
J. Misread altimeter	0.167	-0.528
K. Go IFR on a VFR clearance	-0.170	0.539

Figure 16



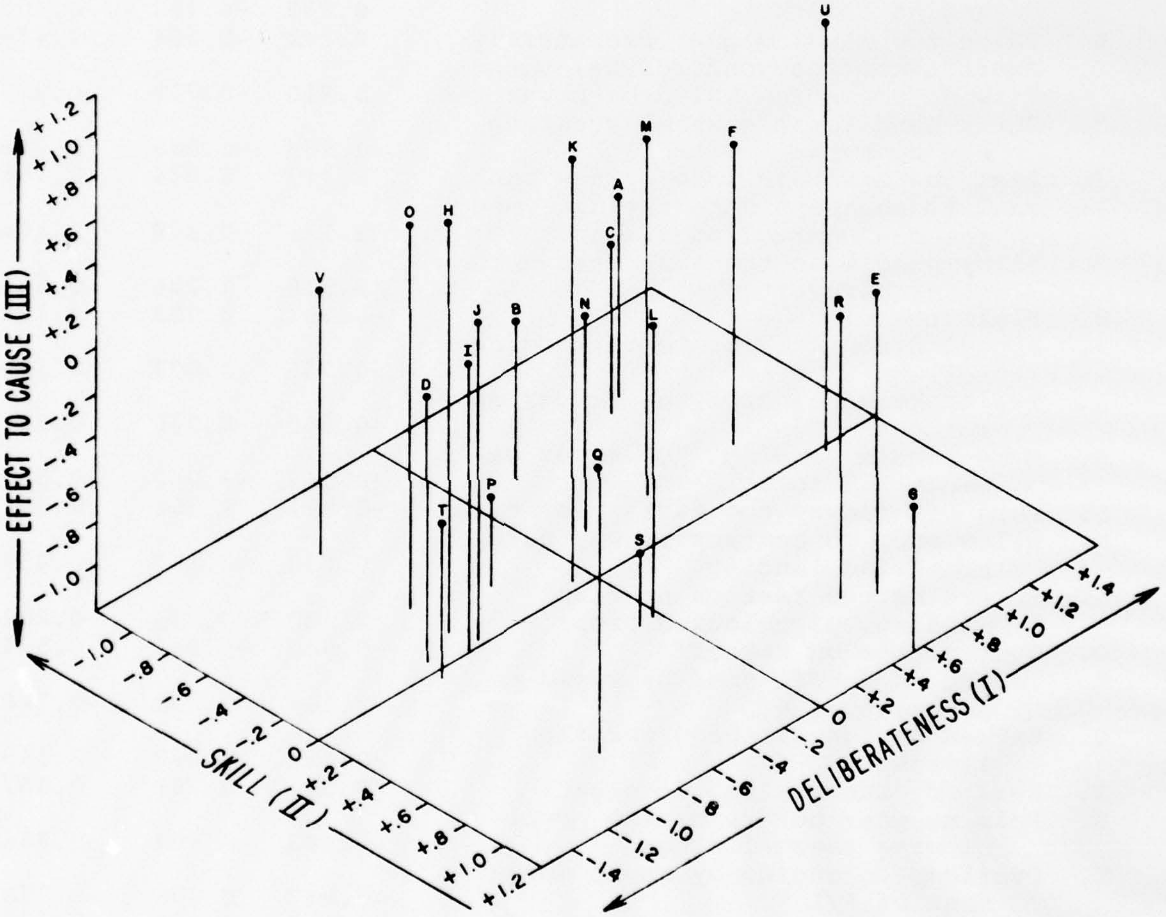
Three-dimensional representation of interpoint distances among the 18 Acceptable Errors. Combined, 103 Pilots.

TABLE XIII

ACCEPTABLE INATTENTION ERRORS--103 PILOTS COMBINED

	Behavior	Dimensions		
		I	II	III
A.	Take off with flaps not set at "take-off and approach"	0.772	-0.574	-0.118
B.	Allow improper fuel transfer procedures	-0.550	0.689	-0.668
C.	Check list not completed	0.620	-0.407	-0.631
D.	Take off with trim tabs set improperly	1.001	0.072	-0.340
E.	Not recognizing a pitchlock condition	-0.825	-0.384	-0.087
F.	Discharge HRD into wrong engine during transfer	-0.532	-0.194	-0.351
G.	Not investigating cause of "anti ice" light illumination	-0.463	0.787	0.376
H.	Secure an engine in-flight prior to determine if actual malfunction exists	-0.949	0.000	-0.058
I.	Attempt to start a decoupled engine	-0.997	0.050	0.488
J.	Decouple the prop due to excessive airspeed on restart	-0.483	-0.786	0.355
K.	Restart an engine in-flight with circuit breakers not properly reset	0.138	0.149	0.045
L.	Improper use of de-icing equipment	-0.823	0.836	-0.364
M.	Not securing engine start when bleed air did not return to pre-start pressure	-0.478	-0.127	0.791
N.	Unable to raise gear due to gear pins being left in	1.040	0.075	0.157
O.	Fueling/access panel not properly secured for flight	1.012	0.507	0.308
P.	Ingest engine intake cover during night start	1.097	0.200	0.179
Q.	Take off with pitot covers left on	1.027	-0.079	0.199
R.	Call for wrong engine to be feathered	-0.607	-0.815	-0.279

Figure 17



Three-dimensional representation of interpoint distances among the 22 Runway Environment Technique Errors, Combined, 103 Pilots.

TABLE XIV

RUNWAY ENVIRONMENT TECHNIQUE ERRORS--103 PILOTS COMBINED

	Errors	Dimensions		
		I	II	III
A.	Attempt an abort after refusal when engine fails	0.935	-0.767	-0.307
B.	Raise the landing gear prematurely	0.242	-0.684	-0.479
C.	Abort takeoff beyond refusal speed when smoke removal door pops open	0.810	-0.709	-0.307
D.	Shift hand to nose wheel steering too soon	-0.905	-0.065	0.048
E.	Taxi the aircraft into a snow bank	0.719	0.824	0.186
F.	Fail to maintain safe flying speed, enter uncontrolled flight	1.121	-0.258	0.154
G.	Allow prop wash to cause damage to other aircraft	0.519	1.226	-0.589
H.	Flare too high	-0.781	0.003	0.152
I.	Applying too much brake on landing rollout	-0.781	0.003	0.152
J.	Tap brake while applying rudder on rollout	-0.670	-0.010	0.321
K.	Make a hard landing, "G" meter exceeds 5.2 "G's"	-0.157	-0.062	0.550
L.	Turn off runway too fast, blow tire	-0.071	0.355	0.164
M.	Allow prop to contact runway during crosswind landing	0.532	-0.267	0.419
N.	Reversing too fast on no-flap landing, pitchlocked prop	0.182	-0.223	-0.202
O.	Over-rotate on takeoff	-0.640	-0.342	0.504
P.	Induce an autofeather by rapid movement of P/L	-0.364	-0.239	-0.798
Q.	Exceed design airspeed for flap setting	-0.853	0.842	0.149
R.	Taxi off the taxiway at night	0.574	0.798	0.087
S.	Raising gear before brakes cool blowing thermal plugs	-0.143	0.402	-0.856
T.	Overtemp an engine by rapid movement of P/L	-0.947	0.078	-0.525
U.	Make a wheels-up pass	1.277	0.077	0.790
V.	Retract gear before flaps during a wave-off	-0.635	-0.802	-0.034

CHAPTER VI

SERIOUSNESS

As previously described, each group of pilots was asked to sort the sixty errors into seven slots in a box, from "most serious" to "least serious." Average rankings (means) for the seriousness of the errors were computed for the first group of pilots, the second group of pilots and an aggregate of all 103 pilots combined. A discriminant analysis program was run between the first group of 51 pilots and the second group of 52 pilots. The results of this analysis showed that the second group of pilots assigned more seriousness to the errors than did the first group. Group 2 assigned a higher mean seriousness than Group 1 to 49 of the sixty errors, while Group 1 had higher means than Group 2 for only eleven errors. More seriousness being attached to errors by Group 2 could be the result of the intervening accidents previously mentioned but could also result from differences in safety programs at the two bases and/or other stimuli.

Group membership (location 1 or location 2), based on the seriousness ranking of the errors, could be predicted with 77.67% accuracy. As the following table illustrates, some of the pilots in Group 1 (11, or 21.6%) ranked the errors in a manner similar to the members of Group 2, and some of the pilots in Group 2 (12, or 23.1%) ranked the errors in a manner similar to that of Group 1:

TABLE XV

GROUP CLASSIFICATION BASED ON LOCATION BY DISCRIMINANT ANALYSIS

	Respondent's Sorting Correctly Predicted His Location (HIT)	Respondent's Sorting Did Not Predict His Location (MISS)
Patrol Base Location 1 (N=51)	40 (78.4%)	11 (21.6%)
Patrol Base Location 2 (N=52)	40 (76.9%)	12 (23.1%)

Percent of "grouped" cases correctly classified: 77.67%

Time constraints would not allow for identification of those cases that did, or did not classify properly. Certainly an area of fertile ground for future study would be to learn if the majority of cases not correctly classified were younger or older pilots, or pilots with low or high flight hour accumulation.

When queried, the computer identified the ten errors that discriminated best between the two groups. Table XVI shows the ten most discriminating errors, and the direction of the seriousness assigned by the two groups.

TABLE XVI

Ten Most Discriminating Errors for Group Classification & Direction

DISCRIMINANT ERROR	Location 1	Location 2
ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING	less serious	more serious
TAKEOFF WITH A DOWNING DISCREPANCY	less serious	more serious
FAILURE TO USE ALL AVAILABLE NAV AIDS TO DETERMINE POSITION	more serious	less serious
TAP BRAKE WHILE APPLYING RUDDER ON ROLLOUT	less serious	more serious
APPLYING TOO MUCH BRAKE ON LANDING ROLLOUT	less serious	more serious
NOT SECURING ENGINE START WHEN BLEED AIR DID NOT RETURN TO PRESTART PRESSURE	less serious	more serious
REVERSING TOO FAST ON NO FLAP LANDING, PITCHLOCKED PROP	less serious	more serious
SHIFT HAND TO NOSEWHEEL STEERING TOO SOON	less serious	more serious
OVER ROTATE ON TAKEOFF	less serious	more serious
ALLOW CREW ENTRY INTO LOAD CENTER DURING FLIGHT	more serious	less serious

Again seriousness ranking differences could have been affected by the accidents occurring in the interval between surveys, but the author believes that cultural variations resulting from command influence, geographic location, aircraft model, etc., also had an impact upon the group rankings. Two facts support this belief. First, the most effective discriminator between the two groups is ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING. One of the slight differences between aircraft models flown by the two groups is in the landing gear configuration, and thus the consequences for making an overweight landing are not the same for the group operating one model as they are for the other.

Second, to point out the effect of an accident on the seriousness ranking of a subculture, the third most discriminant error (and one of the two ranked as more serious by the first group) is FAILURE TO USE ALL AVAILABLE NAV AIDS TO DETERMINE POSITION. The survey of the first group of pilots was made less than one month after an aircraft and crew was lost under circumstances that pointed to the commission of this type error. These two associations point out that there is ethnographic import to the seriousness ranking, and whatever the stimulus for the differences, further and more sophisticated study of these differences should bear fruitful results.

A second discriminant analysis program was conducted for all 103 pilots, tasking the computer to search for differences in seriousness ranking of pilots with low P-3 flight hours (40 - 799 hrs.), medium P-3 flight hours (800 - 1499 hrs.), and high P-3 flight hours (more than 1500 hrs.). This was an attempt to determine how attitudes toward seriousness of errors change as a pilot gains in experience and accumulates flight hours. Table XVII below shows the results of group classification by flight hour accumulation.

TABLE XVII

GROUP CLASSIFICATION BASED ON FLIGHT HOURS BY DISCRIMINANT ANALYSIS

	Respondent's Sorting Correctly Predicted His Flight Hour Grp. (HIT)	Respondent's Sorting Did Not Predict His Grp. (MISS)
Low Flt Hr Pilot (N 44)	30 (68.2%)	14 (31.8%)
Med Flt Hr Pilot (N 32)	21 (65.6%)	11 (34.4%)
High Flt Hr Pilot (N 27)	16 (59.3%)	11 (40.7%)

Percent of "grouped" cases correctly classified: 65.05%

The MISSES in Tables XV and XVII above represent an interesting group of pilots. If a pilot's ranking of seriousness causes him to be misclassified he may be in a subculture of pilots who, although they have a high number of flight hours, continue to view seriousness in the same way as the low flight hour group. Without stating which group has the optimum view of seriousness, the pilots in the group by virtue of their experience that do not conform to the group "norms" might bear special study.

The ten errors that most discriminated among the three flight time groups with a direction of seriousness assigned are shown in Table XVIII.

TABLE XVIII

Ten Most Discriminating Errors for Flight Hour Group Classification and Direction

DISCRIMINANT ERROR	DIRECTION OF SERIOUSNESS		
	← MORE SERIOUS		
EXCEED DESIGN AIRSPEED FOR FLAP SETTING	LOW	HIG	MED
RAISING GEAR BEFORE BRAKES COOL BLOWING THERMAL PLUGS	HIG	MED	LOW
FLARE TOO HIGH	HIG	LOW	MED
IMPROPER USE OF DEICING EQUIPMENT	HIG	LOW	MED
MAKE A WHEELS UP PASS	HIG	MED	LOW
NOT INVESTIGATING CAUSE OF "ANTI ICE" LIGHT ILLUMINATION	MED	HIG	LOW
GO IFR ON A VFR CLEARANCE	MED	LOW	HIG
MAKE A HARD LANDING "G" METER EXCEEDS 5.2G's	MED	LOW	HIG
TAKE OFF WITH FLAPS NOT SET AT "T.0. AND APPROACH"	MED	LOW	HIG
INDUCE AN AUTO FEATHER BY RAPID P/L MOVEMENT	LOW	MED	HIG

Nine of the ten errors listed above are from the Acceptable and Runway Environment Technique Clusters described in the previous chapters. Interestingly, it is not the most serious errors that discriminate, but generally the less serious, innocuous, acceptable errors that best portray the discrimination. This phenomenon may support the "pilot" versus "aviator" concept described in Chapter V, in that attitudes towards Acceptable Errors (errors that "pilot"-type flyers are likely to make) and attitudes towards Runway

Environment Technique Errors (errors that "aviator"-type flyers are likely to make) are attitudes that change most as a pilot gains in experience.

Table XIX shows the aggregate seriousness ranking by 103 pilots for all sixty errors. Listed to the right is the position of each error as ranked by each flight hour group. It is apparent from this table that all three groups agree that FAIL TO MAINTAIN SAFE FLYING SPEED, ENTER UNCONTROLLED FLIGHT is the most serious error and SHIFT HAND TO NOSEWHEEL STEERING TOO SOON is the least serious error. The errors between all vary in seriousness, with some varying to a small degree and some to a larger degree.

The study of these changes in seriousness obviously requires further research. Ultimately, however, they may give us clues as to how to structure our safety programs, training sequencing, or even primary flight training error emphasis. What is needed is to link pilots' attitudes toward the seriousness of errors with some real-world indicator of the actual seriousness in some desired criterion such as dollars or lives lost. Then some form of sequenced error emphasis in training or safety programs could be presented to attempt to close the gap between the seriousness applied to errors by pilots and the real seriousness of errors in terms of cost. A check on the changes in attitudes toward seriousness might be in the form of card sorting much

TABLE XIX

SERIOUSNESS RANKING FOR ALL 103 PILOTS

RANK		LOW	MED	HIGH
1	FAIL TO MAINTAIN SAFE FLYING SPEED, ENTER UNCONTROLLED FLIGHT	1	1	1
2	ATTEMPT AN ABORT AFTER REFUSAL WHEN ENGINE FAILS.	2	2	4
3	FLY BELOW GCA MINIMUMS ON ACTUAL APPROACH.	7	3	2.5
4	ALLOW PROP TO CONTACT RUNWAY DURING CROSSWIND LANDING.	4.5	4	5
5	TAKE OFF WITH DOWNING DISCREPANCY.	3	7	8
6	LET AIRCRAFT DESCEND BELOW SAFE ALTITUTE AT NIGHT.	6	5	7
7	MAKE A WHEELS UP PASS.	8	3.5	2.5
8	ABORT TAKEOFF BEYOND REFUSAL SPEED WHEN SMOKE REMOVAL DOOR POPS OPEN.	9	6	6
9	CALL FOR WING ENGINE TO BE FEATHERED.	4.5	10	9
10	CONFUSION AS TO IFR ALTITUDE ASSIGNMENT, NEAR MISS.	12	8.5	10
11	DISCHARGE HRD INTO WRONG ENGINE DURING TRANSFER.	14	11	13.5
12	FLY INTO A KNOWN THUNDERSTORM AREA.	11	13.5	17.5
13.5	TAKE OFF WITH PITOT COVERS LEFT ON.	13	16	15.5
13.5	NOT SECURING ENGINE START WHEN BLEED AIR DID NOT RETURN TO PRE-START PRESSURE.			
15	FLIGHT SHOULD NOT HAVE BEEN FLOWN, WEATHER.	15.5	15	13.5
16	MISREAD ALTIMETER.	15.5	19	11.5
17	CHECK LIST NOT COMPLETED.	15	18	11.5
18	REVERSING TOO FAST ON NO FLAP LANDING, PITCHLOCKED PROP.	10	22.5	17.5
20	TAKE OFF WITH FLAPS NOT SET AT "TAKE-OFF AND APPRAOCH."	17	17	19
20	ALLOW CREW ENTRY INTO LOAD CENTER DURING FLIGHT.	22	12	25
20	INJURY RESULTS TO CREWMAN FROM PILOT INDUCED AIRCRAFT MANEUVERS.	24	13.5	20
22	NOT RECOGNIZING A PITCHLOCK CONDITION.	19	20.5	15.5
23	DESCEND THROUGH 200 FT IN DAYTIME MAD PATTERN.	20	24.5	21
24	CONTINUE FLIGHT WITH HAIL DAMAGED AIRCRAFT.	21	26	26.5
25	SALVAGE A LANDING FROM A POOR APPROACH THAT SHOULD HAVE BEEN A WAVE-OFF.	25	28.5	22
26	NOT INVESTIGATING CAUSE OF "ANTI-ICE" LIGHT ILLUMINATION.	23	27	31
27	TAXI OFF THE TAXIWAY AT NIGHT.	30.5	20.5	23.5
28	RAISE THE LANDING GEAR PREMATURELY.	30.5	24.5	23.5
29	DECOUPLE THE PROP DUE TO EXCESSIVE AIRSPEED ON RESTART.	27	22	33
30	CREWMAN INJURED DURING HEAVY WEATHER FLYING.	26	30	28
31	TAXI THE AIRCRAFT INTO A SNOW BANK.	29	33.5	29.5
32.5	RESTART AN ENGINE IN-FLIGHT WITH CURCUIT BREAKERS NOT PROPERLY RESET.	33	28.5	29.5
32.5	ATTEMPT TO START A DECOUPLED ENGINE.	35	33.5	34.5
34	GO IFR ON VFR CLEARANCE.	36	35	32
35	DECLARE A LOW FUEL STATE DUE TO HEADWINDS.	32	31.5	39
36	INDUCE AN AUTO FEATHER BY RAPID MOVEMENT OF P/L.	39	38	26.5
37	INGEST AN ENGINE INTAKE COVER DURING NIGHT START.	28	36.5	44.5
38	TURN OFF RUNWAY TOO FAST, BLOW TIRE.	40	31.5	37.5
39	RAISING GEAR BEFORE BRAKES COOL BLOWING THERMAL PLUGS.	37	39.5	36
40	SECURE ENGINE IN FLIGHT BEFORE DETERMINING IF ACTUAL MALFUNCTION EXISTS.	38	36.5	34.5
41	SET UP RADIOS/HSI WRONG FOR CLIMBOUT CLEARANCE.	34	39.5	40.5
42	ALLOW PROP WASH TO CAUSE DAMAGE TO OTHER AIRCRAFT.	44	43	37.5
43	MAKE A HARD LANDING, "G" METER EXCEEDS 5.2 "G's".	42.5	42	42
44	RETRACT GEAR BEFORE FLAPS ON WAVEOFF.	42.5	41	46
45	TAKE OFF WITH TRIM TABS SET IMPROPERLY.	41	46.5	44.5
46	ALLOW IMPROPER FUEL TRANSFER PROCEDURES.	42.5	44.5	47
47	EXCEED DESIGN AIRSPEED FOR FLAP SETTING.	47	46.5	49
48	OVER ROTATE ON TAKEOFF.	45.5	56.5	43
49	IMPROPER USE OF DEICING EQUIPMENT.	48	50	48
50	FAILURE TO USE ALL AVAILABLE NAVAIDS TO DETERMINE POSITION.	50	44.5	53
51	TAP BRAKE WHILE APPLYING RUDDER ON ROLLOUT.	57	51	40.5
52	FUELING/ACCESS PANEL NOT SECURED FOR FLIGHT.	51	48	54
53	OVERTEMP AN ENGINE BY RAPID P/L MOVEMENT.	52.5	52	50.5
54	ACCOMPLISH AN UNAUTHORIZED OVERWEIGHT LANDING.	52.5	49	55
55	FAILURE TO NOTE VOR OFF FLAG.	49	53	58
56	FLARE TOO HIGH.	55	58	50
57	APPLYING TOO MUCH BRAKE ON LANDING ROLL.	56	59	52
		54	54	56
58.5	ALLOW CABIN ALTITUDE TO EXCEED 10,000 FT.	59	56.5	57
58.5	UNABLE TO RAISE GEAR DUE TO GEAT PINS BEING LEFT IN.	58	55	59
60	SHIFT HAND TO NOSE WHEEL STEERING TOO SOON.	60	60	60

like that conducted in this study. Again, this study is only scratching the surface in error research, but the potential is promising for very effective results.

CHAPTER VII

ATTRIBUTES

As briefly described in Chapter IV, the second fleet pilot study group of 52 pilots, in addition to the sorting and seriousness ranking, were asked to rank order thirteen errors in terms of the following four attributes: CAREER, RATTLE, EMBARRASSMENT and FUN. The thirteen errors were chosen because they fell close to the three axes of the multidimensional scaling of all sixty errors for the first fleet pilot group, near the ends or midpoints of those axes. Errors were also selected that were distributed throughout the three major clusterings. It is believed that although the thirteen are a small, manageable number of errors, they also represent the entire action space of the total sixty errors.

Each pilot was asked to accomplish each of the following using the same card deck of thirteen selected errors:

> Rank order these errors from "most" to "least" as you perceive they would ruin your career if they were to happen to you. (Titled CAREER)
>
> Rank order these errors from "most" to "least" as you perceive they would rattle you or break your concentration if they were to happen to you. (Titled RATTLE)
>
> Rank order these errors from "most" to "least" as you perceive they would embarrass you if you made them and your squadron was notified. (Titled EMBARRASSMENT)

> Although making these errors would be no real fun, strange as it may seem, there is some positive affect from making errors. For the sake of research, rank order these errors from "most" to "least" as you perceive they are fun. (Titled FUN)

A word should be said here about the attribute of fun. In the "Eight Ball Study" and other sports related studies, Roberts, et al., found that certain behaviors had positive affect for the players even though the behaviors were in fact, mistakes or examples of poor play. An example from the "Eight Ball Study," is MAKING A BLAST SHOT. This behavior in the game of "Eight Ball" was an example of poor play but for many players, fun to perform. Many pilots, including the author, found it difficult to think about error making as fun, but, with some explanation the pilots were able to rank order the thirteen errors on this attribute. For example, some pilots did agree that a certain positive affect was associated with salvaging a landing from a poor approach.

The thirteen errors shown in Table XX are listed in order of adverse impact, as perceived by the 52 pilots. This rank order, based upon mean position runs from most adverse effect (TAXI OFF THE TAXIWAY AT NIGHT) to least adverse effect (FAILURE TO NOTE VOR OFF FLAG).

TABLE XX

CAREER RANK ORDER

	CAREER	RATTLE	EMBARRASS	FUN
TAXI OFF THE TAXIWAY AT NIGHT	1	4	2	12
MAKE A WHEELS UP PASS	2	1	1	11
ABORT T.O. BEYOND REFUSAL, SMOKE REMOVAL DOOR POPS OPEN	3	3	4	9
CALL FOR WRONG ENGINE TO BE FEATHERED	4	2	6	10
CREWMAN INJURED DURING HEAVY WEATHER FLYING	5	7	7	13
TAKE OFF WITH PITOT COVERS LEFT ON	6	5	3	7
DECLARE A LOW FUEL STATE DUE TO HEADWINDS	7	8	8	8
UNABLE TO RAISE GEAR DUE TO GEAR PINS BEING LEFT IN	8	10	5	2
INDUCE AN AUTO FEATHER BY RAPID P/L MOVEMENT	9	6	9	4
GO IFR ON A VFR CLEARANCE	10	11	12	3
SALVAGE A LANDING FROM A POOR APPROACH...	11	9	10	1
EXCEED DESIGN AIRSPEED FOR FLAP SETTING	12	12	11	5
FAILURE TO NOTE VOR OFF FLAG	13	13	13	6

The career attribute was chosen for the written listing in Table XX since it represents, in the author's view, the pilot's perception of how "the system" (the Navy as an organization) looks at the error action space. Stated in another way, TAXI OFF THE TAXIWAY AT NIGHT and MAKE A WHEELS UP PASS are not as likely to be tolerated by cognizant Navy officials as EXCEED DESIGN AIRSPEED FOR FLAP SETTING and FAILURE TO NOTE VOR OFF FLAG. In Table XX, then, we have a rank ordering of errors that approximates the real world acceptance of these errors by Naval authorities--at least as the pilots themselves perceive that acceptance. Listed to the right on Table XX are the averages of rank order standings for each of the other three attributes. It is apparent that the attributes of RATTLE and EMBARRASSMENT show much the same rank ordering pattern as the CAREER attribute, and as might be expected the attribute of FUN is ranked in roughly an inverse order when compared to the other three attributes.

An examination of this table poses some interesting questions. For example, the error perceived to be the number one career wrecker, TAXI OFF THE TAXIWAY AT NIGHT, as compared with the third from the least (11th in rank order) perceived career wrecker, SALVAGE A LANDING FROM A POOR APPROACH THAT SHOULD HAVE BEEN A WAVEOFF, tells us several interesting things. If a pilot runs his aircraft off the taxiway at night, he feels it will affect his career, it will rattle him somewhat, it will embarrass him, and it will not, relatively speaking, be fun. On the other hand, to continue on to a landing from an approach that was so poorly executed that the approach should have been abandoned will not, in the pilot's perception, seriously affect his career, nor rattle or embarrass him, but he does perceive it as fun, in fact it is number one in the fun ranking. Paradoxically, however, common sense tells us that taxiing off the taxiway at night is not the type of error that will ordinarily result in extensive damage to the aircraft and loss of life. Available evidence indicates clearly that the approach and landing phase are the most critical portions of the flight, and approach and landing accidents are much more likely to cause fatalities and aircraft damage than taxiing off the taxiway at night. Simple comparison of average aircraft speeds for example, when each error occurs tells the story, 5-10 knots taxiing and 120-140 knots during the approach and landing. The same argument can be applied to GO IFR ON A VFR CLEARANCE and EXCEED DESIGN A/S FOR FLAP SETTING. Both errors are perceived as not likely to rattle, embarrass, nor affect one's career, but are, in a way, fun. The risk of mid-air collision or collision with the ground is always present when a pilot goes IFR on a VFR clearance, and the risk of structural failure of flaps and resulting uncontrolled flight is a real possibility and present when exceeding design airspeed limitations for the flap setting. Both have the potential to result in much greater damage than taxiing the aircraft off the taxiway.

The task then is to change pilots' perceptions of the "system" and their attitudes, in order to make it more career damaging, more embarrassing and less fun to commit the errors that are likely to lead to loss of lives and aircraft damage. Of course the goal is not to make pilots less conscious of the taxiing error, but instead to make him more aware of the real implications of the salvage-a-landing error. One answer might be in flight recorders that will allow post flight analysis of pilots' actions, by higher authority, leading to discovery of errors of the salvage-a-landing type. In other words, it may be advisable to change attitudes toward errors to bring these attitudes more in line with the real costs, in the broadest sense, of each error.

Because of the exploratory nature of this study, a number of other promising attributes were left for study in the future. These include real importance, admiration, shame, blame and luck. Obviously this ground is fertile for future research.

CHAPTER VIII

CONCLUSION, NEW DIRECTIONS

This analysis of some of the factors involved in error structuring and attitudes toward errors may be likened to sculpting the Venus de Milo with a blunt sledge hammer. The author is neither a trained behavioral scientist, anthropologist nor a safety expert. Moreover, knowledge of mental organization itself is still in the discovery stage. Practical recommendations cannot be made without further, more refined study, but we believe that the novel approach presented here tells a great deal about the real world of pilot errors and suggests a wide range of promising avenues for further research.

What have we learned? We have learned (although certainly not conclusively) that it is possible to use hierarchical clustering techniques to make explicit certain implicit patterning of pilot errors that existed in the P-3 pilot population when the survey was taken. Our evidence demonstrates, we believe, that pilots have a sort of cognitive map of the error space into which they fit things which go wrong. They have error clusters that give dimension, shape and structure to the error domain. A further study of this domain may show cultural differences and give us indicators of the optimum or safest structuring and how to tailor our training and safety programs to achieve that optimum structuring. This whole concept can be applied to any other aircraft, pilots in general, submarines, ships or any vehicle or machine operated by man.

This study also suggests, but does not fully demonstrate, that multidimensional scaling can identify significant dimensions of the error space for the P-3 pilot population. This underlying constellation of errors that has interpretable dimensions tells us how pilots view errors, gives us clues as to how to impart knowledge about these errors and gives us directions for the further study of errors.

The use of scaling and discriminant analysis in the study of pilots' perception of the seriousness of errors has shown us a variation in a certain percentage of errors between groups of pilots with varying amounts of flight hours, as well as differences which appear to be associated with factors unique to the two locations. These differences in attitudes must be examined more closely, but we believe that they too hold significant implications for the structure of training and safety programs.

The scaling of pilots attitudes toward the attributes of FUN, CAREER, RATTLE and EMBARRASSMENT suggests rather convincingly that it is possible to use a selected subset of errors to model the larger domain, and that pilots' attitudes expressed toward errors may not coincide with what is optimum from a safety viewpoint or what is desired by their superiors.

The basic thrust of this study has been to discover group attitudes and perceptions toward errors on a broad cultural plane. The next step must be taken with care and cannot be taken without a great deal of carefully designed research. That step is to bridge the gap from broad cultural group attitudes to individual performance and behavior. The ultimate goal of this research would be eventually to use our knowledge of error space structuring in such a way that given groups' or individuals' problems could be diagnosed and corrected.

In all, this study was intended to examine whether pilot errors are culturally patterned; in general this patterning does seem to exist and to match the realities of the situation. However, there is evidence of bias and lack of reality as well. It is this area of bias and lack of reality that requires much further study and ultimately, perhaps, correction in the future.

NOTES

Chapter I

1. Clayton Knight and K.S. Knight, Plane Crash - Mysteries of Major Air Disasters and How They Were Solved (New York: Greenburg, 1958), p. 127.

2. J.S. Shuckburgh, "Accident Statistics and the Human Factor Element," Aviation, Space and Environmental Medicine, January 1975, p. 76.

3. John M. Roberts and Gary Chick, "Butler County Eight Ball, A Behavioral Space Analysis," In press: Sports, Games and Play: Social and Psychological Viewpoints Jeffrey H. Goldstein, Editor.

4. Roberts deals with mapping in earlier studies.

Chapter II

1. R.G. D'Andrade, "U-Statistics Hierarchical Clustering," In press: Psychometrika.

2. Several highly experienced P-3 pilots were consulted when the opinion of an informed judge was required; some were utilized as subjects for pre-testing before interviewing Fleet Pilots.

3. The KYST Program; Kruskal, Young and Seery, 1973, which is a factor analysis-type program that plots relationships among the data, giving form or structure to the information. In a way it organizes the "space" of the data so that observations regarding the data can be made.

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This exploratory, behavioral study describes an attempt to determine cognitive mapping of, and attitudes toward pilot errors among a group of 103 P-3 pilots interviewed by the author. Clustering programs, multidimensional scaling techniques and descriminant analysis programs were applied to the sorting of 60 P-3 pilot errors accomplished by the 103 pilots. Results indicate that although there is a basic underlying structure to the cognitive map of errors among the 103 pilots, there are cultural differences in the error structuring of groups stationed at different locations and groups of pilots

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with varying flight hour accumulation. It also appears that attitudes toward the seriousness of pilot errors differs among the same groups. Findings are discussed in relation to possible implications in training or safety programs.