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FURTHER DEVELOPMENT OF AUTOMATED GAT-1 PERFORMANCE MEASURES

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This technical report has been reviewed and is approved.

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Flying Training Division

Approved for publication.

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This report describes a systematic, statistically-directed search for automated flight measurements that correlate with pilot proficiency. The approach is based on two separate experiments carried out in a GAT-1 trainer: a basic experiment (Experiment 1) with 326 measurements on each of 30 *S*s in three experience groups, and an expanded experiment (Experiment 2) with 2436 measurements on each of 30 new *S* from the same three experience groups. Experiment 1 consisted of four different flight tasks, each about 10 minutes long, and Experiment 2 consisted of these and six additional tasks. The results of these experiments show that there is little difficulty in obtaining measurements that correlate with experience. More than 5% of the measurements of each experiment were statistically significant (0.01 level). Tables of more than 400 important measurements are given with group means

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and standard deviations and further cross-tabulations to show which tasks and families of measurements are best at discriminating among pilots. Three different statistical methods were used to select a set of measurements from Experiment 1 and combine them into two new canonical variables, each a linear-weighted combination of the measurements in the set, to discriminate optimally among the three groups of subjects. Applying the canonical variables to the repeated measurements of Experiment 2 allowed several deductions about the best selection procedure to be made.

PREFACE

This study represents a portion of the work being done under Project 1123, Flying Training Development, under the direction of Dr. William V. Hagin. This effort was documented under Task 112301, Development of Performance Measurement Techniques for Air Force Flying Training, and Work Unit 11230105, Further Development of Automated GAT-1 Performance Measures; Dr. Edward E. Eddowes Task Scientist and Contract Monitor.

The research was accomplished by Dr. John W. Hill, Bioinformation System Group, Stanford Research Institute, under Contract Number F41609-72-C-0012. This effort covered the period of time between January 1971 and May 1973.

The authors are grateful to those who have substantially contributed to this project. Mr. Kenneth W. Gardiner provided valuable assistance in designing the flight tasks used in the experiments. Elizabeth Primrose and Cheryl Nemig obtained Qualified subjects for the experiment, ran them through the test series, and helped in the analysis of the results. Mr. A. F. Ferrara built up the computer interface and kept the GAT-1 flying throughout the study in spite of innumerable breakdowns.

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FURTHER DEVELOPMENT OF AUTOMATED GAT-1 PERFORMANCE MEASURES

I. INTRODUCTION

Pilot proficiency has previously been measured subjectively, and the resulting unreliability and lack of precision have made comparisons of pilot training programs a major problem. Consequently, various automated measurements have been sought by previous investigators. Early work by Krendel and McRuer (1960) showed no differences in single-axis compensatory tracking ability with pilot proficiency; the ultimate skill levels were achieved after a few practice sessions for all the subjects (*S*s) involved. More recently, Garber and Krasnitskii (1968) found a small group of psychophysical variables that correlate with progress on initial flight training. Goebel, Baum, and Hagin (1971) found that several performance measures obtained from undergraduate pilots' first few hours of training time in a GAT-1 correlated with future performance. Their test battery included a number of tasks and a variety of measurements on each task.

This report describes a reanalysis and expanded study of the statistical approach of Hill and Goebel (1971) which selected test measurement that discriminated among changing pilot skills over the first 100 hours of flight training. The experimental system for generating these measurements consisted of a GAT-1 trainer interfaced to a small on-line computer. Performance measurements were based on 16 flight variables of the GAT-1 which were continuously monitored during ten simulated flight tasks. Basic performance measures consisting of means and standard deviations of selected flight variables and correlations between pairs of variables during each task were developed. It was believed that in sufficiently complex simulated flights, the *S*s' differing abilities to divide their attention, and hold a number of variables constant could be used to measure their different skill levels based on their different amounts of flying experience.

Since compensatory tracking affords stable measurements of human performance, especially in the crossover region (McRuer, Graham, Krendell, & Resner, 1965), and can provide a number of models of pilot performance, a tracking task was included into Experiment 1. It was expected that two-dimensional tracking in the GAT-1, with its dependencies on several flight variables, would provide better discrimination of pilots on the basis of their experience than the single-variable tracking using a joystick often used in studies of psychomotor performance in the laboratory.

The two-dimensional tracking tasks (roll and pitch tracking) produced a surprisingly large number of measurements that separated the three experience groups of pilots studied in the previous Hill and Goebel (1971) research. Since the pilot-vehicle describing functions from the roll-tracking portion of the roll and pitch tracking task accounted for such a large number of discriminating tracking measurements, an assortment of new tracking tasks involving roll tracking was explored in the present experiment. One-, two-, and three-dimensional tracking tasks were included in the second experiment, as were variations in the amplitude and band-width of the roll command signal. Tracking tasks, based on the new flight variables, yaw, altitude, and ground position, also were included.

The types of measurements derived from the tracked variables were greatly expanded in Experiment 2. A frequency analysis of the coupling between variables in multicoordinate tracking tasks (cross-frequency analysis) was devised. A remnant analysis was included to determine smoothness of an individual *S*'s internally generated response in carrying out a task. Several variables were derived from the describing function by fitting different constants and the simple crossover model of McRuer et al. (1965) to the individual *S*'s data. Estimates of pilot gain, crossover, and equivalent time delay were obtained from the describing function. Similar measures were derived from the cross-frequency and remnant analysis. These new tasks and new families of measurements resulted in an increase in the number of measurements per *S* from 326 to 2,436.

Because of an error in the calculation of describing functions of the previous study (Hill & Goebel, 1971), this report includes a complete reanalysis of the previous data with corrected describing functions. Because of this change, and an additional error found in the multivariate discriminate analysis (the previous stepwise analysis was not terminated early enough in the step-by-step procedure), the corrected description of the previous study presented in this report as Experiment 1 should be considered a replacement for the entire previous report (Hill & Goebel, 1971).

II. EXPERIMENT 1

Background

The describing functions of the previous study were not correct because the command signal used for the calculation of the *S*'s response was 90° out of phase. This problem was corrected by using the function X(g + 1) − 1, where g is the previous gain and X is the ratio of the correct command signal to the previous command signal. During this recalculation, several new variables were derived from the old data to make the old data comparable with the data of the new experiment. The variables added are given below and the calculations for obtaining them are described in Appendix A:

- Gains measured in decibels
- High frequency gain
- High frequency crossover
- High frequency phase
- Low frequency gain
- Low frequency crossover
- Low frequency phase
- Equivalent time delay

The second problem with the previous data analysis was that no limit for terminating the multivariate discriminant analysis was placed on the step-by-step procedure. The previous analysis terminated itself after 27 steps, ideally separating the three groups of ten *S*s. This, of course, represents a perfectly solvable problem and a statistical procedure is not necessary to solve it; 27 linear equations in 27 unknowns is a straightforward problem of algebra. The multivariate analyses were repeated using a realistic limit[1] to determine if an added variable in the analysis significantly contributed to the separation of the groups. When no additional variables were found that met this criterion, the analysis was terminated automatically.

Method

Apparatus. An existing interface between a link General Aviation Trainer (GAT-1) and a LINC-8 computer system (described by Hill, Gardiner, & Bliss, 1969) was enlarged to permit continuous monitoring of eight flight variables (airspeed, altitude, climb, roll, pitch, heading, glideslope, and localizer) and to allow the computer to supply signals to two GAT-1 variables (roll and pitch) for tracking tasks. Computer processing of the data to provide usable output was divided into two stages because of the limited memory size and computational power of the LINC-8 computer. The LINC-8 was used to accumulate simple sums, cross products, and Fourier sums; and to generate the sums of sines command signals on line. The time scale for these accumulations was based on a 15-Hz clock.[2] The variables were sampled, and sum, products, and command signals were updated every 1/15 second. The sums output from the LINC-8 recorded on paper tape at the end of the test runs were further processed by formula translation (FORTRAN) programs to calculate the means, standard deviations, correlation coefficients, and gains and the phase shifts for the tracking tasks.

Three hundred and twenty six individual test measurements were made for each *S* over the four-task test series. Many measurements had the same name but were measured in different tasks. Consequently, a numbering system was used to identify each of them. The numbering system is given in Appendix B by numbers placed to the right of the computer printout in the same relative positions as the values of the measurements.

Subjects. Thirty *S*s (three groups of ten) were selected on the basis of their flying experience and were run through the test series. Subjects in the beginner (B) group had little or no flying experience (less than ten hours); *S*s in the intermediate (I) group had moderate experience (25 to 50 hours); and *S*s in the

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[1] A description of the program BMD07M, including a description of the step-by-step calculations performed, is given in References 7. The F-to-enter and F-to-delete levels were set to 2.5, and the tolerance level was set to 0.0001 for all computations reported.

[2] A stable clock was obtained by dividing the 60-Hz line frequency by 4.

advanced (A) group had extensive experience (more than 100 hours) and, in addition, had logged 20 or more hours in the previous six months. The majority (approximately 80 percent) of the *S*s had 1-1/2 hours of experience in the GAT-1 trainer from a previous flight test. Many *S*s, expecially the advanced pilots, volunteered for the tests; others were obtained by offering them $5.00 for a 2-1/2 hour session.

Procedure. A pre-test pilot familiarization period and four simulated flight tasks were selected for the experiment. They are described as follows.

Pilot Familiarization

Each *S* was asked to perform the following series of maneuvers to become accustomed to the GAT-1 and its flight characteristics prior to his attempting the experimental test tasks:

(1) A takeoff and climb to 1000 ft heading due east.

(2) A 180° left standard rate level turn in 1 minute.

(3) A 180° right standard rate level turn in 1 minute.

(4) A 500 ft climb at 500 ft/minute.

(5) A power change to 1800 rpm and back to 2400 rpm.

(6) A 500 ft descent at 500 ft/minute while keeping airspeed at 100 mph.

(7) A level flight while switching on half flaps and then full flaps and maintaining altitude at 1000 ft.

This familiarization procedure took from 15 to 30 minutes, depending on the *S*. More warming-up time was spent with the B group than with the I or A groups. If a *S* did not reasonably complete one of the warm-up maneuvers, he was given a second opportunity before going on to the next.

Simulated Flight Tasks

(1) *Task I–Roll and Pitch Tracking.*

In this test the *S* was instructed to hold altitude at 1000 ft and heading at 90° (due east) while maintaining level flight with a power setting of 2400 rpm. He was told that a simulated rough air would make the trainer pitch and roll slowly and that he was to maintain altitude and heading as well as possible during the test run.

This test was basically a two-coordinate compensatory tracking task with sum-of-sine-wave command signals introduced into the roll and pitch axes to simulate rough air. The amplitudes of the individual command frequencies are given in Tables 1 and 2. In addition to the means, standard deviations, and correlations among the six monitored variables, the gain and phase of the pilot-vehicle describing function for both roll and pitch tracking were recorded.

Table 1. **Amplitudes of the Roll Command Frequencies (Tasks I, II)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
1	0.002	121.42
5	0.010	24.27
15	0.029	8.36
29	0.057	4.26
64	0.125	1.94
98	0.191	1.27
157	0.307	0.79
239	0.467	0.52

Table 2. **Amplitudes of the Pitch Command Frequencies (Tasks I, II)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
2	0.004	30.05
7	0.014	8.57
14	0.027	4.44
27	0.053	2.27
59	0.115	1.04
81	0.158	0.76
145	0.283	0.42
274	0.535	0.22

A long warm-up[3] time (34.2 seconds) was provided in this test to allow the *S* to adapt to the command signals that started abruptly with the onset of the run. During the remainder of the test (545 seconds) the *S*'s performance was continuously monitored. The six flight variables monitored in this test are listed in the computer printout shown in Appendix B under the analysis entitled, "Roll and Pitch Tracking."

(2) *Task II–Roll and Pitch Tracking with Power Changes.*

Task II was identical to Task I except that he *S* was additionally required to perform the series of power changes according to the schedule shown in Table 3. As in Task I the *S* first set up the trainer with proper altitude (1000 ft), heading (90°), and power (2400 rpm). Then he set the minute hand of the aircraft clock to between 1 and 2 minutes before the hour and continued to hold heading and altitude. When the time reached 0 minutes and 0 seconds, the *S* called "Mark" to the experimenter (*E*), who started the computer. The variables measured in Task II are shown in Appendix B under the analysis entitled, "Roll and Pitch Tracking with Power Changes."

Table 3. **Sequence of Power Changes for Task II**

Time after Start (min)	Power (RPM)
1	2000
3	2600
5	2000
7	2600
9	2400

(3) *Task III–Flight Profile.*

This test task consisted of five short (2 to 3 minute) maneuvers performed in quick succession. The sequence of maneuvers is shown in Table 4. The *S* set up the clock as in Task II and called "Mark" at the beginning of the first maneuver (time 0) and at the beginning of the other maneuvers, as indicated in Table 4. When *E* heard "Mark" he started the computer monitor. The *S* was monitored for only the first 75 percent (approximately) of each maneuver, to keep the mean flight measurements from being biased if *S* completed the maneuver too quickly and to allow *E* time for entering commands at the teletype to set up for the next maneuver.

[3]The warm-up time was a time before the *S*'s performance was monitored, during which the LINC-8 generated the sum-of-sines command signals.

Table 4. **Sequence of Events in the Flight Profile (Task III)**

Maneuver Monitoring Duration (s)	GAT-1 Time (min)	Subtasks
Pretest		Hold altitude at 500 ft Hold heading at 90° Hold power at 2400 rpm
A. Climb - 95	0	Call "Mark" Change power to 2600 rpm Climb at 500 ft/min to 1500 ft
B. Right turn - 95	2-1/2	Call "Mark" Start right standard 360° turn Hold altitude of 1500 ft Hold airspeed of 110 mph
C. Slow flight - 145	5	Call "Mark" Reduce speed to 80 mph Hold altitude at 1500 ft Hold heading at 90°
D. Descending turn - 85	8	Call "Mark" Switch on half flaps Lower power to 1200 rpm Start left standard 360° turn Descend at 500 ft/min to 500 ft
E. Descent - 85	10	Call "Mark" Switch on full flaps Raise power to 2500 rpm Descend at 250 ft/min to ground Hold heading at 90°

The flight variables monitored and the output in each of the five maneuvers are given in Appendix B. No command signals were generated by the computer for the flight profile, but the rough air (internally generated by the GAT-1) was kept at its maximum value for the duration of the test.

(4) *Task IV–ILS Landing Approach*

In this final task *S* was instructed to climb to 2300 ft with power at 2400 rpm and a heading of 288° and fly toward the simulated airport at Seaport Beach. In addition to the instrument heading, a visual airport reference was used consisting of a piece of paper pinned to the cloth drape surrounding the trainer at a compass heading of 288°. The GAT-1 position plotter was used to position the trainer approximately 12 miles from the airport, directly on the approach beam. As the *S* flew into the glide slope beam and the glide slope needle crossed zero, he was instructed to call "Mark" to *E* and to begin descending at 100 mph, while keeping the glide slope and localizer needles crossed.

Since many of the *S*s had never flown an instrument landing system (ILS) approach, even many of the *S*s in the *A* group, a warm-up was given before the monitored test. The warm-up consisted of placing an *S* on the localizer beam before he started climbing to 2300 ft and letting him follow the beam while climbing, and then again while descending several hundred feet on the beam after the glide slope had been intercepted. During the warm-up period *E* gave *S* verbal help to keep him on the beam and suggested the strategy for returning to the beam if he drifted off. After this warm-up, the data run began, and the variables given in Appendix B were monitored.

In each of the monitored runs, for each of the simulated flight tasks described above, all the unchanging flight variables were monitored, but the remaining variables were not. For example, in a descending turn, altitude and heading were not monitored, but airspeed, rate of descent, roll angle, and pitch angle were monitored.

Determination of Discriminative Efficiency of Test Measures. A one-way analysis of variance was performed on each of the 326 sets of test measurements to determine the ability of each measure to distinguish independently among the beginning (B), intermediate (I), and advanced (A) groups of *S*s. This use of the analysis of variance statistic is not in accordance with standard practices in psychological research and is in error judged by conventional criteria. The rationale for this nonstandard use of analysis of variance is presented subsequently and may be evaluated best in view of the specific requirements of the study. The distribution of the F values obtained from these analyses is shown in Table 5. In terms of the number of test variables with an F value greater than the limit shown and less than the next higher limit shown. The 50 measures with which it was possible to reject the null hypothesis for the three groups of *S*s at the 5-percent level (F greater than 3.35) are shown in Table 6, together with the significance level achieved. In addition, Table 6 gives the mean of the measure for each group, the mean over all three groups, and the standard deviation over all three groups. The 50 statistically significant variables have been marked in the annotated final analysis printout of Appendix B so that they may be easily identified by name.

***Table 5.* Distribution of F Values for Experiment 1**

F Limits	Significance	Variables
0	0.50	157
1.0		44
1.5		28
2.0		27
2.5	0.10	15
3.0		5
3.35	0.05	14
4.24	0.025	18
5.49	0.01	4
6.49	0.005	3
7.81	0.002	3
8.81	0.001	8
Total		326

To determine which of the four flight tests and which of the generic types of variables measured in the tests contributed most to differentiation, the summary shown in Table 7 was made. Of the four tasks, Tasks I through III contributed high proportions of significant variables (based on the number significant divided by the total number available from each task). Only 9 percent of the Task IV variables were significant. Since all the tasks contributed measures which discriminated among the B, I and A groups, it appears that a group of tests requiring several different skills and types of coordination, should be used to differentiate between the skill levels of pilots, rather than only one test.

Of the four types of measurements made in the tasks (means, standard deviations, correlations, and tracking parameters), the standard deviations produced the highest proportion (32 percent) of the significant differences between *S*s. The tracking measurements were second best (after standard deviations) in ability to separate the groups of *S*s, with 18 percent of them being significant. A breakdown of the tracking measures into those obtained in roll and pitch tracking, also given in Table 7, shows that almost all the significant tracking measures were obtained from roll-tracking gains. In fact, roll tracking was the most efficient task for generating significant measures with 34 percent of those measured significant at the 5 percent level. The most efficient variables of all were the roll gains, with 19 of the 32 measures (59 percent) statistically significant.

Table 6

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 1

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
22	4.34	.025	.015160	.080270	-.039740	.018563	.091176
27	4.02	.050	.016330	.077060	-.037080	.01877[illegible]	.0900[illegible]
32	3.64	.050	23.504	33.332	50.193	35.[illegible]76	22.365
35	5.51	.010	1.186	1.637	2.083	1.636	.604
36	9.92	.001	.655200	.922570	1.190650	.922807	.26885[illegible]
37	9.48	.001	.412370	.549650	.712370	.5581[illegible]0	.154220
38	4.81	.025	.325440	.414300	.466830	.402190	.103066
75	4.77	.02[illegible]	2.948	2.249	1.530	2.242	1.026
77	4.86	.025	2.967	2.137	1.535	2.213	1.031
98	6.28	.010	7.133	8.072	14.731	9.[illegible]	5.226
100	13.48	.001	1.[illegible]16	1.381	2.004	[illegible].500	.393
101	10.71	.001	.594570	.851930	1.117000	.[illegible]54500	.252398
102	4.59	.025	.[illegible]23820	.534080	.628920	.528940	.151540
132	3.39	.050	433.525	441.600	462.225	445.783	25.413
138	4.00	.050	1.988	2.154	1.223	1.788	.785
140	3.79	.050	2.008	2.121	1.242	1.791	.776
156	4.93	.025	6.079	5.832	3.968	[illegible].293	1.644
158	3.66	.050	186.621	192.167	126.796	168.528	59.913
160	3.99	.050	2.519	2.506	1.858	2.294	.599
172	4.99	.025	1409.	1437.	1489.	1445.	57.
173	3.63	.050	10.675	22.925	38.725	24.108	23.343
177	5.89	.010	7.767	6.214	4.511	6.164	2.123
181	4.34	.025	2.417	1.917	1.521	1.952	.682
184	5.26	.025	-.284770	.032620	.015760	-.078797	.246315
189	5.04	.025	-.454580	-.206610	-.225190	-.295460	.194462
199	3.40	.050	-439.375	-476.100	-385.000	-433.492	78.609
203	4.74	.025	156.234	174.024	96.985	142.414	58.564
205	5.13	.025	2.318	2.460	1.403	2.060	.801
206	4.97	.025	-.457200	-.696710	-.266030	-.473313	.306110
209	3.67	.050	-.298590	-.445960	-.192420	-.312323	.210122
210	5.19	.025	.577790	.725500	.571330	.624873	.121057
213	3.88	.050	-173.125	-169.725	-211.400	-184.750	37.173
241	7.27	.005	5.606	3.749	2.803	4.053	1.672
243	7.27	.005	5.642	3.933	2.829	4.135	1.662
245	4.66	.025	1.163600	.629900	.543600	.779033	.492202
268	4.53	.025	26.[illegible]04	28.377	32.983	29.421	4.709
270	3.48	.050	9.372	12.919	14.394	12.228	4.373
271	3.83	.050	.610	2.930	6.136	3.225	4.481
272	8.49	.002	-4.475	-1.091	1.328	-1.413	3.164
273	8.62	.002	-8.392	-5.536	-3.103	-5.677	2.851
274	5.94	.010	-9.800	-8.087	-6.763	-8.217	1.976
278	8.40	.002	-5.514	-2.946	-.600	-3.020	2.681
284	7.61	.005	15.552	17.609	22.559	18.573	4.129
286	10.96	.001	.449	2.353	5.932	2.911	2.659
287	10.58	.001	-5.325	-1.683	.745	-2.088	2.971
288	5.03	.025	-8.120	-5.747	-4.218	-6.028	2.772
290	5.16	.025	22.231	24.000	27.863	24.698	4.011
293	9.23	.001	-5.814	-3.341	-1.344	-3.500	2.331
294	11.30	.001	.119520	.161580	.215440	.165513	.045221
322	3.64	.050	-165.987	-133.117	-145.311	-148.138	27.532

Table 7. **Breakdown of the Important Variables in Experiment 1**

Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Task I	95	15	16
Task II	95	14	15
Task III	101	18	18
Task IV	35	3	9
Task Totals	326	50	
Means	44	5	11
Deviations	44	14	32
Correlations	102	7	7
Tracking	136	24	18
Variable Totals	326	50	
Roll gains	32	19	59
Roll phases	16	0	0
Roll derived	20	4	20
Ptich gains	32	0	0
Pitch phases	16	0	0
Pitch derived	20	1	5
Tracking Totals	136	24	

To understand better the differences among pilot groups evidenced in the pilot-vehicle describing functions (gains and phases), the describing functions for Task I shown in Figures 1 and 2 were studied. Where differences among groups exist, they were repeatable across the frequency spectrum. It is obvious from Figures 1 and 2 that the two derived variables, high and low frequency roll gain, contain all the useful gain information in the roll-describing function for separating groups. The low frequency roll gain differences were not significant because of their normal high variability, but differences in high frequency pitch phase were significant, with the B group showing greater phase shift (equivalently greater lag or reaction time) than the I or A groups.

The correlation coefficients were the least productive in showing significant differences among pilots. Since only 7 percent of them were significant at the 5 percent level, there is little evidence to indicate that they contribute to pilot skill differentiation and probably the correlations should be eliminated from the tests. On the other hand, only 5 percent of the pitch tracking measures were significant at the 5 percent level.

III. DISCRIMINANTS IDENTIFIED IN EXPERIMENT 1

One of the objectives of this study is to determine statistically the measures that can be used to define or evaluate pilot performance over the first 100 hours of training. The approach is to use a linearly weighted sum of automated performance measures (a discriminant or factor) that optimally differentiates among the three groups of *S*s. Different means of obtaining this discriminant, using an analysis of variance and a "canned" stepwise multivariate discriminant analysis program, are described in this section. Three discriminant functions were obtained from the data pool of Experiment 1 for later application to the data pool of Experiment 2. This comparison allows estimation of the usefulness and reliability of the three methods for obtaining such discriminants described in this section.

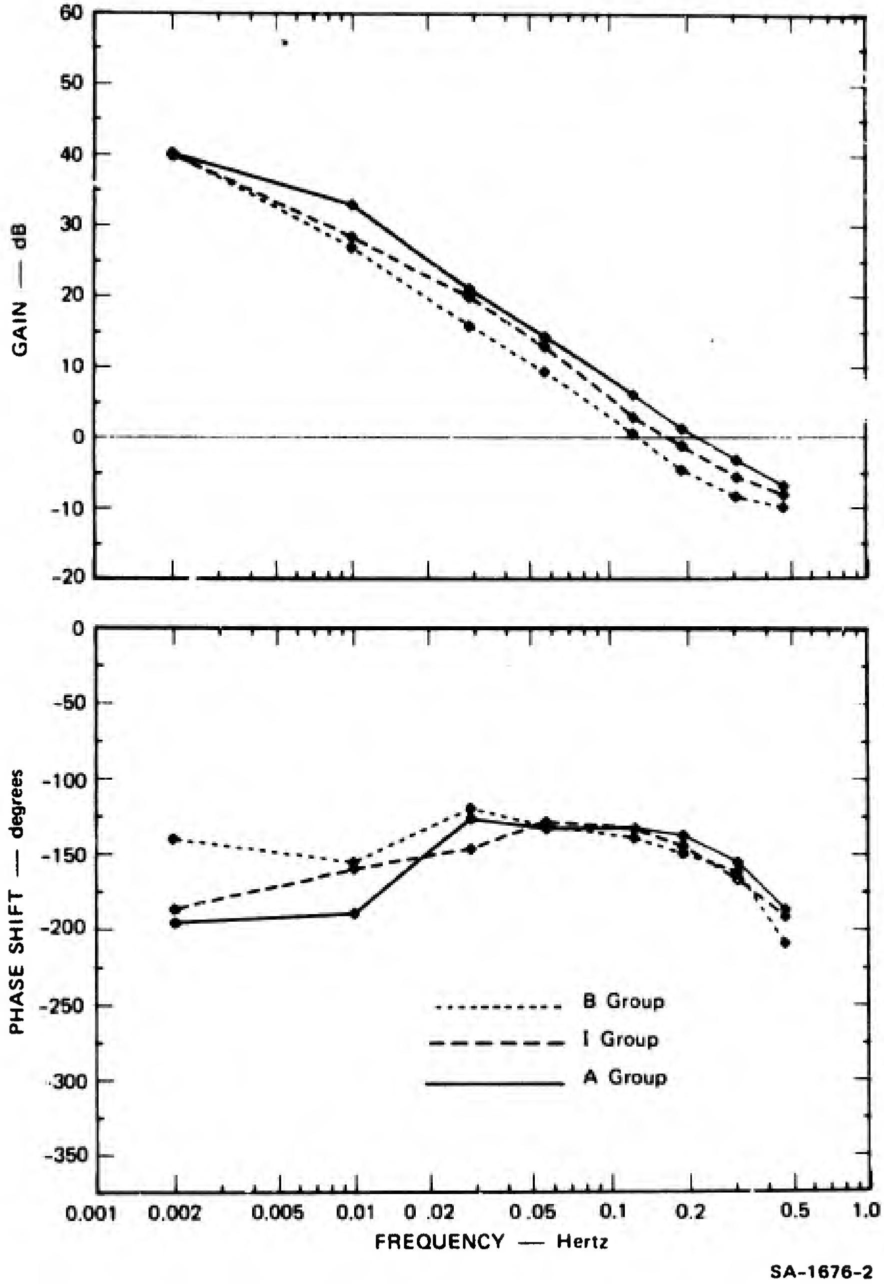


FIGURE 1 PILOT-VEHICLE DESCRIBING FUNCTIONS FOR ROLL TRACKING IN TASK I

Each data point represents the average of ten subjects.

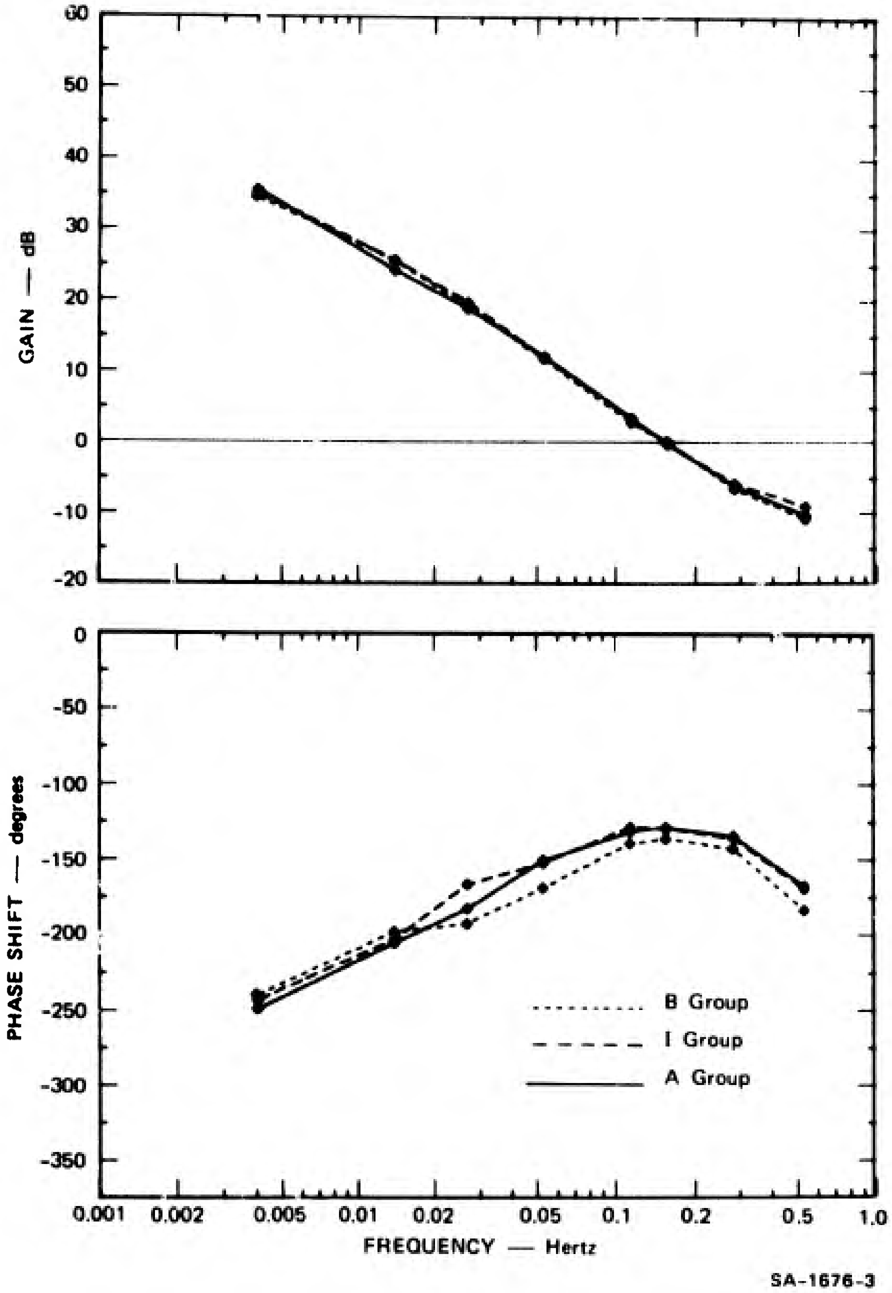


FIGURE 2 PILOT-VEHICLE DESCRIBING FUNCTIONS FOR PITCH TRACKING IN TASK I

Each data point represents the average of ten subjects.

AM Discriminant – Determined by Analysis of Variance Followed by Multivariate Discriminant Analysis

This two-stage method of determining a discriminant is based on an initial selection of mesures using a one-way analysis of variance of each measure to determine its ability to separate correctly the different performance of the three groups of subjects. The resulting set of measures with an acceptable significance level is entered into a multivariate discriminant analysis program. The primary requirement for this two-stage method is to reduce the size of the set of measures set so all measures found to discriminante satisfactorily between B, I and A groups may be entered simultaneously into the analysis program. The multivariate program handles only 71 variables while in Experiment I there were 326 measures; consequently, the one-way analyses of variance were employed in identifying the "best" 71 of 326 for entry into the multiple discriminant analysis.

The distribution of F values shown in Table 5 was used to select the measures for input to the multivariate discrimination program. The set of measures with F values larger than a given F criterion consisted of two groups: those representing a real difference among the three experience level groups of pilot subjects, and those representing chance statistical fluctuations in the data. As the criterion F value is raised, fewer measures are included, but they are more likely to show real, repeatable differences. As the criterion is lowered, more variables are included, and a larger portion of them are variables significant by chance, showing differences among groups that will not be repeated in subsequent tests.

As a compromise between losing important variables and gaining variables significant only by chance, an F criterion of 2.5 was chosen. This value is achieved by 10 percent of the Fs computed on samples drawn from the *same* population. A smaller F criterion would begin to include more false positives than positives, and a larger F criterion would eliminate too many discriminating variables. It can be seen that the analysis of variance statistic was used to aid decision making in a way other than that for which it is characteristically employed.

The 70 variables meeting the $F = 2.5$ criterion were entered into the stepwise multivariate discriminant analysis program, BMD07M, for the final selection of the most important flight variables. The program went through eight iterations before it stopped adding the variable with the highest F value at each step and recomputing the F values of the remaining unselected variables on the basis of the remaining pooled variance. In this way, eight of the 70 flight variables were selected by the program as being significant in discriminating among the three groups of pilots before the F level of the remaining variables became lower than that required for further computation. These final variables are listed in Table 8, with their initial F values [2 and 27 df (degrees of freedom)] and final F values [2 and 20 df] to test the null hypothesis among the three groups. The variables with the highest final F values are the most efficient in separating the three groups.

Table 8. **AM Discriminant Summary**

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
100	.125 Hz Roll, tracking gain, II	13.47	18.04	3.35	− .0179	1.50
153	Climb rate, III-B	2.60	8.12	.0199	− .00749	22.9
189	Pitch-altitude correlation, III-C	5.04	6.01	− .613	−5.67	− .295
210	Pitch-climb correlation, III-D	5.19	11.64	−8.10	−7.67	.624
225	Pitch-airspeed correlation, III-E	3.02	6.54	1.43	4.39	− .396
241	Roll standard deviation, IV	7.27	2.81	− .273	− .495	4.05
245	Localizer standard deviation, IV	4.65	6.41	−1.710	1.54	.779
313	.014 Hz Pitch tracking gain, II	3.33	11.23	− .235	.0867	25.6

After selecting the variables that best discriminate, the BMD07M program performed a coordinate rotation in eight-space to find new orthogonal variables (canonical variables or factors) that account for most of the dispersion (or variance) in the data. The value of the two canonical variables, C_1 and C_2, for each pilot in the test series is given by:

$$C_1 = \sum_{j=1}^{r} u_j (x_j - \bar{x}_j) \quad (1)$$

$$C_2 = \sum_{j=1}^{r} v_j (x_j - \bar{x}_j) \quad (2)$$

Where r is the number of discriminating variables chosen (eight) in this case, u_j and v_j are the first and second canonical weighting coefficients, x_j is the value of the eight variables obtained for the given pilot, and $\bar{x}_j$ is the grand mean for each of the discriminating variables. These data are given in Table 8. The individual values of the two canonical variables for the 30 pilots are shown in Figure 3, as determined from the coefficients and grand mean of Table 8 using Eqs. (1) and (2).

MM Discriminant–Determined by a Two-Stage Multivariate Discriminant Analysis

A second procedure for selecting the variables that best discriminate among the three groups of subjects is to break the 326 variables into groups of 71 or fewer variables and run the multivariate analysis to determine the variables significant in separating the three groups. This procedure may allow more interaction among variables in separating the groups than the previous method.

For this analysis the 326 variables were divided into the five groups shown in Table 9 and independently entered in the BMD07M multivariate discrimination program. The last group (Group 5) contained the derived tracking variables from Task I and II added in this reanalysis. These include the tracking gains measured in decibels and the constants fitted to the describing function.

The 47 selected test variables were again entered into a multivariate discriminant analysis for final selection. Fifteen of the 47 flight variables were selected before the statistical termination procedure was reached. These final variables are listed in Table 10 with their initial *F* values (2 and 27 df) and final *F* values (2 and 13 df). The individual values of the two canonical variables for each of the 30 *S*s plotted using the coefficients and grand means of Table 10 and Eqs. (1) and (2) are shown in Figure 4.

Table 9. **Summary of First Multivariate Analysis**

Variable Group	Tasks	Number of Variables	Number of Significant Variables
1	I	65	6
2	II	65	17
3	III-A, III-B, III-C	67	11
4	III-D, III-E, IV	69	6
5	I, II	60	7
	Total of all tasks	326	47

Close examination of the initial F values of the MM Discriminant of Table 10 reveals that more than half the variables chosen (8 out of 15) are not significant (5% test) in their ability to separate the three groups. Several variables even have *F* values close to 1.00 or below it, suggesting that they are but random variables contributing to the separation of the 30 particular *S*s of the *S* pool but not to separation of experience groups in general.

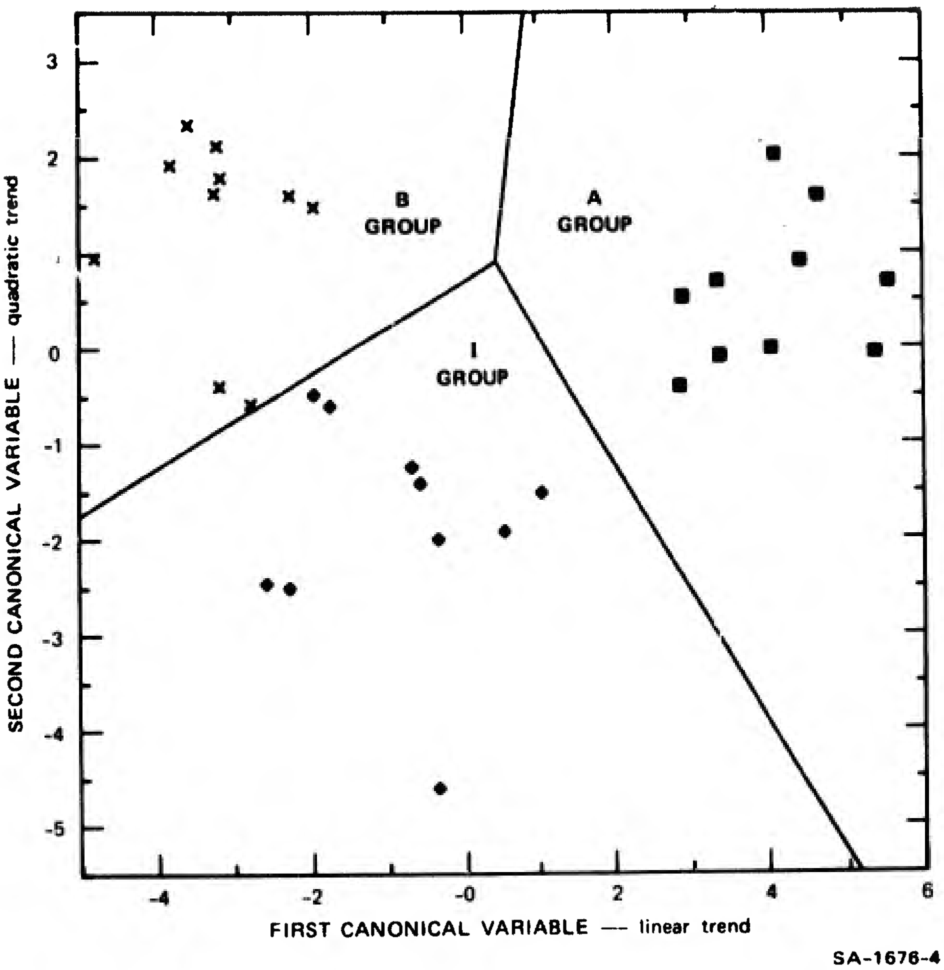


FIGURE 3 CLUSTER PLOT OF THE AM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

Table 10. **MM Discriminant Summary**

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
22	Pitch-roll correlation, I	4.34	6.09	−12.7	−3.24	.0186
79	Climb-airspeed correlation, II	1.12	26.41	−30.4	−2.99	− .180
98	.029 Hz Roll tracking gain, II	6.28	2.62	.353	.287	9.97
100	.125 Hz Roll tracking gain, II	13.47	35.79	8.15	1.01	1.50
153	Climb rate, III-B	2.60	27.95	.050	.007	22.9
183	Airspeed-altitude correlation, III-C	1.78	9.58	3.45	4.29	.108
196	Roll-yaw correlation, III-C	.85	6.61	− 5.18	3.16	.950
205	Pitch standard dev., III-D	5.12	2.82	− .142	−1.35	2.06
210	Pitch-climb correlation, III-D	5.18	23.56	−23.6	−1.75	.625
225	Pitch-airspeed correlation, III-E	3.01	22.33	7.66	7.40	− .397
241	Roll standard deviation, IV	7.27	31.64	− 1.83	.242	4.05
284	.029 Hz Roll tracking gain (db), II	7.61	7.37	− .620	− .876	18.6
291	Low frequency roll crossover, II	.50	7.38	− .580	.938	.647
307	Low frequency pitch phase I	.39	14.95	− .100	− .114	−195.
313	.014 Hz Pitch tracking gain (db), II	3.33	9.98	− .208	.265	25.6

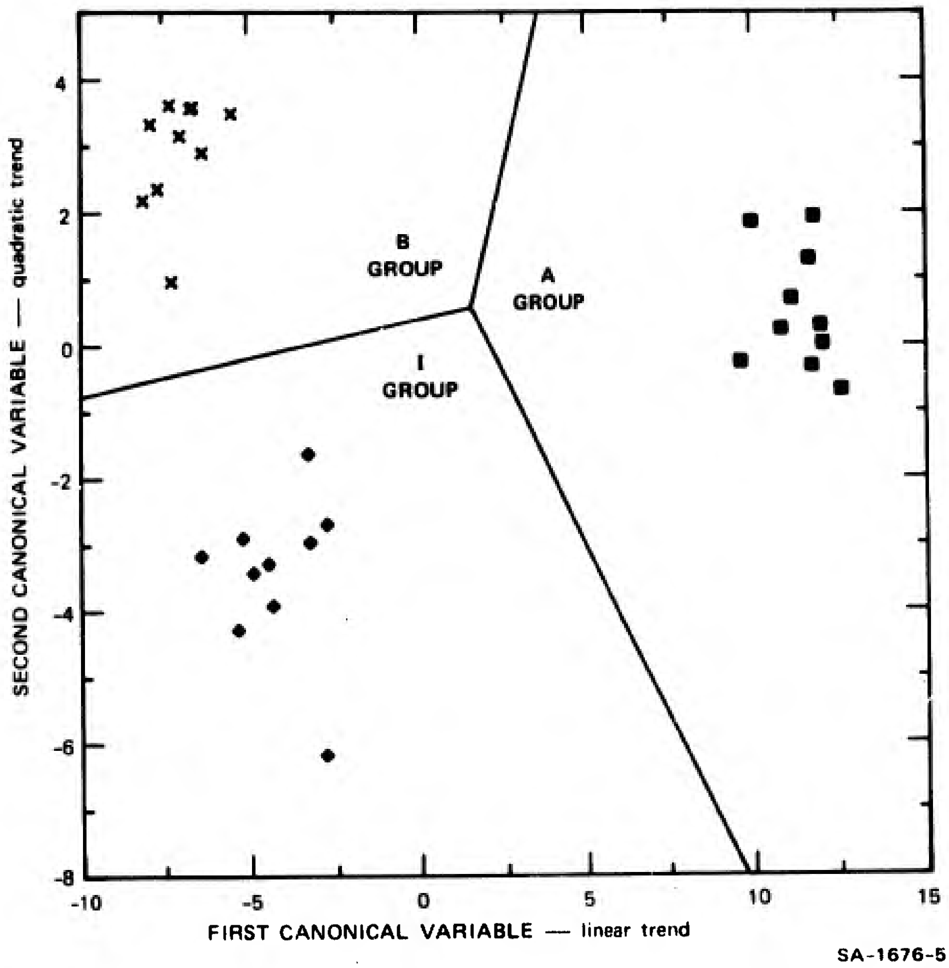


FIGURE 4 CLUSTER PLOT OF THE MM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

Because of the concern that the BMD07M program might not be capable of meaningful selection of variables from a large base (326) using only 27 df, some experiments with randomly generated variables were carried out.

Discriminants from Random Pools of Variables

Since no statistics are known on how well a stepwise multivariate discriminant analysis can be expected to select from pools of 60 to 70 variables to differentiate among three groups of 10 subjects, empirical d were obtained by running the program with random numbers. No statistic is available in the BMD07M program for determining the significance of the variable added at each step in further separating the groups. To solve this problem, the calculation of Mahalanobis distance, D^2 (approximately chi square distributed), based on the U statistic as described by Rao (1970) was added to the program. Since D^2 is additive, the change in D^2 (2 df) with each added variable did not contribute to the separation among groups. In addition to the incremental D^2 calculation, the program was modified to print out the classification matrix after each step.

To obtain empirical distributions of the D^2 statistic and classification speed, the following experiment was carried out. Ten separate sets of random data were generated, using a random number generator.[4] Each set of data consisted of 70 random number (corresponding to flight variables) for each of 30 hypothetical "subjects." Ten "subjects" were arbitrarily assigned to each group (10 beginners, 10 intermediate, and 10 advanced). Each data bank, a 30 x 70 matrix of random numbers, was entered into the BMD07M stepwise discriminant program.

The results of the random data runs were quite surprising. Table 11 shows the number of "subjects" correctly classified by the stepwise discrimination procedure for each of the first 12 discriminating variables. It can be seen that on the average, the best one of the 70 random "flight variables" correctly classified 15.9 "subjects," and on the average only nine selected random "flight variables" are needed to classify correctly all 30 "subjects." The most typical discriminant of the ten runs (closest to average in separating ability) is shown in Figure 5.

These results indicate that the stepwise multivariate discriminant procedure is being misused in this application where it is expected to search large pools of variables (from approximately 50 up to 326) to select a few significant variables. Its use should be restricted to cases where the number of variables in the pool is much less than the number of pilots. The diversity of combinations available in such a large pool of random variables is put to quick use in separating groups.

Table 11. **Number of "Random" Pilots Correctly Classified**

Number of Discriminating Variables	Worst of Ten Runs	Average of Ten Runs	Best of Ten Runs
1	14	15.9	18
2	17	18.8	21
3	19	21.0	24
4	19	23.0	26
5	22	24.9	28
6	22	25.0	29
7	23	26.7	30
8	25	27.4	30
9	27	28.5	30
10	28	29.2	30
11	29	29.9	30
12	29	29.9	30

[4]Ten uniformly distributed random numbers, each obtained by the CDC 6400 FTN random number generator (RGEN), were summed to obtain individual samples from an approximately normally distributed process having a mean of 5.0 and standard deviation of 0.8.

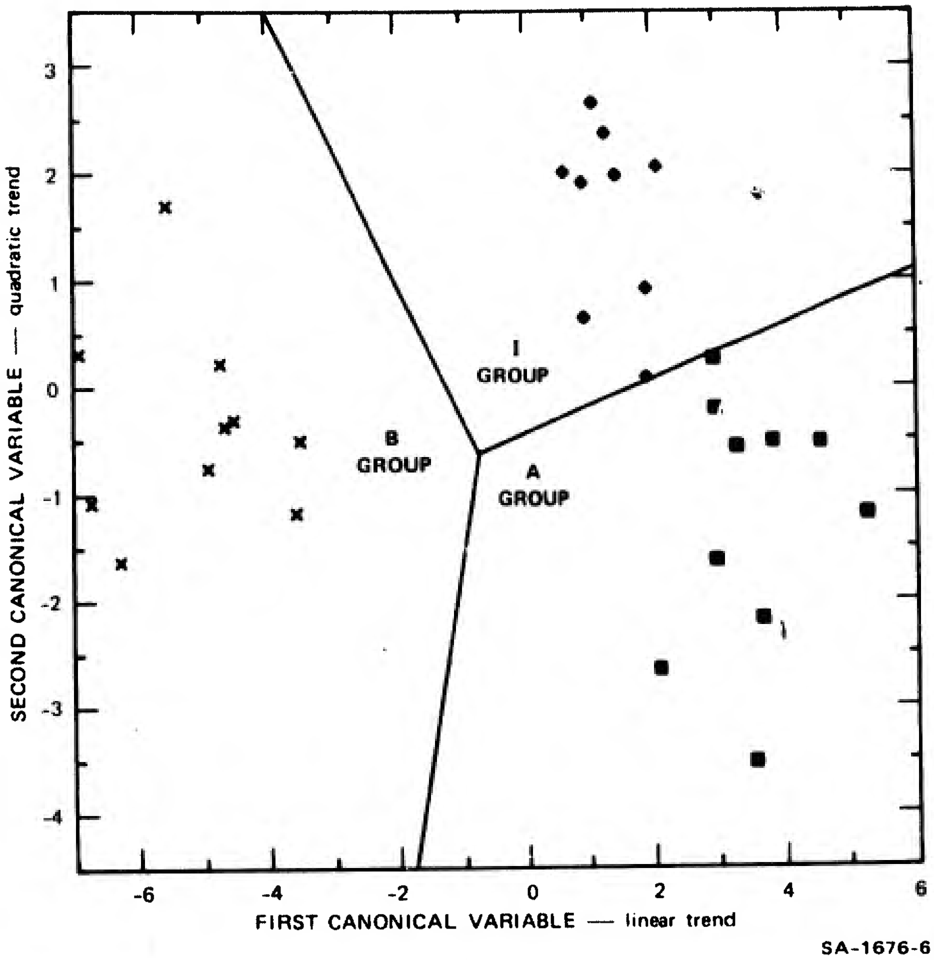


FIGURE 5 CLUSTER PLOT OF TYPICAL RANDOM DISCRIMINANT APPLIED TO 30 HYPOTHETICAL SUBJECTS

Experiment 1 Conclusions

The results with random data indicate that the multivariate discriminant analysis should not be used as a selection tool in this application. The fact that the majority of variables in the MM discriminant are not statistically significant in their own right suggests that the MM procedure is selecting variables that differentiate among the particular 30 *S*s of the analysis, but will not be useful in differentiating among new *S*s. This failure is useful because it suggests a rule for choosing candidate variables: a variable must be statistically significant in separating the three groups of *S*s by itself. Only if this is true do we have some assurance that the variable shows a difference that will be repeated by other *S*s.

This is exactly the approach used to obtain the AM discriminant. The large number of variables (70) entered in the multivariate analysis, however, still called for the analysis procedure to do the selection, possibly causing the resulting variables to be weighted so that particular, unrepeatable, differences among *S*s are used to differentiate among the three groups. A better method of selection would be to increase the level of confidence (alpha) criterion for acceptance from the .10 level previously used to a higher level, say the .01 or the .001 level. A level of confidence of .01 in this study would have reduced the number of candidate variables from 70 to 18.

In addition to raising the significance level of acceptance of a variable, common sense indicates that many of the variables are highly correlated and hence redundant, and that some generic types of measurements are not effective above chance in generating statistically significant variables.

The describing functions of Figures 1 and 2 indicate that the tracking variables are highly correlated. Where differences among groups exist, they are repeatable across the entire frequency spectrum. Also, according to the way they are derived from these curves (Appendix A), gain and crossover measures are highly correlated, as are high frequency phase and equivalent time delay.

The results of Experiment 1 indicate that the correlation coefficients do not produce significant variables above the chance level. Only 7 out of 102 (6.8 percent) are significant at the 5 percent level. This is less than half as many as the other families and suggests that the correlations are not reliable in distinguishing among pilots.

With this background, the following rules for reducing the number of candidate variables are proposed:

- *Rule 1* - Eliminate the tracking parameters (describing function) in favor of the parameters derived from them.
- *Rule 2* - From the derived tracking parameters eliminate the parameter of each following pair with the lowest F value.

  -Low frequency gain, low frequency corssover

  -High frequency gain, high frequency crossover

  -High frequency phase, equivalent time delay.
- *Rule 3* - Eliminate the 102 correlation coefficients.

In experiment 1, application of Rule 1 would eliminate 96 individual tracking gain and phase components (Variables 31 to 46, 50 to 65, 96 to 111, 115 to 130, 267 to 274, 297 to 304, 283 to 289, and 312 to 319). Application of Rule 2 would eliminate 3 variables from each of the 4 tracking analyses (12 variables) that are, by construction, highly correlated.

Applying these three rules to the data would reduce the number of variables from 326 to 116. Using significance level as the last criterion for selecting a small number of variables from the pool of 116, we find 5 qualifying variables above the 0.01 level and 14 above the 0.025 level. As a test of the efficacy of these rules, each of these groups was separately entered in the BMD07M program, and the two discriminants obtained were identical and are shown in Table 12 with their initial F values (2 and 27 df) and final F values (2 and 26 df). The individual values for the two canonical variables for each of the 30 *S*s plotted using the coefficients and grand means of Table 12 and Eqs. (1) and (2) are shown in Figure 6.

Table 12. **RAM Discriminant Summary**

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
241	Roll standard deviation, IV	7.27	4.69	– .39	– .45	4.05
294	High frequency roll crossover, II	11.30	8.12	17.70	–13.35	.166

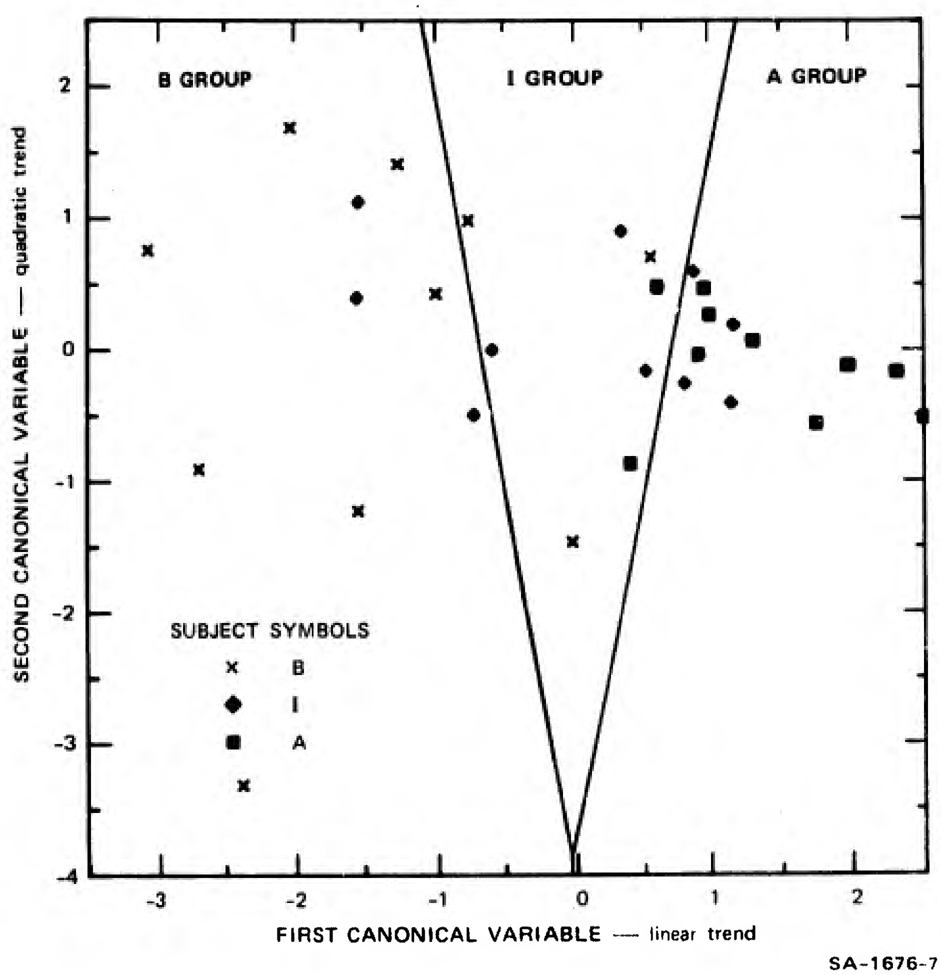


FIGURE 6 CLUSTER PLOT OF THE RAM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

One of the differences among the RAM discriminant and the previous discriminants is the dominance of the linear canonical variable in separating the three groups. With the AM, MM, and Random discriminants, cluster plots had a triangular shape; with the RAM discriminant, the clusters lie in a straight line. This difference further suggests that the three previous discriminants were building group differences from peculiar differences among *S*s in the 30 *S* pool the same way that differences can be built up by using a pool of random numbers. It also seems logical and desirable that pilot performance measures should be measured on a single axis (the first canonical or linear variable) of increasing skill with monotonically increasing changes from B through I to A groups rather than the up-down-up changes resulting from the second canonical (quadratic) variable.

IV. EXPERIMENT 2

Introduction

Experiment 2 was a considerably expanded version of Experiment 1 designed to fulfill the following requirements:

- Replicate the measurements of Experiment 1 to obtain data for verifying the reliability of the discriminants based on 30 new *S*s.
- Include additional flight variables, particularly all the *S*s' control inputs (throttle, rudder, elevator, and aileron).
- Determine if roll tracking alone was the task that discriminated among groups, or if it was the particular two-dimensional tracking procedure used in Experiment 1. For this purpose one-, two-, and three-dimensional tracking tasks (including roll) were explored, as well as tasks with varied bandwidth and amplitude of the roll command signal.
- Experiment with several types of direct and derived tracking measurements based on the remnant spectrum and cross-coupling between tracking tasks.

Method

Apparatus. In this experiment more flight variables were recorded and controlled, and a visual reference system was added as shown in Figure 7. The interface between the GAT-1 and LINC-8 computer was enlarged to allow continuous monitoring of eight additional flight variables (power, absolute heading, rate of turn, rudder, elevator, aileron, northing from a reference station, and radial distance from a reference station) and to allow the computer to introduce signals into three additional GAT-1 variables (yaw, altitude, and north-south position) for tracking tasks.

The LINC-8 computer program was modified to subtract a continuously changing ramp function from specified variables so that changes from the required profile could be monitored. For example, the actual altitude difference from the profile specified by 500 ft/min climb starting at an altitude of 500 ft could be monitored exactly like other, unchanging flight variables. The ability to monitor linearly changing variables was used to follow altitude deviations during steady climbs and descents and heading deviations during fixed rate turns.

The LINC-8 tracking program was expanded to permit tracking command signals to be composed of 16 different sine wave components. The Fourier analysis was expanded from 8 to 16 frequencies, and the ability to perform Fourier analysis of a flight variable at several different sets of frequencies was added. With 16 instead of 8 data points, the pilot-vehicle describing functions were expected to be smoother and the variables derived from them (like average gain, crossover frequencies, and equivalent time delay) were expected to be more stable. Analyzing one flight variable at the frequencies contained in the command signal of another flight variable is called a cross-frequency analysis. The cross-frequency analysis permitted the coupling from one variable to another during a multidimensional tracking task to be determined (i.e., in roll and pitch tracking how much of the pitch command the *S* coupled into roll and vice versa). Analyzing a tracking flight variable at frequencies not in any command signal permitted the self-generate response of the pilot, the remnant, to be measured. Breaking the remnant power into high and low frequency portions permitted estimates of the jerkiness or smoothness of the *S*'s control handling to be made.

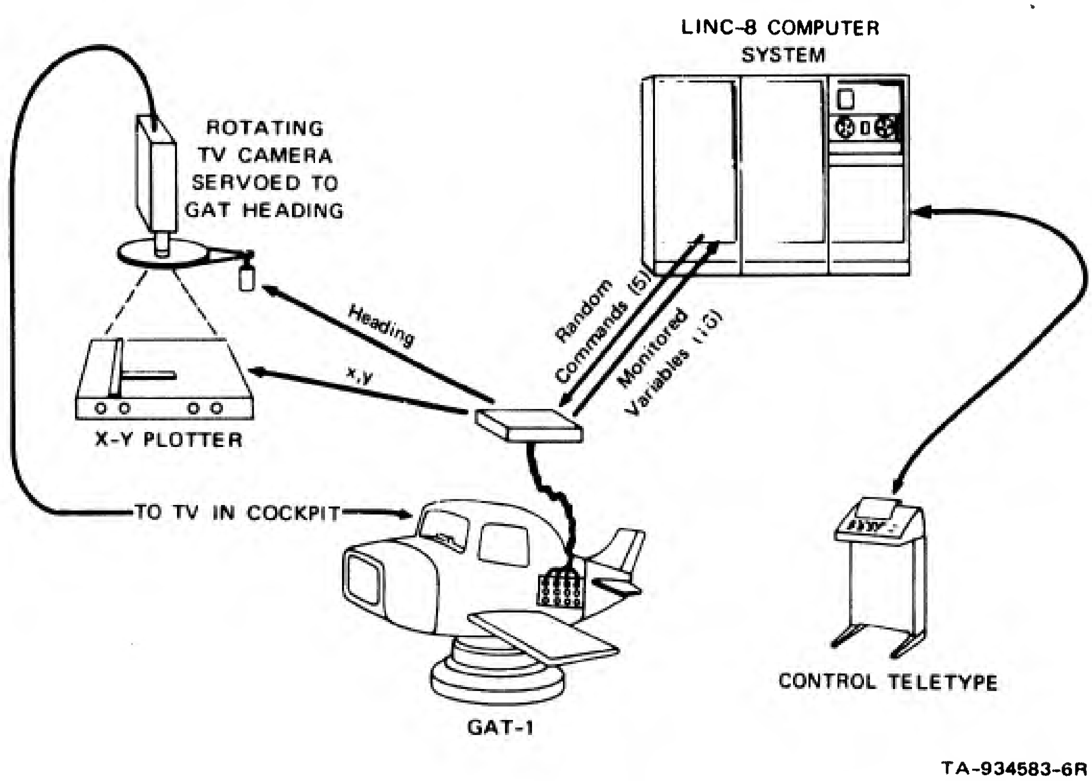


FIGURE 7 EQUIPMENT CONFIGURATION FOR EXPERIMENT 2

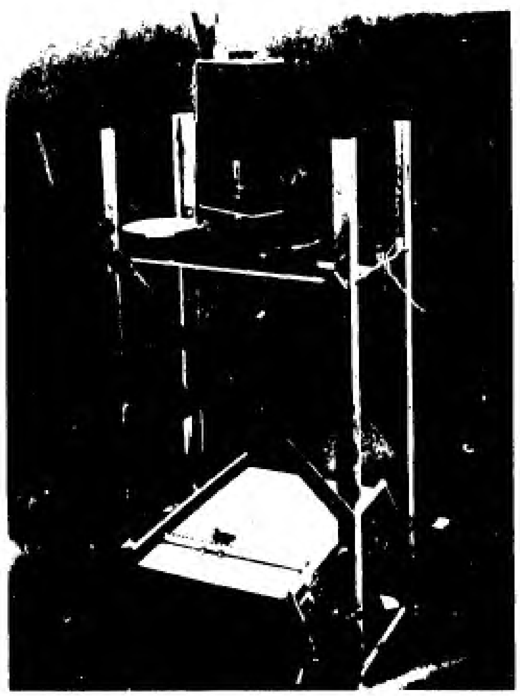
To carry out simple maneuvers entailing ground reference, the simulated ground reference system shown in Figure 8 was built. The visual reference system consisted of an x-y plotter and a closed circuit TV system. An 11 by 17 inch commercial x-y plotter was used to indicate the x and y coordinates of the GAT-1, using a scale of approximately 1 inch per mile. This afforded considerably greater resolution and smoothness than the original plotter supplied with the GAT-1.

A TV camera, positioned about 3 ft above the x-y plotter on a stand, viewed about a 7 by 9 inch area on the plotter's bed. Served from a potentiometer in the base of the GAT-1, the TV camera followed rotation of the GAT-1. In this way, "up" on the TV monitor always corresponded to the direction of travel, and the turning direction to correct position errors was easily measured.

A small portable TV monitor on the instrument panel of the GAT-1 provided the test subject with ground reference information. On the monitor, the subject saw a plot of his required ground course and a small moving circle (bullseye) representing the position of the aircraft above the ground.

Subjects. Thirty *S*s were selected on the basis of their flying experience, using the procedure described in Experiment 1. Many *S*s in the advanced group volunteered for the test; the remainder were obtained by offering them $10.00 for completing two test sessions, each approximately 2.5 hours long.

(a) HEADS-UP DISPLAY



(b) TV CAMERA ON ROTATING STAND

TA-934583-10

FIGURE 8 GROUND POSITION VISUAL DISPLAY SYSTEM

The subject observes his changing position (bullseye) on the ground reference using closed-circuit TV. The ground track shown represents a circle 2 miles in diameter.

Procedure. After performing the same warm-up and the same four tasks of Experiment 1 (Tasks I through IV), each *S* was run through six additional tasks (Tasks V through X). Since 2,436 individual test measurements were made on each *S* in the test series, many having the same name but measured in different tests, a numbering system similar to that used for the variables of Experiment 1 was used here. The number of each measurement is given in Appendix C by numbers placed to the right of the computer printout. When more than one measurement is printed on a line, the variables are numbered consecutively from left to right across the line with only the number of the last variables on the line being given. The description of the computational procedure used to obtain the test variables is given in Appendix A.

Pilot Familiarization

All pilots followed the same warm-up procedure used in Experiment 1.

Simulated Flight Tasks

(1) *Tasks I Through IV*

Task I, Roll and Pitch Tracking; Task III, Roll and Pitch Tracking with Power Changes; Task III, Flight Profile; and Task IV, ILS Landing Approach, were the same as the corresponding tasks of Experiment 1 except for the enlarged set of measurements obtained.

(2) *Task V–Roll Tracking*

This task was the same as Task I in both its requirements of the *S* and its duration. Instead of the separate sum-of-sine command signals introduced into the roll and pitch axes, a command signal was introduced only into the roll axis. When combined with Task I and Task VI, this task provides data for comparison of one-, two-, and three-dimensional compensatory tracking tasks including roll tracking. The amplitudes of the individual roll command frequencies are given in Table 13. In addition to the means, standard deviations, and correlations among the 12 monitored variables, the roll describing function, roll remnant analysis, and test variables derived from them were obtained (Appendix C).

Table 13. **Amplitudes of the Roll Command Frequencies (Task V)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	28.72
13	0.025	19.90
16	0.031	16.16
20	0.039	12.93
25	0.049	10.34
33	0.064	7.82
41	0.080	6.30
51	0.100	5.04
63	0.123	4.10
81	0.158	3.19
101	0.197	2.56
127	0.248	1.98
161	0.314	1.60
203	0.396	1.27
255	0.498	1.01
321	0.627	0.81

(3) *Task VI–Roll, Pitch, and Yaw Tracking*

Task VI is the same as Task I in both its requirements of the *S* and its duration. Sum-of-sine command signals described in Tables 14, 15, and 16 were introduced into the three axes. It should be noted that this task was considered harder by many *S*s than the other tracking tasks, and earned it the nickname "airsick." In addition to the analyses of Task V, cross-frequency and remnant analyses were performed on the tracking data. The test measurements obtained are indicated in Appendix C by name, and the computations required to obtain them are given in Appendix A.

Table 14. **Amplitudes of the Roll Command Frequencies (Task VI)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	14.18
13	0.025	10.21
16	0.031	8.29
20	0.039	6.63
25	0.049	5.29
33	0.064	4.01
41	0.080	3.23
51	0.100	2.58
63	0.123	2.10
81	0.158	1.63
101	0.197	1.31
127	0.248	1.04
161	0.314	0.82
203	0.396	0.65
255	0.498	0.52
321	0.627	0.41

Table 15. **Amplitudes of the Pitch Command Frequencies (Task VI)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
10	0.020	6.53
14	0.027	4.68
17	0.033	3.86
22	0.043	2.98
26	0.051	2.52
35	0.068	1.87
43	0.084	1.52
53	0.104	1.23
64	0.125	1.02
87	0.170	0.75
111	0.217	0.59
131	0.256	0.50
172	0.336	0.38
207	0.404	0.31
273	0.533	0.24
355	0.693	0.18

Table 16. **Amplitudes of the Yaw Command Frequencies (Task VI)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
11	0.021	4.61
15	0.029	3.38
18	0.035	2.81
24	0.047	2.11
29	0.057	1.74
37	0.072	1.37
49	0.096	1.03
54	0.105	0.94
73	0.143	0.70
95	0.186	0.53
117	0.229	0.43
147	0.287	0.35
193	0.377	0.26
237	0.463	0.21
265	0.518	0.19
347	0.678	0.15

(4) *Task VII–Reduced Bandwidth Roll Tracking*

This task is identical to Task V in performance and analysis except that the reduced bandwidth command signal described in Table 17 was substituted for the one previously used. Frequencies above 0.1 Hz were reduced to 25 percent of the original amplitude. Frequencies of 0.1 Hz and lower were slightly increased in amplitude to keep the energy in the command signal (mean square) the same as that in the Task V command signal.

Table 17. **Reduced Banwidth Roll-Tracking Command Signal Amplitudes (Task VII)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	29.45
13	0.025	29.41
16	0.031	16.58
20	0.039	13.26
25	0.049	10.59
33	0.064	8.02
41	0.080	6.46
51	0.100	5.17
63	0.123	1.05
81	0.158	0.81
101	0.197	0.66
127	0.248	0.52
161	0.314	0.41
203	0.396	0.32
255	0.498	0.26
321	0.627	0.21

(5) *Task VIII–Reduced Amplitude Roll Tracking*

This task is identical to Task V in performance and analysis. The command signal was the same as that given in Table 13 except that the amplitudes were reduced by one-third to make the task easier.

(6) *Task IX–Ground Reference Turning Maneuver*

Task IX calls for the *S* to fly a circular path over the ground in full rough air while keeping his altitude constant at 1000 ft and his airspeed constant at 100 mph. The task was designed to be a half-standard turn (360 degrees rotation in four minutes) and *S* was so informed. *S* approaches from the west on the tangent line and performs one full turn. Because of the novelty of the task, *S*s were given one warm-up try before the monitored run. *S* called "Mark" when he met the circle, at which time *E* started the performance monitor. *S* was monitored for the first three minutes of the turning task. Unique flight variables recorded in this task were: the heading deviations from the heading profile specified by the half-standard turn (90° per minute) and the radius from the aircraft (bullseye) to center of the circle measured in feet.

(7) *Task X–Altitude and Position Tracking*

This task is similar to Task I in calling for the *S* to hold his altitude at 1000 ft and his airspeed at 100 mph. Instead of holding a constant heading as in Task I, however, *S* is requested to hold his north-south position constant using the visual reference system. The sum-of-sine command signals given in Tables 18 and 19 were added into position and altitude flight variables to make this a two-dimensional tracking task. The task corresponds to flying over a straight line on the ground at a constant altitude under severe side winds and up and down drafts. This task introduced two new compensatory tracking tasks: altitude and position tracking. Both of these tracking tasks require an additional degree of integration on *S*'s part more than the axis (roll, pitch, or yaw) tracking paradigms previously used. The tasks are, therefore, harder in that they require more anticipation and planning than axis tracking. Except for the new command signals, the analyses are the same as the two-dimensional analysis of Task I.

Table 18. **Amplitudes of the North-South Position Command Frequencies (Task X)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (Feet)
2	0.004	213
5	0.010	203
8	0.016	133
12	0.023	79
14	0.027	67
19	0.037	51
21	0.041	47
25	0.049	43

Table 19. **Amplitudes of the Altitude Command Frequencies (Task X)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (Feet)
1	0.004	27.7
4	0.010	26.1
7	0.016	14.6
10	0.023	10.4
15	0.027	6.9
18	0.037	5.4
23	0.041	3.8
32	0.049	1.5

Results

Each of the 2,436 test measurements was given a one-way analysis of variance to determine its relative importance in separating the three groups. The distribution of F values obtained from these analyses is shown in Table 20. The 420 variables that were statistically significant at the 5 percent level are listed in Appendix D, along with significance level, group, means, grand means, and standard deviation within a group. In addition to this tabular listing, the 420 significant variables have been marked in the final analysis printout in Appendix C by arrows so that they may be cross-referenced by name and easily tabulated.

Table 20. **Distribution of F Values for Experiment 2**

F Limits	Significance	Variables
0	0.50	1,024
1.0		372
1.5		219
2.0		198
2.5	0.10	137
3.0		66
3.35	0.05	142
4.24	0.025	122
5.49	0.01	61
6.49	0.005	40
7.81	0.002	24
8.81	0.001	31
Total		2,436

To determine which of the ten flight tasks contributed more statistically significant variables and to compare new tasks with the previous tasks, the breakdown by task of Table 21 was made. The most efficient tasks are Task I and Task V, both requiring roll tracking. The rest have lower, more or less equal percentages, except for Task X (altitude and position tracking with the visual reference system) which stands out with a lower percentage. Task IX, the other task using the visual reference system, has a payoff in significant variables similar to the coordinated turning portions of Task III not using the reference system. In general, the new tasks of Experiment 2 identified significant variables similar to those identified in Experiment 1.

Table 21. **Breakdown of Important Variables of Experiment 2 by Task**

Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Task I	240	66	28
Task II	240	40	17
Task III	424	54	13
Task IV	104	12	12
Task V	173	52	30
Task VI	579	89	15
Task VII	173	34	20
Task VIII	173	38	22
Task IX	90	13	14
Task X	240	22	9
Total	2,436	420	

The four generic types of measurements made in Experiment 2 are each broken down into two portions in Table 22 to assess the importance of the additional test variables introduced in Experiment 2. The upper number in Columns 2 and 3 is the number of Experiment 1 variables that were duplicated in Experiment 2. The second number is the number of additional test variables measured in Experiment 2. The third number is the total of the first and second numbers.

Table 22. **Breakdown of Important Variables of Experiment 2 by Generic Type**

Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Means			
Dupliations	44	8	18
Additional	123	22	18
Total	167	30	18
Deviations			
Duplications	44	21	47
Additional	123	33	27
Total	167	54	32
Correlations			
Duplications	102	8	8
Additional	812	91	11
Total	914	99	11
Tracking			
Duplications	128	43	34
Additional	1,060	194	18
Total	1,188	237	20
Variable totals	2,436	420	

The number of statistically significant new means did not change proportionally, since 18 percent were significant in each case. The proportion of standard deviations and tracking measurements, however, decreased, and proportion of correlations increased. Overall, the proportion of statistically significant Experiment 1 variables was higher (25 percent) than the proportion of additional variables of Experiment 2 (16 percent).

Because of the large number of flight variables (16), an important question to ask is: Which direct measurements are essential? To answer this question as well as to compare new direct measurements of the flight variables (means and standard deviations) with the previous set, the data of Table 23 were obtained from Appendix C. The results in Table 23 are clear-cut because proportions and numbers of important direct measurements are generally either large or small.

This data suggests that the following flight variables be deleted from the experiment:

- Power
- Rudder
- Aileron
- Northing
- Radius
- Glide Slope
- Left/Right turns
- Heading deviation

On the whole, the added flight variables were not so important as the ones previously used. Only two, turn rate and elevator, are regular contributors of significant variables. Of these, turn rate provides the highest number of significant variables.

Table 23. **Breakdown of Important Means and Standard Deviations of Experiment 2**

Flight Variable	Number of Test Measurements Available	Number Significant (5% Test)	Percentage Significant (5% Test)
Turn rate	28	13	46
Power	28	3	11
Rudder	28	1	4
Elevator	28	10	36
Aileron	28	1	4
Northing	20	0	0
Radius	2	1	50
Airspeed	28	9	32
Altitude	28	9	32
Fixed reference	20	7	
Changing reference	8	2	
Climb rate	28	6	21
Roll	28	10	36
Pitch	28	9	32
Yaw (heading)	28	11	39
Fixed reference	22	8	36
Changing reference[a]	6	3	50
Glide slope	2	0	0
Left/right turns	2	0	0
Total measurements	334	83	

[a]Referred to as heading deviations in the computer analysis of Appendix C.

With the added ability to monitor a changing reference, as in the changing altitude and changing yaw (or heading) tasks, 14 new measurements were made in the flight profile. Five of these (35 percent) were statistically significant compared with 36 percent of the fixed reference altitude and yaw measurements. This is judged insufficient evidence to show that the changing reference monitoring capability contributed to pilot performance measurement.

The results of the roll, pitch, and yaw cross-frequency analyses are tabulated in Table 24. The denominators of each fraction-like entry represent the number of test variables available from the particular analysis [Fourier, mean square error (MSE), or derived] in combination with the particular flight variable - command frequency combination. The numerator of each fraction is the number of available test variables that are statistically significant (5 percent test).

There was little evidence from Table 24 suggesting that the remnant analyses were important. The proportion of variables accounting for mean square remnant error, the variables judged most important in this case, did not exceed 8 percent.

Considering the cross-frequency analyses of Table 24 (one flight variable analyzed at command frequencies of another axis), there was little to suggest that this cross-analysis is important. One possibly important combination was the pitch-at-roll combination with 6 of 18 variables statistically significant. In the three pitch-at-roll analyses carried out in Experiment 2, however, none of the six significant MSE variables were significant more than once each, suggesting that the pitch-at-roll differences among groups are not repeatable.

The roll, ptich, and yaw describing function analyses (roll-at-roll, pitch-at-pitch, and yaw-at-yaw reference in Table 24) were the most important tracking analyses, and the roll describing function was the most important of these. A survey of the seven variables derived from (or fitted to) each describing

Table 24. **Numbers of Significant/Available Test Variables Pooled for All Roll, Pitch, or Yaw Tracking Tasks**

Flight Variables at Given Frequencies	Fourier Analysis	MSE Analysis	Derived Variables
Roll at roll	90/240	15/36	21/42
Roll at pitch	8/64	3/18	1/8
Roll at yaw	8/32	0/6	0/2
Roll at remnant	10/80	3/36	
Pitch at roll	10/64	6/18	1/8
Pitch at pitch	15/96	4/18	6/21
Pitch at yaw	1/32	0/6	0/2
Pitch at remnant	3/32	0/18	
Yaw at roll	4/32	2/6	1/2
Yaw at pitch	4/32	0/6	0/2
Yaw at yaw	7/48	3/6	2/7
Yaw at remnant	0/10	0/6	

Table 25. **Frequently Significant Tracking Measures**

Derived Tracking Measurements	Number of Test Measures Available	Number Significant (5% Test)
High frequency roll gain	6	6
High frequency roll crossover	6	5
Low frequency roll gain	16	4
Low frequency roll crossover	16	4
High frequency pitch gain	13	2
High frequency pitch crossover	13	2

function showed that the most reliable significant variable was high frequency roll gain. In the six roll-tracking tasks, the high frequency roll gain measurement was statistically significant in separating the pilot groups in all six tasks. This and other frequently repeated significant measures are shown in Table 25.

These results suggest that the roll describing function is a very reliable measurement for measuring pilot performance. In six different tracking tasks of varying difficulty and dimensionality, the high frequency portion of the roll describing function was always statistically significant.

Table 26 breaks down the results of the altitude and position tracking tasks into three measurement families and six different cross-analyses. There was no evidence to suggest that any one of the 18 families of test measurements is useful in differentiating the groups of pilots. A probable explanation for this is that the difficulty of the task and the low tracking gains resulted in highly variable performances.

Table 27 shows a tabulation of the number of significant tracking variables in the single-axis analyses (roll and roll frequencies, pitch at pitch, and so on). The number of available variables included those of the frequency analysis, mean square error analysis, and derived variables (those fitted to the describing function). In comparing Tasks V, I, and VI, which are 1-, 2-, and 3-dimensional tracking, respectively, it was observed that Task V, 1-dimensional roll tracking, has the highest proportion of its variables statistically significant.

Table 26. **Numbers of Significant/Available Test Variables for Position and Altitude Tracking (Task X)**

Flight Variables at Given Frequencies	Fourier Analysis	MSE Analysis	Derived Variables
Position at position	1/24	0/6	0/7
Position at altitude	0/16	0/6	0/2
Position at remnant	0/8	0/6	
Altitude at position	3/16	0/6	0/2
Altitude at altitude	1/24	0/6	0/7
Altitude at remnant	1/8	0/6	
Totals	6/96	0/36	0/18

Table 27. **Comparison of Dimensionality and Command Spectrum Based on All Single-Axis Tracking Analyses**

Task	Tracking Axis	Number of Available Variables	Number Significant (5% Test)	Percent Significant (5% Test)
I	Roll	37	18	49
	Pitch	37	14	38
II	Roll	37	15	41
	Pitch	37	2	5
V	Roll	59	31	53
VI	Roll	59	22	37
	Pitch	59	9	15
	Yaw	59	12	20
VII	Roll	59	18	31
VIII	Roll	59	22	37

The results suggested that single coordinate roll tracking was best for separating the groups of pilots. The fact that single-axis roll tracking discriminated among groups contradicted the results of Krendel and McRuer (1960) who found that single-axis tracking did not discriminate among pilot skills. The explanation for this discrepancy probably lies in the different test environments. The "job sample" approach using the GAT-1 may have measured differences in skill levels, whereas the "bench-top" tests using joystick and display may not have provided a suitable test environment.

Using Table 27 to compare the three types of command signals used in the single-coordinate, roll-tracking tasks (Tasks V, VII, and VIII), it can be seen that the normal roll-tracking command signal (Task V) had the highest proportion of statistically significant test variables. The lower proportion (31 percent) of significant variables with reduced bandwidth roll tracking than with standard roll tracking (53 percent) suggested greater higher frequency amplitudes would be better in differentiating the three groups. The lower proportion of significant variables (37 percent) in reduced amplitude roll tracking than in standard roll tracking (53 percent) furnished further evidence in favor of this interpretation.

V. APPLICATION OF DISCRIMINANTS TO EXPERIMENT 2 DATA

Results

To determine how well the three discriminants obtained from the data of Experiment 1 separated the three groups of *S*s in Experiment 2, the three discriminants (AM, MM, and RAM) were applied to Experiment 2 data. Measurements of the first and second canonical variables were obtained for each *S* using Eqs. (1) and (2) with the weights given in Tables 8, 10, and 12, and the measurements of test variables obtained from 30 new *S*s for the three discriminants are shown in Figures 9, 10, and 11. The decision lines[5] for separating the three groups are the same as sown earlier in the corresponding plots from Experiment 1. (Figures 3, 4, and 6.).

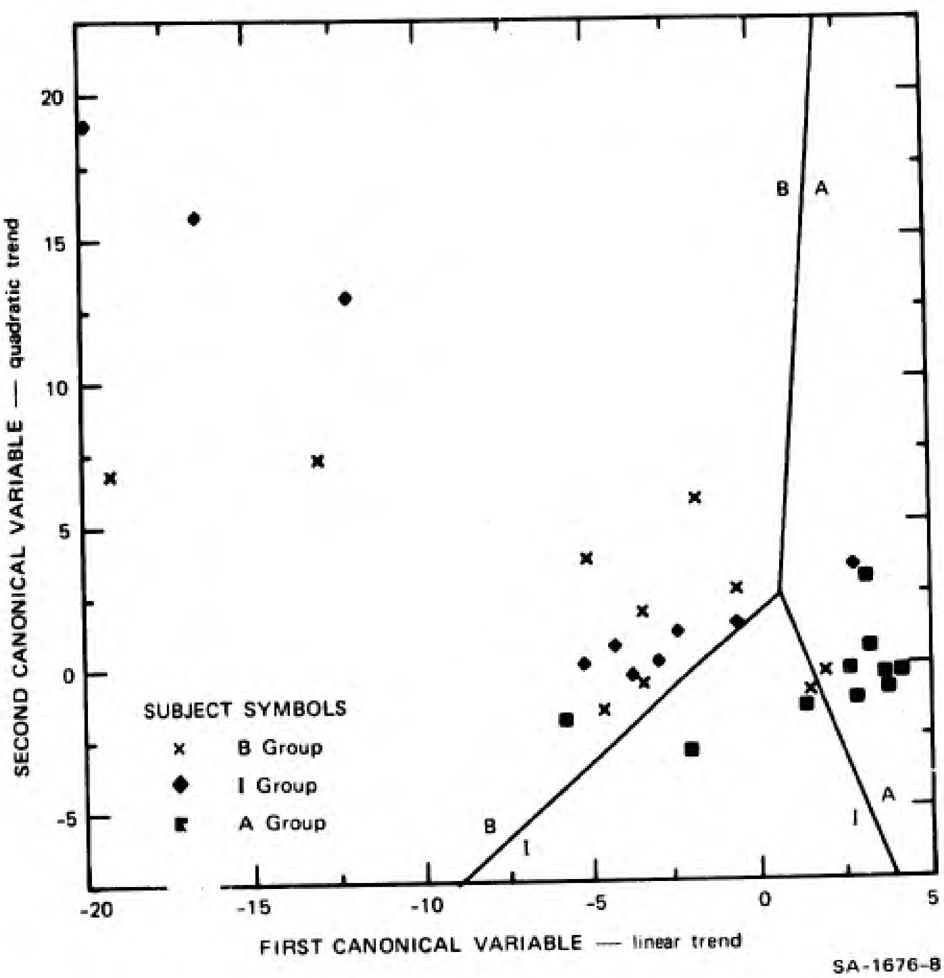


FIGURE 9 CLUSTER PLOT OF THE AM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

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[5] Sometimes called decision planes, a y-shaped group of three radial lines in this case.

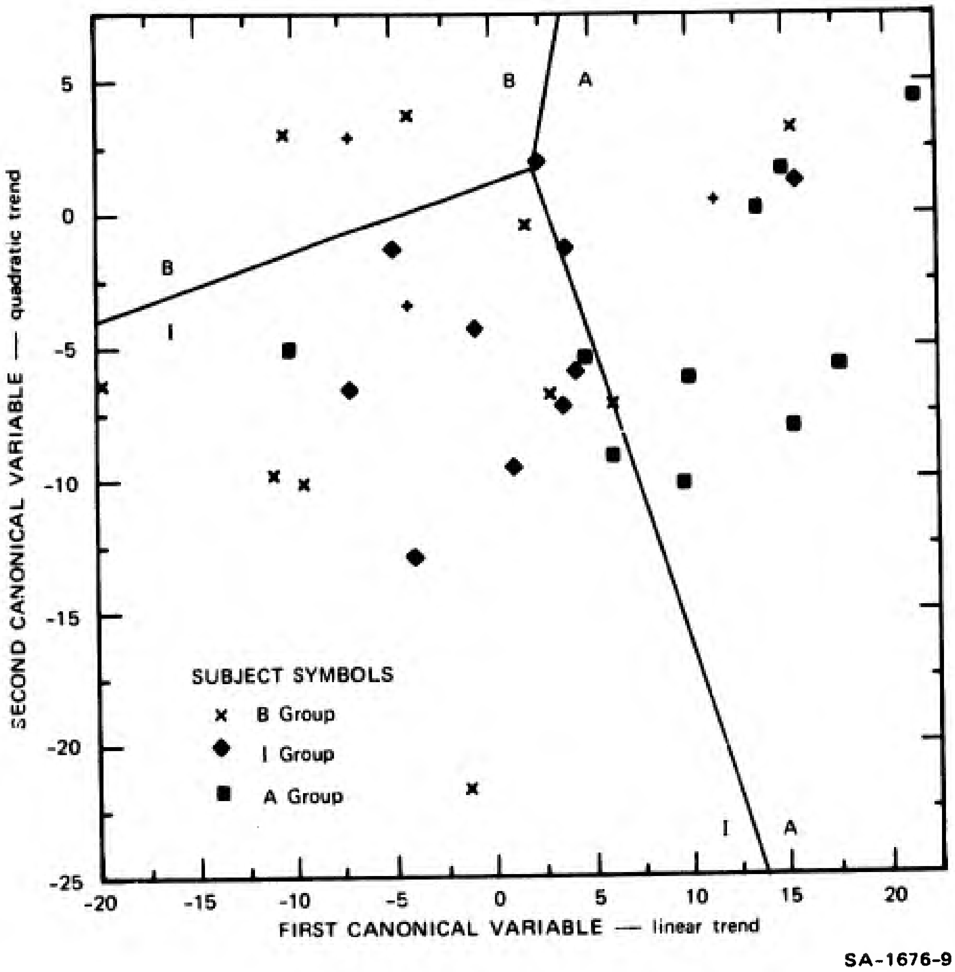

FIGURE 10 CLUSTER PLOT OF THE MM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

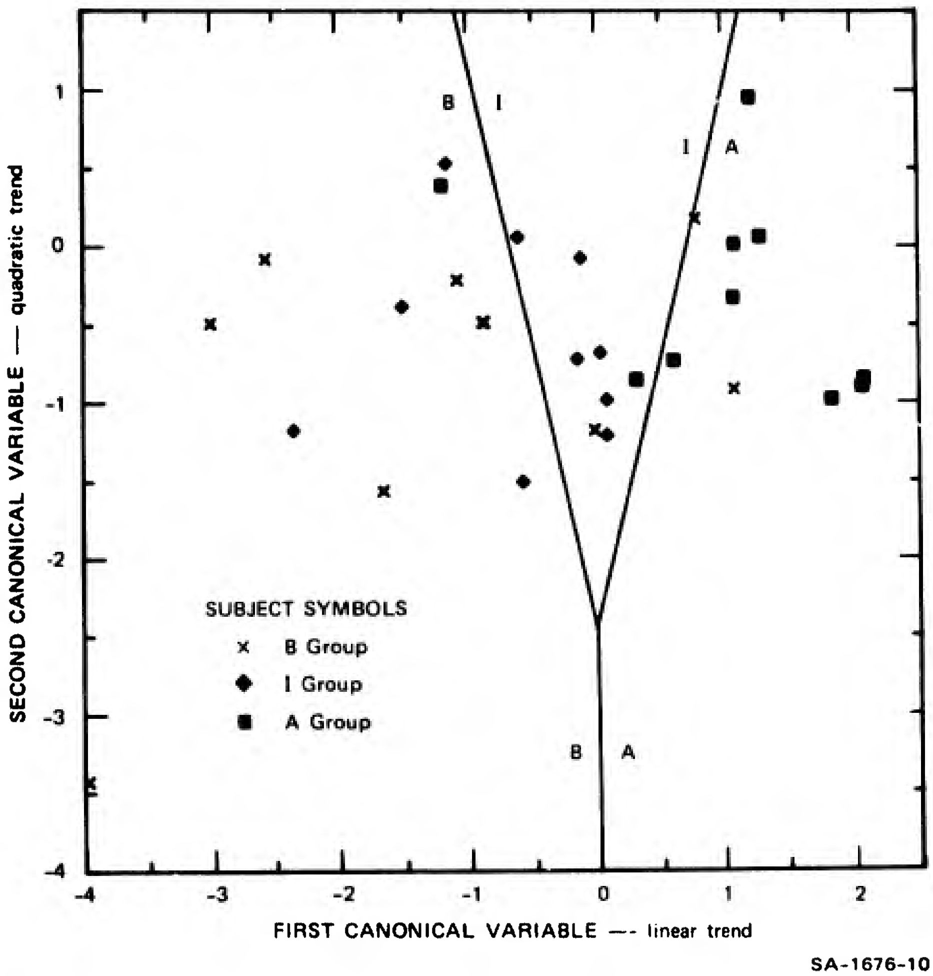

FIGURE 11 CLUSTER PLOT OF THE RAM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

It is obvious from these plots that the three groups are more dispersed and overlap considerably more than when the discriminants were applied to the data from which they were derived (Figures 3, 4, and 6). The three new cluster plots suggest that the second canonical variable, accounting for the quadratic separation between the three groups, did not appear to influence the separation of the new pilots. The plots suggested that only the first canonical variable, accounting for the linear separation of the three groups, was meaningful. Such a linear separation could be made by constructing vertical decision lines for separating the three groups on Figures 9, 10, and 11

To determine how well the three discriminants separate the *S*s of Experiment 2, the classification matrices for each discriminant were obtained and are shown in Table 28. The number of *S*s from Experiment 2 (B, I, and A identified on left of the matrices) that fell into each classification determined by the *S*s from Experiment 1 (B, I, and A identified on top of the matrices) are shown.

Table 28. **Classifications of Experiment 2 Subjects Using Discriminants Generated Using Experiment 1 Data**

AM Classification

		Experiment 1		
		B	I	A
Experiment 2	B	8	1	1
	I	9	0	1
	A	1	2	7

MM Classification

		Experiment 1		
		B	I	A
Experiment 2	B	2	6	2
	I	0	7	3
	A	0	3	7

RAM Classification

		Experiment 1		
		B	I	A
Experiment 2	B	6	1	3
	I	4	6	0
	A	1	1	8

The AM classification [chi-square (6) = 30.60, p < .001], the MM classification [chi-square (6) = 18.00, p < .01], and the RAM classification [chi-square (6) = 19.2, p < .005] are all significantly different from a random classification. Since all three are significantly different from a random classification. how well each discriminant identified the new *S*s may be determined by inspecting the numbers of *S*s identified correctly to group by the three discriminants as follows:

- AM classification - 15 (50%)
- MM classification - 16 (53%)
- RAM classification - 20 (67%)

which suggests that the RAM discriminant did the better job. Statistically, however, there is insufficient evidence [chi-square (2) = 1.90, p < .05] to show that the three discriminants were significantly different in their ability to classify *S*s correctly.

Discussion

Although there is insufficient evidence to show statistically significant differences in the classifications of the AM, MM, and RAM discriminants, other evidence suggests that the AM and MM discriminants are equally poor in discriminating *S*s' abilities and that the RAM discriminant is considerably better and typifies the best that can be done.

The evidence is based on the perfect discrimination of AM and MM on Experiment 1 data and the poor discrimination on Experiment 2 data, compared with the nearly identical RAM discrimination in both experiments. It is also based on the *E*'s subjective observations of the *S*s' abilities and rank orderings of *S*s' scores in several test variables.

An interesting result of the multivariate analyses was that the AM and MM discriminants based on 8 and 15 variables actually classified fewer pilots correctly than the RAM discriminant, which is based on only 2 variables. This finding emphasizes the concern expressed previously that the stepwise multivariate discriminant analysis, when used as a tool to select among a large number of variables, will construct a discriminant from variables that optimize the separation of the three groups using unreproducible peculiarities of the test variables in the same way random variables are used.

Although the multivariate analysis procedure is set up to select variables and adjust their weights to separate the pilots into three groups, there is evidence that this is not possible nor desirable. In several instances, the experimenter observed that a pilot qualifying for the I group performed either like a B or an A group candidate. Some of the A group were subjectively judged to be performing as I group members. Consequently, the records of an I group subject who performed like a B group subject was examined more closely. His test score on one significant variable after another was compared to the three group means. It was found that his scores were typical of the average B candidate. Forcing the multivariate analysis to classify such an *S* into his proper experience group by selective weighting of the performance measures would result in a useless discriminant. Such a discriminant would force a *S* into an experience group in which he did not belong, and therefore would be based on something other than his skill, as indicated by flight hours.

Another indication of high degree of rank ordering in the data comes from the multivariate discriminant analysis of the RAM variables. After two of the set 14 variables entered into the analysis were selected, the *F*-to-enter for the remaining 12 dropped to low levels. Thus, all the remaining variables were highly correlated with the first two and did not improve the separation into groups. When the analysis program was forced to build a discriminanat from all the variables by making the *F*-to-enter equal to zero, the program balked, dropped variables one after the other because they failed the tolerance test. The data, essentially a set of 14 equations in 30 unknowns, produced a singular solution because each of the 14 equations was nearly the same. A linear combination of these 14 most significant and highly correlated variables would be an excellent and stable measure of performance, but the multivariate analysis cannot construct such a combination.

This is probably the reason the RAM discriminant, composed on only two test variables, was the most successful. The ordering of the 30 *S*s of Experiment 1 (shown previously in Figure 6) along the axis of the linear canonical variable is probably the correct ranking of the *S*s' skill levels. This may be the best categorization that can be made. Whereas the other discriminants, including the discriminant based on random numbers, classified all 30 of the *S*s correctly, the RAM discriminant classified only 19 of them correctly.[6] The similar ability of the RAM discriminant to classify *S*s from Experiment 2 (20 correctly classified) further suggests that this is the best that can be done: the variable skill levels of *S*s in each group limit the ability of performance measures to distinguish among groups.

Conclusions

This research effort assumed that the number of hours of flying experience a pilot has logged represents a defensible measure of his flying skill. The Federal Aviation Administration's qualification criteria for certification eligibility supports this assumption in its requirement for increased numbers of hours of flying experience for the higher levels of pilot ratings. Furthermore, the common notion of skill growth as a function of experience suggests that the assumption that pilot skill may be represented by hours of flying time is reasonable.

Forming groups of subjects based on different levels of flying experience in order tc determine if their flying performance measurements could be used to categorize the subjects into their appropriate experience groups then was warranted based on the assumption of the relation of flying experience to flying skill. With this in mind, a flying performance measurement system was conceived in which combinations of aircraft parameters and derived variables based on them would indicate the skill level of the pilot who produced the measured performance. Presumably, the measured performance characteristics would permit designation of the hours of flying experience, that is, flying skill the performance represented. The pilot with 100 hours who flys like the average 150-hour pilot would be above average in skill and vice versa.

This study sought to evaluate by means of a cross validation test the results of earlier research, which demonstrated that measured aircraft parameters could be combined to classify accurately the flying performances of the pilots who produced them. The classification equations were generated by a multiple discriminant analysis in combination with other statistical and procedural techniques applied to the data of Experiment 1. Experiment 2 provided an additional set of nearly identical performance measures of different subjects.

If the discriminants derived from the subject's performance measurements of Experiment 1 could have been used to correctly classify the subject's performance measurements of Experiment 2, then the concept and the procedures employed would have been confirmed and further development of the statistical approach to the development of a pilot performance measurement system applying the concept and procedures would have been warranted. The results of the cross validation accomplished in Experiment 2, however, disconfirmed the concept and procedures tested and suggested that further refinement was not warranted.

The most important outcome of this research was not that discriminants derived from one set of performance measures were not perfectly accurate when used to classify new performance measures, but that the proliferation of performance measures decreased rather than increased the efficiency of the technique and that the variable skill levels of subjects in each group limited the ability of performance measures to distinguish among groups. This finding is interpreted as indicating that the idea of using combinations of measures selected from among a large number of aircraft attitude, or state variables to develop a measure of the skill of the pilot who controls the aircraft using the procedures employed in the present research, and the idea of relating pilot skill to hours of flying experience for purposes of establishing face validity of a measurement system are not viable and should not be pursued further.

Considering only these essentially negative conclusions based on the data, it would be easy to overlook the systematic strength of the research. The outcome of this study has been interpreted to indicate that the statistical approach cannot be applied in the development of a practical pilot performance measurement system. It is rarely the case where research results serve to demonstrate convincingly the inadequacy of the concept underlying the procedures, apparatus and materials used. The answer provided by this study is clear and the virtue of the work is defined by the clarity of the negative conclusion.

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[6] A RAM classification based only on the linear canonical variable would have raised this to 20 for Experiment 1 and would also have been 20 for experiment 2.

REFERENCES

1. **Dixon, W.J.** *Biomedical computer programs.* University of California Press, Los Angeles, California, 1969.

2. **Garber, E.I., & Krasnitskii, V.S.** *Use of multidimensional regression analysis for predicting flight training quality.* A70-38964, Technical Information Service, American Institute of Aeronautics and Astronautics, Inc., 740 Third Avenue, New York, N.Y., 1968.

3. **Goebel, R.A., Baum, D.R., & Hagin, W.V.** *Using a ground trainer in a job sample approach to predicting pilot performance.* AFHRL-TR-71-50, AD-741 747. Williams AFB, ARiz.: Flying Training Division, Air Force Human Resources Laboratory, November 1971.

4. **Hill, J.W., Gardiner, K.W., & Bliss, J.C.** *Design study of a tactile cuing system for pilot training.* AFHRL-TR-69-12, AD-697 491. Wright-Patterson AFB, Ohio.: Air Force Human Resources Laboratory, August 1969.

5. **Hill, J.W., & Goebel, R.A.** *Development of automated GAT-1 performance measures.* AFHRL-TR-71-18, AD-732 616. Williams AFB, Ariz.: Flying Training Division, Air Force Human Resources Laboratory, May 1971.

6. **Krendel, E.S., & McRuer, D.T.** A servomechanism approach to skill development. *Journal of Franklin Institute,* 1960, **269**(1), 24-42.

7. **McRuer, D., Graham, D., Krendel, E., & Resner, W., Jr.** *Human Pilot Dynamics in compensatory systems–theory, models, and experiments with controlled elements and forcing function variations.* Technical Report 115-1, AFFDL-TR-65-15, Systems Technology, Inc., Hawthorne, California, 1965.

8. **Rao, C.R.** *Advanced statistical methods in biometric research.* Darien, Connecticut: Hafner Publishing Co., 1970.

APPENDIX A. COMPUTER PROCESSING OF THE GAT-1 DATA

Computation of Test Variables for Experiment 1

The LINC-8 computer accumulated 36-bit (triple-precision) sums of the input numbers

$$S_k = \sum_{i=1}^{64\ RTIM} INPUT_k(i)$$

and 36-bit sums of the input cross-products

$$P_{jk} = \sum_{i=1}^{64\ RTIM} INPUT_j(i)\ INPUT_k(i),$$

where k $(1 \leqslant k \leqslant 8)$ and j $(1 \leqslant j \leqslant k)$ were channel numbers, and 64 RTIM was the total number of 1/15-s steps taken in a given test run. The computer generated up to eight sums-of-sines command signals of the form

$$C_k(i) = \sum_{l=1}^{8} A_{kl} \sin\left(\frac{2\pi\ F_{kl}}{64\ RTIM} i\right)$$

where A_{kl} was the amplitude coefficient for the k^{th} command signal (all equal in this case), F_{kl} was the frequency for the k^{th} command signal, and the sine function was approximated by a function table having 64 entries.

While a monitoring run was in progress, the computer saved all the input numbers, $INPUT_k(i)$, on a disk scratch file to obtain Fourier sums at the command signal frequencies after the test run had been completed. The Fourier sums for each channel, k, and at each command frequency, F_{kl} were:

$$A_{kl} = \sum_{i=1}^{64\ RTIM} \sin\left(\frac{2\pi\ F_{kl}}{64\ RTIM} i\right) INPUT_k\ (i)$$

$$B_{kl} = \sum_{i=1}^{64\ RTIM} \left(\frac{2\pi\ F_{kl}}{64\ RTIM} i\right) INPUT_k(i)$$

These data on punched tape served as the input for a second computer program that provided the usable output. This FORTRAN program first converted the numbers into the correct units by multiplying by the correct scale factor. The means and standard deviations were computed from the scaled sums, products, and Fourier coefficients as follows:

$$MEAN_k = S_k$$

$$SD_k = \sqrt{P_{kk} - S_k^{\ 2}}$$

The between-signal correlation coefficients, r_{jk}, were

$$r_{jk} = \frac{\sqrt{P_{jk} - S_j S_k}}{SD_j SD_k}$$

To calculate an *S* gain and phase shift at each of the command signal frequencies, both the error signal and the response signal amplitude phase must be known. The error components, E_{kl}, are

$$|E_{kl}| = \sqrt{A_{kl}^2 + B_{kl}^2}$$

$$\angle E_{kl} = \tan^{-1}(A_{kl}/B_{kl})$$

To obtain these compoenents for the *S*'s response, R_{kl}, the command signal, must be known. The command amplitudes were measured and built into the FORTRAN analysis program. By using the command amplitude, C_{kl}, the response was calculated by the complex number subtraction

$$R_{kl} = C_{kl} - E_{kl},$$

and the magnitude and phase of R_{kl} were computed in the same way that they were computed for E_{kl}. Finally, the gain and phase shift of the *S* at each command frequency were calculated and printed out:

$$GAIN_{kl} = \frac{|R_{kl}|}{|E_{kl}|}$$

$$PHASE_{kl} = \angle R_{kl} - \angle E_{kl}$$

The gain in decibels was determined by the formula

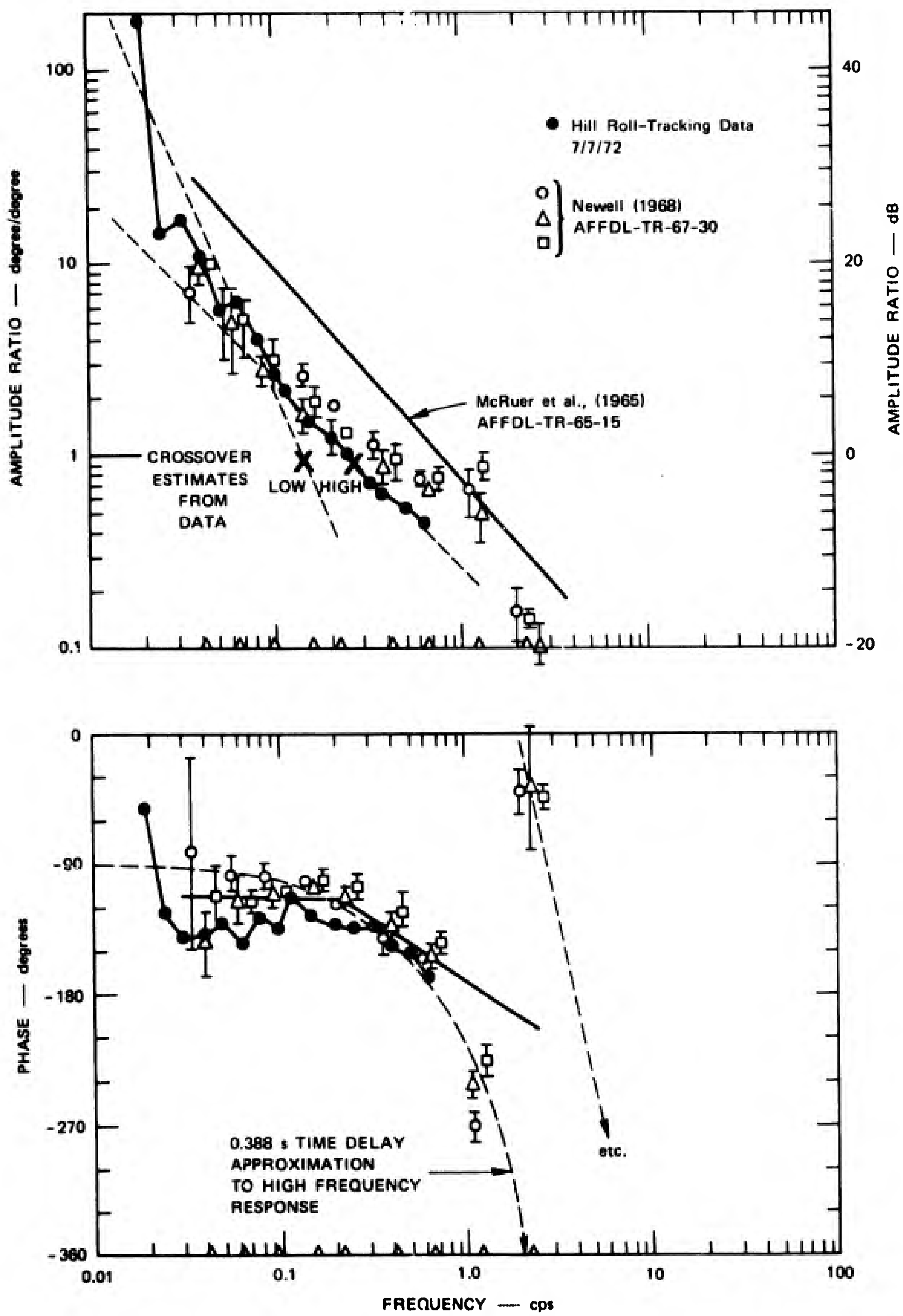
$$GAIN\,(dB)_{kl} = 20 \log_{10} GAIN_{kl}$$

The gain and phase shift plotted as a function of frequency became the "Pilot-Vehicle Describing Function" of McRuer et al., (1965). From this describing function, several derived measurements were obtained. The gains and phases from the higher and lower half of the frequencies[7] were averaged together to produce the "Hi" and "Low" frequency gain and "Hi" and "Low" frequency phase listed in Appendix B. Figure A-1 illustrates how the other three derived parameters were obtained by least-mean-square fitting straight lines to the four higher and lower frequency gains and determining the intercept frequency at zero Hz. The equivalent time delay was obtained by a least-mean-square fit of the model, e^{-st}, to the higher frequency phase shifts to estimating the operator time delay parameter, t, of the McRuer et al., (1965) Simple Crossover Model.

Additional Test Variables for Experiment 2

The variables based on means, standard deviations, correlation coefficents, and the describing function of Experiment 2 were computed as described for Experiment 1. Additional analyses added in Experiment 2 were the cross-frequency and remnant analyses. Both of these required the Fourier analysis of a flight variable at different sets of frequencies instead of just one set. The procedure and formulation used have already been described in the first part of this appendix.

[7] The 4 highest and lowest frequencies when 8 are used, and the 8 highest and 8 lowest frequencies when 16 are used.



SOURCE: Graphs from F. D. Newell, *Human Transfer Characteristics in Flight and Ground Simulation for the Roll-Tracking Task*, AFFDL-TR-67-30, April 1968.

SA-1676-1

FIGURE A-1 $Y_p Y_c$ WITH CONTROLLED ELEMENT K/s

In the cross-frequency analysis, the Fourier sine and cosine coefficients, A_{ke} and B_{ke} for the k^{th} flight variable were obtained and analyzed at the command frequencies of some other flight variable (the m^{th}). The isolation in decibels and the phase shift in degrees were calculated as follows:

$$\text{ISOLATION}_{ke} = 10 \log_{10} \left(\frac{A_{ke}^{\ 2} + B^2_{ke}}{C^2_{me}} \right)$$

$$\text{PHASE}_{ke} = \tan^{-1} (A_{ke}/B_{ke})$$

In the remnant analysis, the Fourier sine and cosine coefficier ts A_{ke} and B_{ke} for the k^{th} flight variable were analyzed at the remnant frequencies. These are a set of fre.quencies different from those of any other command signal. The amplitude of the remnant, relative to the total power in the k^{th} variable, was

$$\text{Amplitude}_{ke} = 10 \log_{10} \frac{\left(A_{ke}^{\ 2} + B_{ke}^{\ 2}\right)}{SD_k^2}$$

In addition, the mean square error accountered for the k^{th} variable by the frequencies of the m^{th} variable was computed by summing 16 terms:

$$\text{MSE accounted for} = \sum_{e=1}^{16} A_{ke}^{\ 2} + B_{ke}^{\ 2}$$

The high and low frequency portions were computed from the first 8 and second 8 of this sum.

Taken together, the MSE accounted for by the command signal input to the flight variable itself and the command signals input to other flight variables can be put in the form[8] shown as follows:

MSE ACCOUNTED FOR BY

	Total MSE	Roll Frequency	Pitch Frequency	Yaw Frequency	Remnant Frequency
Roll Axis	164.82	18.19	9.99	80.70	8.02
Pitch Axis	7.67	.79	2.78	.46	.44
Yaw Axis	14.08	1.47	1.45	5.57	1.07

These data are the cross-coupling of the command inputs from one flight variable to another caused by the *S*. When cross-coupling MSE is substantially grater than the remnant MSE (a random set of frequencies), the excess can be attributed to *S*.

In addition to this basic cross-coupling matrix, the coefficients of a high frequency and low frequency cross-coupling matrices (based only on the upper and lower eight frequencies) were computed. Also, data for three normalized cross-coupling matrices (total, high frequency, and low frequency) were obtained from these three matrices by dividing each entry by the total MSE for its axis. In total, data for six different cross-coupling matrices were computed and printed for the two and three-dimensional tracking analyses.

[7] The 4 highest and 4 lowest frequencies when 8 are used, and the 8 highest and 8 lowest frequencies when 16 are used.

[8] Numbers are taken from the roll, pitch, and yaw data of Appendix C. Units are degrees squared. The three-by-three array in the center is defined as the cross-coupling matrix.

APPENDIX B. FINAL PRINTOUT OF 326 PARAMETERS MEASURED ON ONE SUBJECT IN EXPERIMENT 1

Variables significant at the 5-percent level are marked by arrows, ←, on the printouts that follow.

ZEIDLER, ADVANCED

ROLL AND PITCH TRACKING

VARIABLE NUMBERS

....	MEAN	SD	UNITS	VARIABLE NUMBERS	
AIRSPEED	105.76	2.89	MPH	1	7
ALTITUDE	978.53	25.31	FEET	2	8
CLIMB RATE	20.25	108.76	FT/MIN	3	9
ROLL	-.22	1.85	DEGREES	4	10
PITCH	3.60	2.03	DEGREES	5	11
YAW	.02	1.86	DEGREES	6	12

CORRELATION COEFFICIENTS, R(I,J)

-.398					13				
-.591	.232				14	15			
.262	-.085	-.140			16	17	18		
-.212	-.153	.249	.062		19	20	21	22	
.252	-.077	-.133	.995	.064	23	24	25	26	27

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)			
.002	125.032	41.94	-275.34	31	267	39
.010	44.767	33.02	-183.66	32	268	40
.029	13.233	22.43	-154.67	33	269	41
.057	4.935	13.87	-139.44	34	270	42
.125	1.606	4.11	-129.29	35	271	43
.191	1.063	.53	-134.02	36	272	44
.307	.633	-3.97	-161.26	37	273	45
.467	.429	-7.35	-197.61	38	274	46

MEAN SQUARE FORCING FUNCTION	7291.19	DEG*DEG	30
MEAN SQUARE ERROR ACCOUNTED FOR	.41	DEG*DEG	28
MEAN SQUARE RESPONSE ACCOUNTED FOR	7258.42	DEG*DEG	29
LOW FREQUENCY GAIN	27.81	DB	275
LOW FREQUENCY CROSSOVER	.39	HZ	276
LOW FREQUENCY PHASE	-188.28	DEGREES	277
HI FREQUENCY GAIN	-1.67	DB	278
HI FREQUENCY CROSSOVER	.20	HZ	279
HI FREQUENCY PHASE	-155.54	DEGREES	280
EQUIVALENT TIME DELAY	.65	SECONDS	281

PITCH ANALYZED AT THE PITCH FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)			
.004	59.169	35.44	-268.45	50	297	58
.014	22.083	26.88	-240.83	51	298	59
.027	16.120	24.15	-202.28	52	299	60
.053	3.290	10.34	-160.50	53	300	61
.115	1.663	4.42	-150.45	54	301	62
.158	.996	-.04	-150.21	55	302	63
.283	.517	-5.73	-145.85	56	303	64
.535	.363	-8.79	-177.52	57	304	65

MEAN SQUARE FORCING FUNCTION	468.99	DEG*DEG	49
MEAN SQUARE ERROR ACCOUNTED FOR	.92	DEG*DEG	47
MEAN SQUARE RESPONSE ACCOUNTED FOR	480.05	DEG*DEG	48
LOW FREQUENCY GAIN	24.20	DB	305
LOW FREQUENCY CROSSOVER	.25	HZ	306
LOW FREQUENCY PHASE	-218.01	DEGREES	307
HI FREQUENCY GAIN	-2.54	DB	308
HI FREQUENCY CROSSOVER	.17	HZ	309
HI FREQUENCY PHASE	-156.01	DEGREES	310
EQUIVALENT TIME DELAY	.54	SECONDS	311

ZEIDLER, ADVANCED

ROLL AND PITCH TRACKING WITH POWER CHANGES

VARIABLE NUMBERS

....	MEAN	SD	UNITS		
AIRSPEED	101.34	9.79	MPH	66	72
ALTITUDE	987.73	25.05	FEET	67	73
CLIMB RATE	16.50	118.45	FT/MIN	68	74
ROLL	-1.82	2.17◆	DEGREES	69	75
PITCH	4.18	2.19	DEGREES	70	76
YAW	-1.57	2.17◆	DEGREES	71	77

CORRELATION COEFFICIENTS, R(I,J)

-.131					78				
-.130	.248				79	80			
.100	-.218	-.172			81	82	83		
-.562	-.113	.300	.080		84	85	86	87	
.099	-.216	-.169	.997	.084	88	89	90	91	92

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)			
.002	292.448	49.32	-276.91	96	282	104
.010	12.490	21.93	-67.23	97	283	105
.029	10.035◆	20.03◆	-141.19	98	284	106
.057	7.984	18.04	-144.17	99	285	107
.125	1.511◆	3.59◆	-141.91	100	286	108
.191	.916◆	-.76◆	-144.19	101	287	109
.307	.639◆	-3.90◆	-156.56	102	288	110
.467	.471	-6.54	-185.28	103	289	111

MEAN SQUARE FORCING FUNCTION	7291.19	DEG*DEG	95
MEAN SQUARE ERROR ACCOUNTED FOR	.61	DEG*DEG	93
MEAN SQUARE RESPONSE ACCOUNTED FOR	7290.98	DEG*DEG	94
LOW FREQUENCY GAIN	27.33◆	DB	290
LOW FREQUENCY CROSSOVER	.26	HZ	291
LOW FREQUENCY PHASE	-157.38	DEGREES	292
HI FREQUENCY GAIN	-1.90◆	DB	293
HI FREQUENCY CROSSOVER	.19◆	HZ	294
HI FREQUENCY PHASE	-156.98	DEGREES	295
EQUIVALENT TIME DELAY	.62	SECONDS	296

PITCH ANALYZED AT THE PITCH FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)			
.004	15.695	23.92	-22.28	115	312	123
.014	12.531	21.96	-178.85	116	313	124
.027	9.265	19.34	-110.60	117	314	125
.053	2.475	7.87	-125.06	118	315	126
.115	1.712	4.67	-124.82	119	316	127
.158	1.114	.94	-132.65	120	317	128
.283	.436	-7.21	-153.33	121	318	129
.535	.320	-9.90	-191.34	122	319	130

MEAN SQUARE FORCING FUNCTION	468.99	DEG*DEG	114
MEAN SQUARE ERROR ACCOUNTED FOR	1.54	DEG*DEG	112
MEAN SQUARE RESPONSE ACCOUNTED FOR	453.94	DEG*DEG	113
LOW FREQUENCY GAIN	18.27	DB	320
LOW FREQUENCY CROSSOVER	.45	HZ	321
LOW FREQUENCY PHASE	-109.20◆	DEGREES	322
HI FREQUENCY GAIN	-2.87	DB	323
HI FREQUENCY CROSSOVER	.17	HZ	324
HI FREQUENCY PHASE	-150.54	DEGREES	325
EQUIVALENT TIME DELAY	.57	SECONDS	326

ZEIDLER, ADVANCED

1000-FOOT CLIMB

	MEAN	SD	UNITS	VARIABLE NUMBERS	
AIRSPEED	95.09	6.11	MPH	131	136
CLIMB RATE	402.25◆	105.95	FT/MIN	132	137
ROLL	-1.35	2.12◆	DEGREES	133	138
PITCH	8.20	1.86	DEGREES	134	139
YAW	-1.08	2.14◆	DEGREES	135	140

CORRELATION COEFFICIENTS, R(I,J)

				VARIABLE NUMBERS			
-.555				141			
-.707	.227			142	143		
-.483	.515	.459		144	145	146	
-.703	.226	1.001	.447	147	148	149	150

ZEIDLER, ADVANCED

LEVEL 360 TURN

	MEAN	SD	UNITS	VARIABLE NUMBERS	
AIRSPEED	109.86	4.68◆	MPH	151	156
ALTITUDE	1444.79	41.37	FEET	152	157
CLIMB RATE	-15.00	160.02◆	FT/MIN	153	158
ROLL	6.93	26.73	DEGREES	154	159
PITCH	2.85	2.06◆	DEGREES	155	160

CORRELATION COEFFICIENTS, R(I,J)

				VARIABLE NUMBERS			
-.614				161			
-.571	.174			162	163		
.456	-.039	-.337		164	165	166	
-.239	-.253	.639	-.280	167	168	169	170

ZEIDLER, ADVANCED

SLOW FLIGHT

	MEAN	SD	UNITS	VARIABLE NUMBERS	
AIRSPEED	79.54	5.40◆	MPH	171	177
ALTITUDE	1433.59◆	38.43	FEET	172	178
CLIMB RATE	8.75◆	118.97	FT/MIN	173	179
ROLL	3.11	1.70	DEGREES	174	180
PITCH	7.33	1.54◆	DEGREES	175	181
YAW	3.40	1.73	DEGREES	176	182

CORRELATION COEFFICIENTS, R(I,J)

					VARIABLE NUMBERS				
.185					183				
-.012◆	.174				184	185			
.386	-.041	.454			186	187	188		
-.248◆	-.117	.750	.258		189	190	191	192	
.375	-.043	.450	.995	.262	193	194	195	196	197

ZEIDLER, ADVANCED

DESCENDING 360 TURN

..............MEAN	.....SD	....UNITS	VARIABLE NUMBERS	
AIRSPEED 80.94	4.63	MPH	198	202
CLIMB RATE -405.00◆	96.53◆	FT/MIN	199	203
ROLL -16.3[illegible]	20.02	DEGREES	200	204
PITCH 2.41	1.88◆	DEGREES	201	205

CORRELATION COEFFICIENTS, R(I,J)

			VARIABLE NUMBERS		
-.341◆			206		
-.278	.147		207	208	
-.045◆	.580◆	-.333	209	210	211

ZEIDLER, ADVANCED

500-FOOT DESCENT

..............MEAN	.....SD	....UNITS	VARIABLE NUMBERS	
AIRSPEED 74.79	3.88	MPH	212	217
CLIMB RATE -195.50◆	68.28	FT/MIN	213	218
ROLL -3.67	4.53	DEGREES	214	219
PITCH .17	2.40	DEGREES	215	220
YAW -3.48	4.55	DEGREES	216	221

CORRELATION COEFFICIENTS, R(I,J)

				VARIABLE NUMBERS			
-.681				222			
.611	-.435			223	224		
-.773	.620	-.486		225	226	227	
.610	-.440	.998	-.486	228	229	230	231

ZEIDLER, ADVANCED

ILS LANDING APPROACH

..............MEAN	.....SD	....UNITS	VARIABLE NUMBERS	
AIRSPEED 98.00	7.28	MPH	232	239
CLIMB RATE -268.75	147.87	FT/MIN	233	240
ROLL -11.02	3.74◆	DEGREES	234	241
PITCH 2.85	2.25	DEGREES	235	242
YAW -10.88	3.76◆	DEGREES	236	243
GLIDESLOPE -1.09	1.98	DEGREES	237	244
L/R -.02	.47◆	DEGREES	238	245

CORRELATION COEFFICIENTS, R(I,J)

						VARIABLE NUMBERS					
-.707						246					
.192	-.133					247	248				
-.656	.670	-.060				249	250	251			
.190	-.130	.991	-.057			252	253	254	255		
.063	.282	.109	-.174	.111		256	257	258	259	260	
.258	.111	.203	-.134	.182	.115	261	262	263	264	265	266

APPENDIX C FINAL PRINTOUT OF 2436 PARAMETERS MEASURED ON ONE SUBJECT IN EXPERIMENT 2

Variables significant at the 5-percent level are marked by arrows, ←, in the following computer printouts.

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PINNEO, 10/23/72                                                                              NUMBER OF
                                                                                          LAST VARIABLE
ROLL AND PITCH TRACKING                                                                  PRINTED ON LINE

...............MEAN.....SD....UNITS
TURN RATE        -.50      .65◆DEG/SEC                                                               2
POWER         2285.72     7.23  RPM                                                                  4
RUDDER           2.73     4.87  PCT RIGHT                                                            6
ELEVATOR        -1.82     4.40  PCT FRONT                                                            8
AILERON          2.71     9.75  PCT RIGHT                                                           10
NS DEV        -666.32   368.91  FEET                                                                12
AIRSPEED       109.07     2.33◆MPH                                                                  14
ALTITUDE      1047.58    26.53◆FEET                                                                 16
CLIMB RATE      58.30   122.01◆FT/MIN                                                               18
ROLL            -1.84     4.77◆DEGREES                                                              20
PITCH            2.69◆    1.80◆DEGREES                                                              22
YAW             -1.11     2.15◆DEGREES                                                              24

CORRELATION COEFFICIENTS, R(I,J)

  -.053◆                                                                                            25
  -.380  -.007                                                                                      27
  -.001  -.027   .014◆                                                                              30
   .484  -.054   .027◆  .163◆                                                                       34
  -.028   .121  -.190   .055    .208                                                                39
  -.019  -.745   .059   .133    .050◆ -.076                                                         45
   .059  -.376  -.109◆  .123    .094◆  .046◆  .426                                                  52
  -.100  -.524   .030◆  .352    .019   .037   .703   .270                                           60
   .819  -.024◆  .140  -.036    .327  -.182  -.036  -.030  -.128                                    69
   .065   .108  -.154◆ -.221   -.016   .023  -.227   .180◆ -.291    .001                            79
  -.044   .151◆  .117  -.084    .119  -.146  -.151  -.076  -.247   -.014    .048◆                   90

ROLL       ANALYZED AT THE ROLL      FREQUENCIES

 FREQ    GAIN       GAIN    PHASE
 (HZ)               (DB)    (DEG)
 .002  114.576      41.18  -276.07                                                                  93
 .010   32.812      30.32  -110.71                                                                  96
 .029   15.570      23.85   -46.36◆                                                                 99
 .057    3.829◆     11.66◆ -103.74                                                                 102
 .125    2.626◆      8.39◆ -148.96                                                                 105
 .191    1.651◆      4.35◆ -116.20                                                                 108
 .307     .891◆     -1.00◆ -147.76                                                                 111
 .467     .676◆     -3.41◆ -170.06                                                                 114
MEAN SQUARE FORCING FUNCTION                            7713.56 DEG*DEG
ROLL      MEAN SQUARE ERROR (MSE)                         22.72 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY ROLL     FREQUENCIES                  4.71◆DEG*DEG       20.71 PCT            116
 BY LOW FREQUENCIES ONLY                                   1.63 DEG*DEG        7.16 PCT            118
 BY HIGH FREQUENCIES ONLY                                  3.08 DEG*DEG       13.55◆PCT            120
LOW FREQUENCY GAIN                         26.75◆DB                                                121
LOW FREQUENCY CROSSOVER                      .36 HZ                                                122
LOW FREQUENCY PHASE                      -134.22 DEGREES                                           123
HI FREQUENCY GAIN                           2.08◆DB                                                124
HI FREQUENCY CROSSOVER                       .30◆HZ                                                125
HI FREQUENCY PHASE                       -145.74◆DEGREES                                           126
EQUIVALENT TIME DELAY                       .515◆SEC                                               127

ROLL       ANALYZED AT THE PITCH     FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)     (DB)      (DEG)
 .004    -29.68    -104.39                                                                         129
 .014    -23.95◆   -331.50◆                                                                        131
 .027    -24.21    -259.57                                                                         133
 .053     -4.55     -39.66                                                                         135
 .115     -7.05◆   -125.92                                                                         137
 .158    -10.08    -264.60                                                                         139
 .283      2.61    -252.83                                                                         141
 .535    -12.34    -290.48                                                                         143
ROLL      MEAN SQUARE ERROR (MSE)                         22.72 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY PITCH    FREQUENCIES                  1.88 DEG*DEG        8.26 PCT            145
 BY LOW FREQUENCIES ONLY                                   1.57 DEG*DEG        6.93 PCT            147
 BY HIGH FREQUENCIES ONLY                                   .30◆DEG*DEG        1.33◆PCT            149
LOW FREQUENCY PHASE                      -183.78 DEG◆                                              150
HIGH FREQUENCY PHASE                     -279.40 DEG                                               151
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ROLL        ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)      (DB)
 .006    -18.28                                                                                152
 .016    -19.22                                                                                153
 .021    -20.32                                                                                154
 .045    -14.67                                                                                155
 .104    -22.38                                                                                156
 .139    -25.09                                                                                157
 .240    -30.95                                                                                158
 .389    -43.04                                                                                159
ROLL      MEAN SQUARE ERROR (MSE)                          22.72 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY REMNANT   FREQUENCIES                  1.82 DEG*DEG       8.00 PCT        161
 BY LOW FREQUENCIES ONLY                                    1.60 DEG*DEG       7.02 PCT        163
 BY HIGH FREQUENCIES ONLY                                    .22 DEG*DEG        .97 PCT        165

PITCH       ANALYZED AT THE ROLL       FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)      (DB)      (DEG)
 .002    -66.20◆  -108.77                                                                      167
 .010    -42.65   -156.79◆                                                                     169
 .029    -33.75   -204.75                                                                      171
 .057    -26.72    -48.80                                                                      173
 .125    -25.87   -111.13                                                                      175
 .191    -20.90   -216.91                                                                      177
 .307    -19.17   -212.40                                                                      179
 .467    -24.65   -329.71                                                                      181
PITCH     MEAN SQUARE ERROR (MSE)                           3.23 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY ROLL      FREQUENCIES                   .07 DEG*DEG       2.09 PCT        183
 BY LOW FREQUENCIES ONLY                                     .05 DEG*DEG       1.61 PCT        185
 BY HIGH FREQUENCIES ONLY                                    .02◆DEG*DEG        .49◆PCT        187
LOW FREQUENCY PHASE                        -129.78 DEG                                         188
HIGH FREQUENCY PHASE                       -249.98 DEG                                         189

PITCH       ANALYZED AT THE PITCH      FREQUENCIES

 FREQ     GAIN        GAIN     PHASE
 (HZ)                 (DB)     (DEG)
 .004     85.298◆     38.62◆  -249.04◆                                                         192
 .014     13.434      22.56   -248.94                                                          195
 .027     14.294      23.10   -187.14                                                          198
 .053      4.373      12.82   -176.72                                                          201
 .115      2.319       7.30   -151.62                                                          204
 .158      1.507◆      3.56◆  -141.28                                                          207
 .283       .834◆     -1.58◆  -138.27                                                          210
 .535       .415      -7.63   -145.48◆                                                         213
MEAN SQUARE FORCING FUNCTION                              501.87 DEG*DEG
PITCH     MEAN SQUARE ERROR (MSE)                           3.23 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY PITCH     FREQUENCIES                  1.36◆DEG*DEG      42.23 PCT        215
 BY LOW FREQUENCIES ONLY                                     .56 DEG*DEG      17.30 PCT        217
 BY HIGH FREQUENCIES ONLY                                    .81◆DEG*DEG      24.93 PCT        219
LOW FREQUENCY GAIN                           24.28 DB                                          220
LOW FREQUENCY CROSSOVER                        .23 HZ                                          221
LOW FREQUENCY PHASE                        -215.46◆DEGREES                                     222
HI FREQUENCY GAIN                              .47◆DB                                          223
HI FREQUENCY CROSSOVER                         .24◆HZ                                          224
HI FREQUENCY PHASE                         -144.16 DEGREES                                     225
EQUIVALENT TIME DELAY                         .402◆SEC                                         226

PITCH       ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)      (DB)
 .006     20.52                                                                                227
 .016     20.51                                                                                228
 .021     20.45                                                                                229
 .045     20.07◆                                                                               230
 .104     18.06                                                                                231
 .139     15.67                                                                                232
 .240     -1.68                                                                                233
 .389      9.52◆                                                                               234
PITCH     MEAN SQUARE ERROR (MSE)                           3.23 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY REMNANT   FREQUENCIES               1769.86 DEG*DEG   54817.48 PCT        236
 BY LOW FREQUENCIES ONLY                                 1413.20 DEG*DEG   43770.80 PCT        238
 BY HIGH FREQUENCIES ONLY                                 356.66 DEG*DEG   11046.68 PCT        240
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PINNEO, 10/23/72

ROLL AND PITCH TRACKING WITH POWER CHANGES

NUMBER OF LAST VARIABLE PRINTED ON LINE

.....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.50	.79◆	DEG/SEC	
POWER	2201.68	245.08	RPM	242
RUDDER	-.48	8.58	PCT RIGHT	244
ELEVATOR	-2.58	3.74	PCT FRONT	246
AILERON	5.98	9.09	PCT RIGHT	248
NS DEV	-160.24	122.86	FEET	250
AIRSPEED	103.19	10.38	MPH	252
ALTITUDE	1060.09	37.08◆	FEET	254
CLIMB RATE	57.79◆	153.35	FT/MIN	256
ROLL	.29	5.91◆	DEGREES	258
PITCH	3.66◆	2.38	DEGREES	260
YAW	-1.93	2.42◆	DEGREES	262
				264

CORRELATION COEFFICIENTS, R(I,J)

.032											
-.443	-.027										265
-.020	.153	.010									267
.438	-.006	-.118◆	.094								270
-.157	-.078	.474	-.113	-.181							274
-.024	-.771	.005	-.160	.109	.141						279
-.003	.306	-.186◆	.174	.123	-.283	-.031					285
-.081	-.096◆	.009	.350	.090	-.027	.315	.264				292
.643	-.044◆	.338◆	-.016	.175	.259	-.039	-.205	-.097			300
.029	.528	-.075	-.058	-.071	-.101	-.663	.178	-.441	-.023		309
-.008	-.077	-.081	-.020◆	.304	-.028	.099	.050	-.035	-.147	-.031	319
											330

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)			
.002	32.508	30.24	-31.25			333
.010	38.158	31.63	-107.41			336
.029	9.657	19.70◆	-113.02			339
.057	3.572	11.06◆	-133.82			342
.125	1.837◆	5.28◆	-125.41			346
.191	1.252◆	1.96◆	-137.85◆			348
.307	.844◆	-1.47◆	-151.89			351
.467	.603◆	-4.39◆	-181.08			354
MEAN SQUARE FORCING FUNCTION				7713.56 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)				34.96 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES				12.49 DEG*DEG	35.73 PCT	356
BY LOW FREQUENCIES ONLY				8.26 DEG*DEG	23.63 PCT	358
BY HIGH FREQUENCIES ONLY				4.23 DEG*DEG	12.10◆PCT	360
LOW FREQUENCY GAIN			23.16◆DB			361
LOW FREQUENCY CROSSOVER			.83◆HZ			362
LOW FREQUENCY PHASE			-96.38 DEGREES			363
HI FREQUENCY GAIN			.34◆DB			364
HI FREQUENCY CROSSOVER			.25 HZ			365
HI FREQUENCY PHASE			-149.06 DEGREES			366
EQUIVALENT TIME DELAY			.573 SEC			367

ROLL ANALYZED AT THE PITCH FREQUENCIES

FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)				
.004	-29.88	-244.99				369
.014	-21.24	-90.52				371
.027	-18.88	-56.54				373
.053	-6.26	-103.79				375
.115	-8.67◆	-250.17				377
.158	-3.76	-216.01				379
.283	-6.38	-292.36				381
.535	-13.22	-348.22				383
ROLL MEAN SQUARE ERROR (MSE)				34.96 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY PITCH FREQUENCIES				1.70 DEG*DEG	4.85 PCT	385
BY LOW FREQUENCIES ONLY				1.48 DEG*DEG	4.23 PCT	387
BY HIGH FREQUENCIES ONLY				.22 DEG*DEG	.62◆PCT	389
LOW FREQUENCY PHASE			-123.96 DEG			390
HIGH FREQUENCY PHASE			-307.68 DEG			391

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ROLL       ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .006    -13.67                                                                           392
 .016    -21.96                                                                           393
 .021    -24.13                                                                           394
 .045    -23.04                                                                           395
 .104    -38.96                                                                           396
 .139    -35.63                                                                           397
 .240    -34.71                                                                           398
 .389    -40.81                                                                           399
ROLL       MEAN SQUARE ERROR (MSE)                         34.96 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY REMNANT    FREQUENCIES                 2.06 DEG*DEG       5.90 PCT   401
 BY LOW FREQUENCIES ONLY                                    2.03 DEG*DEG       5.81 PCT   403
 BY HIGH FREQUENCIES ONLY                                    .03 DEG*DEG        .08 PCT   405

PITCH      ANALYZED AT THE ROLL       FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)     (DB)      (DEG)
 .002    -54.18     -1.38                                                                 407
 .010    -42.70◄   -52.34                                                                 409
 .029    -27.81   -281.67                                                                 411
 .057    -23.93◄  -357.98                                                                 413
 .125    -19.57    -30.98                                                                 415
 .191    -32.45   -244.82                                                                 417
 .307    -18.45   -247.87◄                                                                419
 .467    -17.82   -340.97                                                                 421
PITCH      MEAN SQUARE ERROR (MSE)                          5.66 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY ROLL       FREQUENCIES                  .17◄DEG*DEG       2.95◄PCT   423
 BY LOW FREQUENCIES ONLY                                     .14◄DEG*DEG       2.45◄PCT   425
 BY HIGH FREQUENCIES ONLY                                    .03 DEG*DEG        .49 PCT   427
LOW FREQUENCY PHASE                          -173.34 DEG                                  428
HIGH FREQUENCY PHASE                         -259.49 DEG◄                                 429

PITCH      ANALYZED AT THE PITCH      FREQUENCIES

 FREQ    GAIN        GAIN     PHASE
 (HZ)                (DB)     (DEG)
 .004    15.380      23.69    -15.92                                                      432
 .014    16.493      24.35   -157.57                                                      435
 .027     7.268      17.23   -159.93                                                      438
 .053     3.610      11.15   -149.92                                                      441
 .115     2.504       7.97   -125.37                                                      444
 .158     1.324       2.44   -123.09                                                      447
 .283      .707      -3.01   -108.35                                                      450
 .535      .368      -8.69   -152.3                                                       453
MEAN SQUARE FORCING FUNCTION                              501.87 DEG*DEG
PITCH      MEAN SQUARE ERROR (MSE)                          5.66 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY PITCH      FREQUENCIES                 2.92 DEG*DEG      51.61◄PCT   455
 BY LOW FREQUENCIES ONLY                                    2.44 DEG*DEG      43.05◄PCT   457
 BY HIGH FREQUENCIES ONLY                                    .48 DEG*DEG       8.56 PCT   459
LOW FREQUENCY GAIN                              19.10 DB                                  460
LOW FREQUENCY CROSSOVER                           .90 HZ                                  461
LOW FREQUENCY PHASE                           -120.84 DEGREES                             462
HI FREQUENCY GAIN                                -.32 DB                                  463
HI FREQUENCY CROSSOVER                            .22 HZ                                  464
HI FREQUENCY PHASE                            -127.28 DEGREES                             465
EQUIVALENT TIME DELAY                            .328 SEC                                 466

PITCH      ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .006    -11.03                                                                           467
 .016    -19.89                                                                           468
 .021    -16.82◄                                                                          469
 .045    -15.75                                                                           470
 .104    -24.15                                                                           471
 .139    -24.48                                                                           472
 .240    -30.60                                                                           473
 .389    -35.25                                                                           474
PITCH      MEAN SQUARE ERROR (MSE)                          5.66 DEG*DEG     100.00 PCT
MSE ACCOUNTED FOR BY REMNANT    FREQUENCIES                  .82 DEG*DEG      14.51 PCT   476
 BY LOW FREQUENCIES ONLY                                     .77 DEG*DEG      13.66 PCT   478
 BY HIGH FREQUENCIES ONLY                                    .05 DEG*DEG        .86 PCT   480
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PINNEO, 10/23/72

1000 CLIMB

..............MEAN	.....SD	....UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE -.43	.59	DEG/SEC	
POWER 2457.28	37.52	RPM	482
RUDDER 1.03	4.66	PCT RIGHT	484
ELEVATOR -2.51◆	1.39◆	PCT FRONT	486
AILERON 10.71	4.84	PCT RIGHT	488
NS DEV -57.57	48.09	FEET	490
AIRSPEED 93.14	3.15	MPH	492
ALTITUDE 1143.64	34.26	FEET	494
CLIMB RATE 627.14	181.53	FT/MIN	496
ROLL 1.84	2.97◆	DEGREES	498
PITCH 8.27	1.74	DEGREES	500
YAW -1.11	2.16	DEGREES	502
			504

CORRELATION COEFFICIENTS, R(I,J)

.078											
-.702	-.008										505
-.021	-.216	.120									507
.593	-.024	-.324	.137								510
-.152	.438	.084	.123	-.089							514
-.102	-.720	.231	.234	-.036	-.385						519
-.046	-.617	.132	.161	-.006	-.448	.761					525
-.250	-.133	.257	.387	-.160	.586	.211	.045				532
.887	.096	-.342	.009	.457	-.155	.003	.033	-.163◆			540
.251	-.278	-.285	-.179	.250	-.433◆	.276	.360	-.587	.137		549
.095	.100	.017	-.016	.224	.060	-.291	-.248	-.167	.096	.034	559
											570

PINNEO, 10/23/72

LEVEL 360 DEGREE RIGHT TURN

..............MEAN	.....SD	....UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE 2.88	.62	DEG/SEC	
POWER 2451.23	9.66	RPM	572
RUDDER 19.12	3.40	PCT RIGHT	574
ELEVATOR -2.99◆	2.72◆	PCT FRONT	576
AILERON -9.63	3.99	PCT RIGHT	578
HEAD DEV. -320.95	7.77	DEGREES	580
AIRSPEED 109.91	3.31	MPH	582
ALTITUDE 1567.37	54.27	FEET	584
CLIMB RATE 162.26	209.06	FT/MIN	586
ROLL 15.49	6.44◆	DEGREES	588
PITCH 2.66	1.97	DEGREES	590
			592

CORRELATION COEFFICIENTS, R(I,J)

-.445										
.284	-.404									593
.348	-.335	.318								595
-.011	.184	-.084	.043							598
-.641	.643	-.482	-.310	.268						602
.377	-.794	.379	.343◆	-.140	-.545					607
.503	-.705	.408	.296	-.198	-.690	.744				613
-.244	-.383	-.063	.113	.007	.048	.607◆	.121			620
.929	-.527	.585	.392	-.140	-.728	.459	.607	-.209		628
.295	-.156	.164	.018◆	-.198	-.330	.057	.330	-.435	.325	637
										647

PINNEO, 10/23/72

SLOW FLIGHT

NUMBER OF LAST VARIABLE PRINTED ON LINE

....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.54◆	.68	DEG/SEC	649
POWER	1746.61	179.22◆	RPM	651
RUDDER	4.88	6.86	PCT RIGHT	653
ELEVATOR	-2.24◆	2.69◆	PCT FRONT	655
AILERON	3.87	6.53	PCT RIGHT	657
NS DEV	-49.09	68.01	FEET	659
AIRSPEED	81.83◆	6.60◆	MPH	661
ALTITUDE	1582.81	33.66◆	FEET	663
CLIMB RATE	44.65◆	100.69	FT/MIN	665
ROLL	-2.42	2.99◆	DEGREES	667
PITCH	6.50◆	1.48◆	DEGREES	669
YAW	-1.40	2.19	DEGREES	671

CORRELATION COEFFICIENTS, R(I,J)

.057											672
-.645	.342										674
-.021	.606	.275									677
.628	.156	-.282	.208								681
-.154	-.285	.255	-.368	-.443							686
-.117	.035	.372	.271	.029◆	-.301						692
.098	-.517◆	-.269	-.381	-.109◆	1.112	-.368◆					699
.083	.118	-.130	.340	.010◆	.033	-.328	.203				707
.871	.124	-.283	-.006	.466◆	.137	-.060	.124	.079			716
.179	-.154	-.248	-.384◆	.030◆	.173	-.457◆	.380◆	-.265	.174		726
-.037	-.097	.152	-.142	.170◆	.126◆	.084	.098	-.216	-.015	.102	737

PINNEO, 10/23/72

DESCENDING 360 DEGREE LEFT TURN

NUMBER OF LAST VARIABLE PRINTED ON LINE

....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-2.70	.39◆	DEG/SEC	739
POWER	1291.10	115.26	RPM	741
RUDDER	-23.08	3.02◆	PCT RIGHT	743
ELEVATOR	-6.56◆	2.24◆	PCT FRONT	745
AILERON	21.87	5.82	PCT RIGHT	747
HEAD DEV.	30.76◆	21.37	DEGREES	749
AIRSPEED	75.20	3.70	MPH	751
ALTITUDE	1047.21◆	62.16	FEET	753
CLIMB RATE	-454.69	190.67	FT/MIN	755
ROLL	-7.11	2.66◆	DEGREES	757
PITCH	2.62	1.76◆	DEGREES	759

CORRELATION COEFFICIENTS, R(I,J)

.165										760
.149	.290									762
.036	.488	.008◆								765
.227	.392	-.134	.111							769
-.030	.383	-.498	.464	.440						774
-.320	.366	-.304	.254	.550	.409					780
-.131	.434	-.443	.323	.500	.829	.540				787
-.057	.330◆	-.285	.555	.354	.590	.603	.397			795
.869	-.004	.410	-.046	-.156	-.304	-.564	-.389	-.259		804
.141◆	-.015◆	.245	-.399	-.124	-.325	-.400	-.094	-.802	.259	814

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500 FOOT DESCENT

NUMBER OF LAST VARIABLE PRINTED ON LINE

....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.47	1.02◆	DEG/SEC	016
POWER	2363.46	91.95	RPM	018
RUDDER	16.80	11.49	PCT RIGHT	020
ELEVATOR	5.48	3.56	PCT FRONT	022
AILERON	15.57	11.02◆	PCT RIGHT	024
NS DEV	2034.44	36.40	FEET	026
AIRSPEED	71.47◆	6.63	MPH	028
ALTITUDE	1151.75	20.50	FEET	030
CLIMB RATE	-141.03	130.33	FT/MIN	032
ROLL	-.45	4.09◆	DEGREES	034
PITCH	.25	3.65	DEGREES	036
YAW	-3.48	3.90	DEGREES	038

CORRELATION COEFFICIENTS, R(I,J)

-.235											039
-.309	.146										041
.011◆	.184	-.035◆									044
.523	-.101	.065	-.039								048
-.484	.458	-.259	.230◆	-.423							053
-.022	-.243	.600◆	-.237	.403	-.606						059
-.215	.093	.113	.046	.045	.259	.225					066
-.036	-.295	.601	-.089	.314	-.641	.893	.105				074
.089	-.168	-.141	.083	.275	-.442	-.061	-.226	-.037			083
.044	.221	-.594	.207	-.362	.606	-.897	-.073	-.836	.070		093
-.023	.151	.631	-.165	.459	-.565	.650	-.035	.646	-.041	-.663	904

PINNEO, 10/23/72

ILS LANDING APPROACH

NUMBER OF LAST VARIABLE PRINTED ON LINE

....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.52◆	.81◆	DEG/SEC	906
POWER	1821.95	132.38	RPM	908
RUDDER	-8.25	8.01	PCT RIGHT	910
ELEVATOR	-1.84	2.11◆	PCT FRONT	912
AILERON	9.12	8.33	PCT RIGHT	914
AIRSPEED	98.75◆	2.10	MPH	916
ALTITUDE	972.19◆	96.02	FEET	918
CLIMB RATE	-300.45	187.80	FT/MIN	920
ROLL	2.90	3.38◆	DEGREES	922
PITCH	1.63	1.73◆	DEGREES	924
YAW	-15.79	2.76◆	DEGREES	926
GLIDESLOPE	-.45	1.76	DEGREES	928
LEFT/RIGHT	.93	.44	DEGREES	930

CORRELATION COEFFICIENTS, R(I,J)

.066												931
-.810	.064											933
-.027	.158	.109										936
.606	.105	-.390	.221									940
.033	-.167	-.049	.219	.087								945
.014	.167	.149	-.026◆	-.101	.122							951
.057	.496	-.035	.358	.121	.505	.200						958
.705◆	.035	-.218	.016	.428	.024	.223	-.010					966
-.122	-.504◆	.116	-.223	-.216	-.104	.057	-.548	.018				975
.011	-.001	.056	-.052	-.221	-.163	.072	-.034	.140	.004			985
.036	.195	.067	-.174	-.022	-.429	-.220	-.496	.109	-.039◆	.111		996
.123	.070	-.080	.007	.076	.147	.076	.078	.133	-.002	.096	-.036	1008

PINNEO, 10/23/72

ROLL TRACKING

NUMBER OF LAST VARIABLE PRINTED ON LINE

	MEAN	SD	UNITS	
TURN RATE	-.53	1.23	DEG/SEC	1010
POWER	2144.01	111.72	RPM	1012
RUDDER	-2.93	13.39	PCT RIGHT	1014
ELEVATOR	-1.92	3.09	PCT FRONT	1016
AILERON	8.42	15.21	PCT RIGHT	1018
NS DEV	-1062.37	156.26	FEET	1020
AIRSPEED	98.80	1.75	MPH	1022
ALTITUDE	1048.32	32.83	FEET	1024
CLIMB RATE	02.99	144.73	FT/MIN	1026
ROLL	1.16	[illegible].96	DEGREES	1028
PITCH	3.66	1.82	DEGREES	1030
YAW	-2.16	3.01	DEGREES	1032

CORRELATION COEFFICIENTS, R(I,J)

-.036											1033
-.467	.058										1035
-.063	.142	.174									1038
.460	.100	.321	.158								1042
-.108	.080	-.053	-.011	.045							1047
.028	-.194	-.025	.223	-.025	.059						1053
.035	-.136	.005	.058	-.056	-.213	.164					1060
-.034	.558	.044	.346	.038	.039	.323	.235				1068
.750	-.059	.184	.027	.656	-.179	.024	.003	-.036			1077
.031	-.394	-.056	-.217	-.065	-.028	-.007	.179	-.423	.017		1087
-.008	-.024	.167	.008	.278	-.047	-.091	.009	-.129	.059	.084	1098

ROLL [illegible]YZED AT THE ROLL FREQUENCIES

FREQ (HZ)	[illegible]	GAIN (DB)	PHASE (DEG)	
.018	25.411	28.10	-109.46	1101
.025	21.862	26.77	-149.50	1104
.031	9.304	19.37	-99.09	1107
.039	12.031	21.61	-74.73	1110
.049	9.358	19.42	-162.91	1113
.064	4.399	12.87	-137.92	1116
.080	5.354	14.57	-161.17	1119
.100	4.256	12.58	-91.14	1122
.123	2.222	6.93	-133.00	1125
.158	1.550	3.81	-126.83	1128
.197	1.326	2.45	-124.43	1131
.248	.955	-.40	-134.42	1134
.314	.763	-2.35	-141.02	1137
.396	.595	-4.51	-155.98	1140
.498	.513	-5.79	-173.88	1143
.627	.505	-5.93	-192.49	1146

MEAN SQUARE FORCING FUNCTION	963.47 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)	63.32 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES	29.88 DEG*DEG	47.18 PCT	1148
BY LOW FREQUENCIES ONLY	7.86 DEG*DEG	12.42 PCT	1150
BY HIGH FREQUENCIES ONLY	22.01 DEG*DEG	34.77 PCT	1152
LOW FREQUENCY GAIN	19.41 DB		1153
LOW FREQUENCY CROSSOVER	.34 HZ		1154
LOW FREQUENCY PHASE	-123.24 DEGREES		1155
HI FREQUENCY GAIN	-.72 DB		1156
HI FREQUENCY CROSSOVER	.26 HZ		1157
HI FREQUENCY PHASE	-147.76 DEGREES		1158
EQUIVALENT TIME DELAY	.474 SEC		1159

ROLL ANALYZED AT THE REMNANT FREQUENCIES

FREQ (HZ)	AMPLITUDE (DB)	
.023	-22.08	1160
.037	-31.07	1161
.041	-19.07	1162
.045	-18.60	1163
.059	-29.48	1164
.076	-21.69	1165
.094	-17.86	1166
.119	-21.78	1167
.146	-18.63	1168
.182	-25.01	1169
.242	-29.42	1170
.297	-54.49	1171
.385	-54.55	1172
.441	-33.25	1173
.607	-51.67	1174
.650	-41.76	1175

ROLL MEAN SQUARE ERROR (MSE)	63.32 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES	5.23 DEG*DEG	8.26 PCT	1177
BY LOW FREQUENCIES ONLY	4.06 DEG*DEG	6.41 PCT	1179
BY HIGH FREQUENCIES ONLY	1.18 DEG*DEG	1.86 PCT	1181

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ROLL, PITCH AND YAW TRACKING

....	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.70	2.17	DEG/SEC	1183
POWER	2120.24	70.01	RPM	1185
RUDDER	1.06	13.42	PCT RIGHT	1187
ELEVATOR	-2.78	6.19	PCT FRONT	1189
AILERON	5.46	17.06	PCT RIGHT	1191
NS DEV	-613.48	299.48	FEET	1193
AIRSPEED	98.13	2.38	MPH	1195
ALTITUDE	1052.08	33.35	FEET	1197
CLIMB RATE	70.36	163.30	FT/MIN	1199
ROLL	-2.34	12.84	DEGREES	1201
PITCH	3.31	2.77	DEGREES	1203
YAW	-1.53	3.75	DEGREES	1205

CORRELATION COEFFICIENTS, R(I,J)

-.068											1206
-.610	.094										1208
-.071	.027	.153									1211
.517	.010	-.130	.035								1215
-.055	.148	-.058	.028	.002							1220
.168	-.001	.014	.258	.049	-.211						1226
.075	.110	.009	.078	-.006	.374	.208					1233
.117	.294	-.014	.350	-.020	-.017	.738	.286				1241
.921	-.061	-.290	-.028	.457	-.100	.202	.095	.134			1250
.031	-.123	-.022	-.371	.055	.006	-.123	.177	-.299	.018		1260
-.261	-.012	.366	-.008	.257	-.129	-.079	-.086	-.214	-.224	.117	1271

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.018	13.938	22.88	-123.62	1274
.025	4.165	12.39	-54.40	1277
.031	4.929	13.86	-197.82	1280
.039	5.410	14.66	-153.97	1283
.049	3.747	11.47	-144.24	1286
.064	2.365	7.48	-162.89	1289
.080	3.639	11.22	-198.54	1292
.100	3.050	9.69	-148.81	1295
.123	4.532	13.13	-88.45	1298
.158	1.170	1.36	-117.61	1301
.197	.864	-1.27	-108.49	1304
.248	1.055	.46	-133.72	1307
.314	.758	-2.40	-142.69	1310
.396	.613	-4.25	-164.33	1313
.498	.409	-7.76	-170.23	1316
.627	.509	-5.86	-213.45	1319

MEAN SQUARE FORCING FUNCTION	253.33 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)	164.82 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES	18.19 DEG*DEG	11.03 PCT	1321
BY LOW FREQUENCIES ONLY	12.90 DEG*DEG	7.83 PCT	1323
BY HIGH FREQUENCIES ONLY	5.29 DEG*DEG	3.21 PCT	1325
LOW FREQUENCY GAIN	12.96 DB		1326
LOW FREQUENCY CROSSOVER	.35 HZ		1327
LOW FREQUENCY PHASE	-148.06 DEGREES		1328
HI FREQUENCY GAIN	-.82 DB		1329
HI FREQUENCY CROSSOVER	.26 HZ		1330
HI FREQUENCY PHASE	-142.37 DEGREES		1331
EQUIVALENT TIME DELAY	.487 SEC		1332

ROLL ANALYZED AT THE PITCH FREQ..NCIES

FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.020	-17.66	-102.87	1334
.027	-10.81	-207.42	1336
.033	-7.70	-254.53	1338
.043	-6.29	-68.41	1340
.051	-4.24	-321.06	1342
.068	2.27	-204.05	1344
.084	-4.66	-88.28	1346
.104	1.25	-197.48	1348
.125	-1.67	-216.18	1350
.170	-12.64	-225.05	1352
.217	-.10	-161.82	1354
.256	2.10	-274.51	1356
.336	-5.32	-4.64	1358
.404	-1.98	-12.01	1360
.533	-7.13	-26.36	1362
.693	-6.17	-62.23	1364

ROLL MEAN SQUARE ERROR (MSE)	164.82 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY PITCH FREQUENCIES	9.99 DEG*DEG	6.06 PCT	1366
BY LOW FREQUENCIES ONLY	9.18 DEG*DEG	5.57 PCT	1368
BY HIGH FREQUENCIES ONLY	.81 DEG*DEG	.49 PCT	1370
LOW FREQUENCY PHASE	-180.51 DEG		1371
HIGH FREQUENCY PHASE	-145.41 DEG		1372

ROLL ANALYZED AT THE YAW FREQUENCIES

FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.021	-.12	-277.97	1374
.029	-.20	-260.31	1376
.035	2.01	-277.34	1378
.047	5.53	-291.96	1380
.057	9.43	-280.35	1382
.072	12.14	-317.48◆	1384
.096	13.52	-5.05	1386
.105	9.36	-12.07	1388
.143	7.77	-23.75	1390
.186	10.94	-33.71◆	1392
.229	10.25	-62.45	1394
.287	11.67◆	-78.75◆	1396
.377	11.88◆	-111.69	1398
.463	8.79◆	-136.02	1400
.518	7.41◆	-167.31	1402
.678	4.65◆	-214.82	1404

ROLL MEAN SQUARE ERROR (MSE)	164.82 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY YAW FREQUENCIES	80.70 DEG*DEG	48.96 PCT	1406
BY LOW FREQUENCIES ONLY	74.76 DEG*DEG	45.36 PCT	1408
BY HIGH FREQUENCIES ONLY	5.94 DEG*DEG	3.60 PCT	1410
LOW FREQUENCY PHASE -215.32 DEG			1411
HIGH FREQUENCY PHASE -130.48 DEG			1412

ROLL ANALYZED AT THE REMNANT FREQUENCIES

FREQ (HZ)	AMPLITUDE (DB)	
.023	-25.98	1413
.037	-21.45	1414
.041	-23.18	1415
.045	-23.89	1416
.059	-21.07◆	1417
.076	-19.16	1418
.094	-24.38	1419
.119	-30.62	1420
.146	-23.51	1421
.182	-32.15	1422
.242	-35.25	1423
.297	-43.35	1424
.385	-39.39	1425
.441	-40.67◆	1426
.607	-48.58	1427
.650	-61.83	1428

RULL MEAN SQUARE ERROR (MSE)	164.82 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES	8.02◆DEG*DEG	4.87 PCT	1430
BY LOW FREQUENCIES ONLY	7.09◆DEG*DEG	4.30 PCT	1432
BY HIGH FREQUENCIES ONLY	.93 DEG*DEG	.56 PCT	1434

PITCH ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.018	-34.90	-188.63	1436
.025	-52.69	-202.83◆	1438
.031	-36.30	-.15	1440
.039	-30.88	-337.45	1442
.049	-28.83◆	-109.49◆	1444
.064	-25.81	-56.48	1446
.080	-10.45	-54.76	1448
.100	-13.05	-311.54	1450
.123	-19.25	-235.00◆	1452
.158	-20.63	-60.46◆	1454
.197	-26.65	-41.36	1456
.248	-17.53	-202.29	1458
.314	-20.46	-223.72	1460
.396	-24.79	-274.57	1462
.498	-18.45	-330.58	1464
.627	-20.56	-77.41	1466

PITCH MEAN SQUARE ERROR (MSE)	7.67 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES	.79 DEG*DEG	10.35 PCT	1468
BY LOW FREQUENCIES ONLY	.74 DEG*DEG	9.63 PCT	1470
BY HIGH FREQUENCIES ONLY	.06 DEG*DEG	.73 PCT	1472
LOW FREQUENCY PHASE -157.66 DEG			1473
HIGH FREQUENCY PHASE -200.38 DEG			1474

PITCH ANALYZED AT THE PITCH FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.020	24.721	27.86	-259.41	1477
.027	9.608	19.65	-243.4:	1480
.033	7.989	18.05	-176.37	1483
.043	66.955	36.52◆	-24.40	1486
.051	5.611	14.98	-199.79	1489
.068	4.633	13.32	-148.75	1492
.084	2.454	7.80	-123.41	1495
.104	1.731	4.76	-136.44	1498

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 .125    1.623     4.21  -113.68
 .170     .888    -1.03  -120.90                                                      1501
 .217     .727    -2.77  -136.56                                                      1504
 .256     .678◆   -3.37◆ -128.64                                                      1507
 .336     .598◆   -4.47◆ -138.03                                                      1510
 .404     .385◆   -8.28◆ -118.23                                                      1513
 .533     .144   -16.86  -237.95                                                      1516
 .693     .271   -11.36  -195.72                                                      1519
MEAN SQUARE FORCING FUNCTION                                                          1522
PITCH     MEAN SQUARE ERROR (MSE)                    52.54 DEG*DEG
MSE ACCOUNTED FOR BY PITCH     FREQUENCIES            7.67 DEG*DEG     100.00 PCT
 BY LOW FREQUENCIES ONLY                              2.78 DEG*DEG      36.22 PCT     1524
 BY HIGH FREQUENCIES ONLY                             1.37 DEG*DEG      17.86 PCT     1526
LOW FREQUENCY GAIN                                    1.41 DEG*DEG      18.37 PCT     1528
                                      17.87 DB
LOW FREQUENCY CROSSOVER                 .19 HZ                                        1529
LOW FREQUENCY PHASE                -164.00 DEGREES                                    1530
HI FREQUENCY GAIN                    -5.49◆DB                                         1531
HI FREQUENCY CROSSOVER                 .17◆HZ                                         1532
HI FREQUENCY PHASE                 -148.71 DEGREES                                    1533
EQUIVALENT TIME DELAY                 .482 SEC                                        1534
                                                                                      1535

PITCH       ANALYZED AT THE YAW         FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)     (DB)      (DEG)
 .021   -24.88     -87.68
 .029   -26.52    -157.15◆                                                            1537
 .035   -23.35    -217.31                                                             1539
 .047   -16.70    -190.16                                                             1541
 .057   -16.62     -20.19                                                             1543
 .072    -8.66     -35.92                                                             1545
 .096   -15.56    -139.74                                                             1547
 .105    -7.93     -59.71                                                             1549
 .143    -8.41     -75.50                                                             1551
 .186    -6.30    -214.20                                                             1553
 .229   -10.18    -179.92                                                             1555
 .287    -7.14    -312.71                                                             1557
 .377    -6.22    -264.27                                                             1559
 .463   -12.93     -42.48                                                             1561
 .518   -10.92     -31.31                                                             1563
 .678   -17.23    -288.92                                                             1565
PITCH      MEAN SQUARE ERROR (MSE)                                                    1567
MSE ACCOUNTED FOR BY YAW      FREQUENCIES             7.67 DEG*DEG     100.00 PCT
 BY LOW FREQUENCIES ONLY                               .46 DEG*DEG       6.01 PCT     1569
 BY HIGH FREQUENCIES ONLY                              .36 DEG*DEG       4.71 PCT     1571
LOW FREQUENCY PHASE                                    .10 DEG*DEG       1.30 PCT     1573
HIGH FREQUENCY PHASE              -113.48 DEG                                         1574
                                  -190.35 DEG                                         1575

PITCH       ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .023   -21.53
 .037   -21.67                                                                        1576
 .041   -22.84                                                                        1577
 .045   -29.68                                                                        1578
 .059   -18.90                                                                        1579
 .076   -26.57                                                                        1580
 .094   -28.21                                                                        1581
 .119   -18.36                                                                        1582
 .146   -24.21                                                                        1583
 .182   -35.36                                                                        1584
 .242   -32.36                                                                        1585
 .297   -34.51                                                                        1586
 .385   -39.32                                                                        1587
 .441   -40.17                                                                        1588
 .607   -45.10                                                                        1589
 .650   -38.01                                                                        1590
PITCH      MEAN SQUARE ERROR (MSE)                                                    1591
MSE ACCOUNTED FOR BY REMNANT   FREQUENCIES            7.67 DEG*DEG     100.00 PCT
 BY LOW FREQUENCIES ONLY                               .44 DEG*DEG       5.67 PCT     1593
 BY HIGH FREQUENCIES ONLY                              .39 DEG*DEG       5.13 PCT     1595
                                                       .04 DEG*DEG        .54 PCT     1597

YAW         ANALYZED AT THE ROLL        FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)     (DB)      (DEG)
 .018   -37.35     -91.28
 .025   -20.34    -226.30                                                             1599
 .031   -24.16◆    -18.64                                                             1601
 .039   -25.98     -67.71                                                             1603
 .049   -20.12◆   -126.51                                                             1605
 .064   -12.77    -109.98                                                             1607
 .080   -16.75     -74.21                                                             1609
 .100   -23.32◆   -141.64                                                             1611
 .123   -31.59    -186.28                                                             1613
 .158   -19.46    -176.01                                                             1615
 .197   -22.86    -223.86                                                             1617
 .248   -20.97    -193.12◆                                                            1619
 .314   -22.64    -227.93                                                             1621
 .396   -20.44    -272.80                                                             1623
 .498   -27.67    -320.43                                                             1625
 .627   -29.38    -294.46                                                             1627
                                                                                      1629
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YAW        MEAN SQUARE ERROR (MSE)                                   14.08 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY ROLL       FREQUENCIES                           1.47◆DEG*DEG       10.42 PCT        1631
 BY LOW FREQUENCIES ONLY                                              1.44◆DEG*DEG       10.20 PCT        1633
 BY HIGH FREQUENCIES ONLY                                              .03 DEG*DEG         .22 PCT        1635
LOW FREQUENCY PHASE                               -107.03 DEG                                             1636
HIGH FREQUENCY PHASE                              -250.24 DEG◆                                            1637

YAW         ANALYZED AT THE PITCH       FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)    (DB)       (DEG)
 .020    -20.97    -181.98                                                                                1639
 .027    -18.34◆   -306.84                                                                                1641
 .033    -14.98     -32.11                                                                                1643
 .043    -12.03    -122.50                                                                                1645
 .051    -16.95     -77.05                                                                                1647
 .068     -7.18◆   -296.51                                                                                1649
 .084    -13.08    -217.61                                                                                1651
 .104    -10.17    -299.42                                                                                1653
 .125    -16.91    -341.31                                                                                1655
 .170    -26.62    -354.27                                                                                1657
 .217    -30.43◆    -28.53                                                                                1659
 .256    -16.91     -12.04                                                                                1661
 .336    -24.00     -31.10                                                                                1663
 .404    -20.31     -61.79                                                                                1665
 .533    -30.48◆     -9.55                                                                                1667
 .693    -29.56    -359.44                                                                                1669
YAW        MEAN SQUARE ERROR (MSE)                                   14.08 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY PITCH      FREQUENCIES                           1.45 DEG*DEG       10.33 PCT        1671
 BY LOW FREQUENCIES ONLY                                              1.44 DEG*DEG       10.22 PCT        1673
 BY HIGH FREQUENCIES ONLY                                              .02 DEG*DEG         .11 PCT        1675
LOW FREQUENCY PHASE                               -191.75 DEG                                             1676
HIGH FREQUENCY PHASE                              -173.72 DEG                                             1677

YAW         ANALYZED AT THE YAW         FREQUENCIES

 FREQ     GAIN        GAIN     PHASE
 (HZ)                 (DB)     (DEG)
 .021    10.751      20.63   -140.93                                                                      1680
 .029     7.377      17.36   -149.99                                                                      1683
 .035     5.190      14.30   -159.05                                                                      1686
 .047     2.547       8.12   -128.86                                                                      1689
 .057     3.641      11.22   -164.79                                                                      1692
 .072     1.328◆      2.46   -134.71◆                                                                     1695
 .096      .790      -2.05   -141.63                                                                      1698
 .105      .507      -5.90   -132.46                                                                      1701
 .143      .233     -12.66   -142.00◆                                                                     1704
 .186      .282     -11.00   -121.08                                                                      1707
 .229      .294     -10.63   -169.93                                                                      1710
 .287      .205     -13.77   -195.85◆                                                                     1713
 .377      .297     -10.56   -201.50◆                                                                     1716
 .463      .209     -13.61   -233.04◆                                                                     1719
 .518      .230     -12.78   -236.50                                                                      1722
 .678      .269     -11.41   -233.01◆                                                                     1725
MEAN SQUARE FORCING FUNCTION                                         27.74 DEG*DEG
YAW        MEAN SQUARE ERROR (MSE)                                   14.08 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY YAW        FREQUENCIES                           5.57◆DEG*DEG       39.60◆PCT        1727
 BY LOW FREQUENCIES ONLY                                              4.59 DEG*DEG       32.62◆PCT        1729
 BY HIGH FREQUENCIES ONLY                                              .98 DEG*DEG        6.98 PCT        1731
LOW FREQUENCY GAIN                                   8.27 DB                                              1732
LOW FREQUENCY CROSSOVER                               .08 HZ                                              1733
LOW FREQUENCY PHASE                               -144.05 DEGREES                                         1734
HI FREQUENCY GAIN                                  -12.05 DB                                              1735
HI FREQUENCY CROSSOVER                                .00 HZ                                              1736
HI FREQUENCY PHASE                                -191.61◆DEGREES                                         1737
EQUIVALENT TIME DELAY                                .748◆SEC                                             1738

YAW         ANALYZED AT THE REMNANT     FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .023    -17.71                                                                                           1739
 .037    -17.98                                                                                           1740
 .041    -33.12                                                                                           1741
 .045    -17.09                                                                                           1742
 .059    -21.37                                                                                           1743
 .076    -20.42                                                                                           1744
 .094    -23.61                                                                                           1745
 .119    -32.12                                                                                           1746
 .146    -29.42                                                                                           1747
 .182    -33.40                                                                                           1748
 .242    -41.74                                                                                           1749
 .297    -53.66                                                                                           1750
 .385    -64.74                                                                                           1751
 .441    -50.54                                                                                           1752
 .607    -60.00                                                                                           1753
 .650    -49.27                                                                                           1754
YAW        MEAN SQUARE ERROR (MSE)                                   14.08 DEG*DEG      100.00 PCT
MSE ACCOUNTED FOR BY REMNANT    FREQUENCIES                           1.07 DEG*DEG        7.59 PCT        1756
 BY LOW FREQUENCIES ONLY                                              1.04 DEG*DEG        7.42 PCT        1758
 BY HIGH FREQUENCIES ONLY                                              .02 DEG*DEG         .17 PCT        1760
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PINNEO, 10/24/72

REDUCED BANDWITH ROLL TRACKING

--------- PROD(6, 6)= -.00000000

VARIABLE	MEAN	SD	UNITS	NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.52	.68	DEG/SEC	1762
POWER	2274.61	21.19	RPM	1764
RUDDER	2.11	7.91	PCT RIGHT	1766
ELEVATOR	-1.32	2.15	PCT FRONT	1768
AILERON	3.43	10.19	PCT RIGHT	1770
NS DEV	3957.64	.01	FEET	1772
AIRSPEED	108.08	2.53	MPH	1774
ALTITUDE	1040.36	31.47	FEET	1776
CLIMB RATE	59.77	129.02	FT/MIN	1778
ROLL	-1.47	5.35	DEGREES	1780
PITCH	2.87	1.51	DEGREES	1782
YAW	-1.05	2.34	DEGREES	1784

CORRELATION COEFFICIENTS, R(I,J)

-.018											1785
-.414	-.146										1787
-.080	-.013	.013									1790
.342	.026	.241	.066								1794
-.006	-.009	-.010	.007	-.001							1799
.021	-.472	.179	.175	.013	.006						1805
-.024	-.116	.161	.050	-.027	.002	.436					1812
.013	-.207	.012	.274	.057	-.009	.699	.258				1820
.643	-.146	.387	-.102	.408	-.010	.148	.107	-.009			1829
-.075	.161	.005	-.138	-.069	.027	-.264	.111	-.498	-.048		1839
-.008	.091	.159	.050	.390	-.014	.082	-.067	.132	.063	-.046	1850

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.018	25.411	28.10	-114.91	1853
.025	15.451	23.78	-121.54	1856
.031	23.085	27.27	-110.35	1859
.039	17.906	25.06	-83.51	1862
.049	6.539	16.31	-114.50	1865
.064	6.437	16.17	-140.95	1868
.080	5.666	15.07	-130.35	1871
.100	2.784	8.89	-125.98	1874
.123	1.535	3.72	-118.14	1877
.158	2.725	8.71	-153.19	1880
.197	2.009	6.06	-131.11	1883
.248	.845	-1.47	-130.24	1886
.314	.876	-1.15	-144.30	1889
.396	.684	-3.29	-153.79	1892
.498	.527	-5.56	-179.70	1895
.627	.550	-5.20	-187.82	1898

MEAN SQUARE FORCING FUNCTION		991.84 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)		28.59 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES		9.29 DEG*DEG	32.51 PCT	1900
BY LOW FREQUENCIES ONLY		7.88 DEG*DEG	27.57 PCT	1902
BY HIGH FREQUENCIES ONLY		1.41 DEG*DEG	4.94 PCT	1904
LOW FREQUENCY GAIN	20.08 DB			1905
LOW FREQUENCY CROSSOVER	.28 HZ			1906
LOW FREQUENCY PHASE	-118.39 DEGREES			1907
HI FREQUENCY GAIN	.23 DB			1908
HI FREQUENCY CROSSOVER	.29 HZ			1909
HI FREQUENCY PHASE	-149.78 DEGREES			1910
EQUIVALENT TIME DELAY	.482 SEC			1911

ROLL ANALYZED AT THE REMNANT FREQUENCIES

FREQ (HZ)	AMPLITUDE (DB)	
.023	-21.25	1912
.037	-19.02	1913
.041	-21.91	1914
.045	-24.62	1915
.059	-28.26	1916
.076	-31.57	1917
.094	-27.54	1918
.119	-25.63	1919
.146	-21.65	1920
.182	-33.55	1921
.242	-27.44	1922
.297	-33.43	1923
.385	-43.71	1924
.441	-35.96	1925
.607	-46.33	1926
.650	-48.92	1927

ROLL MEAN SQUARE ERROR (MSE)	28.59 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES	1.33 DEG*DEG	4.65 PCT	1929
BY LOW FREQUENCIES ONLY	1.05 DEG*DEG	3.66 PCT	1931
BY HIGH FREQUENCIES ONLY	.28 DEG*DEG	.99 PCT	1933

PINNEO, 10/24/72

REDUCED AMPLITUDE ROLL TRACKING

NUMBER OF LAST VARIABLE PRINTED ON LINE

..............MEAN		....SD....UNITS		NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.52◆	.59	DEG/SEC	1935
POWER	2091.57	48.34	RPM	1937
RUDDER	-.21	7.18	PCT RIGHT	1939
ELEVATOR	-.52	1.90	PCT FRONT	1941
AILERON	6.03	5.10	PCT RIGHT	1943
NS DEV	-437.15	203.88	FEET	1945
AIRSPEED	98.93	1.49◆	MPH	1947
ALTITUDE	1044.43	28.71	FEET	1949
CLIMB RATE	62.30◆	91.56	FT/MIN	1951
ROLL	.01	3.50	DEGREES	1953
PITCH	4.20	1.26	DEGREES	1955
YAW	-1.05◆	1.53◆	DEGREES	1957

CORRELATION COEFFICIENTS, R(I,J)

.011											1958
-.600	.012										1960
.057	.035	.086									1963
.259	.042	.264◆	.170								1967
-.022	.011	.173	.104	-.189							1972
.113	-.103	-.040◆	.276	.101◆	.064						1978
.025	-.037	-.018	.053	.021◆	-.226	.140					1985
.102	.365	.030	.375	.045	.134	.549	.167				1993
.542	-.020	.267	.135	.509	.170	.094	.023◆	.139			2002
-.055	-.218	.045	-.159◆	.018	-.042	-.044◆	.188◆	-.376	-.020		2012
-.024	.106	.145	.027	.204	-.075	-.130	.089	-.053	.084	.212	2023

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.018	13.010	22.29	-98.00◆	2026
.025	13.963	22.90	-156.21	2029
.031	9.441	19.50	-89.57	2032
.039	6.302	15.99	-78.66◆	2035
.049	4.542	13.15	-100.20	2038
.064	4.158	12.38◆	-129.75	2041
.080	10.861	20.72◆	-65.08	2044
.100	4.685	13.42	-100.93	2047
.123	1.496	3.50◆	-108.91	2050
.158	1.299	2.21	-75.64	2053
.197	1.790◆	5.06◆	-119.85	2056
.248	1.429◆	3.10◆	-132.21	2059
.314	.851◆	-1.40◆	-140.36	2062
.396	.591◆	-4.56◆	-161.31	2065
.498	.523◆	-5.63◆	-175.66	2068
.627	.584◆	-4.68◆	-194.85	2071

MEAN SQUARE FORCING FUNCTION	107.06 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)	12.28 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES	3.52◆DEG*DEG	28.67 PCT	2073
BY LOW FREQUENCIES ONLY	1.42◆DEG*DEG	11.59◆PCT	2075
BY HIGH FREQUENCIES ONLY	2.10 DEG*DEG	17.09 PCT	2077
LOW FREQUENCY GAIN	17.54 DB		2078
LOW FREQUENCY CROSSOVER	1.76 HZ		2079
LOW FREQUENCY PHASE	-102.30 DEGREES		2080
HI FREQUENCY GAIN	-.30◆DB		2081
HI FREQUENCY CROSSOVER	.27◆HZ		2082
HI FREQUENCY PHASE	-138.60 DEGREES		2083
EQUIVALENT TIME DELAY	.452 SEC		2084

ROLL ANALYZED AT THE REMNANT FREQUENCIES

FREQ (HZ)	AMPLITUDE (DB)	
.023	-22.93	2085
.037	-24.42	2086
.041	-20.30	2087
.045	-22.65	2088
.059	-15.76	2089
.076	-17.64	2090
.096	-21.00◆	2091
.119	-40.25	2092
.146	-21.81	2093
.182	-21.55◆	2094
.242	-39.82	2095
.297	-25.14	2096
.385	-36.26◆	2097
.441	-46.86	2098
.607	-38.28	2099
.650	-40.55	2100

ROLL MEAN SQUARE ERROR (MSE)	12.28 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES	1.14 DEG*DEG	9.25 PCT	2102
BY LOW FREQUENCIES ONLY	.92 DEG*DEG	7.53 PCT	2104
BY HIGH FREQUENCIES ONLY	.21 DEG*DEG	1.73 PCT	2106

PINNEO, 10/24/72

GROUND REF. MANEUVER -- LEFT CIRCULAR TURN

..............MEAN	.....SD	....UNITS		NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-2.10◆	2.13	DEG/SEC	
POWER	2057.44	101.34	RPM	2108
RUDDER	-6.37	10.73	PCT RIGHT	2110
ELEVATOR	-6.78	8.10	PCT FRONT	2112
AILERON	11.41	10.40	PCT RIGHT	2114
RADIUS	5924.10◆	419.19	FEET	2116
HEAD DEV.	9.66◆	19.48◆	DEGREES	2118
AIRSPEED	95.99	4.21	MPH	2120
ALTITUDE	1077.14	53.35	FEET	2122
CLIMB RATE	32.71	205.18	FT/MIN	2124
ROLL	-8.96	11.61	DEGREES	2126
PITCH	4.17	2.74	DEGREES	2128
				2130

CORRELATION COEFFICIENTS, R(I,J)

.005											
-.631	.207◆										2131
.175	.443	.116									2133
.634	-.030◆	-.332	.147								2136
-.546◆	.394◆	.441	.192	-.399							2140
-.136	.590	.421	.137	-.216	.382◆						2145
-.050	-.573	-.070	-.176◆	-.062	-.231	-.426					2151
-.192	-.161	.188	-.071	-.252	-.205	.141	.368◆				2158
-.405	.255	.290	.198◆	-.313	.373	.256	.321	.435			2166
.928	.051	-.384	.075	.541	-.488◆	.057	-.084	-.105	-.377		2175
.205	-.141	-.159	-.506	.037	-.149	-.065	-.070	-.024	-.488	.316	2185
											2196

PINNEO, 10/24/72

GROUND REF. MANEUVER -- ALTITUDE AND POSITION TRACKING

..............MEAN	.....SD	....UNITS		NUMBER OF LAST VARIABLE PRINTED ON LINE
TURN RATE	-.59	1.86	DEG/SEC	
POWER	2092.67	133.61◆	RPM	2198
RUDDER	3.26	13.52	PCT RIGHT	2200
ELEVATOR	-3.75◆	2.49	PCT FRONT	2202
AILERON	4.01	11.38	PCT RIGHT	2204
NS DEV	76.21	233.38	FEET	2206
AIRSPEED	97.11	3.29	MPH	2208
ALTITUDE	1059.00	59.47◆	FEET	2210
CLIMB RATE	66.15◆	225.71	FT/MIN	2212
ROLL	-2.36	8.90	DEGREES	2214
PITCH	4.34	2.12	DEGREES	2216
YAW	-2.14◆	6.30	DEGREES	2218
				2220

CORRELATION COEFFICIENTS, R(I,J)

.106											
-.820	-.022										2221
-.251	.130	.217									2223
.720	.130	-.513	-.124								2226
-.409◆	.021	.351	.130	-.356							2230
-.160	-.010◆	.244	.052◆	-.133	.115						2235
.015	-.151◆	.011	-.023◆	-.026	-.177	.088◆					2241
-.013	.564	.078	.188	.030	.004	.461	.246◆				2248
.909	.083	-.534	-.236	.655	-.366◆	-.100	.048	-.012			2256
.105	-.441	-.134	-.127	.020	-.062	-.375	.208	-.607	.102		2265
.029	-.199	. .02	-.173	.152	-.301	-.001	.204	.009	.101	-.024	2275
											2286

NS DEV ANALYZED AT THE NS DEV FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.004	2.971	9.46	-324.68	
.010	1.288	2.20	-87.99	2289
.016	.120	-18.38	-45.99	2292
.023	.487	-6.25	-163.38	2295
.027	.775	-2.22	-95.23	2298
.037	.507◆	-5.90	-149.88	2301
.041	.340	-9.38	-145.04	2304
.049	.233	-12.66	-183.99	2307

MEAN SQUARE FORCING FUNCTION	60451.86 FT*FT		2310
NS DEV MEAN SQUARE ERROR (MSE)	54466.98 FT*FT	100.00 PCT	
MSE ACCOUNTED FOR BY NS DEV FREQUENCIES	35055.93 FT*FT	64.36 PCT	2312
BY LOW FREQUENCIES ONLY	27129.41 FT*FT	49.81 PCT	2314
BY HIGH FREQUENCIES ONLY	7926.52 FT*FT	14.55 PCT	2316
LOW FREQUENCY GAIN *	-3.24 DB		2317
LOW FREQUENCY CROSSOVER	.01 HZ		2318
LOW FREQUENCY PHASE	-155.51 DEGREES		2319
HI FREQUENCY GAIN	-7.54 DB		2320
HI FREQUENCY CROSSOVER	.02 HZ		2321
HI FREQUENCY PHASE	-143.54 DEGREES		2322
EQUIVALENT TIME DELAY	4.133 SEC		2323

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NS DEV      ANALYZED AT THE ALTITUDE   FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)      (DB)     (DEG)
 .002      -.76   -230.20                                                          2325
 .008      2.16   -247.03                                                          2327
 .014      6.13   -209.28                                                          2329
 .020      4.72   -212.68                                                          2331
 .029      3.03    -88.48                                                          2333
 .035      7.41    -35.70                                                          2335
 .045      5.16   -344.02                                                          2337
 .063     -4.44   -282.07                                                          2339
NS DEV     MEAN SQUARE ERROR (MSE)                    54466.98 FT*FT    100.00 PCT
MSE ACCOUNTED FOR BY ALTITUDE  FREQUENCIES            11159.90 FT*FT     20.49 PCT     2341
 BY LOW FREQUENCIES ONLY                              10105.02 FT*FT     18.55 PCT     2343
 BY HIGH FREQUENCIES ONLY                              1054.88 FT*FT      1.94 PCT     2345
LOW FREQUENCY PHASE                       -224.80 DEG                                  2346
HIGH FREQUENCY PHASE                      -243.77 DEG                                  2347

NS DEV      ANALYZED AT THE REMNANT    FRFQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .006    -11.94                                                                        2348
 .012    -15.84                                                                        2349
 .018    -22.24                                                                        2350
 .021    -21.59                                                                        2351
 .031    -32.17                                                                        2352
 .039    -33.41                                                                        2353
 .047    -24.78                                                                        2354
 .053    -38.35                                                                        2355
NS DEV     MEAN SQUARE ERROR (MSE)                    54466.98 FT*FT    100.00 PCT
MSE ACCOUNTED FOR BY REMNANT   FREQUENCIES             5857.91 FT*FT     10.75 PCT     2357
 BY LOW FREQUENCIES ONLY                               5610.66 FT*FT     10.30 PCT     2359
 BY HIGH FREQUENCIES ONLY                               247.25 FT*FT       .45 PCT     2361

ALTITUDE   ANALYZED AT THE NS DEV     FREQUENCIES
 FREQ  ISOLATION    PHASE
 (HZ)     (DB)      (DEG)
 .004    -15.08   -262.71                                                              2363
 .010    -10.13   -276.44                                                              2365
 .016    -10.71   -292.72                                                              2367
 .023    -17.52   -110.04                                                              2369
 .027     -9.06   -159.05                                                              2371
 .037    -13.28   -155.64                                                              2373
 .041    -20.13    -90.17                                                              2375
 .049    -20.69   -118.23                                                              2377
ALTITUDE  MEAN SQUARE ERROR (MSE)                      3537.12 FT*FT    100.00 PCT
MSE ACCOUNTED FOR BY NS DEV    FREQUENCIES              570.83 FT*FT     16.14 PCT     2379
 BY LOW FREQUENCIES ONLY                                521.50 FT*FT     14.74 PCT     2381
 BY HIGH FREQUENCIES ONLY                                49.33 FT*FT      1.39 PCT     2383
LOW FREQUENCY PHASE                       -235.48 DEG                                  2384
HIGH FREQUENCY PHASE                      -189.64 DEG                                  2385

ALTITUDE   ANALYZED AT THE ALTITUDE   FREQUENCIES

 FREQ    GAIN        GAIN     PHASE
 (HZ)                (DB)     (DEG)
 .002    1.082        .69   -359.96                                                    2388
 .008    1.111        .91   -150.89                                                    2391
 .014     .762      -2.36   -150.50                                                    2394
 .020     .425      -7.44   -190.53                                                    2397
 .029     .337      -9.44   -117.70                                                    2400
 .035     .092     -20.72   -306.50                                                    2403
 .045     .864      -1.27   -147.37                                                    2406
 .063    1.944       5.78   -231.19                                                    2409
MEAN SQUARE FORCING FUNCTION                            940.55 FT*FT
ALTITUDE  MEAN SQUARE ERROR (MSE)                      3537.12 FT*FT    100.00 PCT
MSE ACCOUNTED FOR BY ALTITUDE  FREQUENCIES             1916.45 FT*FT     54.18 PCT     2411
 BY LOW FREQUENCIES ONLY                               1844.97 FT*FT     52.16 PCT     2413
 BY HIGH FREQUENCIES ONLY                                71.48 FT*FT      2.02 PCT     2415
LOW FREQUENCY GAIN                          -2.05 DB                                   2416
LOW FREQUENCY CROSSOVER                       .00 HZ                                   2417
LOW FREQUENCY PHASE                       -212.97 DEGREES                              2418
HI FREQUENCY GAIN                           -6.42 DB                                   2419
HI FREQUENCY CROSSOVER                        .05 HZ                                   2420
HI FREQUENCY PHASE                        -200.69 DEGREES                              2421
EQUIVALENT TIME DELAY                       6.868 SEC                                  2422

ALTITUDE   ANALYZED AT THE REMNANT    FREQUENCIES
 FREQ   AMPLITUDE
 (HZ)     (DB)
 .006    -10.78                                                                        2423
 .012    -14.85                                                                        2424
 .018    -13.18                                                                        2425
 .021    -23.27                                                                        2426
 .031    -36.81                                                                        2427
 .039    -30.85                                                                        2428
 .047    -35.07                                                                        2429
 .053    -31 00                                                                        2430
ALTITUDE  MEA^ SQUARE ERROR (MSE)                      3537.12 FT*FT    100.00 PCT
MSE ACCOUNTED FOR BY REMNANT   FREQUFNCIES              605.46 FT*FT     17.12 PCT     2432
 BY LOW FREQUENCIES ONLY                                597.90 FT*FT     16.90 PCT     2434
 BY HIGH FREQUENCIES ONLY                                 7.56 FT*FT       .21 PCT     2436
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APPENDIX D. LIST OF THE STATISTICALLY SIGNIFICANT VARIABLES FROM EXPERIMENT 2

The tabular headings across the page are variable number, F value for testing the equality of three group means (with 2 and 27 df), significance level, mean value for each group of 10 *S*s, mean value for all 30 *S*s, and standard deviation within groups.

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STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
2	4.31	.025	.999640	.879360	.546870	.808623	.357310
14	4.82	.025	5.272	3.582	2.912	3.922	1.751
16	5.96	.010	80.631	43.988	34.038	52.886	31.788
18	4.24	.050	245.860	182.820	157.010	195.230	70.218
20	5.07	.025	7.801	6.348	4.074	6.074	2.637
21	4.29	.025	3.872	4.749	3.620	4.081	.905
22	4.22	.050	2.669	2.355	1.848	2.291	.638
24	7.96	.002	6.492	3.360	2.336	4.063	2.427
25	4.70	.025	.027028	-.085475	-.046652	-.035033	.083361
30	4.19	.050	-.004018	.046207	-.024307	.005961	.056061
33	5.32	.025	-.124395	-.062400	.164648	-.007382	.208562
34	4.96	.025	-.026789	-.094982	.029163	-.030869	.088243
44	4.76	.025	.105921	-.000634	.071792	.059026	.078904
48	6.20	.010	.094187	.173212	-.030853	.078849	.130724
50	4.16	.050	.065090	-.077361	.028370	.005366	.114704
51	4.66	.025	-.122680	.137515	-.071105	-.018757	.201738
55	4.80	.025	.110092	.004369	.010020	.041494	.085867
62	7.22	.005	.038522	-.075119	.011552	-.008349	.069869
72	4.52	.025	-.073360	.031502	.003460	-.012799	.080721
77	5.22	.025	.080250	.144680	.208360	.144130	.088683
81	3.53	.050	-.106258	-.059200	.066143	-.033105	.150003
90	3.67	.050	-.058380	.030284	.081661	.017852	.117003
99	4.31	.025	-126.765	-153.370	-108.128	-129.421	34.644
100	3.94	.050	2.387	3.286	5.595	3.756	2.636
101	6.54	.005	5.812	9.820	13.614	9.749	4.823
103	6.50	.005	1.085	1.317	1.889	1.430	.513
104	6.65	.005	-.286	1.954	5.187	2.285	3.373
106	11.91	.001	.577230	.816420	1.173060	.855570	.274789
107	11.36	.001	-5.611	-2.178	1.122	-2.222	3.159
109	10.42	.001	.388626	.482340	.693590	.521519	.153005
110	7.47	.005	-9.263	-6.716	-3.330	-6.437	3.444
112	11.78	.001	.328560	.421760	.522770	.424363	.089506
113	11.92	.001	-9.922	-7.675	-5.766	-7.788	1.905
115	3.73	.050	24.255	10.618	6.421	13.765	15.271
120	3.38	.050	15.818	20.121	27.931	21.290	10.565
121	6.11	.010	22.228	25.175	27.358	24.920	3.295
124	10.41	.001	-6.270	-3.654	-.697	-3.540	2.732
125	9.38	.001	.109553	.149180	.224440	.161058	.060240
126	4.00	.050	-161.840	-157.900	-148.330	-156.023	10.988
127	3.52	.050	.674040	.642350	.554880	.623757	.104096
130	11.27	.001	-19.105	-24.603	-29.746	-24.485	5.012
13[illegible]	4.84	.025	-95.210	-220.946	-214.256	-176.804	101.685
136	5.76	.010	-7.568	-.489	-11.532	-6.529	7.370
148	4.17	.050	.338750	2.021515	.186526	.848930	1.577313
149	8.01	.002	.628	2.884	.972	1.495	1.359
150	4.76	.025	-166.810	-231.240	-210.480	-202.843	47.686
166	5.60	.010	-50.648	-59.785	-62.826	-57.753	8.469
169	4.09	.050	-209.677	-236.545	-100.834	-182.352	112.400
186	4.59	.025	.033068	.052529	.021408	.035668	.023203
187	3.46	.050	.564995	1.049960	.609350	.741435	.455635
192	8.21	.002	-150.478	-240.860	-252.620	-214.653	61.689
193	4.40	.025	18.941	32.352	19.858	23.717	11.298
194	3.56	.050	24.931	29.074	25.693	26.566	3.698
205	6.14	.010	.813	.920	1.291	1.008	.320
206	5.42	.025	-2.722230	-1.048210	1.949130	-.607103	3.215141
208	3.87	.050	.419671	.514850	.647030	.527184	.183637
209	3.41	.050	-9.299	-6.158	-4.095	-6.517	4.485
213	4.08	.050	-181.610	-171.530	-153.020	-168.720	22.699
214	3.38	.050	2.628	2.028	1.521	2.059	.953
218	4.44	.025	1.042880	1.116300	.745640	.968273	.294392
222	7.64	.005	-152.744	-189.270	-190.600	-177.538	24.577
223	4.08	.050	-6.019	-3.910	-1.960	-3.963	3.177
224	4.56	.025	.118442	.149846	.191026	.153105	.053884
226	3.75	.050	.481540	.455210	.354700	.430483	.109297
230	4.02	.050	-23.545	-27.834	-13.617	-21.665	11.498
234	4.66	.025	-44.234	-40.565	-27.200	-37.333	13.130
242	4.18	.050	1.002400	.823810	.568600	.798270	.337183
256	5.70	.010	99.469	60.622	43.330	67.807	38.071
257	4.94	.025	19.409	-21.390	20.431	6.150	33.934
260	4.22	.050	7.222	5.580	4.205	5.669	2.325

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
261	5.95	.010	4.544	5.267	4.233	4.681	.687
264	5.16	.025	6.512	3.883	2.851	4.415	2.628
273	7.14	.005	-.139206	-.001906	.171951	.010280	.184490
288	3.50	.050	-.006764	.128328	-.045823	.025247	.154536
294	7.12	.005	.220089	.094655	.025134	.113293	.117071
303	4.35	.025	.127851	.112277	.296912	.179013	.155329
304	4.36	.025	-.047079	.042949	.010402	.002091	.069028
323	6.60	.005	-.105245	-.025951	.032134	-.033021	.084856
338	6.05	.010	14.564	21.408	22.767	19.580	5.653
341	3.68	.050	8.305	11.769	13.465	11.180	4.334
343	5.76	.010	1.134	1.334	1.769	1.412	.428
344	4.24	.025	-.095	2.321	4.667	2.298	3.657
346	5.98	.010	.665666	.785780	1.035000	.828815	.243611
347	4.13	.050	-5.095	-2.274	.124	-2.415	4.065
348	3.56	.050	-150.290	-136.750	-137.320	-141.453	12.835
349	9.24	.001	.403260	.543190	.656640	.534363	.132016
350	9.24	.001	-8.644	-5.387	-3.807	-5.946	2.566
352	8.36	.002	.335850	.396980	.486480	.406437	.082872
353	8.73	.002	-9.799	-8.081	-6.398	-8.093	1.820
360	3.68	.050	16.329	21.002	29.683	22.338	11.166
361	4.68	.025	21.984	27.237	26.935	25.385	4.311
362	3.61	.050	.246953	.330300	.632210	.403154	.337407
364	6.92	.005	-5.908	-3.355	-1.354	-3.539	2.744
376	5.43	.025	-9.914	-3.186	-12.230	-8.444	6.376
389	4.96	.025	.712	2.631	.665	1.336	1.593
408	4.08	.050	-33.536	-33.939	-38.300	-35.258	4.134
412	4.33	.025	-20.058	-26.721	-29.588	-25.456	7.431
419	3.80	.050	-157.110	-256.039	-255.250	-222.800	92.297
422	4.04	.050	.987050	.486550	.322340	.598647	.544755
423	6.10	.010	8.885	6.394	5.333	6.871	2.334
424	4.02	.050	.957110	.447730	.294610	.566483	.547330
425	6.26	.010	8.490	5.816	4.856	6.387	2.379
429	6.47	.010	-206.080	-276.420	-250.960	-244.487	44.263
455	6.15	.010	40.497	44.083	53.126	45.902	8.297
457	6.09	.010	30.402	31.453	42.327	34.727	8.459
469	5.42	.025	-26.394	-19.266	-20.859	-22.173	5.082
487	4.68	.025	-1.943	-5.426	-2.597	-3.322	2.708
488	4.36	.025	4.936	6.526	3.280	4.914	2.458
500	3.53	.050	5.775	3.810	2.668	4.084	2.645
549	4.79	.025	-.058129	-.147780	.064203	-.047235	.153765
555	3.44	.050	.034145	.102043	-.294343	-.052718	.361342
577	4.44	.025	-2.475	-6.954	-3.424	-4.284	3.542
578	6.75	.005	4.750	8.251	4.374	5.792	2.603
590	3.40	.050	11.257	11.204	6.241	9.567	4.945
611	3.48	.050	.276876	.038365	.098624	.137955	.210092
627	4.98	.025	.769390	.480830	.656810	.635677	.205997
641	4.26	.025	-.453170	-.538190	-.262992	-.418117	.216009
648	6.34	.010	-.559290	-.459660	-.497030	-.505327	.063226
651	3.95	.050	379.200	304.662	234.450	306.104	115.169
654	3.79	.050	-4.840	-8.344	-5.284	-6.156	3.098
655	5.18	.025	5.017	7.421	4.448	5.629	2.193
660	3.50	.050	90.020	87.683	84.266	87.323	4.895
661	12.84	.001	12.187	7.488	6.325	8.667	2.739
663	4.66	.025	134.372	68.094	54.868	85.778	62.391
664	7.06	.005	-107.037	2.981	35.180	-22.959	88.740
667	4.71	.025	7.069	4.590	2.927	4.862	3.037
668	11.77	.001	5.586	7.273	7.578	6.812	.989
669	4.31	.025	3.750	2.764	2.165	2.893	1.220
691	8.82	.001	.385272	.095280	.076791	.185781	.184191
694	5.57	.010	.167135	-.261128	-.118506	-.070833	.292277
697	4.44	.025	-.215091	-.080901	.024759	-.090411	.180442
699	8.44	.002	-.537105	-.106922	-.099984	-.248004	.272511
704	4.63	.025	.237085	.010452	.140863	.129467	.167189
712	5.70	.010	.046517	.342819	.244127	.211154	.199859
720	4.17	.050	-.138924	-.436360	-.394110	-.323131	.249230
721	6.31	.010	-.378760	-.133594	-.199885	-.237413	.159618
723	5.80	.010	-.561000	-.192522	-.241592	-.331705	.262623
724	4.86	.025	.361146	.112138	.115460	.196248	.204823
731	4.52	.025	.400860	.204162	.183112	.262711	.178553
732	4.17	.050	-.128893	-.203062	.127874	-.068027	.268776

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
739	7.10	.005	1.856	1.709	.960	1.508	.571
743	3.51	.050	9.837	8.151	3.867	7.285	5.197
744	5.26	.025	-10.201	-14.198	-7.376	-10.592	4.728
745	4.44	.025	7.373	8.665	4.935	6.991	2.844
748	3.90	.050	406.928	167.948	380.516	318.464	209.696
752	4.19	.050	1120.	1101.	920.	1047.	170.
757	7.85	.002	10.857	9.252	4.834	8.314	3.521
759	5.54	.010	3.785	2.807	2.053	2.882	1.167
765	4.42	.025	.001944	.277550	.338515	.206003	.269657
789	3.53	.050	.430530	.245706	.095276	.257171	.282628
805	4.33	.025	.387703	.277475	.004000	.223059	.300180
806	4.46	.025	-.245475	-.178530	.059676	-.121443	.240242
816	5.72	.010	1.967	1.176	.935	1.359	.713
824	3.75	.050	13.652	8.001	8.080	9.911	5.291
827	3.44	.050	71.694	80.541	76.781	76.339	7.571
834	10.81	.001	9.459	5.939	3.103	6.167	3.063
842	4.11	.050	-.239479	.031376	-.024253	-.077452	.223195
844	3.48	.050	.085470	.367478	.215195	.222714	.239285
852	3.93	.050	.233433	-.056908	-.080769	.031919	.278865
856	4.46	.025	.111310	.263319	.4[illegible]7100	.290576	.290912
905	4.55	.025	-.537170	-.377544	-.502630	-.472448	.124506
906	5.20	.025	1.353	1.096	.578	1.009	.547
912	4.01	.050	3.070	2.162	1.811	2.348	1.026
915	4.78	.025	102.898	111.340	102.307	105.515	7.310
917	3.36	.050	907.290	673.160	904.180	828.210	231.803
922	8.63	.002	8.901	6.584	3.249	6.245	3.058
924	3.86	.050	3.279	2.341	1.692	2.437	1.285
926	4.25	.025	12.986	10.592	4.061	9.213	7.082
948	3.94	.050	-.063499	.271872	.045534	.084636	.272641
959	5.38	.025	.855190	.802540	.563230	.740320	.212103
968	3.42	.050	.235903	.040453	-.044664	.077231	.2[illegible]5954
995	3.68	.050	-.224337	.006693	-.015597	-.077747	.210046
1009	4.89	.025	-.495440	-.451220	-.493570	-.480077	.035754
1010	3.74	.050	1.384	1.103	1.008	1.165	.320
1012	4.66	.025	95.115	50.070	33.937	59.707	46.451
1022	8.45	.002	6.121	4.139	2.454	4.238	1.997
1024	5.58	.010	80.978	44.507	29.991	51.825	35.173
1026	3.38	.050	230.120	170.990	125.201	175.437	90.493
1028	3.44	.050	10.825	8.858	7.635	9.106	2.744
1030	4.42	.025	2.784	2.255	1.662	2.233	.844
1032	5.05	.025	5.382	4.111	2.609	4.034	1.954
1041	8.10	.002	.111522	.344720	.474770	.310337	.204553
1051	4.03	.050	-.023515	.082402	.168354	.075747	.151304
1052	5.03	.025	.083696	.032532	-.008347	.035960	.065029
1075	4.50	.025	-.018653	.009205	.074157	.021596	.071006
1076	3.95	.050	-.035073	.000226	.062629	.009261	.078753
1082	3.66	.050	-.025985	.012461	.064545	.017007	.075092
1084	13.36	.001	-.459440	-.328490	-.176699	-.321543	.122402
1108	3.81	.050	5.989	8.023	10.702	8.238	3.827
1109	5.64	.010	14.466	17.357	20.091	17.305	3.744
1115	3.96	.050	7.863	10.847	13.053	10.588	4.140
1117	6.67	.005	2.423	2.701	4.233	3.119	1.193
1118	6.07	.010	6.637	8.003	12.154	8.931	3.688
1120	5.58	.010	1.612	2.337	3.028	2.326	.948
1121	7.12	.005	3.485	6.397	9.362	6.415	3.483
1123	3.42	.050	1.280	2.207	2.207	1.898	.915
1124	6.00	.010	1.621	5.587	6.710	4.639	3.452
1126	7.63	.005	1.027	1.262	1.793	1.361	.449
1127	7.33	.005	-.346	1.450	4.803	1.969	3.053
1129	5.87	.010	.743410	.979010	1.219210	.980543	.310472
1130	6.39	.010	-3.254410	-.755629	1.586260	-.807926	3.028134
1132	5.66	.010	.584790	.770000	.932980	.762590	.231578
1133	6.29	.010	-5.147	-2.881	-.711	-2.913	2.797
1135	5.38	.025	.458720	.615400	.737680	.603933	.190654
1136	6.41	.010	-7.494	-4.728	-2.778	-5.000	2.960
1138	4.98	.025	.371850	.479970	.587210	.479677	.152637
1139	6.00	.010	-9.191	-6.939	-4.753	-6.961	2.864
1141	4.41	.025	.334530	.430030	.489020	.417860	.117381
1142	5.50	.010	-10.038	-7.718	-6.312	-8.022	2.537
1144	6.13	.010	.326420	.425390	.465570	.405793	.091438

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1145	7.65	.005	-9.947	-7.695	-6.724	-8.122	1.890
1147	4.39	.025	86.437	51.681	35.872	57.997	39.050
1149	4.30	.025	57.247	26.614	11.515	31.792	35.534
1150	5.32	.025	36.830	29.677	19.917	28.808	11.640
1152	3.84	.050	29.938	33.546	42.758	35.414	10.668
1153	3.39	.050	13.904	16.589	18.772	16.422	4.188
1154	5.46	.025	.123817	.176070	.225500	.175129	.068833
1156	6.89	.005	-5.475	-2.960	-1.022	-3.152	2.690
1157	5.99	.010	.146422	.200620	.250740	.199261	.067426
1170	3.78	.050	-37.401	-31.553	-30.961	-33.305	5.790
1173	4.64	.025	-45.703	-41.314	-38.255	-41.757	5.496
1174	7.41	.005	-54.996	-44.902	-45.917	-48.605	6.456
1175	3.96	.050	-52.551	-45.393	-45.074	-47.673	6.720
1181	3.98	.050	.375465	.507990	.882650	.588702	.416796
1182	5.67	.010	-.583550	-.476080	-.553240	-.537623	.073571
1195	6.38	.010	6.186	3.941	3.203	4.444	1.944
1197	[illegible]	.010	75.357	45.220	35.261	51.946	27.960
1203	3.99	.050	3.606	2.721	2.331	2.886	1.035
1205	4.52	.025	6.971	5.301	3.882	5.385	2.300
1209	7.38	.005	-.060928	-.151627	-.058979	-.090511	.061640
1215	3.85	.050	-.048087	-.116449	-.009492	-.058009	.087286
1231	5.26	.025	.056660	-.011996	-.042369	.000765	.069928
1245	5.98	.010	-.071550	-.145937	-.046104	-.087863	.067076
1247	3.40	.050	-.041173	-.111872	-.076707	-.076584	.060580
1261	5.01	.025	-.315350	-.370110	-.467740	-.384400	.109109
1262	3.65	.050	-.107872	.068057	.003126	-.012230	.147320
1266	3.87	.050	.026486	.090169	-.051090	.021855	.113771
1278	3.94	.050	5.290	13.216	15.001	11.169	[illegible]
1279	6.58	.005	13.921	19.914	22.267	18.701	[illegible]
1284	7.17	.005	4.409	4.164	9.600	6.058	[illegible]
1285	6.14	.010	11.558	11.509	18.266	13.778	4.959
1290	5.77	.010	1.907	2.899	3.828	2.878	1.265
1291	6.16	.010	4.221	8.558	10.998	7.925	4.373
1293	4.74	.025	1.675	2.031	4.395	2.700	2.147
1294	8.35	.002	3.406	5.722	11.154	6.761	4.351
1306	4.67	.025	-4.548	-1.179	-.387	-2.038	3.235
1311	11.30	.001	.314600	.438920	.572860	.442127	.121480
1312	11.19	.001	-10.844	-7.457	-4.949	-7.750	2.797
1314	8.34	.002	.334350	.401730	.516470	.417517	.100857
1315	8.03	.002	-9.887	-8.113	-5.923	-7.975	2.216
1317	5.71	.010	.310549	.375610	.463790	.383316	.101762
1318	3.91	.050	-11.112	-8.646	-6.946	-8.902	3.349
1320	3.96	.050	35.217	21.031	13.549	23.265	17.482
1322	4.36	.025	27.517	12.069	6.027	15.204	16.786
1325	3.53	.050	5.152	8.345	8.238	7.245	3.051
1326	8.35	.002	10.885	14.173	17.427	14.162	3.580
1327	4.25	.025	.150638	.185850	.392960	.243149	.200785
1329	6.79	.005	-5.735	-3.385	-1.494	-3.538	2.579
1330	4.87	.025	.149987	.186390	.236980	.191119	.062595
1334	7.82	.002	-172.240	-205.088	-109.855	-162.394	54.688
1335	5.75	.010	-11.621	-15.384	-21.275	-16.094	6.417
1344	3.62	.050	-142.151	-217.056	-118.060	-159.089	85.810
1364	3.78	.050	-110.723	-100.569	-199.990	-137.094	89.022
1384	7.23	.005	-151.173	-298.097	-327.490	-258.920	111.063
1392	7.31	.005	[illegible]	-34.987	-32.343	-61.710	56.817
1395	3.54	.050	3.928	6.487	11.297	7.237	6.288
1396	5.82	.010	-116.519	-66.697	-80.012	-87.743	33.819
1397	7.33	.005	1.112	6.774	10.835	6.241	5.703
1399	5.80	.010	-.079	3.850	10.663	4.811	7.139
1401	3.40	.050	-.118	4.925	7.780	4.196	6.858
1403	5.31	.025	-3.440	3.071	6.612	2.081	6.997
1417	3.55	.050	-21.787	-24.784	-27.717	-24.763	4.977
1426	4.45	.025	-45.084	-41.747	-38.260	-41.697	5.117
1429	4.17	.050	12.174	5.871	3.843	7.296	6.725
1431	4.39	.025	11.420	5.281	3.060	6.587	6.533
1438	4.98	.025	-94.195	-151.009	-242.856	-162.687	106.260
1443	3.79	.050	-22.354	-25.529	-30.915	-26.266	7.033
1444	6.06	.010	-151.079	-205.823	-63.128	-140.010	92.512
1452	4.81	.025	-107.197	-104.792	-217.955	-143.315	93.209
1454	5.56	.010	[illegible]	-141.220	-133.765	-170.055	75.833

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1485	4.12	.050	14.247	17.224	21.815	17.762	5.940
1508	4.20	.050	.648420	.751980	.926960	.775787	.217292
1509	3.77	.050	-4.395	-2.527	-1.051	-2.658	2.729
1511	4.60	.025	.391184	.533960	.634810	.519985	.180521
1512	4.05	.050	-9.481	-[illegible].696	-4.527	-6.568	4.069
1514	7.74	.005	.302660	.420340	.548940	.423980	.140000
1515	7.84	.002	-11.534	-7.680	-5.602	-8.272	3.399
1532	3.73	.050	-6.175	-4.168	-2.633	-4.325	2.910
1533	3.48	.050	.162609	.189110	.232670	.194796	.059972
1539	4.44	.025	-183.140	-278.660	-249.570	-237.123	73.497
1602	3.77	.050	-18.785	-24.8[illegible]7	-26.176	-23.263	6.414
1606	10.71	.001	-18.438	-17.6[illegible]1	-26.685	-20.921	4.839
1612	3.47	.050	-16.479	-20.481	-22.932	-19.964	5.528
1621	3.53	.050	-234.200	-199.940	-183.644	-205.928	43.453
1630	3.93	.050	7.246	2.768	1.415	3.810	4.867
1632	3.89	.050	7.133	2.635	1.360	3.709	4.864
1637	4.08	.050	-267.360	-239.140	-241.290	-249.263	24.603
1640	6.84	.005	-15.468	-13.539	-24.772	-17.926	7.260
1648	3.92	.050	-11.985	-14.257	-20.280	-15.508	6.843
1658	4.03	.050	-21.905	-17.706	-25.378	-21.663	6.049
1667	4.54	.025	-201.090	-215.656	-115.370	-177.372	80.377
1693	3.47	.050	.712070	.780450	1.071450	.854657	.323923
1695	7.89	.002	-133.140	-98.146	-113.208	-114.831	19.762
1704	5.33	.025	-157.090	-104.787	-122.481	-128.119	36.444
1713	5.10	.025	-213.370	-167.930	-161.930	-181.077	39.398
1716	5.35	.025	-229.150	-167.502	-186.350	-194.334	43.180
1719	6.70	.005	-231.490	-180.801	-204.370	-205.554	30.997
1725	8.24	.002	-225.640	-188.220	-209.260	-207.707	20.659
1726	3.52	.050	17.819	11.894	8.743	12.819	7.767
1727	4.30	.025	40.407	42.978	56.696	46.694	13.353
1729	3.45	.050	36.480	39.343	50.340	42.054	12.456
1737	7.46	.005	-196.740	-160.430	-168.220	-175.130	22.126
1738	6.52	.005	.751890	.529100	.594170	.625053	.141898
1761	4.80	.025	-.485790	-.445910	-.487220	-.472973	.033828
1773	3.41	.050	100.164	103.350	101.069	101.528	2.813
1776	4.05	.050	54.040	41.997	33.525	43.187	16.200
1780	4.13	.050	8.333	6.293	4.955	6.527	2.646
1784	4.22	.050	4.474	3.224	2.257	3.318	1.711
1793	4.01	.050	.134787	.340841	.418120	.297916	.231215
1806	3.94	.050	-.009359	.037663	.032833	.020379	.041207
1821	3.41	.050	.805470	.584100	.574022	.654531	.223996
1830	4.19	.050	.080772	.121436	.005674	.069294	.090683
1832	6.35	.010	-.052592	.050763	.066964	.021712	.081389
1837	3.96	.050	.059112	.085934	.178344	.107797	.099427
1839	7.10	.005	.084075	.193720	.082844	.120213	.075574
1840	4.79	.025	-.009659	.023656	-.002382	.003939	.025477
1842	4.15	.050	.314995	.125781	.159677	.200151	.156658
1850	3.90	.050	-.043085	.036987	.097268	.030390	.112744
1867	3.53	.050	10.520	12.510	15.141	12.724	3.901
1870	4.58	.025	7.611	10.873	12.652	10.[illegible]79	3.779
1876	4.35	.025	1.746	5.661	7.500	4.969	4.457
1882	5.74	.010	-2.245277	2.044780	2.758155	.852552	3.573461
1884	3.74	.050	.618700	.843830	.973540	.812023	.293610
1885	4.37	.025	-4.847	-2.391	-.385	-2.541	3.382
1890	5.97	.010	.390970	.561460	.600590	.517673	.144273
1891	7.43	.005	-8.885	-5.192	-4.634	-6.237	2.679
1892	4.46	.025	-185.650	-156.310	-164.260	-168.740	22.711
1893	6.56	.005	.357120	.465820	.529600	.450847	.107711
1894	5.90	.010	-9.882	-6.746	-5.594	-7.407	2.889
1896	10.46	.001	.355250	.457570	.559650	.457490	.099950
1897	11.88	.001	-9.267	-6.894	-5.213	-7.125	1.869
1899	5.24	.025	50.251	21.472	12.556	28.093	27.216
1901	5.05	.025	47.459	19.382	10.634	25.825	27.080
1906	3.61	.050	.158429	.213960	.269820	.214070	.092676
1908	7.28	.005	-4.926	-2.060	-.468	-2.485	2.649
1909	5.48	.025	.149069	.207822	.267310	.208067	.079892
1921	3.37	.050	-34.600	-29.471	-28.514	-30.862	5.641
1934	4.53	.025	-.484460	-.450670	-.487630	-.474253	.030420
1947	3.85	.050	4.240	3.890	2.322	3.484	1.647
1950	3.55	.050	36.719	-4.175	41.[illegible]94	24.613	42.010

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1956	4.12	.050	-1.651210	1.135849	-1.182480	-.565947	2.324387
1957	4.48	.025	3.667	3.101	1.799	2.856	1.430
1966	4.37	.025	-.145823	.056273	.162555	.024335	.236917
1975	4.38	.025	-.025901	.164266	.071756	.070040	.143737
1977	5.55	.010	.150489	.041910	.047450	.079950	.082083
1983	4.43	.025	.104619	-.009727	.037626	.044173	.086295
2001	4.07	.050	.019401	.088354	.037110	.048288	.056099
2006	3.69	.050	.024324	.006092	-.068177	-.012587	.080618
2009	5.69	.010	-.415650	-.350663	-.213401	-.326571	.136939
2010	4.39	.025	.027915	.135646	.146416	.103326	.098937
2026	3.58	.050	-168.378	-166.003	-88.787	-141.056	75.661
2039	4.60	.025	-170.550	-102.627	-127.273	-133.483	50.689
2040	4.80	.025	7.384	11.522	12.133	10.347	3.730
2043	4.24	.050	4.644	6.078	10.536	7.086	4.721
2049	4.91	.025	-.161	4.609	4.833	3.094	4.028
2054	7.90	.002	.623910	.862690	1.204540	.897047	.328304
2055	9.22	.001	-4.986	-1.405	1.061	-1.777	3.167
2057	10.26	.001	.461900	.732290	.846300	.680163	.194943
2058	14.76	.001	-7.367	-2.813	-1.704	-3.961	2.470
2060	13.14	.001	.348780	.516630	.664420	.509943	.137760
2061	12.25	.001	-10.169	-5.888	-3.697	-6.585	2.974
2063	6.71	.005	.314520	.387100	.502480	.401367	.115732
2064	6.76	.005	-10.734	-8.413	-6.256	-8.468	2.723
2066	12.13	.001	.279190	.367560	.466550	.371100	.085088
2067	12.02	.001	-11.566	-8.846	-6.738	-9.050	2.208
2069	8.61	.002	.305750	.374500	.454980	.378410	.080502
2070	8.50	.002	-10.459	-8.700	-7.031	-8.730	1.860
2072	5.36	.025	14.347	8.172	6.569	9.696	5.611
2074	6.28	.010	9.736	3.893	2.426	5.352	4.878
2075	4.48	.025	25.186	15.498	14.007	18.231	9.064
2081	12.31	.001	-7.171	-3.840	-2.152	-4.387	2.302
2082	8.11	.002	.110171	.176860	.215300	.167444	.059058
2091	4.27	.025	-29.509	-23.055	-24.803	-25.789	5.111
2094	3.40	.050	-27.562	-34.614	-25.817	-29.331	7.984
2096	4.96	.025	-38.573	-33.723	-30.412	-34.236	5.827
2107	4.87	.025	-1.738	-1.179	-1.717	-1.545	.454
2117	8.22	.002	7189.	9507.	6822.	7839.	1606.
2119	5.81	.010	33.930	122.459	-51.200	35.063	113.895
2120	6.48	.010	31.424	53.466	23.971	36.287	19.049
2133	7.17	.005	-.286785	-.251075	.022317	-.171848	.199689
2138	3.39	.050	-.024124	-.020958	-.190290	-.078457	.166336
2141	5.56	.010	-.315165	-.034911	-.311170	-.220415	.215533
2142	5.37	.025	-.151693	.108788	.209793	.055629	.254526
2151	4.83	.025	.186263	-.073565	.192201	.101633	.218437
2155	4.03	.050	.184360	-.030375	.124211	.092732	.174461
2166	4.37	.025	.502510	.628560	.422300	.517790	.157302
2170	4.07	.050	.279173	.021236	.182274	.160894	.204247
2181	4.23	.050	-.280066	-.045746	-.319933	-.215248	.227883
2200	3.36	.050	62.642	23.113	49.280	45.012	34.711
2203	3.98	.050	-1.974	-5.552	-2.017	-3.181	3.254
2212	4.44	.025	150.475	85.823	64.363	100.220	67.259
2213	4.39	.025	59.575	17.900	51.753	43.076	33.425
2219	3.36	.050	-1.648	-.059	-1.560	-1.089	1.541
2231	5.73	.010	-.363100	-.608710	-.387790	-.453200	.178719
2237	5.00	.025	-.627820	-.945440	-.567293	-.713518	.287224
2239	3.69	.050	-.166403	-.270197	-.066418	-.167673	.167810
2243	6.63	.005	-.096206	-.568220	-.148504	-.270977	.317811
2245	9.01	.001	.000209	-.145178	.066735	-.026078	.114199
2248	9.73	.001	.245434	.570560	.202721	.339572	.203942
2256	3.69	.050	.118048	.261924	.223208	.201060	.122616
2262	4.03	.050	-.334430	-.541760	-.312208	-.396133	.199321
2302	3.59	.050	.339760	.601510	.319730	.420333	.262561
2362	4.19	.050	-2.621	-9.598	-10.268	-7.496	6.540
2368	3.70	.050	-10.586	-14.278	-20.385	-15.083	8.133
2374	4.44	.025	-10.601	-11.685	-15.936	-12.741	4.231
2378	5.24	.025	6060.	1533.	881.	2825.	3895.
2380	5.22	.025	5894.	1420.	835.	2716.	3829.
2394	8.11	.002	-149.046	-211.420	-111.642	-157.369	55.984
2418	8.95	.001	-158.450	-191.390	-133.207	-161.016	30.848
2426	4.04	.050	-26.325	-19.647	-20.792	-22.255	5.620