1MP

UNIVERSITY
OF
VIRGINIA

(NASA-CR-138305) SIMULATORS' VALIDATION STUDY: PROBLEM SOLUTION LOGIC Short-Haul Air Transportation Program (Virginia Univ.) 19 p HC $4.00 CSCL 14B

N74-29610

Unclas
G3/11 44766

SIMULATORS' VALIDATION STUDY:
Problem Solution Logic

Memorandum Report 403213
Short-Haul Air Transportation Program

by
Michael B. Schoultz

March 1974

Department of Engineering Science and Systems

SIMULATORS' VALIDATION STUDY:

Problem Solution Logic

Memorandum Report 403213

Short-Haul Air Transportation Program

by

Michael B. Schoultz

Approved by: [signature]
Ira D. Jacobson

[signature]
A. R. Kuhlthau

National Aeronautics and Space Administration
Grant NGR 47-005-181

March 1974

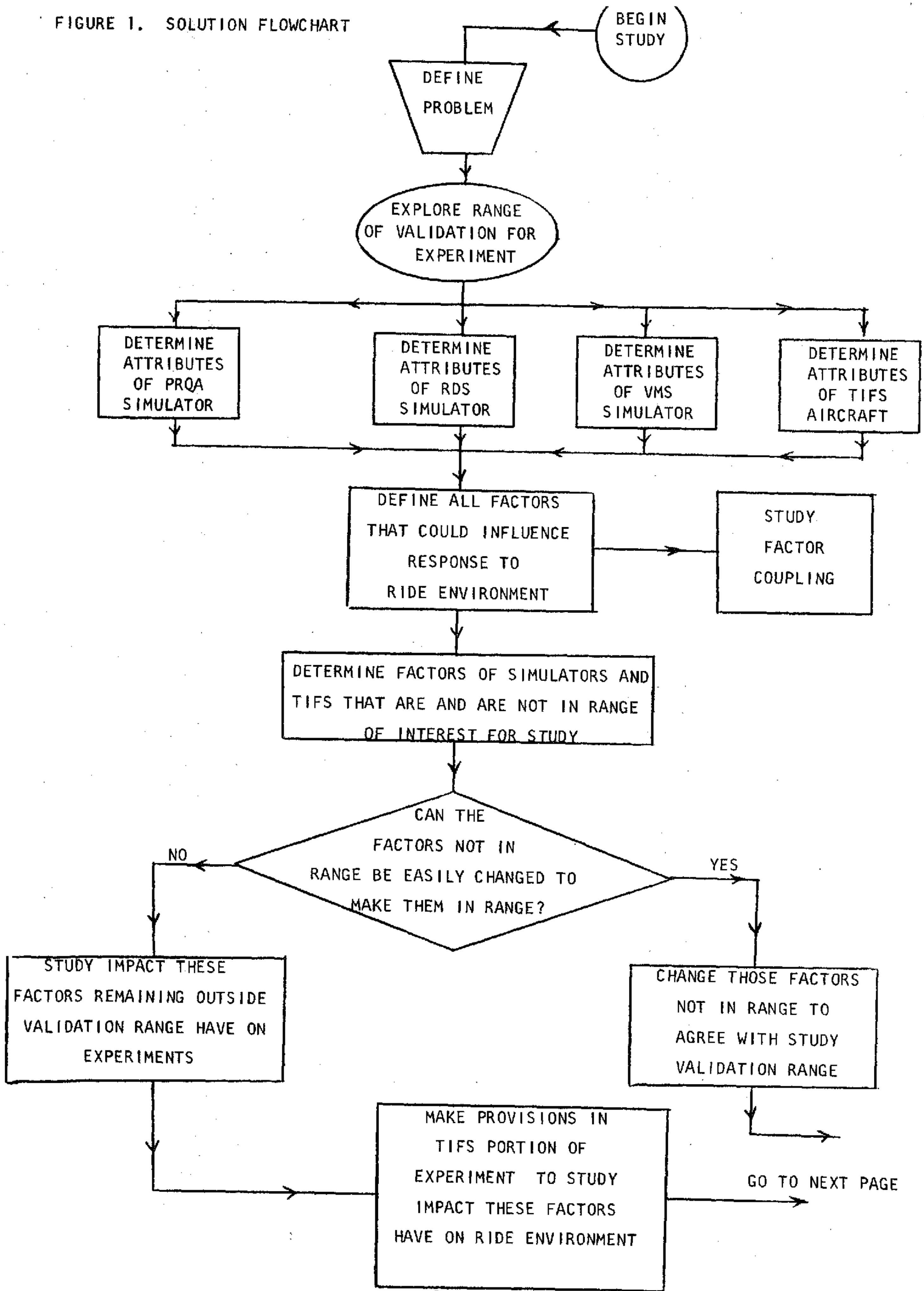
DEPARTMENT OF ENGINEERING SCIENCE AND SYSTEMS
UNIVERSITY OF VIRGINIA

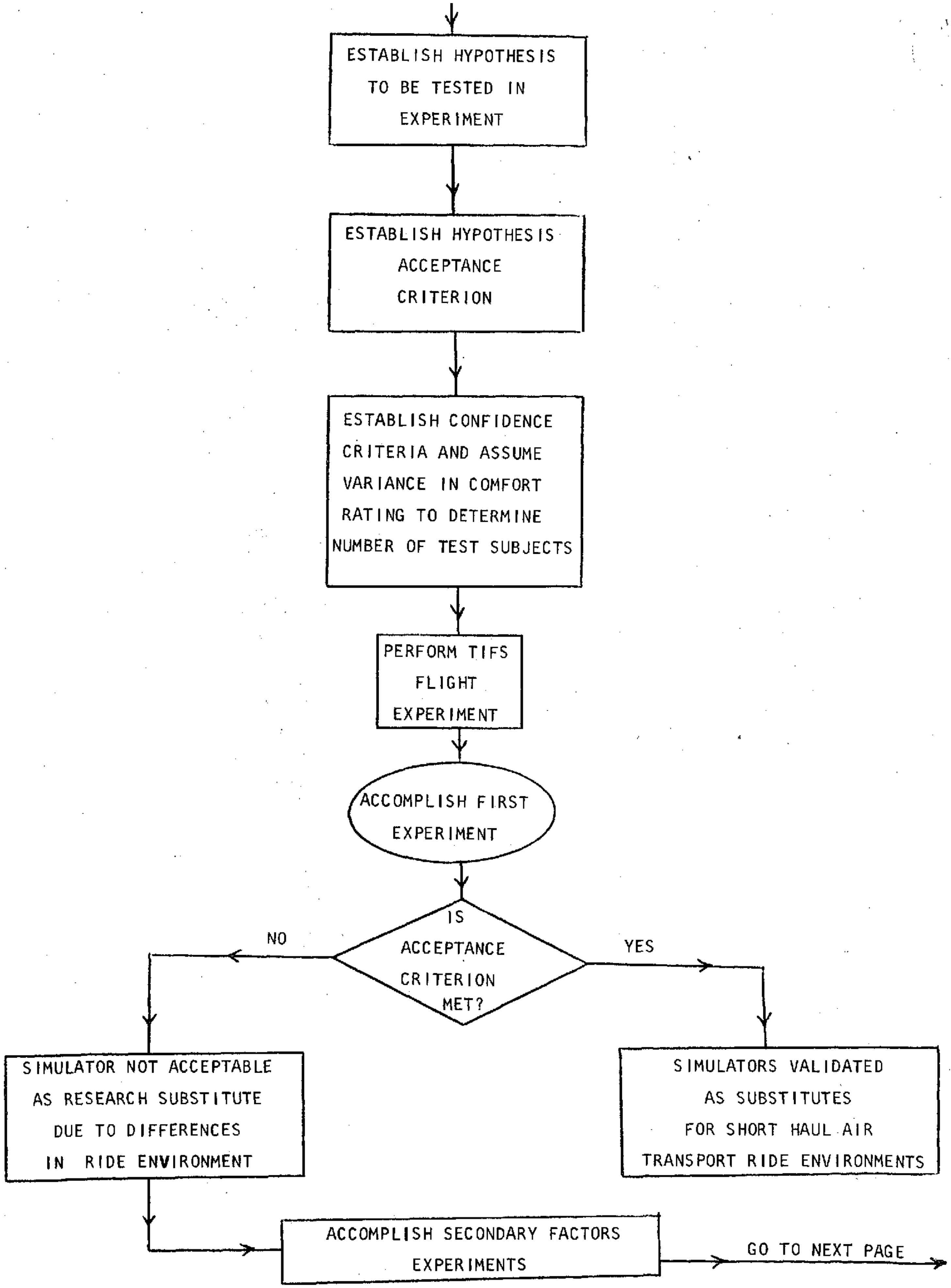
The Langley Research Center has requested that the University of Virginia STOL research group aid in designing a group of experiments to validate the Research Center's ground-based simulators as substitutes for aircraft environment in ride-quality research. This report serves to outline the logic to the approach for solving this problem.

Figure 1 on page 2 presents the overall problem solution flow chart. Foremost in importance in the approach to any solution of a complex problem is the concise definition of the problem. The definition of this problem is to validate the use of NASA Langley Research Center's ground-based simulators as substitutes for aircraft environment in ride-quality research. The validation will entail the design of experiments to compare subjective passenger response to the total flight environment among the three ground-based simulators and the total in-flight simulator. The Research Center ultimately desires to use the ground-based simulators in studies of passenger reaction to the total flight environment of present as well as future aircraft. For this reason, the validation must be made for a wide range of aircraft ride environments. Therefore, a comprehensive study of the range of ride environments must be accomplished early in the study. Such a study must include future short-haul aircraft environments as well as current aircraft environments.

It is important at this point in the study to define all factors (physical, psychological, or otherwise) that could influence, in any respect, a person's response to his environment on board an aircraft. This has been accomplished and is shown in Table 1, page 5. The factors are grouped under the headings physical, psychological, procedural, and

FIGURE 1. SOLUTION FLOWCHART





ESTABLISH HYPOTHESIS TO BE TESTED IN EXPERIMENT
ESTABLISH HYPOTHESIS ACCEPTANCE CRITERION
ESTABLISH CONFIDENCE CRITERIA AND ASSUME VARIANCE IN COMFORT RATING TO DETERMINE NUMBER OF TEST SUBJECTS
PERFORM TIFS FLIGHT EXPERIMENT
ACCOMPLISH FIRST EXPERIMENT
IS ACCEPTANCE CRITERION MET?
NO
YES
SIMULATOR NOT ACCEPTABLE AS RESEARCH SUBSTITUTE DUE TO DIFFERENCES IN RIDE ENVIRONMENT
SIMULATORS VALIDATED AS SUBSTITUTES FOR SHORT HAUL AIR TRANSPORT RIDE ENVIRONMENTS
ACCOMPLISH SECONDARY FACTORS EXPERIMENTS
GO TO NEXT PAGE

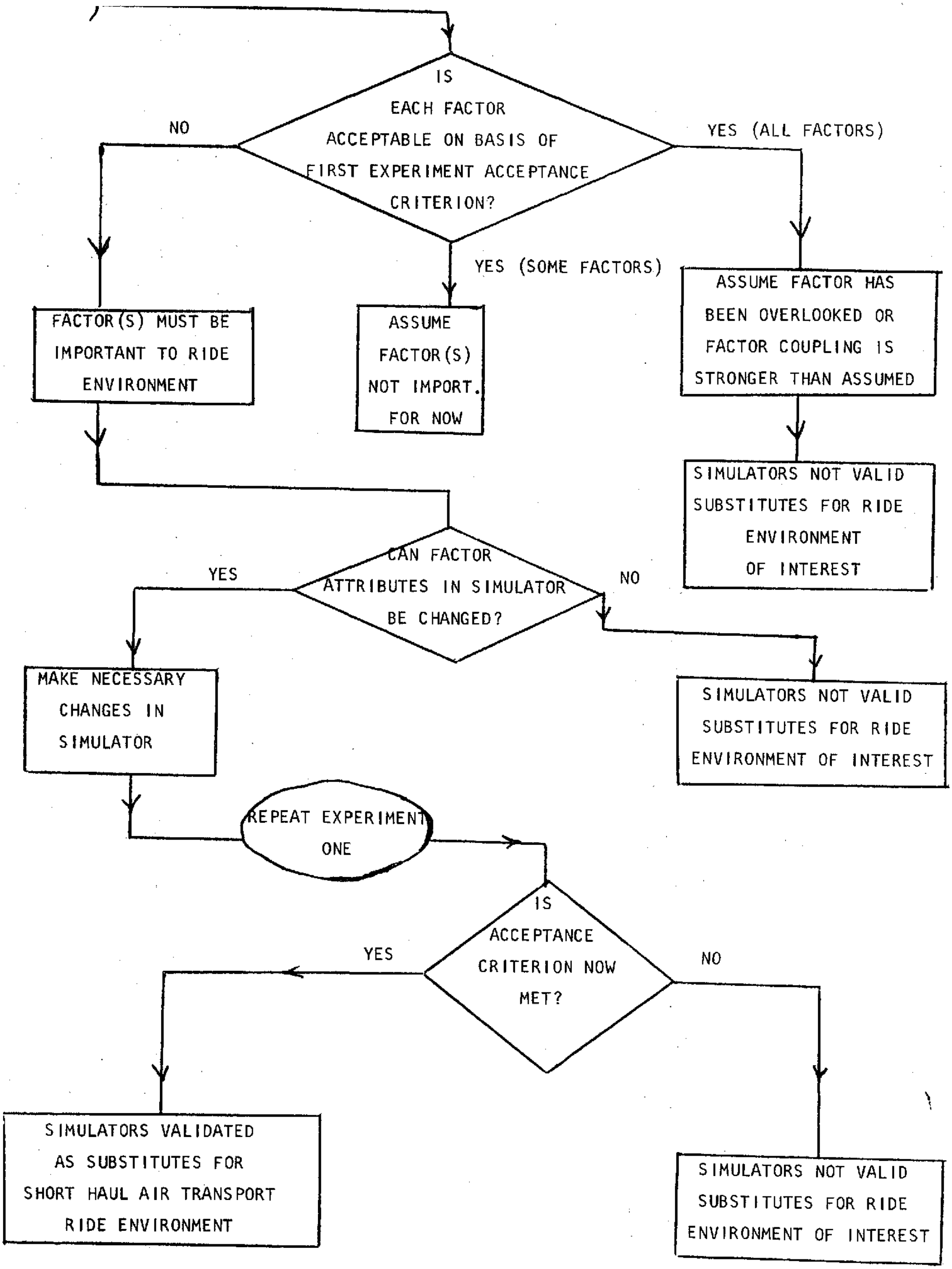

IS EACH FACTOR ACCEPTABLE ON BASIS OF FIRST EXPERIMENT ACCEPTANCE CRITERION?
NO
YES (SOME FACTORS)
YES (ALL FACTORS)
FACTOR(S) MUST BE IMPORTANT TO RIDE ENVIRONMENT
ASSUME FACTOR(S) NOT IMPORT. FOR NOW
ASSUME FACTOR HAS BEEN OVERLOOKED OR FACTOR COUPLING IS STRONGER THAN ASSUMED
SIMULATORS NOT VALID SUBSTITUTES FOR RIDE ENVIRONMENT OF INTEREST
CAN FACTOR ATTRIBUTES IN SIMULATOR BE CHANGED?
YES
NO
MAKE NECESSARY CHANGES IN SIMULATOR
SIMULATORS NOT VALID SUBSTITUTES FOR RIDE ENVIRONMENT OF INTEREST
REPEAT EXPERIMENT ONE
IS ACCEPTANCE CRITERION NOW MET?
YES
NO
SIMULATORS VALIDATED AS SUBSTITUTES FOR SHORT HAUL AIR TRANSPORT RIDE ENVIRONMENT
SIMULATORS NOT VALID SUBSTITUTES FOR RIDE ENVIRONMENT OF INTEREST

TABLE I

FACTORS THAT INFLUENCE RIDE ENVIRONMENT

PHYSICAL	PSYCHOLOGICAL	PROCEDURAL	SAMPLE
(1) Motion (a) Amplitude (b) Frequency (c) Degrees of freedom (d) Time history (e) Exposure duration (2) Environment (a) Noise (b) Lighting (c) Seating (d) Temperature (e) Internal cabin visual field	(1) Anxiety (2) Motivation (3) External visual cues (4) Familiarity with surroundings (5) Attitude	(1) Instructions (2) Time of day (3) Test duration (4) TIFS weather conditions (5) TIFS flight pattern (6) Seating arrangement (7) Experiment order (8) Subject activity	(1) Size (2) Demography (3) Training (4) Somatatype

sample. Under the physical factors are found the motion factors and other factors dealing with the passenger's physical environment. The psychological factors include the passenger's anxiety toward flying, his motivation for flying, his familiarity with his surroundings or his experience with flying, and his visual field external to the aircraft. The procedural and sample factors include those factors more directly under the control of the experimenter. The procedural factors include the duration of the test, the instructions given the test subjects, the subject's seating arrangement, order of the experiments to be performed, subject activity during the experiment, time of day the experiment is performed, and the TIFS aircraft flight pattern and flight weather conditions. The sample factors include the size, demographic and somatotype characteristics of the sample and the subject training procedure. This list represents the factors that the Virginia STOL research team feels may have an effect on ride environment. One secondary objective of this validation study will be to determine which factors, if any, can be effectively eliminated from this list (i.e., can we, after accomplishing the prescribed experiments, regard any of these factors as secondary in importance?).

Because these factors may be singled out for further study later in the program to determine their individual effect on passenger response, it is important to study how these factors are coupled. One means of presenting the factor couplings is by an interaction matrix shown in Figure 2, page 7. This matrix represents the research team's best judgment on factor couplings. It also shows the interaction or coupling effect of one factor on another by entering the row of the desired factor, and reading across the row until the second factor is found in one of the columns. The symbol in that matrix position represents the interaction of the row factor on the column factor. For example, to investigate which factors noise affects, one enters the row

FIGURE 2. FACTOR INTERACTION MATRIX

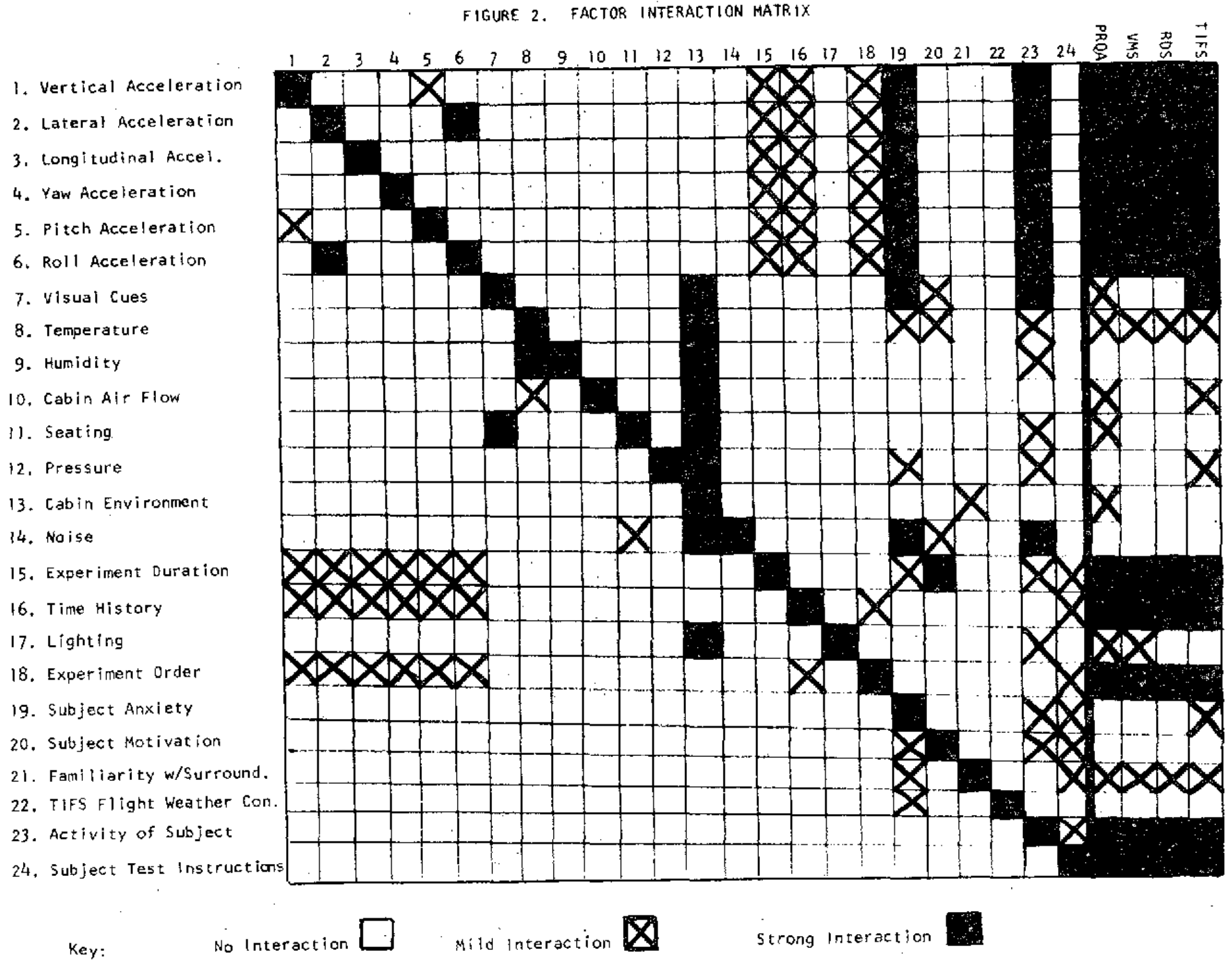
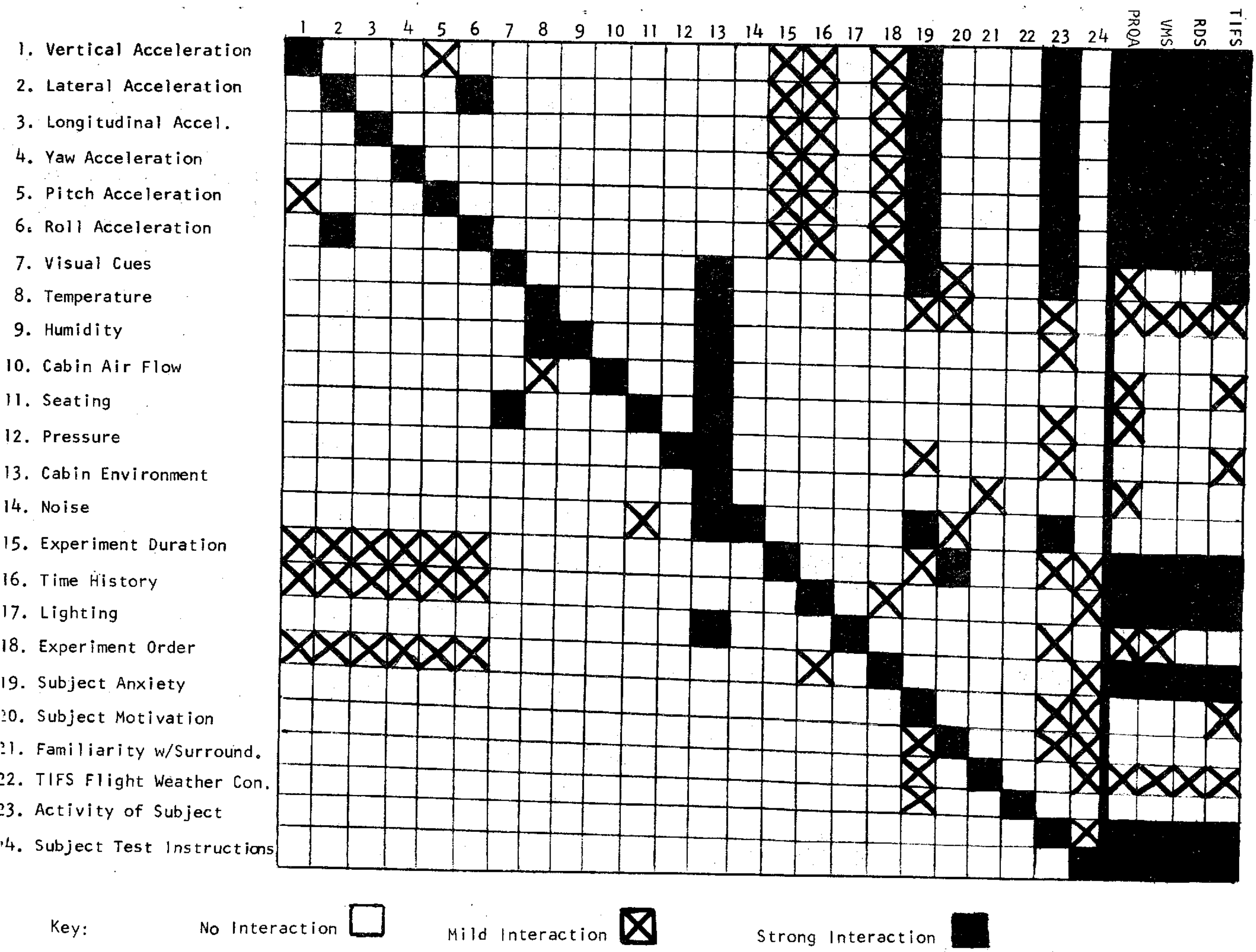


FIGURE 2. FACTOR INTERACTION MATRIX



designated noise and reads across the row, to find that noise interacts mildly with where a person sits (seating factor), strongly with itself (by definition), strongly with experiment duration, subject anxiety, and subject activity, and mildly with subject motivation. Likewise, to consider which factors affect noise, one enters the noise column and reads down the column to find that no factor in the list other than noise itself affects noise. The solid black line serves to separate factor interactions on other factors from factor interactions on each simulator. To consider which factors are most important and which are least important in influencing ride environment for a particular simulator, enter the simulator column and read down.

The next step in the study is to determine all the attributes of the three simulators to be validated and the attributes of the TIFS aircraft to be used as the "control environment." Figures 3 - 6 and Table 2, pages 9 through 13, summarize these attributes. Determining the attributes or characteristics of these systems allows those not within the range of the validation to be identified and, if possible and practical, modified so that they do fall within this range. For those factors that cannot be reasonably altered (i.e., due to prohibitive costs), the impact their differences have on passenger response should be studied and anticipated prior to the experiment's design. In particular, since the TIFS portion of the experiment will be a one-time affair, provisions must be made for isolating on the TIFS flight test those factors that were different so that their isolated effects on passenger response may be studied. Motion fidelity will most certainly represent one of the more important factors that cannot be changed on the simulators to agree with the validation range. Motion fidelity will therefore be one of the environment attributes that must be given special consideration in the design of the TIFS flight experiment.

FIGURE 3. SIMULATORS' MOTION ENVIRONMENT—LONGITUDINAL ACCELERATION

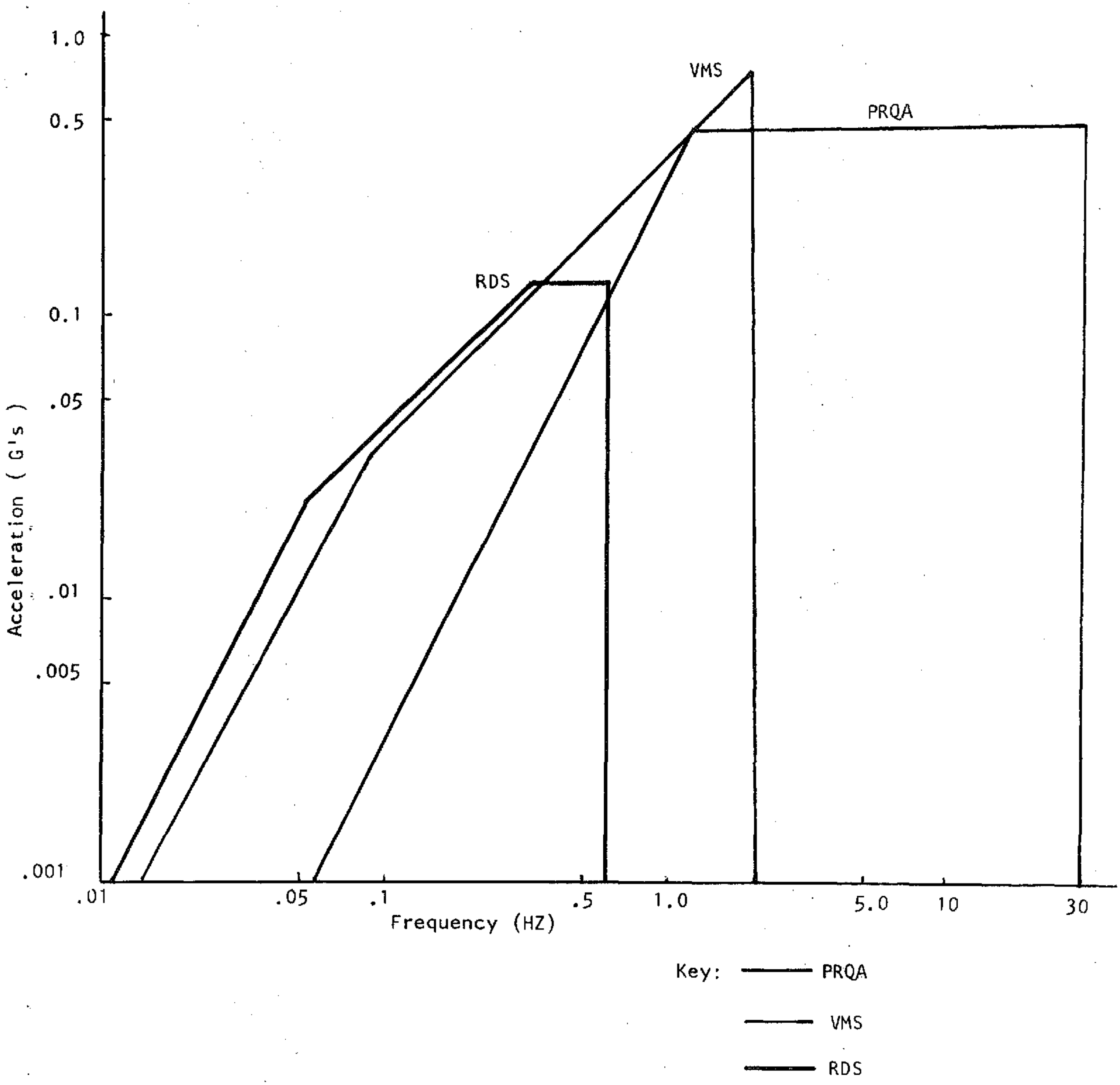


FIGURE 4. SIMULATORS' MOTION ENVIRONMENT—TRANSVERSE ACCELERATION

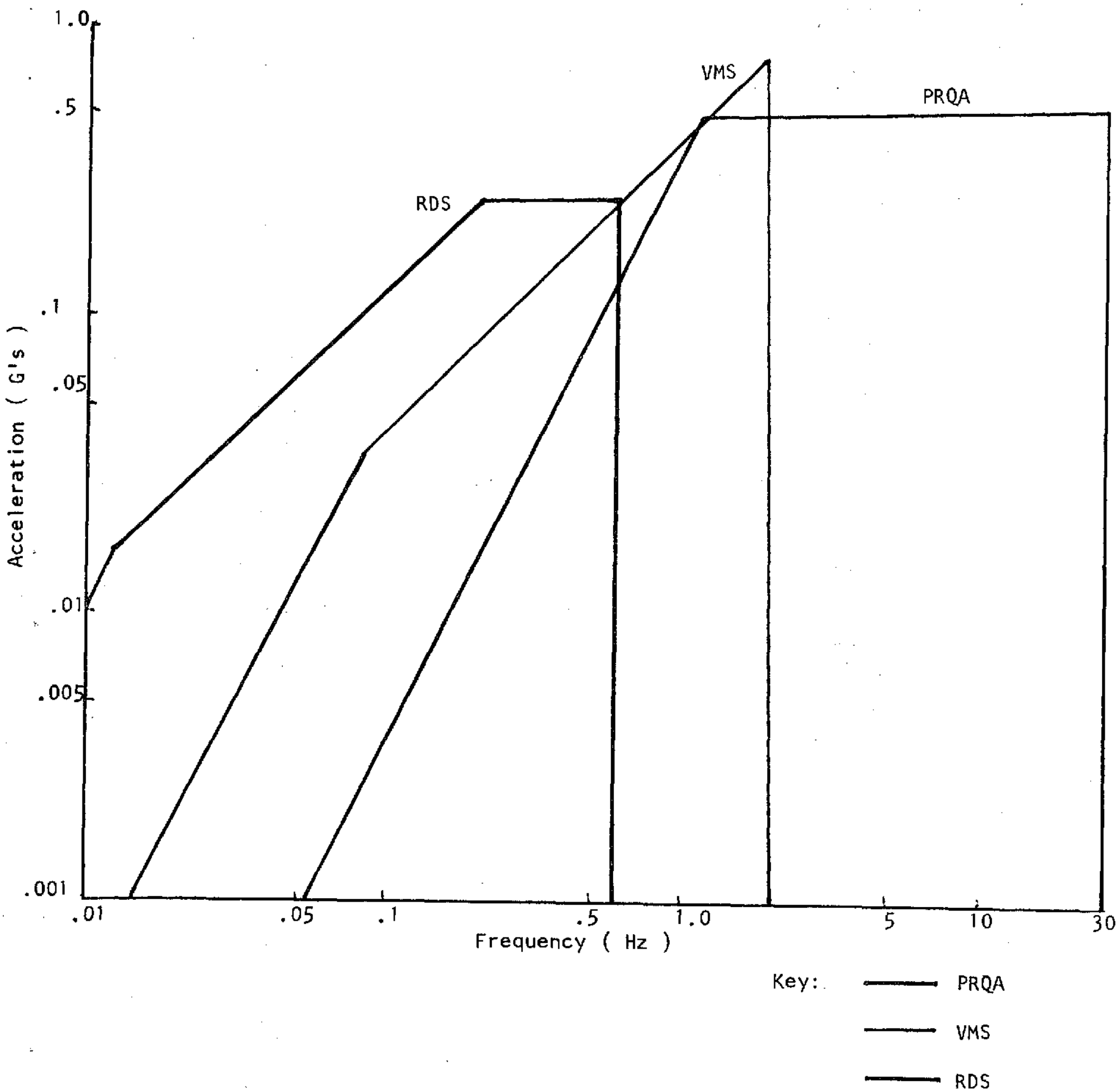


FIGURE 5. SIMULATORS' MOTION ENVIRONMENT—VERTICAL ACCELERATION

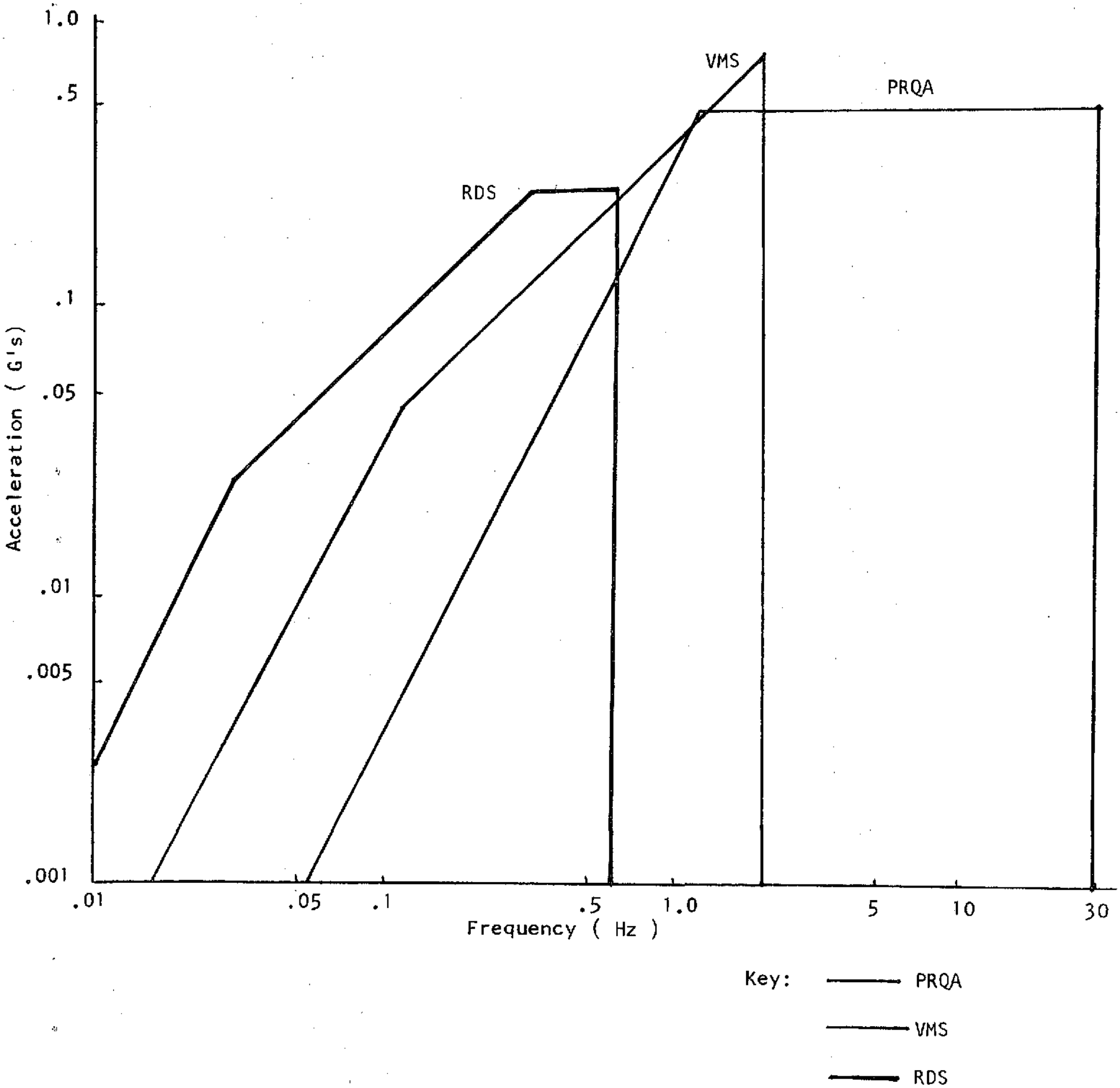


FIGURE 6. SIMULATOR MOTION ENVIRONMENT LIMITS—ANGULAR ACCELERATIONS

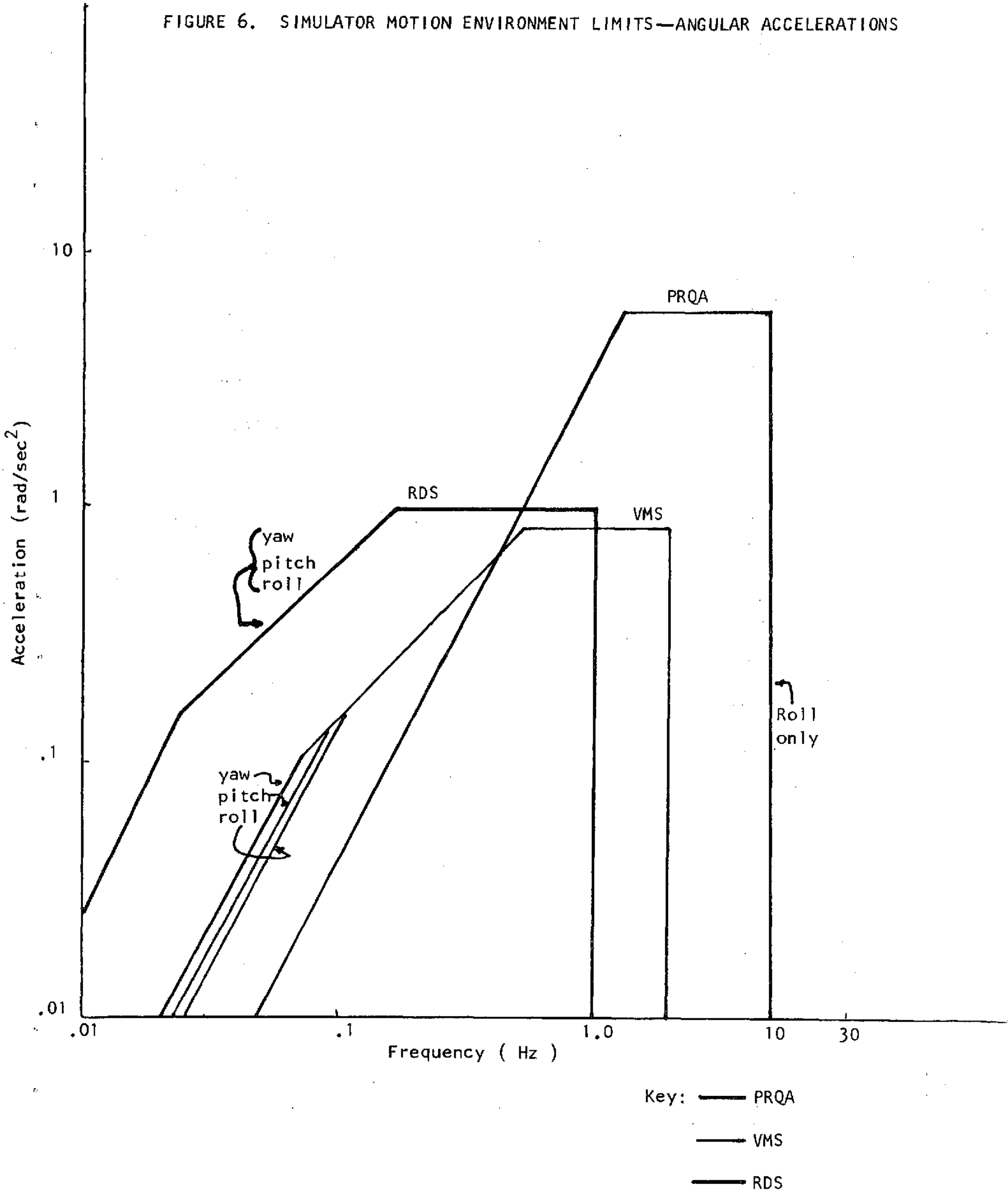


TABLE II

SYSTEM CHARACTERISTICS

SYSTEM ATTRIBUTE	SYSTEM PRQA	RDS	VMS	TIFS
Number of Passengers	6 Coach or 4 1st Class	3	2	10
Interior Physical Simulation of Aircraft	Yes	No	No	Yes
Limit to Maximum Run Segment	None	None	Cost	90 Minutes
Presence of External Visual Cues	Yes	No	Yes, Frt. Wind.	Yes
Presence of External Auditory Cues	No	Some Extraneous	Much Extraneous	Yes
Controllable RMS Acceleration Input	Yes	Yes	Yes	Yes Somewhat
Controllable Acceleration Time History	Good	Good	Good	Poor

For example, a certain portion of the TIFS flight motion must be designed so that it can be completely duplicated (i.e., amplitude, frequency, duration, and time history) by the ground-based simulators. In this manner, other things being equal or secondary in effect, we can determine the importance of motion fidelity on the passenger ride environment.

To validate the use of the LRC simulators as substitutes for the flight environment, we shall compare the response of passengers to the controlled ride environment of the TIFS aircraft with the response of the same group of passengers to the ride environment of the simulators. Prior to the actual design of the experiments, on which the necessary subject responses will be observed, the hypothesis that we wish to test has to be defined and the acceptance criterion has to be chosen. It is recommended that the t-test be used as the mechanism by which to test the desired hypothesis. (For a detailed explanation of hypothesis testing and the t-test, refer to STOL Program Memorandum Report 403212, "Effect of Motion Frequency Spectrum on Subjective Comfort Response," by Ira D. Jacobson, Michael B. Schoultz, and J. Coleman Blake.) The hypotheses for the major validation experiment (experiment one as shown in the solution flowchart) are as follows:

H_1: For a given flight environment, the mean response of the subjects to the simulator environment differs from their mean response to the TIFS environment by more than $\pm \delta$. (The consequence of this hypothesis being true is the rejection of the simulators as substitutes for the true aircraft flight environment.)

H_2: For a given flight environment, the mean response of the subjects to the simulator environment differs from their mean response to the TIFS environment by less than $\pm \delta$. (The consequence of this hypothesis being true is the acceptance of the simulators as substitutes for the true aircraft flight environment.)

We shall choose as our acceptance criterion variable, the probability of occurrence of the observed difference of means when H_1 is true. If our observed difference of means have a lower probability than some arbitrarily selected lower limit, called α, then we will be sufficiently suspicious of H_1 to reject it. The limiting probability, denoted by α_c, is called the level of significance of the test and is the probability of rejecting a true hypothesis. It is most common in this type of hypothesis testing to select a level of significance of 0.001, 0.01, or 0.05. This means there is a .1%, 1%, or 5% probability of rejecting H_1 when H_1 is true, or conversely, a 99%, 95%, or 90% probability of accepting a true hypothesis. It is recommended that the level of significance be either 0.01 or 0.05, and that the t_{crit} for $\delta = 0.1$ and 0.25 also be calculated for comparative purposes. This will allow the research team to know the relative weakness of their hypothesis should it fail the acceptance criteria.

What we now would like to know is whether our subject sample is representative of the true population of people who use air transportation. That is, how large must the sample size be such that we are x% confident the mean value of their response is within $\pm\delta$ of the true mean of the population? The ability to predict the sample size depends on the confidence we desire in our prediction, the difference in means, δ, and the standard deviation of the sample data. (The details of mathematical sampling theory can be found in any intermediate-level statistics book, e.g., Feller, An Introduction to Probability Theory and its Applications, Volume 1, 3rd Edition. For additional information, refer to STOL Program Memorandum by I. D. Jacobson and A. R. Kuhlthau dated March 19, 1973.)

The table below is a tabulation of several sample size calculations assuming a worst case of the standard deviation of sample data to be equal to 0.85. Standard deviations less than this were achieved in 30 out of 35 test data groups in the Allegheny Flight Program.

	Confidence			
δ, Difference in Means	99%	95%	90%	80%
0.1	480	278	196	119
0.25	77	45	32	19
0.5	20	12	8	5

As can be noted, the sample size that is required is a strong function of the difference in means and the confidence that is desired. By decreasing the confidence level for a given δ, or by increasing δ for a given confidence level, the sample size decreases. This table serves to illustrate the tradeoffs between confidence level and difference in means and the number of subjects that will be required.

The first experiment can now be carried out. This experiment shall be conducted essentially assuming the differences in flight environments between the TIFS aircraft and the ground-based simulators to be secondary in nature, while making allowances in the TIFS portion of the flight program (i.e., as in the case of input motion design previously mentioned), if this does not turn out to be the case. It is recommended that the TIFS flight experiment be first since the ground-based simulators can model the motion of the TIFS more precisely than the TIFS can model a given motion. If the acceptance criterion of the test is met, that is, if we can reject H_1 (or conversely, accept H_2), then those differences between the flight environments were not important and the simulators are validated as substitutes for aircraft ride environments. If the acceptance criterion of the test is not met (if we cannot reject H_1), then it must be assumed that the flight environment differences are the primary suspects, and the secondary factor experiments must be performed. These experiments should be designed to test the passenger's response to a single factor, and the test should take the same form as the main experiment. That is, a hypothesis to be tested should be determined and the student's t-test should be used as a criteria for acceptance-rejection. If it should turn out that, on an individual basis, each factor (or a lack of each factor) is not a significant deterrent to a passenger's evaluation of his ride environment, than we must assume one of two things. Most likely, we have ignored an important attribute of the ride environment that is different between the TIFS and the ground-based simulator. Another possibility might be that the human responds to his total ride environment differently then he responds to a partial sub-environment. In either case, we must conclude that the simulators cannot be validated. However, if some isolated factor or factors do contribute significantly to a person's response to his environment, and if this factor or factors can be changed in the ground-based simulator to agree with the actual aircraft environment, then the simulator portion of the experiment should be re-done after these factors have been changed. If the acceptance criterion is now met, the simulators can be validated. If the criterion is not met, or if the factor differences between the simulator and the TIFS cannot be made the same, we must conclude that the simulators cannot be used as valid substitutes for the flight environment.